



**NONRESIDENT  
TRAINING  
COURSE**

---

---



**Gas Turbine Systems  
Technician (Electrical) 3/Gas  
Turbine Systems Technician  
(Mechanical) 3, Volume 2**

**NAVEDTRA 14114**

**DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.**

# **SUMMARY OF GAS TURBINE SYSTEMS TECHNICIAN (ELECTRICAL) 3/GAS TURBINE SYSTEMS TECHNICIAN (MECHANICAL) 3 TRAINING MANUALS**

## **VOLUME 1**

*Gas Turbine Systems Technician (Electrical) 3/Gas Turbine Systems Technician (Mechanical) 3, Volume 1, NAVEDTRA 14113, covers information on the ratings, administration and programs, tools and test equipment, electrical theory and mechanical theory, piping systems and their components, support and auxiliary equipment, the power train, the controllable pitch systems, and engineering electrical systems and their maintenance procedures.*

## **VOLUME 2**

*Gas Turbine Systems Technician (Electrical) 3/Gas Turbine Systems Technician (Mechanical) 3, Volume 2, NAVEDTRA 14114, contains information on the basic fundamentals of gas turbines, the LM2500 gas turbine, the Allison 501-K17 gas turbine generator, engineering systems, electric plant operation, and the control consoles for the CG-, DD-, and FFG-class ships.*

## PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

**COURSE OVERVIEW:** This course is designed to assist enlisted personnel in the advancement to GSE Third Class Petty Officer/GSM Third Class Petty Officer. In completing this course you will demonstrate a knowledge of course materials by correctly answering questions on the following topics: gas turbine fundamentals, the LM2500 gas turbine engine, ship's service gas turbine generator sets, engineering auxiliary and support systems, PACC and PLCC for DD- and CG-class ships, PCC and LOP for FFG-class ships, machinery control system for DDG-class ships, electrical plant operation, and auxiliary equipment and consoles.

**THE COURSE:** This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

**THE QUESTIONS:** The questions that appear in this course are designed to help you understand the material in the text.

**VALUE:** In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

*1991 Edition Prepared by  
GSCS Bradford E. Edwards and  
GSEC(SW) Anthony T. Askew*

Published by  
NAVAL EDUCATION AND TRAINING  
PROFESSIONAL DEVELOPMENT  
AND TECHNOLOGY CENTER

**NAVSUP Logistics Tracking Number  
0504-LP-026-7800**

# **CONTENTS**

<b>CHAPTER</b>	<b>Page</b>
1. Gas Turbine Engine Fundamentals .....	1-1
2. LM2500 Gas Turbine Engine .....	2-1
3. Ship's Service Gas Turbine Generator Sets .....	3-1
4. Engineering Auxiliary and Support Systems .....	4-1
5. PACC and PLCC for DD- and CG-class Ships .....	5-1
6. PCC and LOP for FFG-class Ships .....	6-1
7. Machinery Control System .....	7-1
8. Electrical Plant Operation. ....	8-1
9. Auxiliary Equipment and Consoles .....	9-1
 <b>APPENDIX</b>	
I. Glossary .....	AI-1
II. Abbreviations and Acronyms .....	AII-1
 <b>INDEX</b> .....	INDEX-1



# CHAPTER 1

## GAS TURBINE ENGINE FUNDAMENTALS

This chapter will help you understand the history and development of gas turbine engines (GTEs). It will help you become familiar with the basic concepts used by GTE designers, follow discussions of how the Brayton cycle describes the thermodynamic processes in a GTE, and learn how various conditions and design limitations affect GTE performance. How a GTE develops and uses hot gases under pressure is also thoroughly discussed in this chapter. After reading this chapter, you should have the basic knowledge to be able to describe the principal components of GTEs and their construction, the GTE auxiliary systems, and also be familiar with the nomenclature related to GTEs and GTE technology. A more in-depth coverage of the individual systems and components for the General Electric LM2500 GTE will be discussed in chapter 2 of this TRAMAN. To refresh your memory about the different laws and principles discussed in this chapter, refer to NAVEDTRA 10563, volume 1, chapter 4.

### HISTORY AND BACKGROUND

Until recent years, GTE technology and jet engine technology have overlapped a great deal. The same people have worked in both fields, and the same sciences have been applied to both types of engines. In the past, the jet engine has been used more as a part of aviation. The GTE has been used for electric generation, ship propulsion, and even experimental automobile propulsion. Many operational turbine power plants use a derivative of an aircraft jet engine as a gas generator (GG). When used as such, the engine must be modified by the addition of a power turbine (PT) and reduction gearing to complete the plant.

In nature, the squid was using jet propulsion long before scientists thought of it. Examples of

the reaction principle (Newton's third law) existed in early history. However, practical application of the reaction principle occurred only recently. This delay is due to the slow progress of technical achievement in engineering, fuels, and metallurgy (the science of metals).

Hero, a scientist in Alexandria, Egypt, who lived between the first and third centuries A.D., described what is considered to be the first jet engine (the aeolipile). This device (fig. 1-1) is mentioned in sources dating back as far as 250 B.C., and many sources credit Hero as the inventor.

History records several examples of other scientists using the principle of expanding gases to perform work. Among these were inventions



Figure 1-1.—Hero's aeolipile.

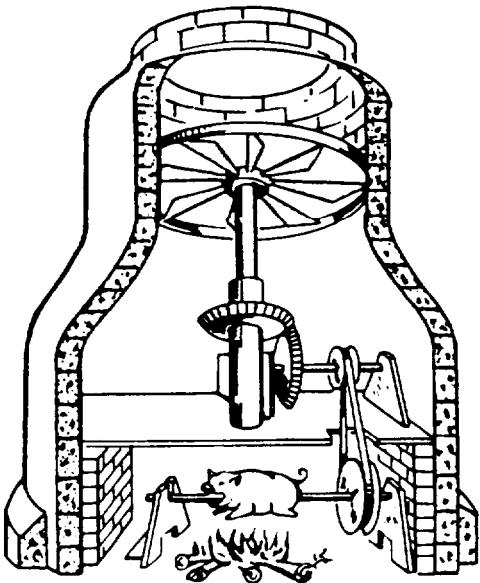


Figure 1-2.—da Vinci's chimney jack.

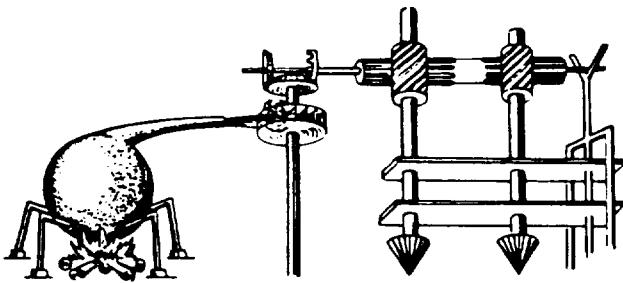


Figure 1-3.—Branca's jet turbine.

of Leonardo da Vinci (around 1500 A.D.) (fig. 1-2) and Giovanni Branca (in 1629) (fig. 1-3).

In the 1680s Sir Isaac Newton described the laws of motion (discussed in GSE3/GSM3, volume 1, chapter 4). All devices that use the theory of jet propulsion are based on these laws. Newton's steam wagon is an example of the reaction principle (fig. 1-4).

In 1791 John Barber, an Englishman, submitted the first patent for a design that used the thermodynamic cycle of the modern GTE. This design was also suggested for jet propulsion.

## TWENTIETH-CENTURY DEVELOPMENT

The patented application for the GTE as we know it today was submitted in 1930 by another



Figure 1-4.—Newton's steam wagon.

Englishman, Sir Frank Whittle. His patent was for a jet aircraft engine. Whittle used his own ideas along with the contributions of other scientists. After several failures, he came up with a working GTE.

### American Development

The United States did not go into the GTE field until 1941. General Electric was then awarded a contract to build an American version of the British-designed Whittle aircraft engine. The engine and airframe were both built in 1 year. The first jet aircraft was flown in this country in October 1942.

In late 1941 Westinghouse Corporation was awarded a contract to design and build the first all-American GTE. Their engineers designed the first axial-flow compressor and annular combustion chamber. Both of these ideas, with minor changes, are the basis for most modern gas turbines in use today.

### Marine Gas Turbine Engine

Using a GTE to propel a ship goes back to 1937 when a Pescara free piston gas engine was used experimentally with a GTE. The free piston engine, or gasifier (fig. 1-5), is a form of diesel engine. It uses air cushions instead of a crankshaft to return the pistons. It was an effective producer of pressurized gases. The German navy used it in their submarines during World War II as an air compressor. In 1953 the French placed in service two small vessels powered by a free piston engine/GTE combination. In 1957 the liberty ship *William Patterson* went into service on a transatlantic run. It had six free piston engines driving two turbines.

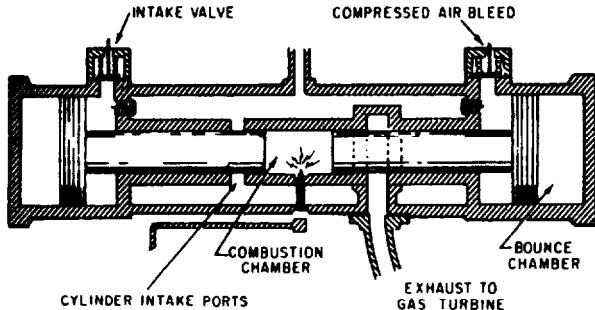


Figure 1-5.—Free piston engine.

At that time applications of the use of a rotary gasifier to drive a main propulsion turbine were used. The gasifier (used as a compressor) was usually an aircraft jet engine or turboprop front end. In 1947 the Motor Gun Boat 2009 of the British navy used a 2500-hp GTE. In 1951 the tanker *Auris*, in an experimental application, replaced one of four diesel engines with a 1200-hp GTE. In 1956 the gas turbine ship *John Sergeant* had a very efficient installation. It gave a fuel consumption rate of 0.523 pounds per hp/hr. The efficiency was largely due to use of a regenerator, which recovered heat from the exhaust gases.

By the late 1950s the marine GTE was becoming widely used, mostly by European navies. All the applications used a dual main propulsion system, combining the gas turbine plant with another conventional form of propulsion machinery. The GTE was used for high-speed operation. The conventional plant was used for cruising. The most common arrangements were the combined diesel and gas (CODAG) or the combined diesel or gas (CODOG) systems. Diesel engines give good cruising range and reliability, but they have a disadvantage when used in antisubmarine warfare. Their low-frequency sounds travel great distances through water. This makes them easily detected by passive sonar. Steam turbines have been combined to reduce low-frequency sound in the combined steam and gas (COSAG) configuration like those used on the British *County* class destroyers. The COSAG configuration requires more personnel to operate. Also they do not have the long range of the diesel combinations. Another configuration that has been successful is the combined gas or gas (COGOG), such as used on the British 42. These ships use the 4,500-hp Tyne GTE for cruising and the Rolls

Royce Olympus, a 28,000-hp engine, for high-speed situations.

The U.S. Navy entered the marine gas turbine field with the *Asheville* class patrol gunboats. These ships have the CODOG configuration with two diesel engines for cruising and a General Electric LM1500 GTE for high-speed operations. The Navy has now designed and is building destroyers, frigates, cruisers, hovercraft, and patrol hydrofoils that are entirely propelled by GTEs. This is a result of the reliability and efficiency of the new GTE designs.

## ADVANTAGES AND DISADVANTAGES

The GTE, when compared to other types of engines, offers many advantages. Its greatest asset is its high power-to-weight ratio. This has made it, in the forms of turboprop or turbojet engines, the preferred engine for aircraft. Compared to the gasoline piston engine, the GTE operates on cheaper and safer fuels. The relatively vibration-free operation of the GTE, compared with reciprocating engines, has made it even more desirable in aircraft. Less vibration reduces strain on the airframe. In a warship, the lack of low-frequency vibration of GTEs makes them preferable to diesel engines because there is less noise for a submarine to pick up at long range. Modern production techniques have made GTEs more economical in terms of horsepower-per-dollar on initial installation. Their increasing reliability makes them a cost-effective alternative to steam turbine or diesel engine installation. In terms of fuel economy, modern marine GTEs can compete with diesel engines and they may even be superior to boiler/steam turbine plants that are operating on distillate fuel.

The GTEs do have a few disadvantages. Since they are high-performance engines, many parts are under high stress. Improper maintenance and lack of attention to details of the maintenance procedures will impair engine performance and may lead to engine failure. A **pencil mark** on a compressor turbine blade can cause failure of the part. Most GTE propulsion control systems are very complex and require the monitoring of numerous operating conditions and parameters. The control systems must react quickly to turbine operating conditions to avoid casualties to the equipment. In shipboard installations special soundproofing is necessary because GTEs produce high-pitched noises that can damage the human ear. The turbine takes in large quantities of air

that may contain substances or objects that can harm it. Also, the large amount of air used by a GTE requires large intake and exhaust ducting, which takes up much valuable space on a small ship. This adds to the complexity of the installation and makes access for maintenance more difficult.

From a tactical standpoint, the GTE has two major drawbacks. The first is the large amount of exhaust heat produced by the engines. Most current antiship missiles are heat-seekers. Therefore, the infrared (IR) signature of a GTE is an easy target. Countermeasures, such as exhaust gas cooling and IR decoys, have been developed to reduce this problem.

The second tactical disadvantage is the requirement for depot maintenance and repair of major casualties. On the whole, the turbines are too complex to overhaul in place. They must be removed and replaced by rebuilt engines if any major casualties occur. However, this problem is reduced by the design of the system. A GTE on a frigate, cruiser, or destroyer can be changed out in about 4 days if crane service and a replacement engine are available. A GTE on a hovercraft can be changed out in 8 hours. Gas turbine ships can operate or be repaired to the same standards as their steam- or diesel-driven counterparts.

## FUTURE TRENDS

As improved materials and designs permit operation at higher combustion temperatures and pressures, GTE efficiency will increase. Even now, GTE main propulsion plants offer fuel economy and installation costs comparable to diesel engines. Initial costs are lower than equivalent steam plants that burn distillate fuels. These improvements have made GTEs the best choice for nonnuclear propulsion of naval ships up to, and including, an underway replenishment ship in size.

At present, marine GTEs use derivatives of aircraft jet engines for GGs. These are slightly modified for use in a marine environment, particularly in respect to corrosion resistance. As marine GTEs become more widely used, specific designs for ships may evolve. These compressors may be heavier and bulkier than aircraft engines and take advantage of regenerators to permit greater efficiency.

The high power-to-weight ratios of GTEs permit the development of high-performance craft, such as the hovercraft and the hydrofoil, the patrol combatant missile the patrol

combatant (PG), and the landing craft, air cushion (LCAC). These crafts are capable of high speed, can carry formidable weapons systems, and are being seen in increasing numbers in our fleet. In civilian versions, hydrofoils have served for many years to transport people on many of the world's waterways. Hovercraft are being used more and more as carriers of people. They are capable of speeds up to 100 knots. If beach gradients are not too steep, they can reach points inland over virtually any type of terrain.

## GAS TURBINE ENGINE THEORY

Two elements are required for proper operation of a GTE. One is expressed by Newton's third law (action/reaction). The other is the convergent-divergent process (or Bernoulli's principle). Convergent means coming closer together, as the inner walls of a tube that is narrowing. Divergent means moving away from each other, as the inner walls of a tube that flares outward. The venturi of an automobile carburetor is a common example of Bernoulli's principle and the convergent-divergent process. Before we discuss GTE construction and design, we will discuss a little more on cycles and theory.

## THEORETICAL CYCLES

A cycle is a process that begins with certain conditions, progresses through a series of additional conditions, and returns to the original conditions. The basic GTE cycle is named for the Boston engineer, George Brayton, who proposed it in the late nineteenth century.

The Brayton cycle is one in which combustion occurs at constant pressure. In GTEs, specific components are designed to perform each function of the cycle separately. These functions are intake, compression, combustion, expansion, and exhaust. Refer to figure 1-6 as we explain the Brayton cycle graphically.

● **Intake**—At point A, air enters the inlet at atmospheric pressure and ambient temperature.

● **Compression**—As the air passes through the compressor, it increases in pressure and temperature and decreases in volume (line A-B).

● **Combustion**—At point B, combustion occurs at constant pressure while the addition of heat causes a sharp increase in volume (line B-C).

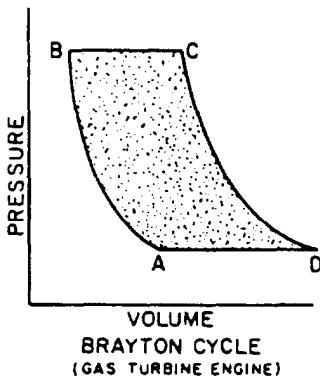


Figure 1-6.—The Brayton cycle.

- **Expansion**—The gases at constant pressure and increased volume enter the turbine and expand through it. As the gases pass through the turbine rotor, the rotor turns kinetic energy into mechanical energy. The expanding size of the passages causes further increase in volume and a sharp decrease in pressure and temperature (line C-D).

- **Exhaust**—The gases are released through the stack with a large drop in volume and at constant pressure (line D-A).

The cycle is continuous and repetitive in a GTE. The functions occur simultaneously throughout the system.

### OPEN, SEMICLOSED, AND CLOSED CYCLES

Most internal-combustion engines operate on an open engine cycle. This means the working fluid is taken in, used, and discarded. The GTEs you will encounter in the Navy operate on the open cycle. In the open cycle all the working fluid passes through the engine only once. The open cycle offers the advantages of simplicity and light weight.

Some GTEs operate on a semiclosed cycle. They use a regenerator, such as used on the *John Sergeant*. The regenerator simply transfers the heat from the turbine exhaust gas to the compressor discharge gas before that gas has energy externally supplied (ahead of the combustor).

The third classification of cycles is the closed cycle, in which energy is added externally. The

closed cycle has been called the “natural” cycle for the GTE because it allows use of any fuel, including nuclear, as an energy source. The typical ship’s steam plant is an example of a closed cycle system.

### BASIC GTE OPERATION THEORY

The following is a description of a practical demonstration of how a GTE operates. Refer to figure 1-7 as you read the description.

A balloon full of air (view A) does nothing unless the trapped air is released. When the air is released, it escapes rearward, causing the balloon to move forward (Newton’s third law) (view B).

If you could devise a way to keep the balloon constantly full of air, it would continue to move forward (view C) as long as the air is allowed to escape from it.

If you place a fan or pinwheel in the escaping airstream, the pressure energy and velocity energy will cause the fan to rotate. Then you can use the escaping air to do work (view D).

Now, if you replace the balloon with a firmly mounted tube or container and keep it filled with air from a fan located in the air opening and driven by an external source, you could use the discharge air to turn a fan at the rear to do work (view E).

If you add fuel and allow combustion to occur (view F), the volume of air and the velocity with which it passes over the exhaust fan are greatly increased (Charles’s law). The horsepower the fan will produce is also increased. The continuous pressure created by the inlet fan, or compressor, prevents the hot gases from going forward.

Now, if you attach a shaft to the compressor and extend it back to a turbine wheel, you have a simple GTE (view G). It can supply power to run its own compressor and still provide enough power to do useful work. It could drive a generator or propel a ship.

By comparing view H with view G, you can see that a GTE is very similar to the balloon

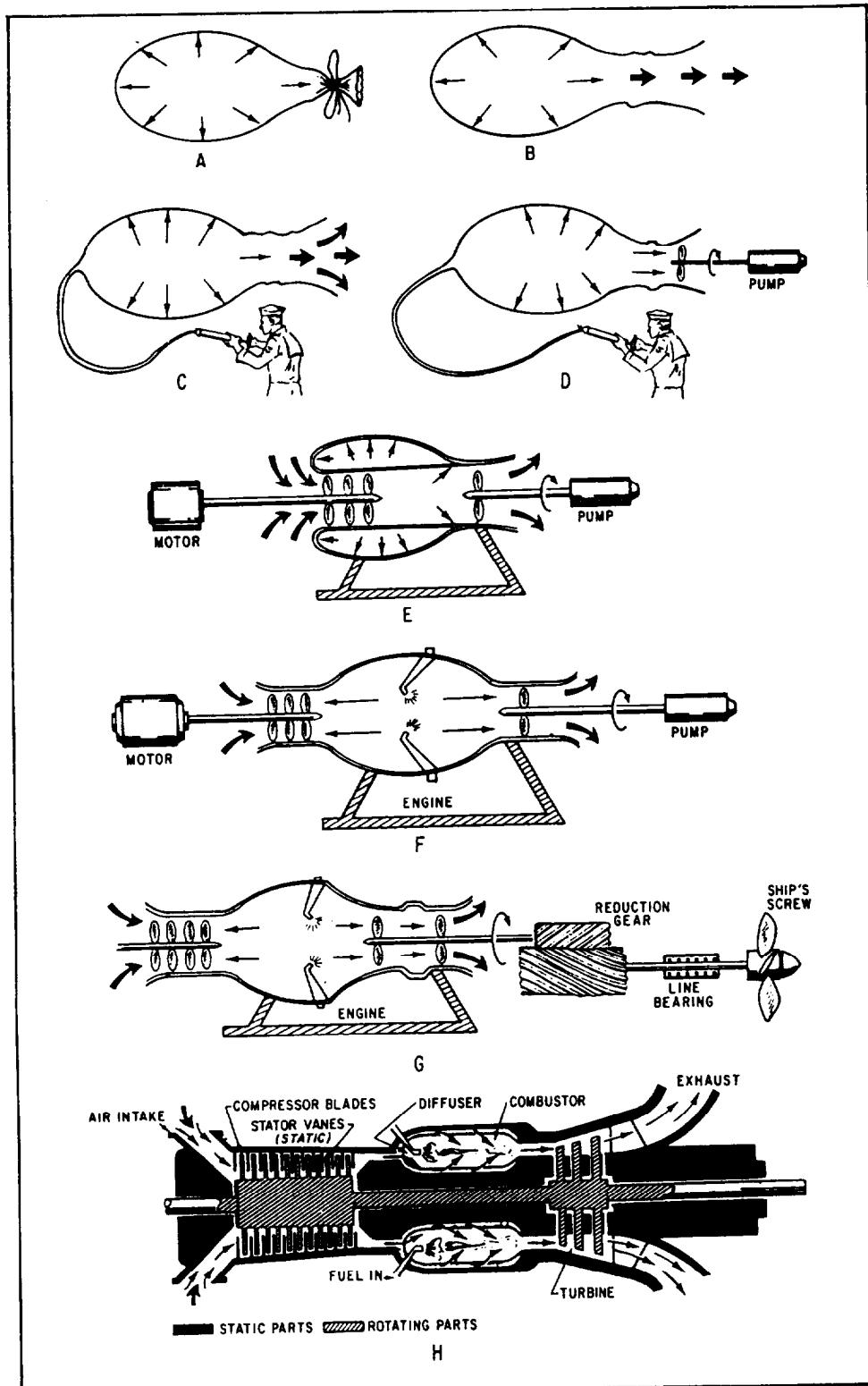


Figure 1-7.—Practical demonstration of GTE operations.

discussed earlier. A review of the gas turbine process is detailed as follows:

1. Air is taken in through the air inlet duct by the compressor. There it is raised in pressure and discharged into the combustion chamber (or combustor).

2. Fuel is admitted into the combustion chamber by the fuel nozzle(s). The fuel-air mixture is ignited by an igniter(s) (not shown) and combustion occurs.

3. The hot and rapidly expanding gases are directed aft through the turbine rotor assembly. There, thermal and kinetic energy are converted into mechanical energy. The gases are then directed out through the exhaust duct.

## CONVERGENT-DIVERGENT PROCESS

Several pressure, volume, and velocity changes occur within a GTE during operation. The convergent-divergent process is an application of Bernoulli's principle. (If a fluid flowing through a tube reaches a constriction or narrowing of the tube, the velocity of the fluid flowing through the constriction increases and the pressure decreases. The opposite is true when the fluid leaves the constriction; velocity decreases and pressure increases.) Boyle's law and Charles's law (discussed in NAVEDTRA 10563, volume 1, chapter 4) also come into play during this process. Refer to figure 1-8 as we apply these laws to the GTE.

Air is drawn into the front of the compressor. The rotor is so constructed that the area decreases toward the rear. This tapered construction gives a convergent area (area A).

Between each rotating stage is a stationary stage or stator. The stator partially converts high velocity to pressure and directs the air to the next set of rotating blades.

Because of its high rotational speed and the aerodynamic shape of its blades, the rotor increases the velocity of the air. Each pair of rotor and stator blades constitutes a pressure stage. Both a pressure increase and a reduction in volume occurs at each stage (Boyle).

This process continues at each stage until the air charge enters the diffuser (area B). There is a short area in the diffuser where no further changes take place. As the air charge approaches the end of the diffuser, you will notice that the opening flares (diverges) outward. At this point, the air loses velocity and increases in volume and pressure. The velocity energy has become pressure energy, while pressure through the diffuser has remained constant. The reverse of Bernoulli's principle and Boyle's law has taken place. The compressor continuously forcing more air through this section at a constant rate maintains constant pressure. Once the air is in the combustor, combustion takes place at constant pressure. After combustion there is a large increase in the volume of the air and combustion gases (Charles's law).

The combustion gases go rearward to area C. This occurs partially by velocity imparted by the

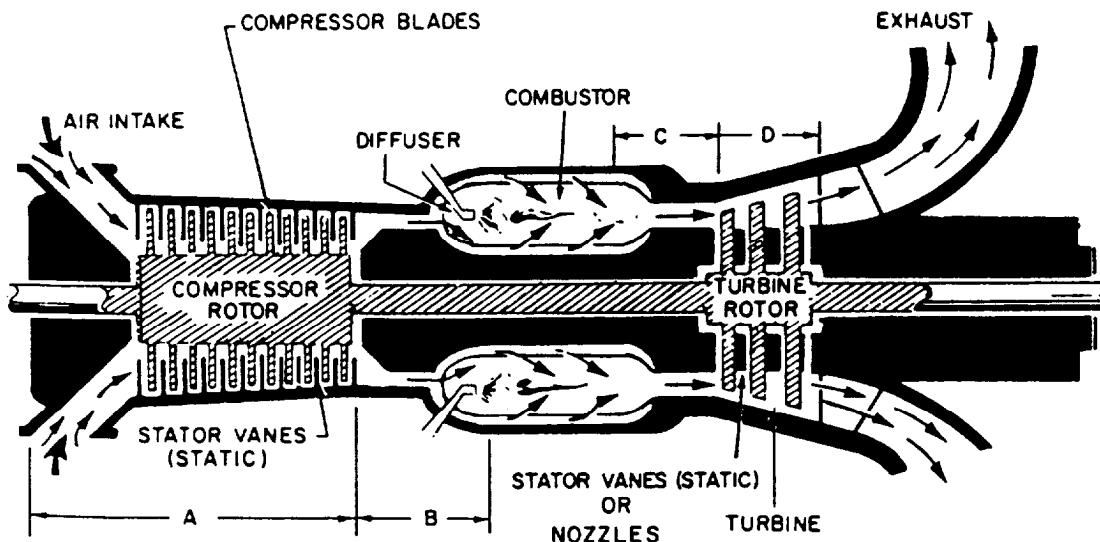


Figure 1-8.—Convergent-divergent process.

compressor and partially because area C is a lower pressure area. The end of area C is the turbine nozzle section. Here you will find a decrease in pressure and an increase in velocity. The high-velocity, high-temperature, low-pressure (LP) gases are directed through the inlet nozzle to the first stage of the turbine rotor (area D). The high-velocity, high-temperature gases cause the rotor to rotate by transferring velocity energy and thermal energy to the turbine blades. Area D is a divergent area. Between each rotating turbine stage is a static stage or nozzle. The nozzles perform the same function as the stators in the compressor.

A turbine nozzle is a stator ring with a series of vanes. The vanes direct the combustion gases uniformly and at the proper angle to the turbine blades. The passages between the vanes are designed as diverging nozzles. Each succeeding stage imparts velocity to the gases as they pass through the nozzle. Each nozzle converts heat and pressure energy into velocity energy by controlling the expansion of the gas.

Each stage of the turbine is larger than the preceding one. The drop in pressure is quite rapid; consequently, each stage must be larger to use the energy of a lower pressure, lower temperature, and larger volume of gas.

Atmospheric air is raised in pressure and velocity and lowered in volume in area A by the compressor. Each stage can only compress air about 1.2 times. In the turbine rotor (area D), the gases give up thermal and pressure energy and

increase in volume through three stages. (If this did not happen rapidly, back pressure from area D would cause area C to become choked.) The gases in the combustor would back up into the compressor. There they would disrupt airflow and cause a condition known as surge, or compressor stall. This condition can destroy an engine in a matter of seconds. Surge will be explained later in our discussion of axial-flow compressors.

The gases from the last turbine stage enter the exhaust duct where they are sent to the atmosphere. The leading portion of the exhaust duct is part of a divergent area. Further divergence reduces the pressure and increases the volume of the warm gases and aids in lowering the velocity. The exhaust gases enter the atmosphere at or slightly above atmospheric pressure. This depends on the length and size of the exhaust duct.

Refer to figure 1-6 and compare the graph and the actual operation of the cycle. Air enters the intake at constant pressure (point A). It is compressed as it passes through the compressor (line A-B in fig. 1-6 and area A in fig. 1-8). Between the end of area B and the beginning of area C in figure 1-8, combustion occurs and volume increases (fig. 1-6, line B-C). As the gases pass through area D (fig. 1-8), the gases expand with a drop in pressure and an increase in volume (fig. 1-6, line C-D). The gases are discharged to the atmosphere through the exhaust duct at constant pressure (fig. 1-6, line D-A and fig. 1-8, exhaust). At this point, you should have the basic knowledge of how a simple gas turbine works.

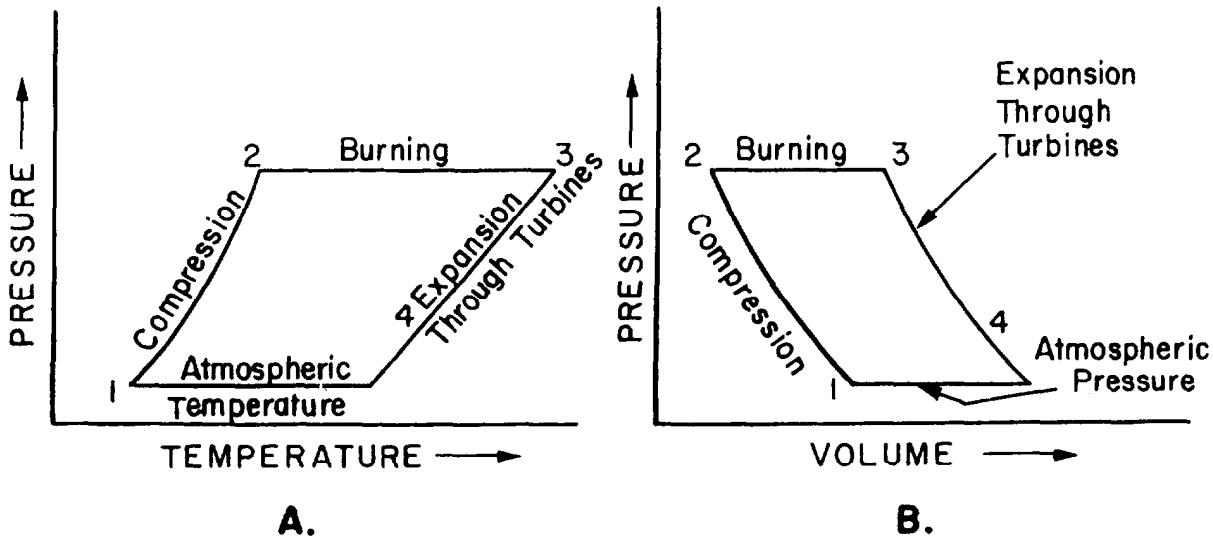


Figure 1-9.—GTE pressure-temperature-volume relationship.

## ADIABATIC COMPRESSION

In an adiabatic stage change, no transfer of heat to or from the system occurs during the process. Theoretically, in the ideal GTE, the air enters the compressor and is compressed adiabatically. In many real processes, adiabatic changes can occur when the process is performed rapidly. Since heat transfer is relatively slow, any rapidly performed process can approach an adiabatic state. Compression and expansion of working fluids are often achieved almost adiabatically. This is the case in today's GTEs.

Figure 1-9 is a schematic representation of a stationary simple GTE. It uses two graphs to show the pressure-temperature-volume relationships at various process states. The major components of the GTE are the compressor for the process from 1 to 2, the combustor for the process from 2 to 3, and the turbine for the process from 3 to 4. The heat rejection process from 4 to 1, which completes the cycle, is carried out by exhausting the hot gas and allowing it to mix with the atmosphere.

In an initial simplified analysis, the compressor is taken to include the inlet nozzle and ducting and any exit diffuser leading to the combustor. Thus, for the compressor inlet condition (point 1), the air being drawn from the surroundings has zero velocity, ambient temperature, and ambient pressure. For the exit condition (point 4), the air has zero velocity at some elevated pressure and temperature that are measured. View A of figure 1-9 depicts a pressure-temperature graph for a simple GTE, while view B depicts a pressure-volume graph. The distance between adjacent numbers on each of the diagrams represents an event of the combustion cycle. A combustion cycle includes compression of air, burning of the compressed air and fuel mixture, expansion of gases, and removal of gases. By comparing the numerical points on both graphs (point 1 to 2 on view A with point 1 to 2 on view B), you can get a better understanding of the pressure-temperature-volume relationship of a simple GTE.

During operation the work produced by the compressor turbine rotor is almost the same amount as the work required by the compressor. The mass flow available to the compressor turbine is about the same as the mass flow handled by the compressor. This allows the heat of compression to be about the same value as the heat of expansion. Allowances are made for

factors such as bleed air, pressure of fuel added, and heat loss to turbine parts.

As the high-temperature, high-pressure (HP) gases enter the turbine section, they expand rapidly. Relatively little change in the temperature of the gases occurs. The net power available from the turbine is the difference between the turbine-developed power and the power required to operate the compressor.

## FACTORS AFFECTING ENGINE PERFORMANCE

Many factors, such as aerodynamics and thermodynamics, have a direct effect on efficient GTE performance. In this chapter we will discuss only two common factors, the effect of ambient temperatures and the effect of compressor cleanliness. As a gas turbine technician, you will be concerned with these in your daily operation of the GTE.

### Effect of Ambient Temperature

In discussions of temperature effects on GTEs, you will often hear the term *Navy standard day*. This term refers to a theoretical condition seldom duplicated except in some permanent test situations and is used only as a reference or standard. A standard day is indicated by the following conditions at sea level: barometric pressure—29.92 Hg, humidity (water vapor pressure)—0.00 Hg, and temperature—59°F. Operation of engines above or below 50°F will proportionally affect engine power output by as much as 15 or 20 percent.

The power and efficiency of a GTE are affected by both outside and inside variables. Air has volume that is directly affected by its temperature. As the temperature decreases, the volume of air for a given mass decreases and its density increases. Consequently, the mass weight of the air increases, causing the engine to operate more efficiently. This happens because less energy is needed to achieve the same compression at the combustion chambers. Also, cooler air causes lower burning temperatures. The resulting temperatures extend turbine life. For example, a propulsion GTE is operating at 100 percent GG speed with 100 percent PT speed. The ambient (external air) temperature is 70°F. If the temperature were increased to 120°F, the volume of air required would increase. The mass weight would decrease. Since the amount of fuel added is limited by the inlet temperature the turbine will

withstand, the mass weight flow cannot be achieved; the result is a loss of net power available for work. The plant may be able to produce only 90 to 95 percent of its rated horsepower.

On the other hand, if the ambient temperature were to drop to 0°F, the volume of air (mass) required would decrease. However, the mass weight would increase. Since the mass weight is increased and heat transfer is better at higher pressure, less fuel is needed to increase volume. This situation produces quite an efficient power plant. It has a GG speed of 85 to 90 percent and a PT speed of 100 percent. In a constant speed engine, the differences in temperature will show up on exhaust gas temperature. In some cases, it will show up on the load the engine will pull. For instance, on a hot day of 120°F, the engine on a 300-kW generator set may be able to pull only 275 kW. This is due to limitations on exhaust or turbine inlet temperature. On a day with 0°F ambient temperature, the same engine will pull 300 kW. It can have an exhaust or turbine inlet temperature that is more than 100°F, lower than average. Here again, less fuel is needed to increase volume and a greater mass weight flow. In turn, the plant is more efficient.

### **Effect of Compressor Cleanliness**

Another factor that will have a great effect on performance is the condition of the compressor. A clean compressor is essential to efficiency and reliability. During operation at sea, the compressor takes in a high volume of salt-contaminated air. Salt buildup is relatively slow in the compressor and will occur more on the stator vanes and the compressor case than on rotating parts. Centrifugal force tends to sling salt contaminants off the rotor blades.

Any oil ingested into the engine coats the compressor with a film and will rapidly increase contamination of the compressor. The film traps any dust and other foreign matter suspended in the air. The dust and dirt absorb more oil, which traps more dirt, and so forth. If left unattended, the buildup of contamination (either oil or salt) will lead to a choking of the compressor and a restricted airflow. This restricted airflow will require the main fuel to schedule more fuel to produce an equivalent horsepower. The combustion gas temperatures will rise until loss of power, and damage to the turbine may result. Contamination, if not controlled, can induce a surge condition in the compressor during engine start. It will also reduce the life of the compressor

and turbine blading through corrosion of the engine parts.

## **TYPES OF GAS TURBINE ENGINES**

The different types of GTEs all use the same basic principles already discussed. A GTE is classified by its construction (the type of compressor, combustor, or shaft system used). The compressor may be either centrifugal or axial type. The combustor may be annular, can-annular, or can type. The type of shaft used on a GTE may be either single shaft, split shaft, or twin spool. These classifications will be discussed in the following paragraphs.

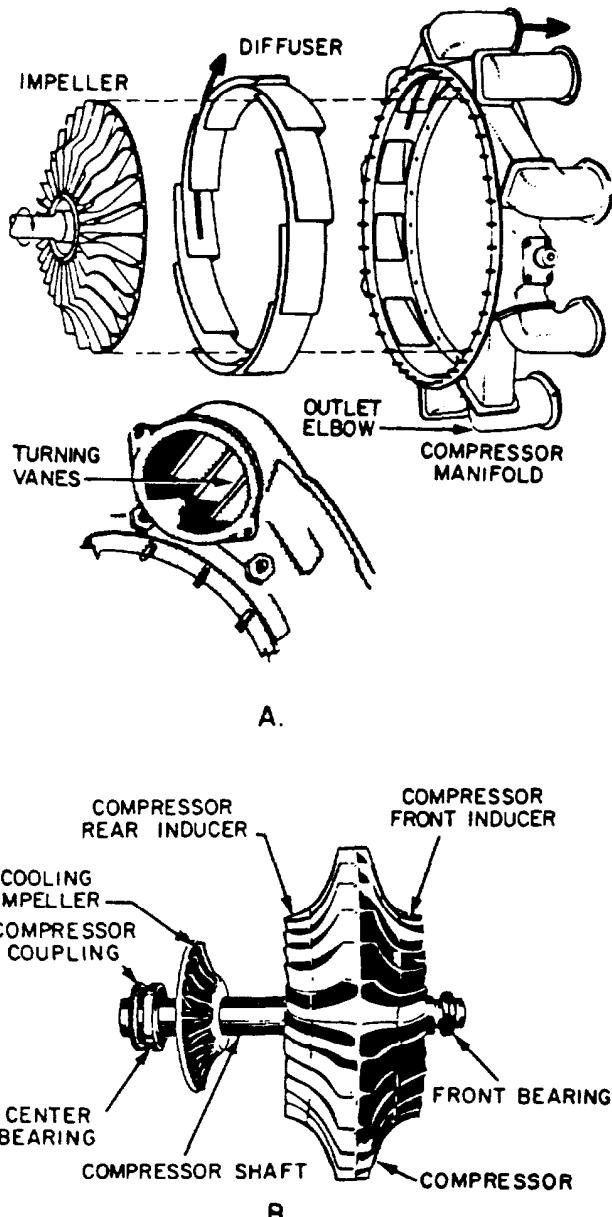
### **CLASSIFICATION BY COMPRESSOR TYPE**

The compressor takes in atmospheric air and compresses it to a pressure of several atmospheres. A GTE may be classified by compressor type, based on the direction of the flow of air through the compressor. The two principal types of compressors are the centrifugal flow and the axial flow. The centrifugal-flow compressor draws in air at the center or eye of the impeller and accelerates it around and outward. In the axial-flow compressor, the air is compressed while continuing its original direction of flow (parallel to the axis of the compressor rotor).

### **Centrifugal Compressor**

The centrifugal compressor is usually located between the accessory section and the combustion section. The basic compressor section consists of an impeller, diffuser, and compressor manifold. The diffuser is bolted to the manifold. Often the entire assembly is referred to as the diffuser. For ease of understanding, we will discuss each unit separately.

The impeller may be either single entry or dual entry (fig. 1-10). The main differences between the single-entry and dual-entry impeller are the size of the impeller and the ducting arrangement. The single-entry impeller permits convenient ducting directly to the inlet vanes. The dual-entry impeller uses a more complicated ducting to reach the rear side of the compressor. Single-entry impellers are slightly more efficient in receiving air, but they must be of greater diameter to provide sufficient airflow. This increases the overall diameter of the engine.



**Figure 1-10.—Centrifugal compressors.** A. Single entry.  
B. Dual entry.

Dual-entry impellers are smaller in diameter and rotate at higher speeds to ensure a sufficient airflow. Most modern GTEs use the dual-entry compressor to reduce engine diameter. Because the air must enter the engine at almost right angles to the engine axis, a plenum chamber is required for dual-entry compressors. The air must surround the compressor at a positive pressure before entering the compressor to ensure an undisturbed flow.

**PRINCIPLES OF OPERATION.**—The compressor draws in the air at the hub of the impeller and accelerates it radially by centrifugal force through the impeller. It leaves the impeller at a high velocity and a low pressure and flows through the diffuser (fig. 1-10, view A). The diffuser converts the high-velocity, LP air to low-velocity, HP air. The compressor manifold diverts the flow of air from the diffuser (an integral part of the manifold) into the combustion chambers.

**CONSTRUCTION.**—In a centrifugal compressor the manifold has one outlet port for each combustion chamber. The outlet ports are bolted to an outlet elbow on the manifold (fig. 1-10, view A). The outlet ports ensure that the same amount of air is delivered to each combustion chamber. Each outlet port elbow contains from two to four turning vanes to change the airflow from radial to axial flow and to reduce air pressure losses by presenting a smooth turning surface.

The impeller is usually made from a forged aluminum alloy that is heat-treated, machined, and smoothed for minimum flow restriction and turbulence. Some types of impellers are made from a single forging, while in other types the inducer vanes are separate pieces that are welded in place.

Centrifugal compressors may achieve efficiencies of 80 to 84 percent at pressure ratios of 2.5:1 to 4:1 and efficiencies of 76 to 81 percent at pressure ratios of 4:1 to 10:1.

Some advantages of centrifugal compressors are as follows:

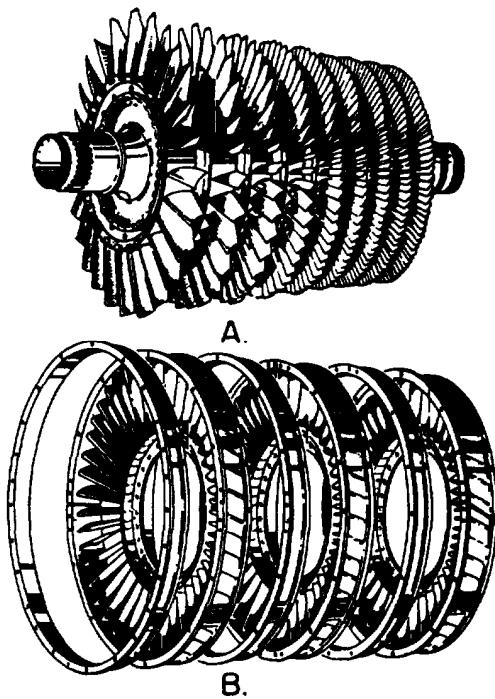
- Rugged, simple in design
- Relatively light in weight
- Develop high-pressure ratio per stage

Some disadvantages of centrifugal compressors are as follows:

- Large frontal area
- Lower efficiency than axial-flow compressors
- Difficulty in using two or more stages due to the air loss that occurs between stages and seals

#### Axial-Flow Compressors

The purpose of the axial compressor is the same as the centrifugal compressor. They both



**Figure 1-11.—Components of an axial-flow compressor.**  
A. Rotor. B. Stator.

take in ambient air and increase its velocity and pressure. The air is then discharged through the diffuser into the combustion chamber.

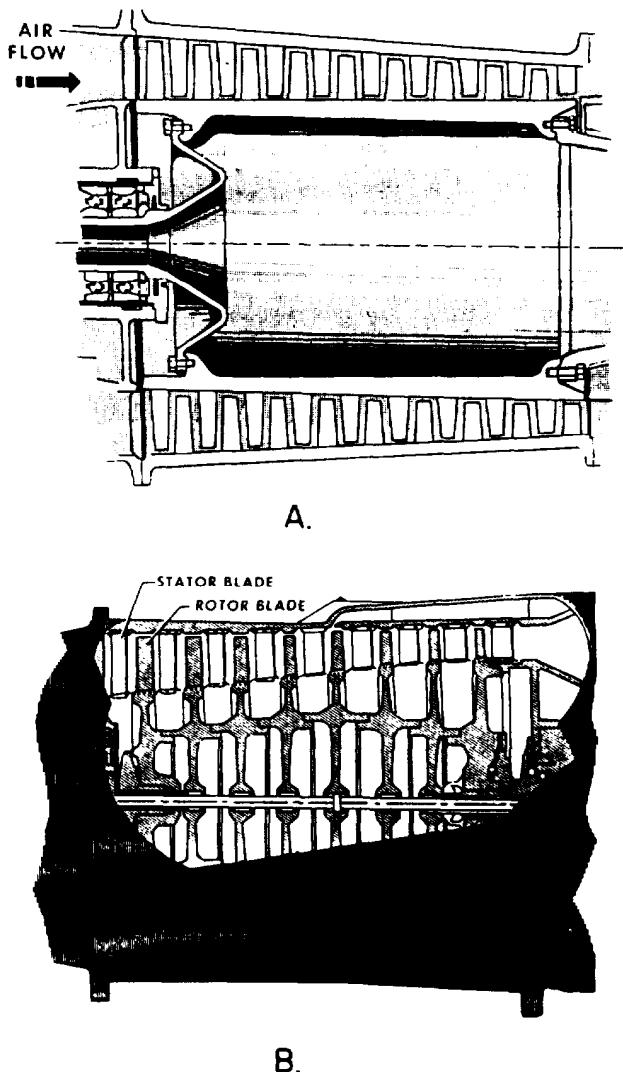
The two main elements of an axial-flow compressor are the rotor and the stator (fig. 1-11). The rotor has fixed blades which force the air rearward much like an aircraft propeller. Behind each rotor is a stator which directs the air rearward to the next rotor. Each consecutive pair of rotor and stator blades constitutes a pressure stage.

The action of the rotor at each stage increases compression and velocity of the air and directs it rearward. By virtue of this increased velocity, energy is transferred from the compressor to the air in the form of velocity energy. The stators at each stage act as diffusers, partially converting this high velocity to pressure.

The number of stages required in a compressor is determined by the amount of air and total pressure rise required by the GTE. The greater the number of stages, the higher the compression ratio. Most present-day engines have 8 to 16 stages.

**COMPRESSOR CONSTRUCTION.**—The rotor and stators are enclosed in the compressor case. Today's GTEs use a case that is horizontally divided into upper and lower halves. The halves are bolted together with fitted bolts and dowel pins located at various points for casing alignment. This ensures proper casing half alignment. Other assemblies can then be bolted to either end of the compressor case.

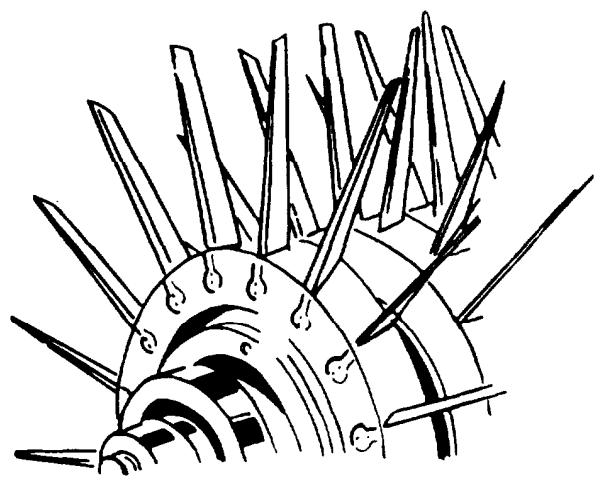
On some older design engines, the case is a one-piece cylinder open on both ends. The one-piece compressor case is simpler to manufacture, but any repair or detailed inspection of the compressor rotor requires engine removal and delivery to a shop. At the shop it is disassembled for inspection or repair of the rotor or stator. On



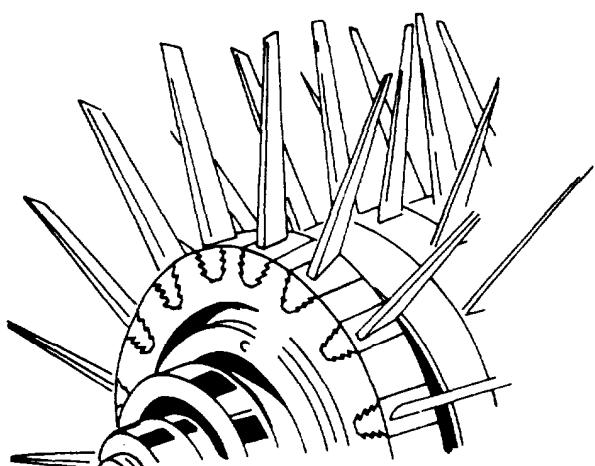
**Figure 1-12.—Compressor rotors.** A. Drum type. B. Disk type.

engines with the split case, either the upper or lower case can be removed, allowing the engine to remain in place for maintenance and inspection.

The compressor case is usually made of aluminum or steel. The material used will depend on the engine manufacturer, the weight requirements of the engine, and the accessories attached to the case. The compressor case may have external connections made as part of the case. These connections are normally used as bleed air ports to aid in the prevention of stalls during starting and acceleration or at low-speed operation.



A. BULB TYPE



B. FIR-TREE TYPE

Figure 1-13.—Rotor blades.

The two main types of axial compressor rotors are the drum type and the disk type.

**Drum Type.**—The drum-type rotor (fig. 1-12, view A) consists of rings that are flanged to fit one against the other. The entire assembly may then be held together by through bolts (often called tie bolts). The drum is one diameter over its full length. The blades and stators vary in their radial length from the front to the rear of the assembly. The compressor case tapers accordingly. This type of construction is satisfactory for low-speed compressors where centrifugal stresses are low.

**Disk Type.**—The disk-type rotor (fig. 1-12, view B) consists of a series of disks of increasing diameter which are machined from forgings and shrunk fit over a steel shaft. Another method of rotor construction is to machine the disks and shaft from a single aluminum forging and bolt steel stub shafts on the front and rear of the assembly. The stub shafts provide bearing support surfaces and splines for joining the turbine shaft. The blades decrease in length from entry to discharge. This is due to a progressive reduction in the annular working space (drum to casing) toward the rear. The working space decreases because the rotor disk diameter increases. The disk-type rotors are used almost exclusively in all present-day, high-speed engines.

**COMPRESSOR BLADING.**—Each stage of an axial compressor has a set of rotor and stator blades. Stator blades may also be referred to as vanes. The construction of these blades is important to efficient operation of a GTE.

**Rotor Blades.**—The rotor blades are usually made of aluminum, titanium, or stainless or semistainless steel. Methods of attaching the blades in the rotor disk rims vary. They are commonly fitted into the disks by either the bulb or the fir-tree type of roots (fig. 1-13, views A and B). The blades are then locked with grub-screws, lockwires, pins, or keys.

Compressor blade tips are reduced by cutouts, which are referred to as blade profiles. Some manufacturers use a ring (usually called a shroud) that acts as a spacer for the stators. The shroud can also act as a wear surface when the blade tips come into contact with the ring. This rubbing of blade tips maintains the close tolerances necessary to maintain the efficiency of the compressor and the profiles prevent serious damage to the blade or housing.

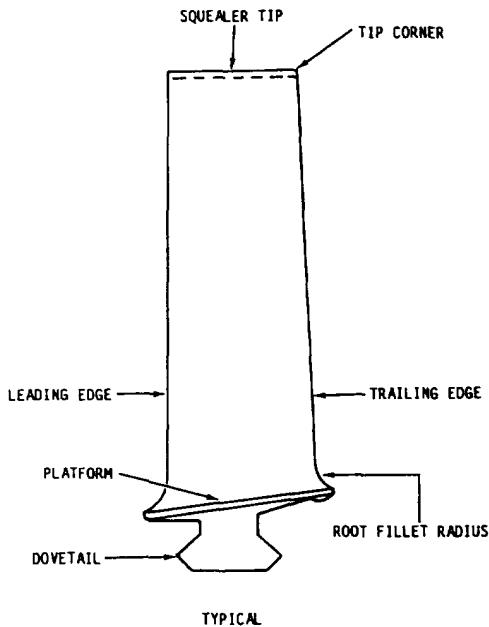


Figure 1-14.—Blade with squealer tip.

Another method of maintaining minimum clearance is to metal-spray the case and stators. Thin squealer tips on the blades and vanes (fig. 1-14) contact the sprayed material. The abrasive action of the blade tip cuts into the sprayed material, thus obtaining minimum clearance.

The primary causes of rubbing are an excessively loose blade or a malfunction of a compressor support bearing. This causes the compressor rotor to drop.

Large compressors have loose-fitting blades on the first several stages. These move during acceleration to minimize vibration while passing through critical speed ranges. Once up to speed, centrifugal force locks the blades in place and little or no movement occurs. Movement of the blades also occurs during rundown. On a clean engine some of the blades may have as much as 1/4-inch radial movement, which can cause a tinkling sound during rundown.

Large compressor rotors have long blades on the first stage. They have a wing tip on the blade faces called a midspan platform (fig. 1-15). The platform gives some radial support to the blades during acceleration. This midpoint support is needed because of the length and amount of movement of the blades.

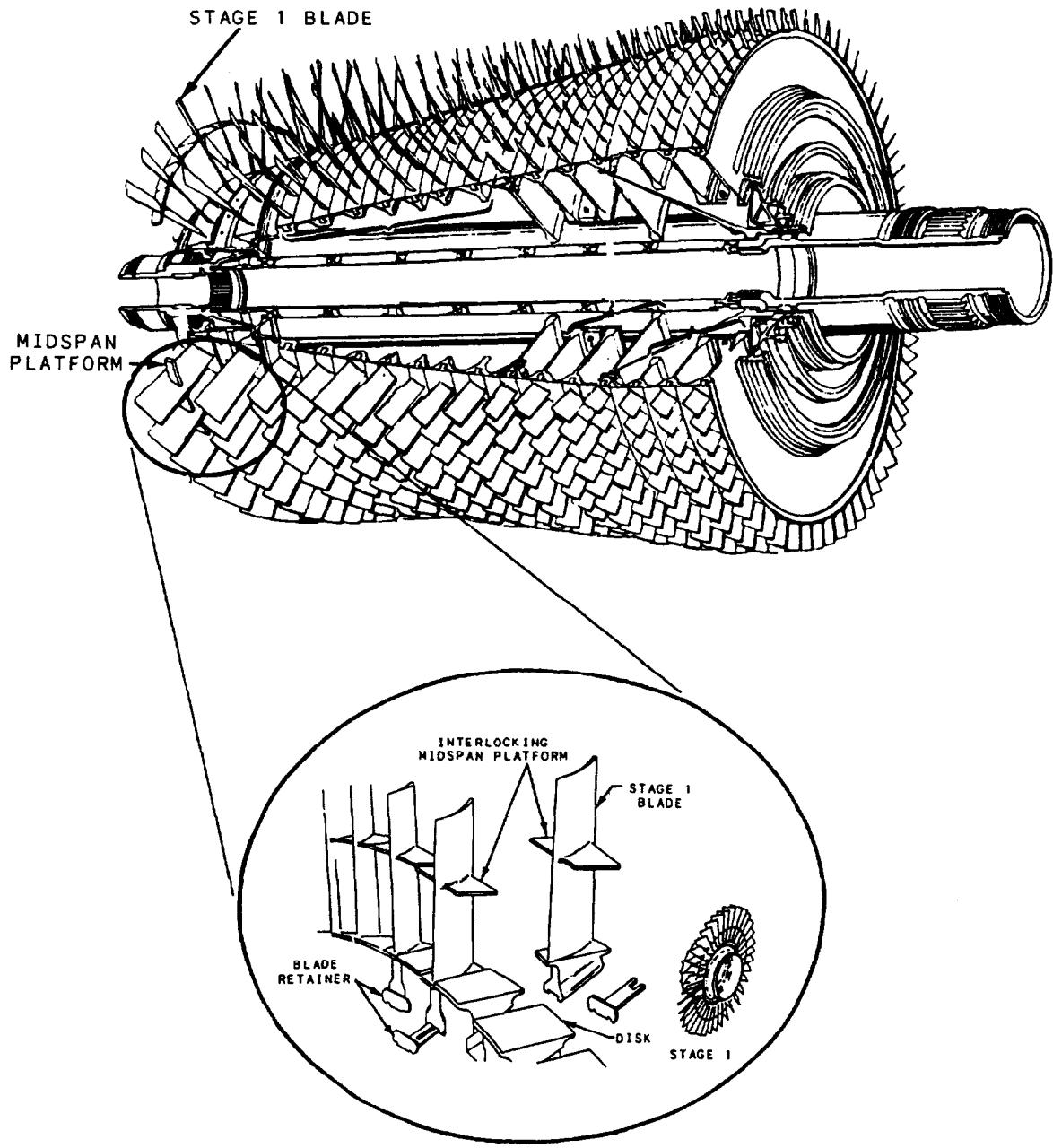
**Stators.**—The stator vanes project radially toward the rotor axis and fit closely on either side of each stage of the rotor. The function of the stators is twofold: (1) they receive air from the air inlet duct or from each preceding stage of the rotor and deliver the air to the next stage or to combustors at a workable velocity and pressure; (2) they control the direction of air to each rotor stage to obtain the maximum compressor blade efficiency. The stator vanes are made of alloys with corrosion- and erosion-resistant qualities. Frequently, the vanes are shrouded by a band of suitable material to simplify the fastening problem. The outer shrouds are secured to the inner wall of the compressor case by radial retaining screws.

Some manufacturers machine a slot in the outer shrouds and run a long, thin key the length of the compressor case. The key is held in place by retaining screws to prevent the stators from turning within the case. This method is used when a one-piece compressor case is slid over the compressor and stator assembly.

Each pair of vanes in a stator acts as a diffuser. They use the divergent principle: the outlet of the vane area is larger than the inlet. In this diverging area, the high-velocity, LP air from the preceding rotor stage is converted to a low-velocity, HP airflow and directed at the proper angle to the next rotor stage. The next rotor stage will restore the air velocity that was lost because of the pressure rise. The next stator will give a further pressure rise. This process continues for each stage in the compressor.

A pressure rise of about 1.2 times the preceding stage is about as much as a single stage can handle. Higher pressure rises result in higher diffusion rates with excessive turning angles. This causes excessive air instability and low efficiency.

Preceding the first stage compressor blades is a row of vanes known as inlet guide vanes (IGVs). The function of the IGVs varies somewhat, depending on the size of the engine and the air-inlet construction. On smaller engines the air inlet is not totally in line with the first stage of the rotor. The IGVs straighten the airflow and direct it to the first-stage rotor. On large engines the IGVs are variable and move with the variable stators. The variable IGVs on large engines direct the airflow at the proper angle to reduce drag on the first-stage

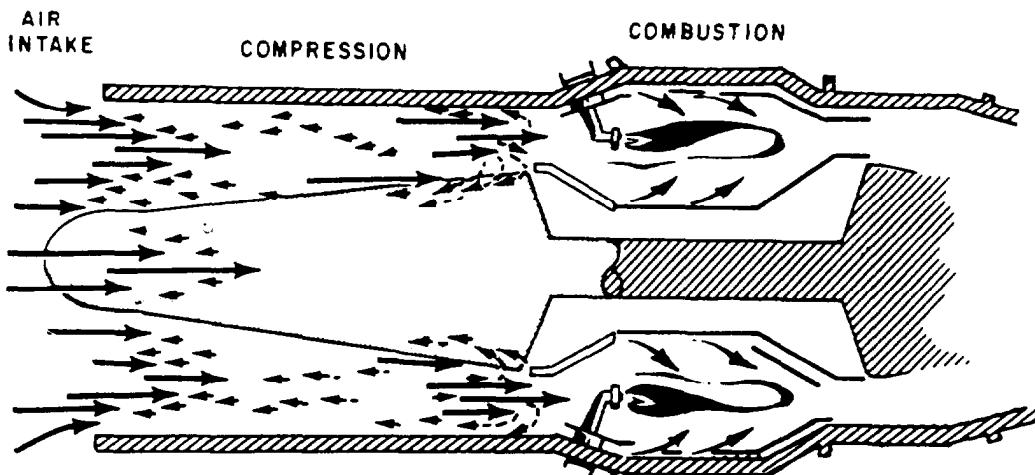


**Figure 1-15.—Large engine compressor rotor with midspan platforms.**

rotor. Variable IGVs achieve the same purposes as variable stator vanes (VSVs).

Some GTEs have moveable, or variable, stators. The position of the variable stators is determined by compressor inlet temperature (CIT) and engine power requirements. They are moved by mechanical linkages that are connected to, and controlled by, the fuel-control governor. Variable stators have two purposes. First, they are

positioned at various angles, depending on compressor speed, to ensure the proper angle of attack of the air in the compressor blades. Varying the stator angle helps to maintain maximum compressor efficiency over the operating speed range of the engine. This is important in variable-speed engines, such as those used for main propulsion. Second, the variable stators on large engines greatly reduce incidences of



**Figure 1-16.—Compressor surge.**

compressor surge. Surge (fig. 1-16) results when the airflow stalls across the compressor blades; that is, air is not smoothly compressed into the combustion and turbine section. Stalling may occur over a few blades or a section of some stages. If enough flow is interrupted, pressure may surge back through the compressor. This occurrence can be minor or very severe with damage to the turbine resulting. If severe disturbance occurs, all the air in the combustor may be used for combustion instead of only the primary air. This would result in a lack of cooling air (secondary) that may cause extreme temperatures which burn the combustor and turbine section. We will discuss primary and secondary air systems later in this chapter.

By a change in the angle of the stators and use of bleed valves, smooth airflow through the compressor is ensured.

Constant-speed engines, such as those used to drive generators, normally do not use variable stators. They are designed to operate at 100 percent rpm all the time. Proper fuel scheduling and use of bleed air valves are used to reduce the probability of compressor surge in these engines.

## CLASSIFICATION BY COMBUSTION CHAMBER DESIGN

The combustion chamber is the component in which the fuel-air mixture is burned. The

combustion chamber consists of a casing, a perforated inner shell, a fuel nozzle, and a device for initial ignition (igniter). The number of combustion chambers used in a GTE varies widely; as few as one and as many as 16 combustion chambers have been used in one GTE. The combustion chamber is the most efficient component of a GTE. The three types of combustion chambers are the (1) can, (2) annular, and (3) can-annular. The can-type chamber is used primarily on engines that have a centrifugal compressor. The annular and can-annular types are used on axial-flow compressors.

### Can Chamber

The can-type combustion chamber has individual liners and cases mounted around the axis of the engine. Each chamber (fig. 1-17) contains a fuel nozzle. This arrangement makes removing a chamber easy, but it is a bulky arrangement and makes a structurally weak engine. The outer casing is welded to a ring that directs the gases into the turbine nozzle. Each of the casings is linked to the others with a short tube. This arrangement ensures that combustion occurs in all the burners during engine start. Inside each of these tubes is a flame tube that joins an adjacent inner liner.

### Annular Chamber

The annular-type combustion chamber is probably one of the most popular combustion

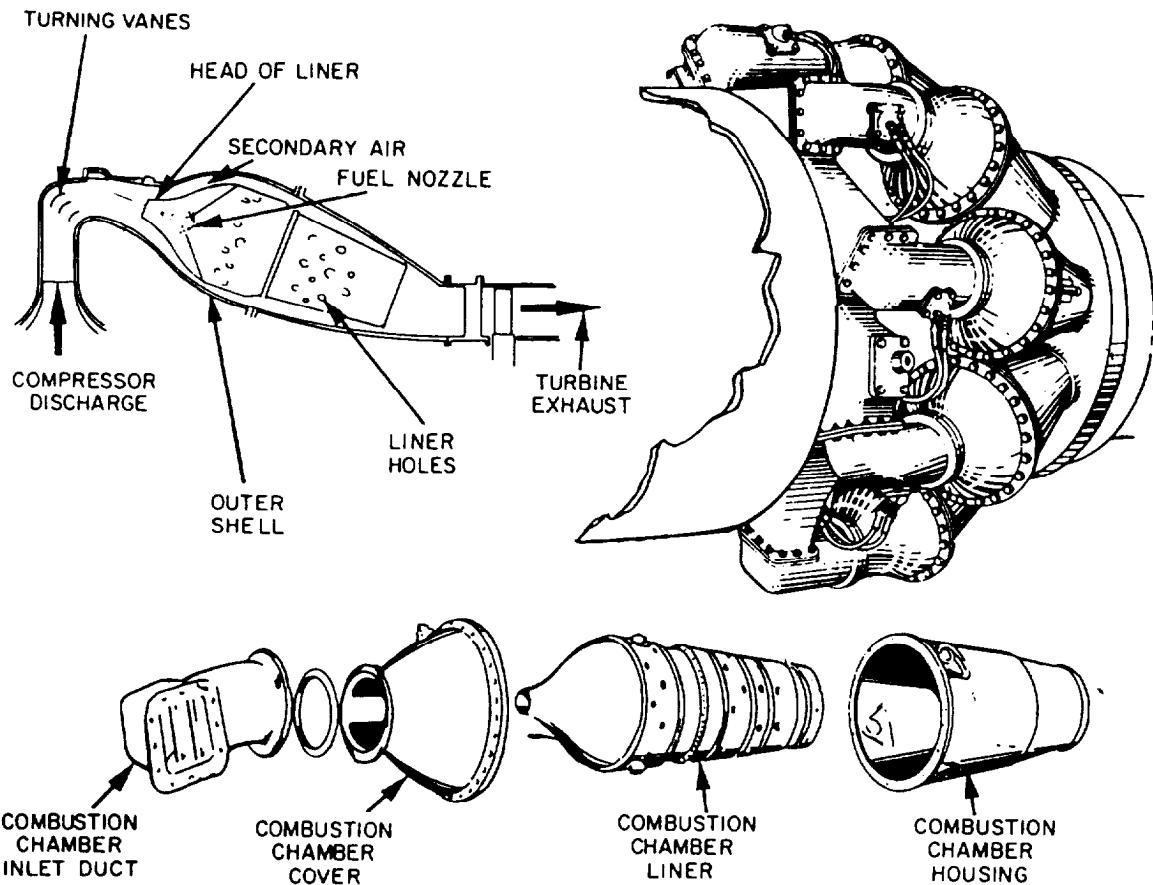


Figure 1-17.—Can-type combustion chamber.

systems in use. The construction consists of a housing and liner the same as the can type (fig. 1-18).

The difference between the two is in the liner. On large engines, the liner consists of an undivided circular shroud extending all the way around the outside of the turbine shaft housing. A large one-piece combustor case covers the liner and is attached at the turbine section and diffuser section.

The dome of the liner has small slots and holes to admit primary air. They also impart a swirling motion for better atomization of fuel. There are holes in the dome for the fuel nozzles to extend through into the combustion area. The inner and outer liners form the combustion space. The outer liner keeps flame from contacting the combustor case. The inner liner prevents flame from contacting the turbine shaft housing.

Figure 1-18.—Annular-type combustion chamber.

## Can-Annular Chamber

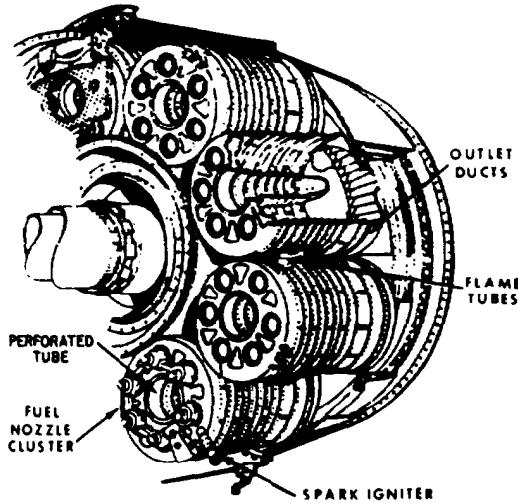


Figure 1-19.—Can-annular type of combustion chamber.

Large holes and slots are located along the liners. They (1) admit some cooling air into the combustion space to help cool the hot gases to a safe level, (2) center the flame, and (3) admit the balance of air for combustion.

The annular-type combustion chamber is a very efficient system that minimizes bulk and can be used most effectively in limited space. There are some disadvantages. On some engines, the liners are one piece and cannot be removed without engine disassembly. Also, engines that use a one-piece combustor dome must be disassembled to remove the dome.

The can-annular type of combustion chamber combines some of the features of both the can and the annular burners. The can-annular type of chamber design is a result of the split-spool compressor concept. Problems were encountered with a long shaft and with one shaft within the other. Because of these problems, a chamber was designed to perform all the necessary functions.

In the can-annular type of chamber, individual cans are placed inside an annular case. The cans are essentially individual combustion chambers (fig. 1-19) with concentric rings of perforated holes to admit air for cooling. On some models each can has a round perforated tube that runs down the middle of the can. The tube carries additional air, which enters the can through the perforations to provide more air for combustion and cooling. The effect is to permit more burning per inch of can length than could otherwise be done.

Fuel nozzle arrangement varies from one nozzle in each can to several nozzles around the perimeter of each can. The cans have an inherent resistance to buckling because of their small diameter. Each can has two holes that are opposite each other near the forward end of the can. One hole has a collar called a flame tube. When the cans are assembled in the annular case, these holes and their collars form open tubes. The tubes are between adjacent cans so a flame passes from one can to the next during engine starting.

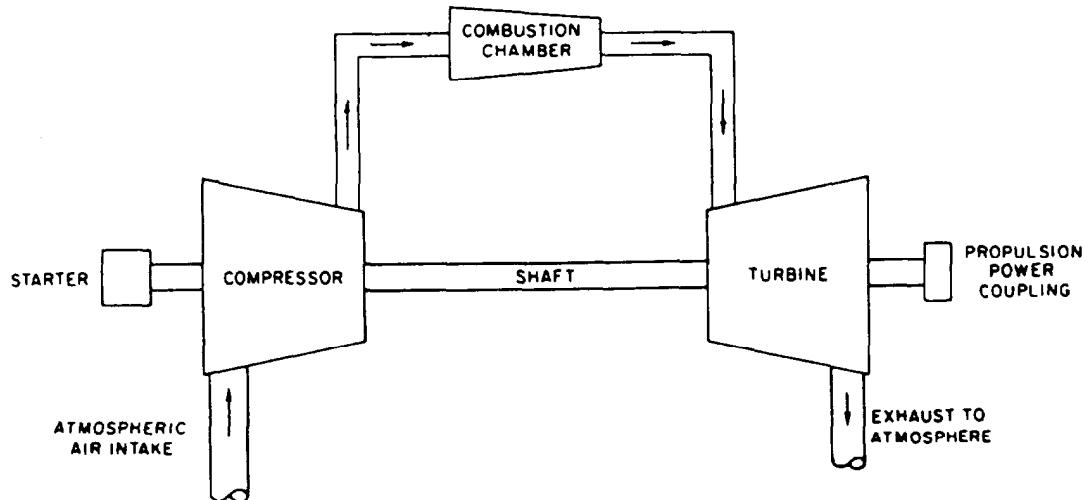


Figure 1-20.—Single-shaft engine.

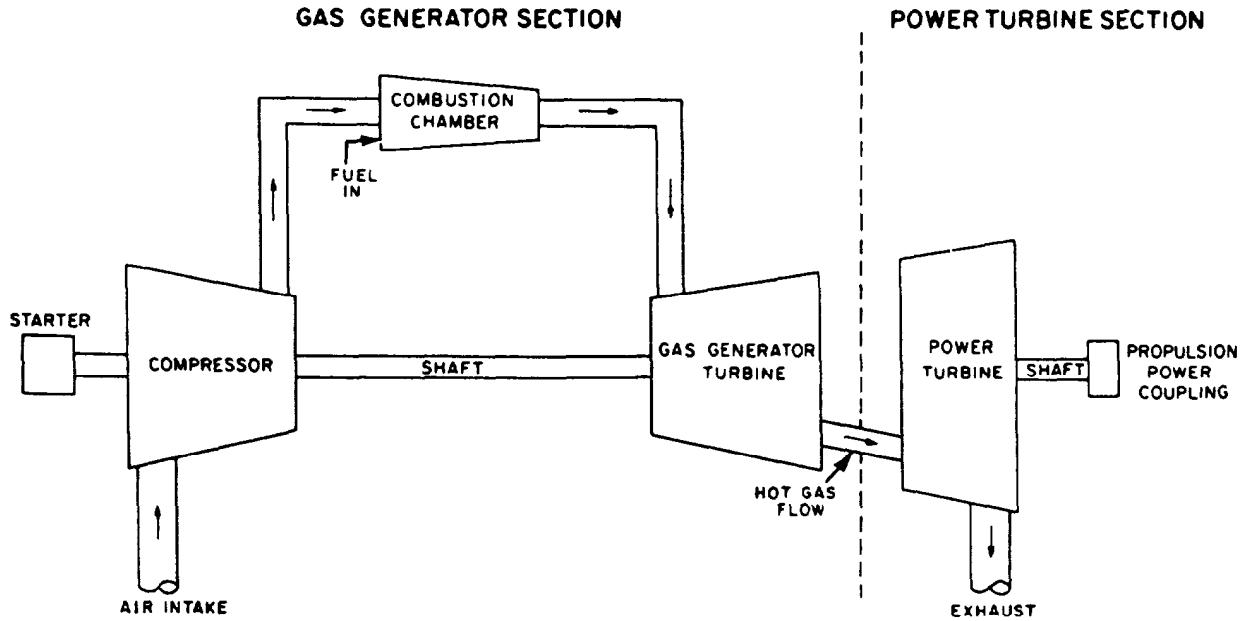


Figure 1-21.—Split-shaft engine.

The short length of the can-annular type of chamber provides minimal pressure drop of the gases between the compressor outlet and the flame area. The relatively cool air in the annular outer can reduces the high temperatures of the inner cans. This air blanket keeps the outer shell of the combustion section cooler. Maintenance on the burners is simple. You can remove and inspect any number of burners just by sliding the case back.

### CLASSIFICATION BY TYPE OF SHAFTING

Several types of GTE shafts are used. These are single shaft, split shaft, and twin spool. Of these, the single shaft and split shaft are the most common in use in naval vessels. The twin-spool-shaft is currently used for marine military application only on the U.S. Coast Guard *Hamilton* class cutters, which use the Pratt-Whitney FT-4 twin-spool GTE.

In current U.S. Navy service, the single-shaft engine is used primarily for driving ship's service generators. The split-shaft engine is used for main propulsion, as a variety of speed ranges is encountered.

Figure 1-20 is a block diagram of a single-shaft GTE. In the engine shown, the power output shaft

is connected directly to the same turbine rotor that drives the compressor. Usually, a speed reducer or reduction gear is located between the rotor and the power output shaft. A mechanical connection still exists throughout the engine.

In the split-shaft engine (fig. 1-21), no mechanical connection exists between the GG turbine and the PT. In this type of engine, the output speed is varied by variation of the generator speed. Also, under certain conditions, the GG can run at a reduced rpm and still provide maximum PT rpm. The reduced rpm greatly improves fuel economy and also extends the life of the GG turbine. The starting torque required is lowered because the PT, reduction gears, and output shaft are stationary until the GG reaches approximate idle speed. Another feature of the multishaft marine propulsion plant is the GG rotates only one way. One design (clockwise rotation or counterclockwise rotation) of the GG can be used on either shaft and still allow the PT to rotate either way. This is done by changing the PT wheel and nozzles. The arrangement shown in figure 1-21 is typical for propulsion GTEs aboard today's ships.

The twin-spool type of GTE is sometimes referred to as a multistage GTE. It has two separate compressors and two separate turbine

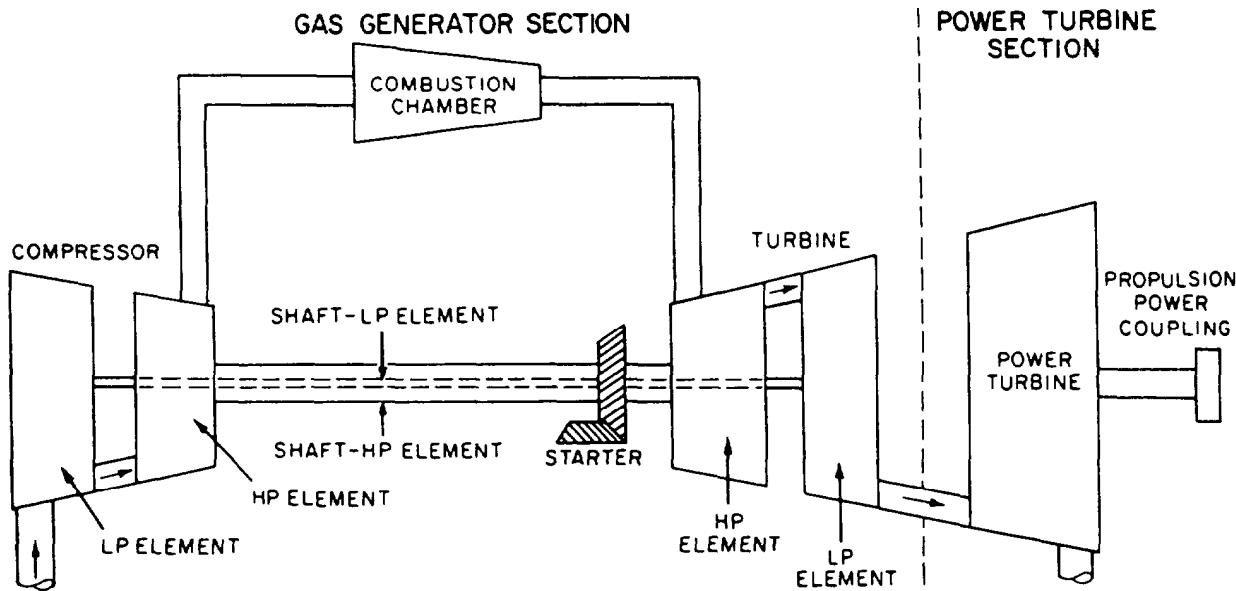


Figure 1-22.—Twin-spool engine.

rotors. They are referred to as LP compressor and turbine rotor and HP compressor and turbine rotor (fig. 1-22). The LP compressor and turbine are connected by a shaft. The shaft runs through the hollow shaft that connects the HP turbine to the HP compressor. The starter drives the HP assembly during engine start. The PT functions the same as in the split-shaft engine. A larger volume of air can be handled as compared to a single- or split-shaft engine. The increase in overall dimensions and complexity makes the engine less desirable for ship's propulsion than the split-shaft engine, as this type of engine has more moving parts.

### TURBINE ASSEMBLIES

The GTEs are not normally classified by turbine type. However, we will discuss turbines now so you will have knowledge of their construction before we describe the General Electric LM2500 GTE in the next chapter.

In theory, design, and operating characteristics, the turbines used in GTEs are similar to those used in steam plants. The GTE differs from the steam turbine chiefly in (1) the type of blading material used, (2) the means provided for cooling the turbine shaft bearings, and (3) the lower ratio of blade length to wheel diameter.

The designations GG and PT are used to differentiate between the turbines. The GG

turbine powers the GG and accessories. The PT powers the ship's propeller through the reduction gear and shafting. Refer to figures 1-21 and 1-22 as we discuss these turbines.

### Gas Generator Turbine

The turbine that drives the compressor of a GTE is located aft of the combustion chamber outlet. The turbine consists of two basic elements, the stator or nozzle, and the rotor. A cutaway view of a stator element is shown in figure 1-23; a rotor element is shown in figure 1-24.

**TURBINE STATORS.**—The stator element of the turbine section is known by a variety of names. The most common are turbine nozzle vanes and turbine guide vanes. In this text, turbine stators are usually referred to as nozzles. The turbine nozzle vanes are located directly aft of the combustion chambers and immediately forward of, and between, the turbine wheels.

Turbine nozzles have a twofold function. First, the nozzles prepare the mass flow for harnessing of power through the turbine rotor. This occurs after the combustion chamber has introduced the heat energy into the mass airflow and delivered it evenly to the nozzles. The stationary vanes of the turbine nozzles are contoured and set at a certain angle. The spaces between the vanes form several small nozzles that discharge the gas as extremely high-speed jets. The

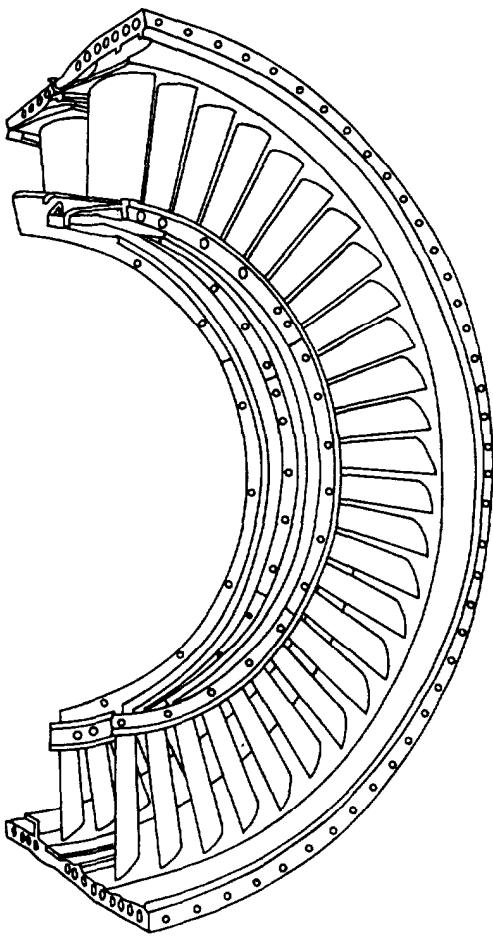


Figure 1-23.—Cutaway view of a turbine stator.

nozzle converts a varying portion of the heat and pressure energy to velocity energy. The velocity energy can then be converted to mechanical energy through the rotor blades.

The turbine nozzle functions to deflect the gases to a specific angle in the direction of turbine wheel rotation. The gas flow from the nozzle must enter the turbine blade passageway while it is still rotating, making it essential to aim the gas in the general direction of turbine rotation.

The turbine nozzle assembly has an inner shroud and an outer shroud between which are fixed the nozzle vanes. The number of vanes varies with different types and sizes of engines. Figure 1-25 shows typical turbine nozzle assemblies.

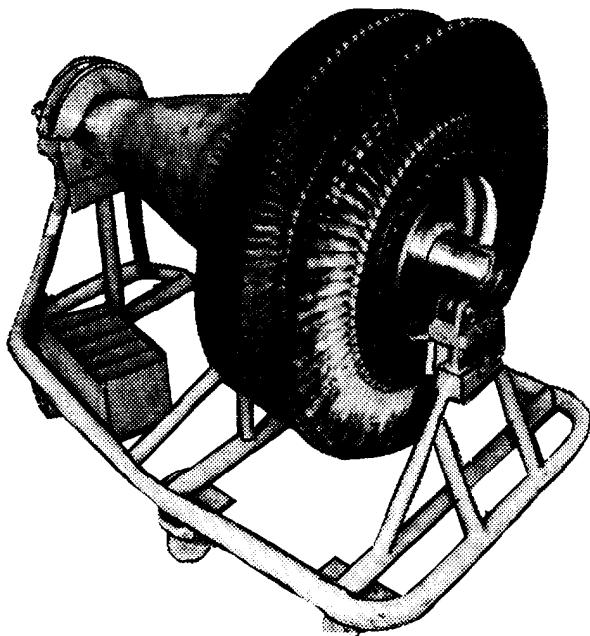


Figure 1-24.—Turbine rotor elements.

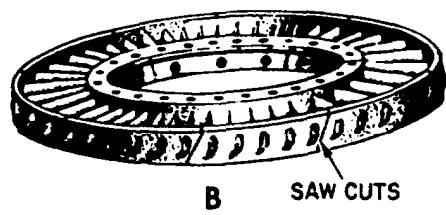
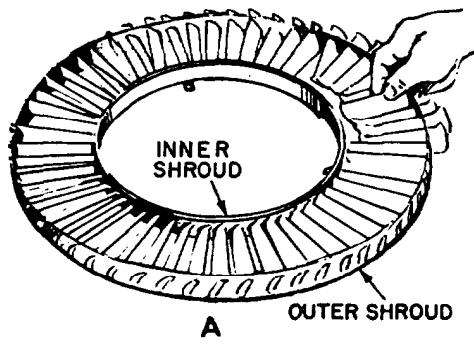


Figure 1-25.—Turbine nozzle assemblies. A. Loose-fitting vanes. B. Welded vanes.

All turbine nozzles must be constructed to allow for thermal expansion, because rapid temperature variances could cause distortion or warping of the metal components. Thermal expansion of turbine nozzles is allowed by one of several construction methods.

In one method the vanes are assembled loosely in the supporting inner and outer shrouds (fig. 1-25, view A). Each of the vanes fits into a contoured slot in the shrouds. The slots conform with the airfoil shape of the vanes. These slots are slightly larger than the vane to give a loose fit. For further support the inner and outer shrouds are encased by an inner and an outer support ring. This adds strength and rigidity to the turbine nozzle. These supports also permit removal of the nozzle vanes as a unit; otherwise, the vanes could fall out of the shrouds as the shrouds are removed.

Another method to allow for thermal expansion is to fit the vanes into inner and outer shrouds. In this method the vanes are welded or riveted into position (fig. 1-25, view B). Either the inner or the outer shroud ring is cut into segments to provide for thermal expansion. The saw cuts dividing the segments will allow enough expansion to prevent stress and warping of the vanes.

The basic types of construction of nozzles are the same for all types of turbines. The turbine nozzles are made of high-strength steel to withstand the direct impact of the hot, HP, high-velocity gases from the combustor. The nozzle vanes must also resist erosion from the high-velocity gases passing over them.

If the inlet gas temperature could be increased by about 750°F, almost a 100 percent increase in specific horsepower could be achieved. Nozzles can not stand up for long to these higher temperatures. Many different methods of increasing nozzle endurance have been tried over the years. One method that was tried was to coat the nozzle with ceramic. Higher temperatures were achieved, but the different expansion rates of the steel and the ceramic caused the coating to break away after several hours of operation. Experiments are still being conducted, even so far as to use an entirely ceramic nozzle.

Another means of withstanding high temperatures is to use newly developed alloys. However, the extreme costs of the alloys prohibit commercial production of such nozzles. Still another method, in wide use today in large engines, is to use air-cooled nozzle vanes. Compressor bleed air is fed through passages to the turbine, where it

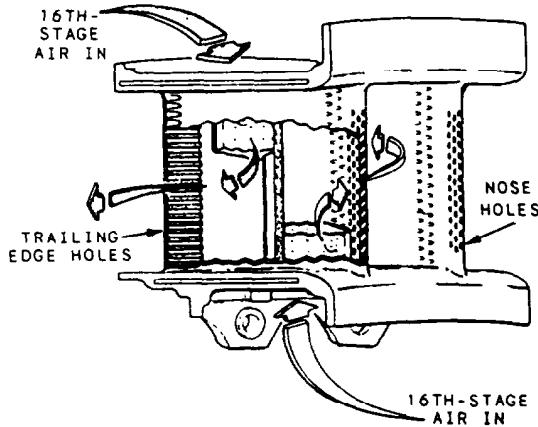


Figure 1-26.—First-stage GG turbine nozzle cooling.

is directed to the nozzle. The air cools both the turbine (discussed later) and the nozzle. The nozzle may also be cooled by air admitted from the outer perimeter of the nozzle ring. The method of getting the air in is determined by the manufacturer.

The nozzle vanes are made with many small holes or slots on the leading and trailing edges (fig. 1-26). Air is forced into the nozzle and out through the slots and holes. The vane is cooled as the air passes through. The air is discharged into the hot gas stream, passing through the remainder of the turbine section and out the exhaust duct.

Figure 1-27 shows temperature comparisons of a nornair-cooled vane and an air-cooled vane. Cooling air is used primarily in the HP turbine section and not in the LP section. By the time the gases reach the LP turbine section, the temperature of the gases is at an acceptable level. In the LP turbine section, metals in current use will last for a long time.

**TURBINE ROTORS.**—The rotor element of the turbine consists of a shaft and bladed wheel(s). The wheel(s) is attached to the main power transmitting shaft of the GTE. The jets of combustion gas leaving the vanes of the stator element act upon the turbine blades, making them rotate. The turbine wheel can rotate in a speed range of about 3,600 to 42,000 rpm. These high rotational speeds impose severe centrifugal loads on the turbine wheel. At the same time, the high temperatures (1050° to 2300°F) result in a lowering of the strength of the material. The engine speed and temperature must be controlled to keep turbine operation within safe limits.

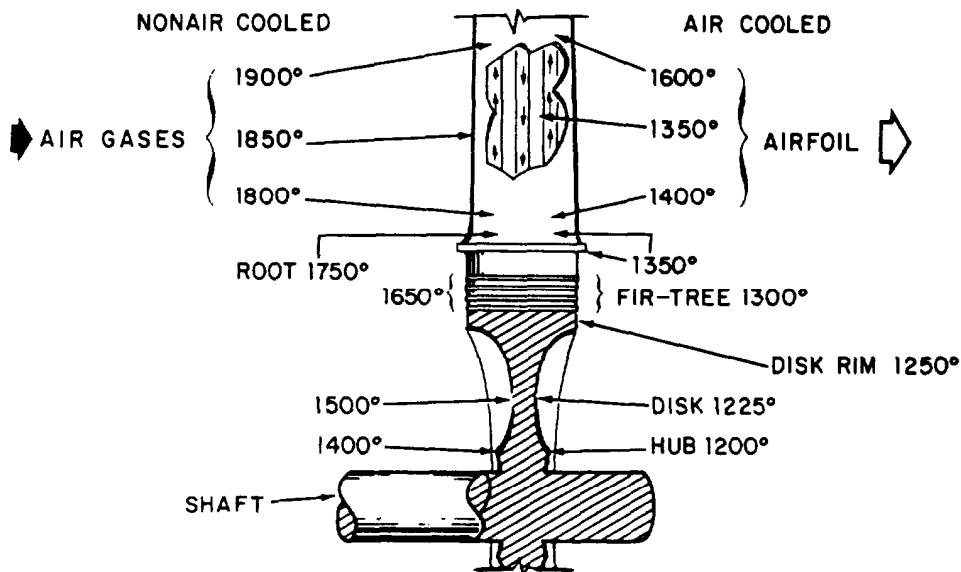


Figure 1-27.—Cooling comparisons between a nonair-cooled vane and an air-cooled vane.

The turbine wheel is a dynamically balanced unit consisting of blades attached to a rotating disk. The disk in turn is attached to the rotor shaft of the engine. When in an unbladed form, we refer to this section of the unit as the turbine disk. The portion of the unit consisting of the turbine blades is called the turbine wheel. The disk acts as an anchoring component for the turbine blades. This enables the blades to transmit to the rotor shaft the energy they extract from the exhaust gases.

The disk rim is exposed to the hot gases passing through the blades and absorbs considerable heat from these gases. In addition, because the rim also absorbs heat from the turbine blades by conduction, the disk rim temperatures are higher than the temperatures of the remote inner portion of the disk. As a result of these temperature gradients, thermal stresses are added to the stresses caused by rotation.

Various means are provided to relieve these stresses. One way is to incorporate an auxiliary fan, which is usually rotor-shaft driven, somewhere ahead of the disk. This will force cooling air back into the face of the disk. Another method of relieving the thermal stresses of the disk is by the method of blade installation. By notching the disk rims to conform with the blade root design, the disk is made able to retain the turbine blades. This space provided by the notches allows for thermal expansion of the disk.

The turbine shaft is usually made from low-alloy steel. It must be capable of absorbing high torque loads, such as exerted when a heavy axial-flow compressor is started. The methods of connecting the shaft to the turbine disk vary. One method used is welding. The shaft is welded to the disk, which has a butt or protrusion provided for the joint. Another method is by bolting. This method requires that the shaft have a hub that matches a machined surface on the disk face. The bolts then are inserted through holes in the shaft hub. They are anchored in tapped holes in the disk. Of the two methods, the latter is more common.

The turbine shaft must have some means for joining the compressor rotor hub. This is usually accomplished by a splined cut on the forward end of the shaft. The spline fits into a coupling device between the compressor and the turbine shafts. If a coupling is not used, the splined end of the turbine shaft fits into a splined recess in the compressor rotor hub. The centrifugal compressor engines use the splined coupling arrangement almost exclusively. Axial compressor engines may use either of these methods.

Various ways of attaching turbine blades are in use today. Some ways are similar to the way compressor blades are attached. The most satisfactory method used is the fir-tree design

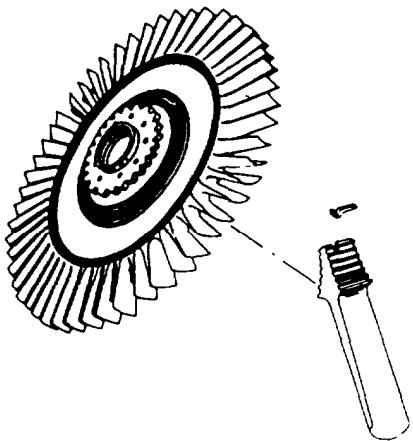


Figure 1-28.—Turbine blade with fir-tree design and tab lock method of blade retention.

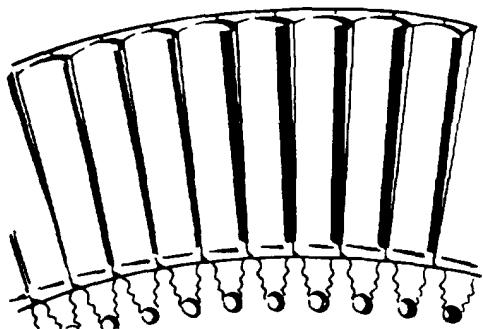


Figure 1-29.—Riveting method of turbine blade retention.

shown in figure 1-28. The blades are retained in their respective grooves by a variety of methods. Some of the more common methods are pinning, locking tabs, riveting, and retaining rings. Figure 1-29 shows a typical turbine wheel using riveting for blade retention.

Turbine blades may be either forged or cast, depending on the metal they are made of. Turbine blades are usually machined from individual forgings. Various materials are used in the forging. Speed and operating temperatures are important factors in deciding what materials go into the turbine blades.

Large engines use an air-cooled blading arrangement on the GG turbine (fig. 1-30). Compressor discharge air is constantly fed through passages along the forward turbine shaft between a spacer and the shaft. A thermal shield directs the cooling air along the face of the disk to cool the disk. The shield is between the first- and second-stage turbine wheels. The air is then directed through slots in the fir-tree portion of the disk, into slots in the blade fir-tree. The air then goes up through holes in the blades to cool the blades (fig. 1-31).

Cooling of the turbine wheel and blades reduces thermal stresses on the rotating members. The turbine nozzles are also air-cooled. By cooling the stationary and rotating parts of the turbine section, higher turbine inlet temperatures are permissible. The higher temperatures allow for more power, a more efficient engine, and longer engine life.

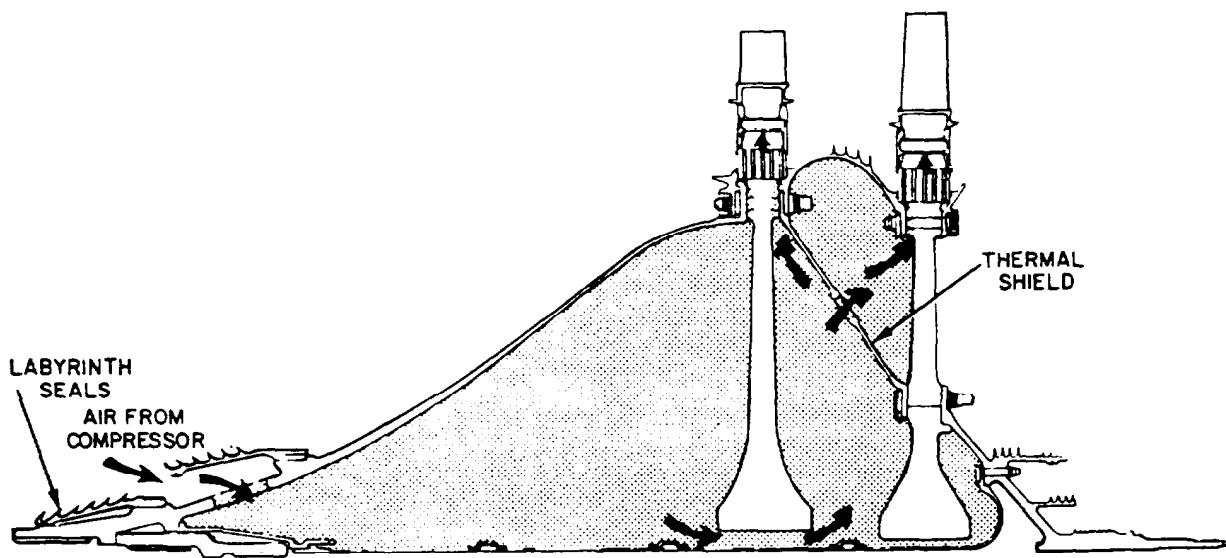


Figure 1-30.—GG turbine rotor cooling airflow.

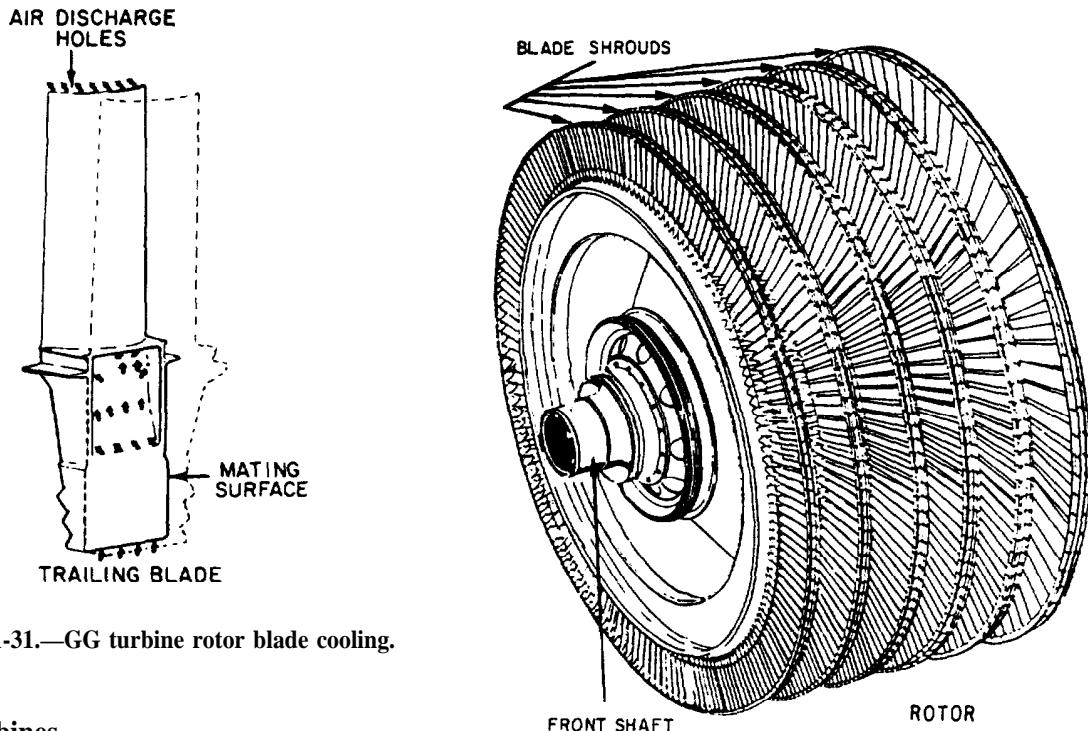


Figure 1-31.—GG turbine rotor blade cooling.

## Power Turbines

The PT (fig. 1-32) is a multistage turbine located behind the GG turbine. The two turbines have no mechanical connection between them. The PT is connected to a reduction gear through a clutch mechanism. Either a controllable reversible pitch (CRP) propeller or a reverse gear is used to change the direction of the ship.

Power turbines are used to extract the remaining energy from the hot combustion gases. They extract this energy in the following three ways, depending upon engine application:

1. The aircraft power turbine is designed so the turbine extracts only enough energy from the gases to run the compressor and accessories.

2. In the solid-wheel turbine (used primarily in small GTEs), as much energy as possible is extracted from the gases to turn the turbine. The turbine provides power for the compressor, accessories, and the airplane propeller or the ship's generator. These engines are designed to run at 100 percent specified rpm all the time. The location of the mechanical connection between the turbine wheel and the reduction gear on the compressor front shaft depends on the design of the installation. Normally, a ship's service generator cannot be disconnected from its GTE except by disassembly. This setup is used for generators to prevent slippage between the engine and the generator.

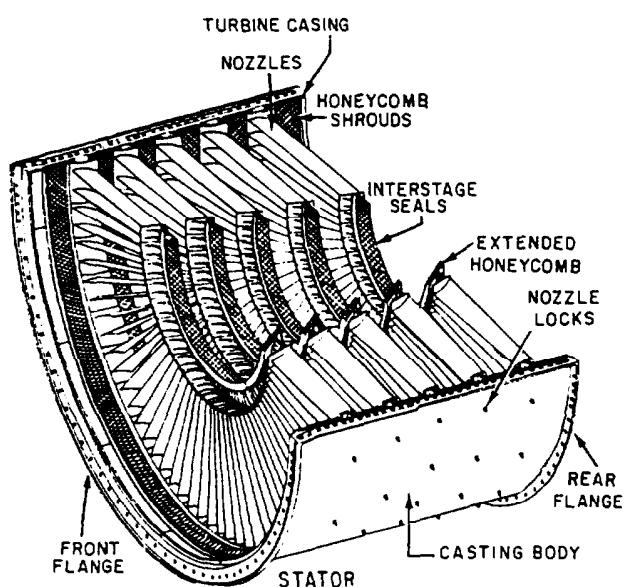


Figure 1-32.—Typical power turbine.

3. Marine propulsion engines use a combination of the previously mentioned two turbine types. The GG has a single- or multiple-stage HP rotor that drives the compressor and accessories and an LP turbine to transmit power to the ship's propeller via the reduction gear and shafting.

Some ships that have two sets of engines use counterrotating PTs. For example, PTs on one main propeller shaft rotate clockwise while the PTs on the other shaft rotate counterclockwise. The GG rotates in the same direction for both sets of engines. The blade angle of the wheel and the nozzles in the PT section determine the directional rotation of the PT. On large ships where different length propeller shafts are permitted, the engine(s) can be mounted to the other end of the reduction gear. This allows for counterrotation of the propellers without changing PT rotation.

You can control the output speed of the PT by varying the GG speed. Since only a portion of the energy is used to drive the compressor, the plant can be operated very efficiently. For example, on a cold day you can have 100 percent power turbine rpm with 80 to 90 percent gas generator rpm. The operating temperature variables discussed earlier in this chapter account for this situation.

The PT is constructed much like the GG turbine. The main differences are (1) the absence of vane and blade cooling air and (2) interlocking shroud tips on the PT blades to reduce vibration. Honeycomb shrouds in the turbine case mate with the blade shrouds to provide a gas seal. They also protect the case from the high-temperature gas. Two popular methods of blade retention are the bulb and the dovetail. These methods were discussed earlier in this chapter.

## MAIN BEARINGS

The main bearings have the critical function of supporting the main engine rotor. For the most part, the number of bearings necessary for proper engine support is decided by the length and weight of the engine rotor. The length and weight are directly affected by the type of compressor used in the engine. Naturally a split-spool axial compressor will require more support than a simple centrifugal compressor engine. The minimum number of bearings required will be three, while some of the later models of split-spool axial compressor engines will require six or more.

While some engines use sleeve bearings, the GTE rotors are usually supported by either ball or roller bearings. In general, ball or roller antifriction bearings are preferred for the following reasons:

- They offer little rotational resistance.
- They facilitate precision alignment of rotating elements.

- They are relatively inexpensive.
- They may be easily replaced.
- They can withstand high momentary overloads.
- They are simple to cool, lubricate, and maintain.
- They can accommodate both radial and axial loads.
- They are relatively resistant to elevated temperatures.

The main disadvantages of ball or roller antifriction bearings are their vulnerability to foreign matter damage and their tendency to fail without appreciable warning.

Usually the bearings are positioned on the compressor or turbine shaft to absorb any axial (thrust) loads or radial loads. The ball bearings are designed to absorb the thrust loads, and the roller bearings are used to support the radial loads because they present a larger working surface.

The elements of a typical ball or roller bearing assembly include a bearing support housing, which must be strongly constructed and supported to carry the radial and axial loads of the rapidly rotating rotor. The bearing housing usually contains oil seals to prevent the oil from leaking from its normal path of flow. The housing also delivers lube oil to the bearing, usually through spray nozzles.

On modern engines, the bearing is mounted in a sump. The bearing sump has a line through which the lube oil is scavenged back to the sump. The bearing sump is also vented to prevent either a pressure or vacuum. The vent goes either to the atmosphere or to an air-oil separator.

## GAS TURBINE ENGINE AUXILIARY SYSTEMS

Up to this point, we have pointed out the physical features and functions of a typical GTE. In this section we will point out the basics of the required auxiliary systems being used on most GTEs of today's Navy. The systems are not discussed in any order of importance. We will give you a broad overview of the systems, which include the air systems, the fuel oil system, the accessory drive system, the lubrication system, the starting systems, and the spark igniter system.

## AIR SYSTEMS

Air is used for many different functions on the GTE. The terms *primary airflow* and *secondary airflow* designate the major systems. Figure 1-33 (At the end of this chapter) shows the LM2500 GTE airflow. See page 1-34 for an overall view and pages 1-35 through 1-37 for details. Although the following discussion on air systems is generic, we are using the LM2500 system discussed in chapter 2 as our example. For a better understanding of primary airflow and secondary airflow, use this figure in conjunction with the following discussion. You should also use this figure when studying the bleed air system in chapter 2 of this manual.

### Primary Airflow

The GG compressor draws air from the ship's inlet plenum. After being compressed, the primary air enters the combustion section, where some of it is mixed with fuel, and the mixture is burned. The remainder of the primary air is used for centering the flame in the combustor and cooling some parts of the GG turbine. The primary air becomes part of the hot combustion gases. Some of the energy in the hot combustion gas is used to turn the GG turbine rotor, which is coupled to, and turns, the compressor rotor. Upon leaving the GG turbine section, the gas

passes into the PT section. Most of the remaining energy is extracted by the PT rotor, which drives the high-speed, flexible-coupling shaft. The shaft provides the power for the ship's drive system. The gas exits from the PT through the turbine rear frame and passes into the exhaust duct and out through the ship's exhaust.

### Secondary Airflow

Secondary air is the source of bearing pressure seal air and bleed air for cooling. Bleed air has numerous other uses. We will not attempt to describe them all because each type of engine has its own peculiarities.

Secondary air is taken from the compressor ahead of the combustion stage. Secondary air is bled from various pressure stages on the compressor due to different pressure requirements at different points in the engine. Occasionally it is bled from the combustor outer case. The air is fed internally through passages to bearing cavities and seals, and it also cools the GG turbine and nozzles. On some engines the air is piped externally to seals where shafts extend outside a housing, such as a reduction gear.

Seal air is used in the GTE air seals, which are of two types: labyrinth/honeycomb, used in the sump and turbine areas, and fishmouth, used in the combustor and turbine midframe (fig. 1-34).

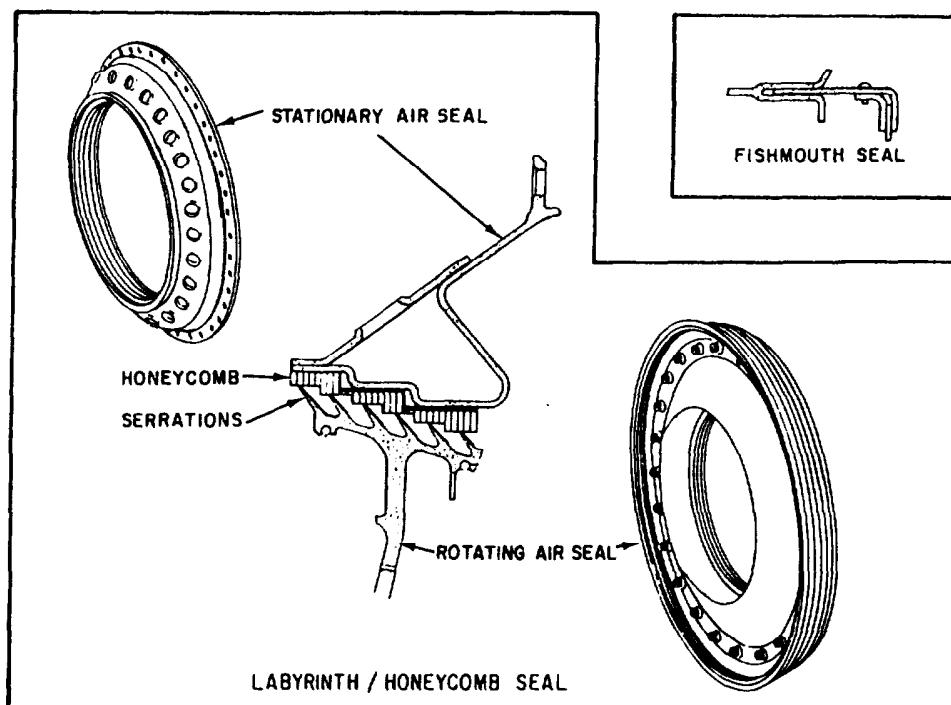


Figure 1-34.—Typical air seals.

The labyrinth/honeycomb seal combines a rotating seal having a serrated surface with a stationary seal having a honeycomb surface. The serrations cut into the honeycomb to maintain close tolerances over a large temperature range. The fishmouth seals are sheet metal, circular, stationary, interlocking seals used to prevent excessive leakage of hot combustion gas from the primary airflow.

## FUEL OIL SYSTEM

The fuel oil system has a number of functions. Primarily, it provides filtered, pressurized, and accurately metered fuel for combustion. While doing this, it controls the power output of the GG, which in turn determines the amount of power delivered by the engine from the PT. Additionally, the fuel system may provide pressurized fuel as a hydraulic medium to actuate the fuel controls. In some engines it controls the angle of the variable compressor stator vanes.

All fuel systems are not alike, but they all have certain elements in common. For example, they must have a fuel pump, a fuel control, a pressurizing valve or its equivalent, a fuel manifold, and fuel nozzles or vaporizers. The fuel pump capacity is great enough to perform any required hydraulic functions in addition to providing combustion fuel. Excess fuel is bypassed in the fuel control and returned to the LP side of the pump. Pressure in excess of the capability of this bypass is dumped by a relief valve in the pump assembly. The fuel pump and fuel control are usually assembled together and mounted on the gearbox.

## ACCESSORY DRIVE SYSTEM

A popular misconception exists that the GTE has only one moving part because the turbine and the compressor are on the same rotating shaft. This is not true. A GTE requires a starting device (which is usually a moving part), some kind of control mechanism, and power takeoffs to drive other components, such as the lube oil and fuel pumps. The accessory drive section of the GTE takes care of these various accessory functions. The primary function of the accessory drive section is to provide space for the mounting of the accessories required for the operation and control of the engine. The accessory drive section also serves as an oil reservoir and/or sump and houses the accessory drive gears and reduction gears.

The gear train of the accessory drive is driven by the engine rotor through an accessory drive shaft coupling. The reduction gearing within the case provides suitable drive speeds for each engine accessory or component. Because the operating rpm of the rotor is so high, the accessory reduction gear ratios are relatively high. The accessory drives are supported by ball bearings assembled in the mounting bores of the accessory case.

Accessories provided in the accessory drive section include the fuel control, with its governing device; the HP fuel oil pump or pumps; the oil sump; the oil pressure and scavenging pump or pumps; the auxiliary fuel pump; and a starter. Additional accessories, which may be included in the accessory drive section or which may be provided elsewhere, include a starting fuel pump, a hydraulic oil pump, a generator, an air-oil separator, and a tachometer. Most of these accessories are essential for the operation and control of any GTE. The particular combination and arrangement and location of engine-driven accessories depend on the use for which the GTE is designed.

The three common locations for the accessory drive section are on the side of the air inlet housing, under the compressor front frame, or under the compressor rear frame. One manufacturer of a generator engine used by the U.S. Navy had the reduction gear attached to the forward end of the compressor and the accessories mounted to the reduction gear.

## LUBRICATION SYSTEM

The GTE lubrication system is designed to supply bearings and gears with clean lube oil at the desired pressures and temperatures. In some installations, the lubrication system also furnishes oil to various hydraulic systems. Heat absorbed by the lube oil is transferred to the cooling medium in a lube oil cooler.

The lubrication system shown in figure 1-35 is the dry-sump type, with a common oil supply from an externally mounted oil tank. The system includes the oil tank, the lube oil pressure pump, the scavenging pumps, the oil cooler, oil filters, the pressure-regulating valve, and filter and cooler bypass valves.

All bearings and gears in the engine and accessory drives are lubricated and cooled by the lubrication system. The lube oil supplied to each bearing in a GTE is specifically controlled by a calibrated orifice which provides the proper flow

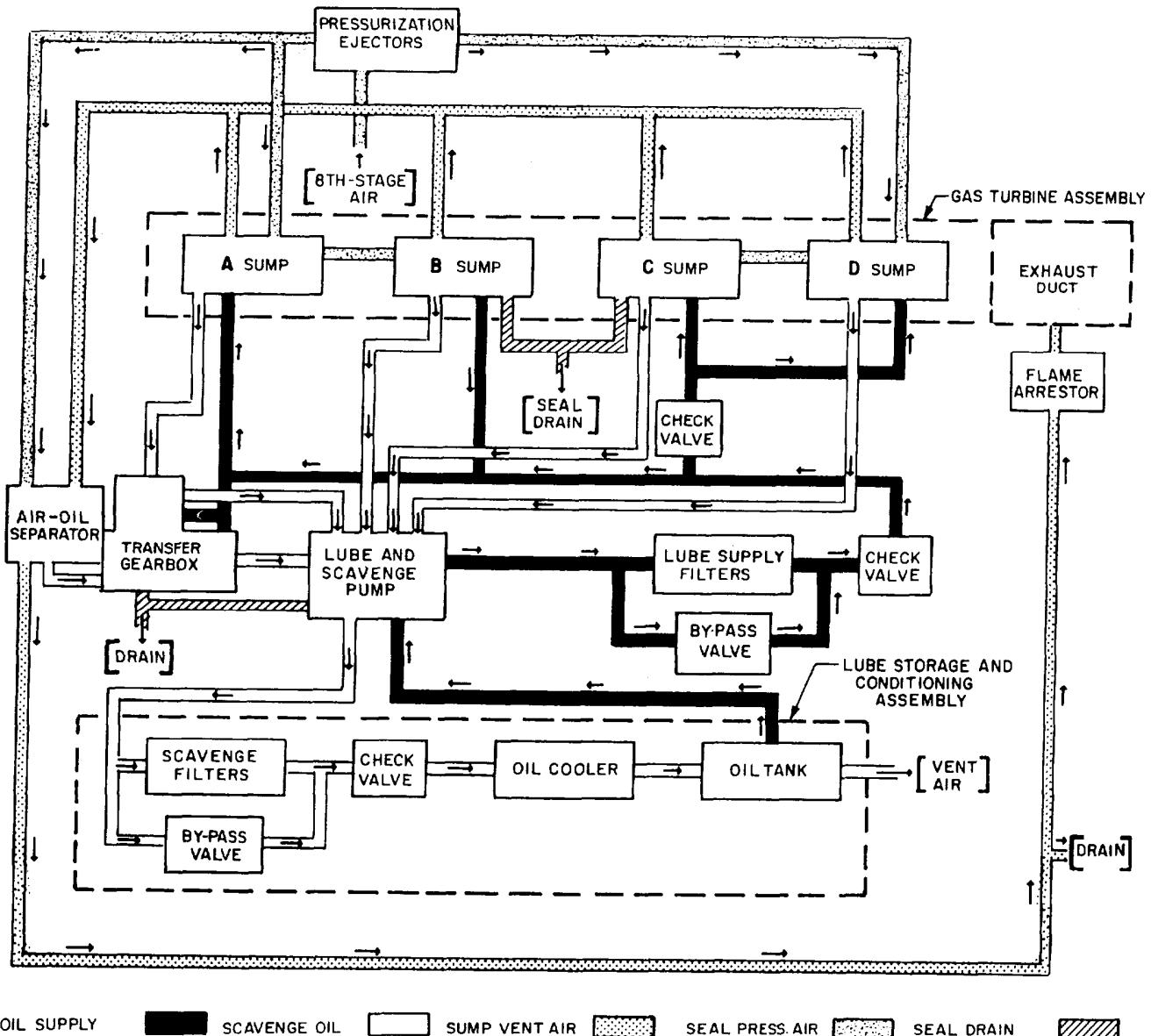


Figure 1-35.—Lubrication system schematic (typical).

of lube oil to the bearing at all engine speeds. This is sometimes known as a calibrated oil system. Since lube oil is supplied to the various parts of the system under pressure, provision is made to prevent the oil from leaking into unwanted areas, such as the compressors and turbines. This is usually accomplished by use of lip-type seals, labyrinth oil seals, or carbon ring pneumatic oil seals. We will discuss these seals in detail later in this section.

The lubrication system provides the GTE bearings, gears, and splines with adequate cool oil to prevent excessive friction and heat. Oil

nozzles direct the oil onto the bearings, the gears, and the splines. Separate scavenge elements in the lube and scavenge pump remove oil from the sumps and the transfer gearbox (accessory drive). The scavenged oil is returned to the lube storage and conditioning assembly where it is filtered, cooled, and stored. Scavenged oil is filtered by a duplex filter mounted on the lube storage tank.

#### Lubrication System Subsystems

The lubrication system is usually divided into three subsystems identified as lube supply, lube

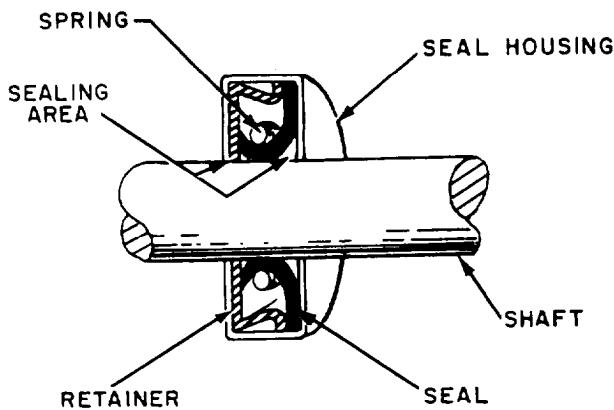


Figure 1-36.—Lip-type seal.

scavenge, and sump vent. We will discuss these subsystems and their components in chapter 2.

### **Oil Seals**

Three types of oil seals are common to the GTEs, the lip-type seal, the labyrinth/windback, and the carbon ring.

**LIP-TYPE SEAL.**—The lip-type seal (fig. 1-36) is used to prevent leakage in one direction only. A metal frame is covered with a synthetic material, usually neoprene. The neoprene is somewhat smaller than the shaft. The elasticity of the neoprene will allow the shaft to slide through the seal. The seal is molded with a lip to retain a spring around the center. The spring keeps a snug fit around the shaft. The construction of the lip-type seal allows for some very slight misalignment and for axial movement of the

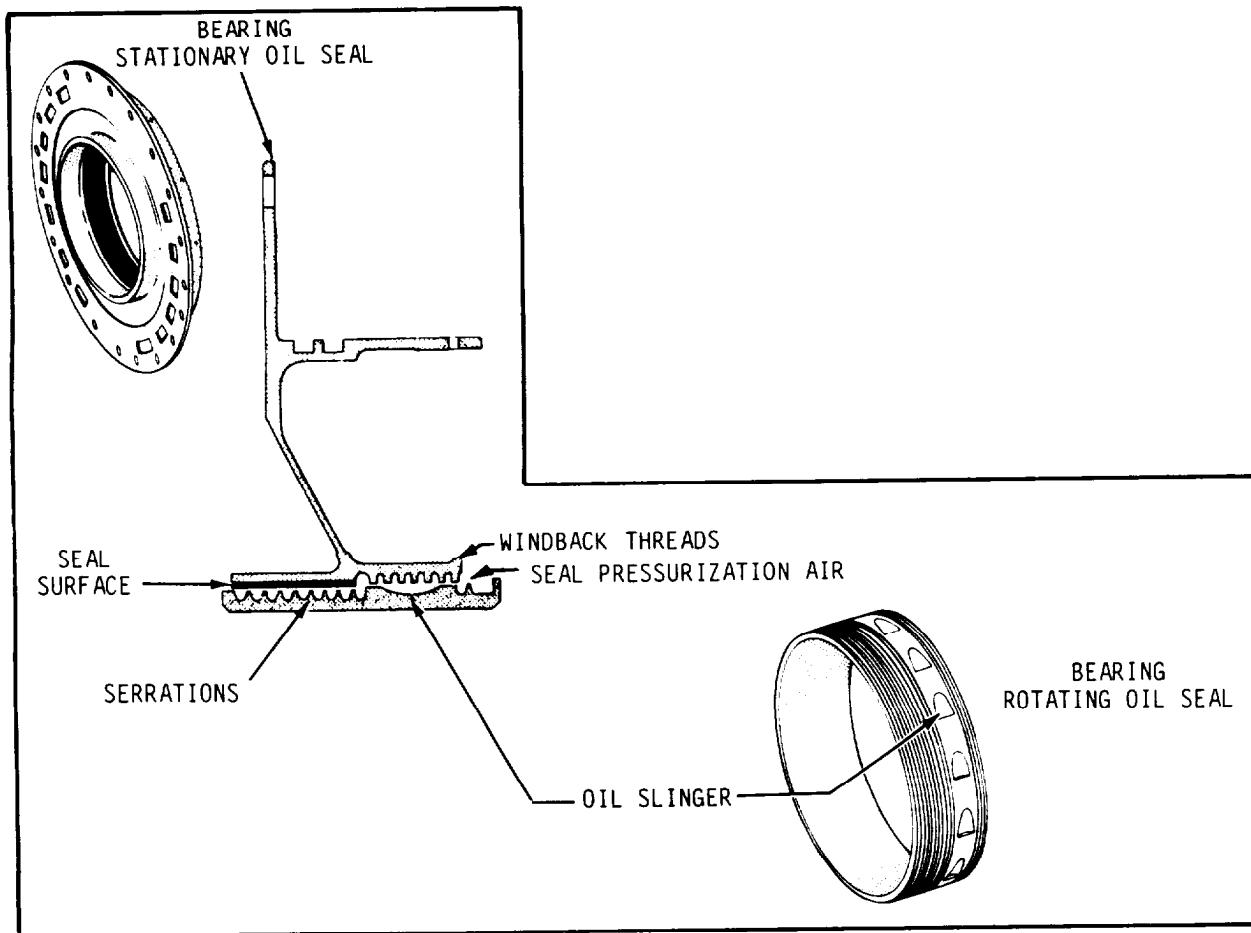


Figure 1-37.—Labyrinth/windback seal.

shaft. The lip seals are used where relatively low speeds and temperatures are encountered.

Two disadvantages of the lip-type seals are that (1) they will seal against only little or no fluid pressure, and (2) they are easily damaged. A burr on the shaft or dirt can tear the seal and cause leakage.

**LABYRINTH/WINDBACK SEAL.**—The labyrinth/windback seals (fig. 1-37) combine a rotating seal having oil slingers and a serrated surface with a stationary seal having windback threads and a smooth rub surface. The oil slingers throw oil into the windback threads, which direct the oil back to the sump area. The serrations cut grooves into the smooth surface of the stationary seal to maintain close tolerances throughout a large temperature range. This seal allows a small amount of seal pressurization air to leak into the sump, thereby preventing oil leakage.

**CARBON RING SEAL.**—The carbon seal (fig. 1-38) has a stationary, spring-loaded, carbon sealing ring and a rotating, highly polished steel mating ring. It prevents oil in the gearbox from leaking past the drive shafts of the starter, fuel pump, and auxiliary drive pad.

Another form of the carbon seal is also in use. The carbon rings are not spring-loaded. They move freely around the shaft and seal axially against the housing. When the engine is up to speed, the rings center themselves radially in the housing. Compressor bleed air is forced between

the carbon rings. The air pressure is forced out along the shaft in both directions. The pressure prevents oil from entering the compressor or turbine and combustion gases from reaching the bearings. The main disadvantage of this seal is minor oil leakage that occurs during start-up and run down as the oil pump moves oil before enough airflow prevents leakage. However, the leakage is so slight that the engine normally will reach its designated overhaul hours of operation before oil accumulation will have any effects.

## STARTING SYSTEMS

The GTEs use a starter to turn the compressor at sufficient speed to initiate and sustain combustion. Both the compressor and the GG turbine must spin. In starting dual axial-flow compressor engines, the starter needs to rotate only the HP compressor. The starter's first requirement is to accelerate the compressor to provide enough airflow and pressure to support combustion in the burners.

Once fuel has been introduced and the engine has fired, the starter must continue to accelerate the compressor above the self-sustaining speed of the engine. The starter must provide enough torque to overcome rotor inertia and the friction and air loads of the engine.

Figure 1-39 shows a typical starting sequence for a GTE. When the starter has accelerated the compressor enough to establish airflow through

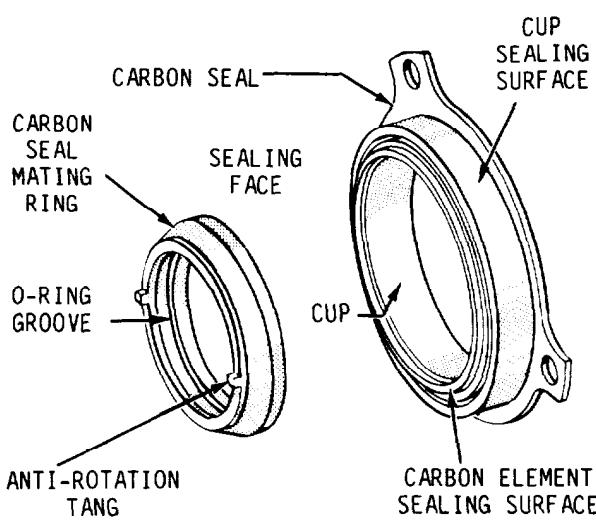


Figure 1-38.—Carbon ring seal.

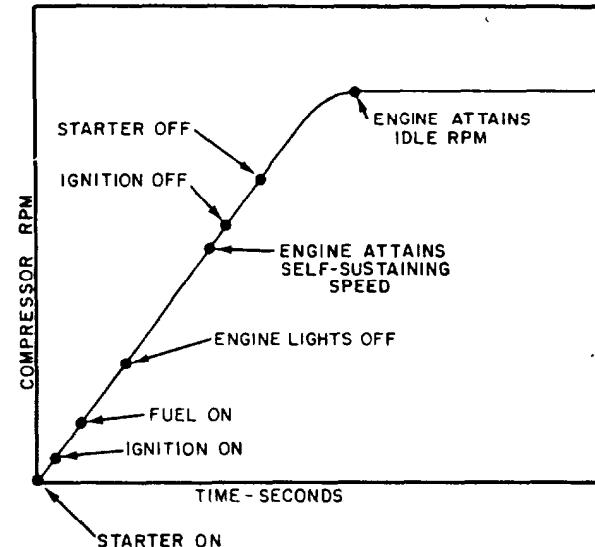


Figure 1-39.—Typical starting sequence for a GTE.

the engine, the ignition is turned on and the fuel valves are opened. The sequence of the starting procedure is important. At the time the fuel/air mixture is ignited, enough airflow must pass through the engine to support combustion.

After the engine has reached its self-sustaining or self-accelerating speed, the starter can be deactivated. If the starter is cut off below the self-sustaining speed, the engine may decelerate because it doesn't have enough energy to overcome its own friction and operating losses. It may also suffer a "hung start" in which it idles at a speed so low that it is unable to accelerate enough to obtain proper operating parameters. A hung-start engine will overheat because of a lack of cooling air. The starter must continue to boost engine speed well above self-sustaining speed to avoid hot or hung (false) starts, or a combination of both. In a hot start, the engine lights off, but because of a lack of adequate cooling and combustion air, the exhaust gas temperature exceeds the allowable limit for the engine.

At the proper points in the starting sequence, the starter and, usually, the ignition system will cut off. The higher the rpm before the starter cuts out, the shorter will be the total time required for the engine to attain idle rpm. This is because the engine and the starter are working together.

All GTE starters must be able to produce enough torque to start the engine properly. The GTEs must reach a certain minimum idle rate for a start to be satisfactory. This requires the torque characteristics of an acceptable starter to exceed by a good margin the amount of torque needed to overcome friction.

The GTEs use three basic types of starters and starter systems—electric, hydraulic, and pneumatic. Pneumatic (air-turbine) starters are the most commonly used on all except smaller engines, which generally use electric starters. Some marine GTE installations use hydraulic starters.

Another type of starter system is the air impingement system. Bleed air from another GTE is used directly in the HP turbine assembly to rotate the GG. Due to the volume of air required, the air impingement system is used primarily in starting aircraft engines and will not be covered in any further detail. We will describe the pneumatic starter system in chapter 2 of this TRAMAN.

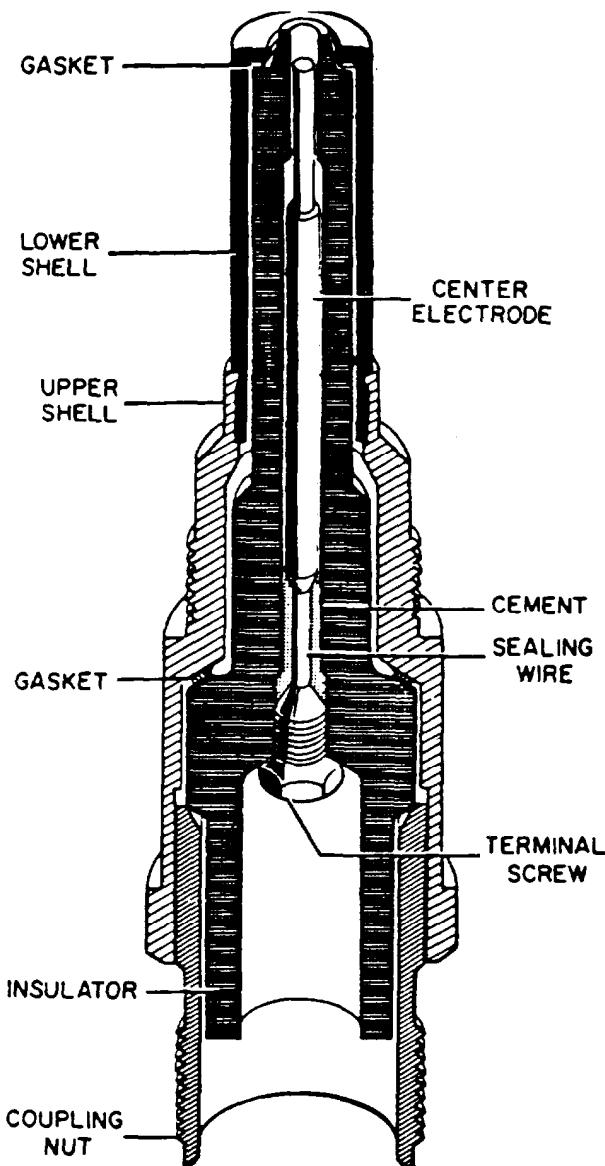


Figure 1-40.—Spark igniter.

## SPARK IGNITER SYSTEM

Once adequate airflow has been established through the combustion area, fuel can be injected and the spark igniters start the burning process. The spark igniters are high-voltage electrical spark producers powered from the ignition exciter circuits.

The ignition exciter derives its input power from the ship's service 60-Hz, 115-volt electrical system. Its function is to produce a high-energy spark at the spark igniter in the engine. This must be accomplished with a high degree of reliability.

under widely varying conditions. These include internal pressure, humidity, temperature, vaporization, and carbon deposits on the spark igniter. To accomplish this, the capacitor discharges a spark of very high energy (about 100,000 watts). This concentration of maximum energy in minimum time achieves an optimum spark for ignition purposes. This spark is capable of blasting carbon deposits and vaporizing globules of fuel.

Spark igniters are of several types. Some resemble common automobile spark plugs. The more common annular gap types are shown in figure 1-40. Since they do not operate continually, they are usually durable and reliable, requiring only occasional cleaning to remove carbon from the tip and ceramic barrel.

## SUMMARY

In this chapter you have learned about the principles and construction of GTEs. We have discussed the evolution of the GTE, the theory of operation, classifications of the different types of engines, and their subsystem components. Many other publications are available that discuss GTE construction in depth. This chapter was provided to give you the basis on which to expand your knowledge of marine GTEs. You may not feel you understand the temperature-pressure relationships in a simple GTE at this point. If so, you should review the sections of this chapter related to theory before continuing on to the material that follows.

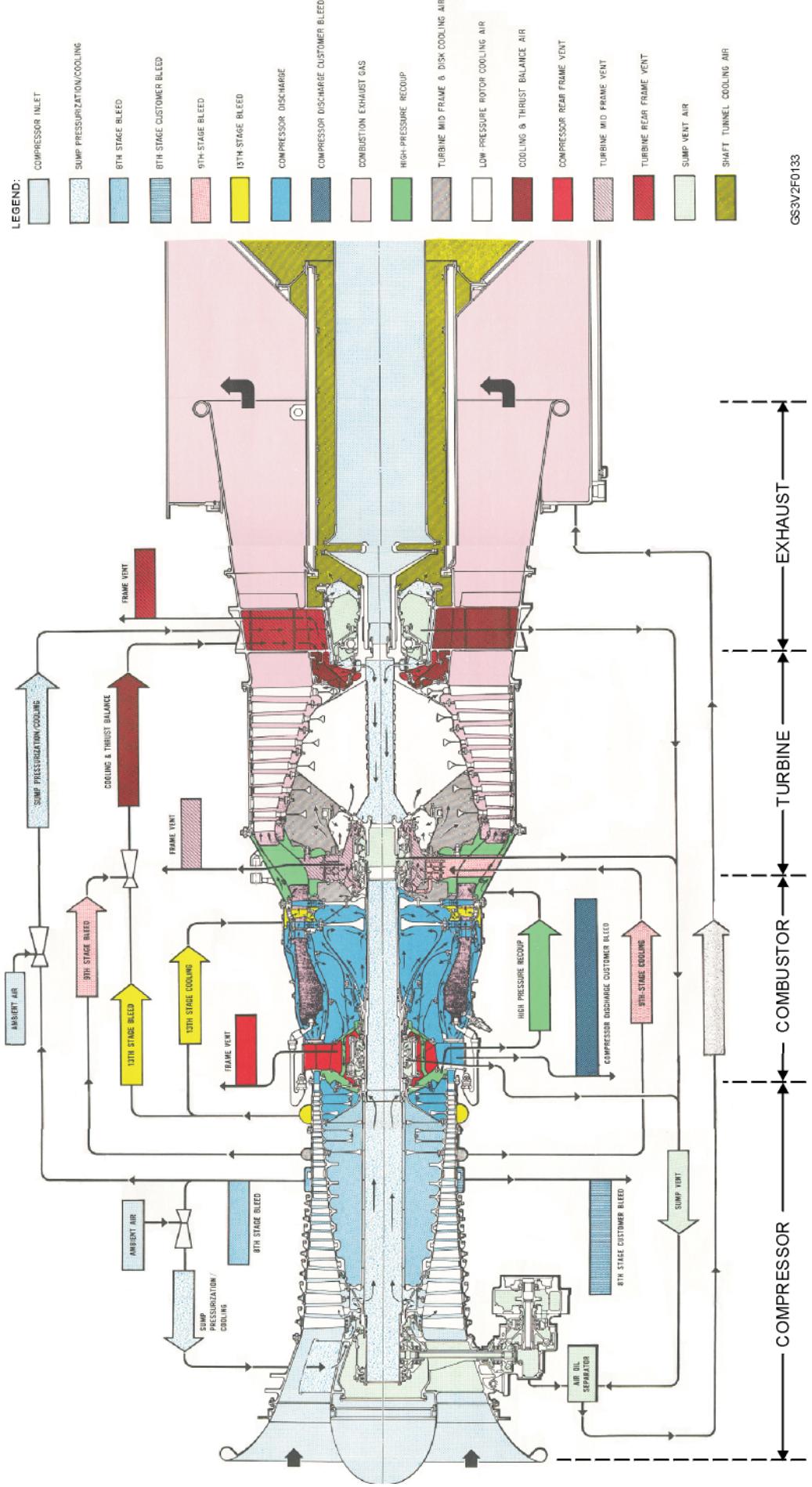


Figure 1-33.—LM2500 GTE airflow

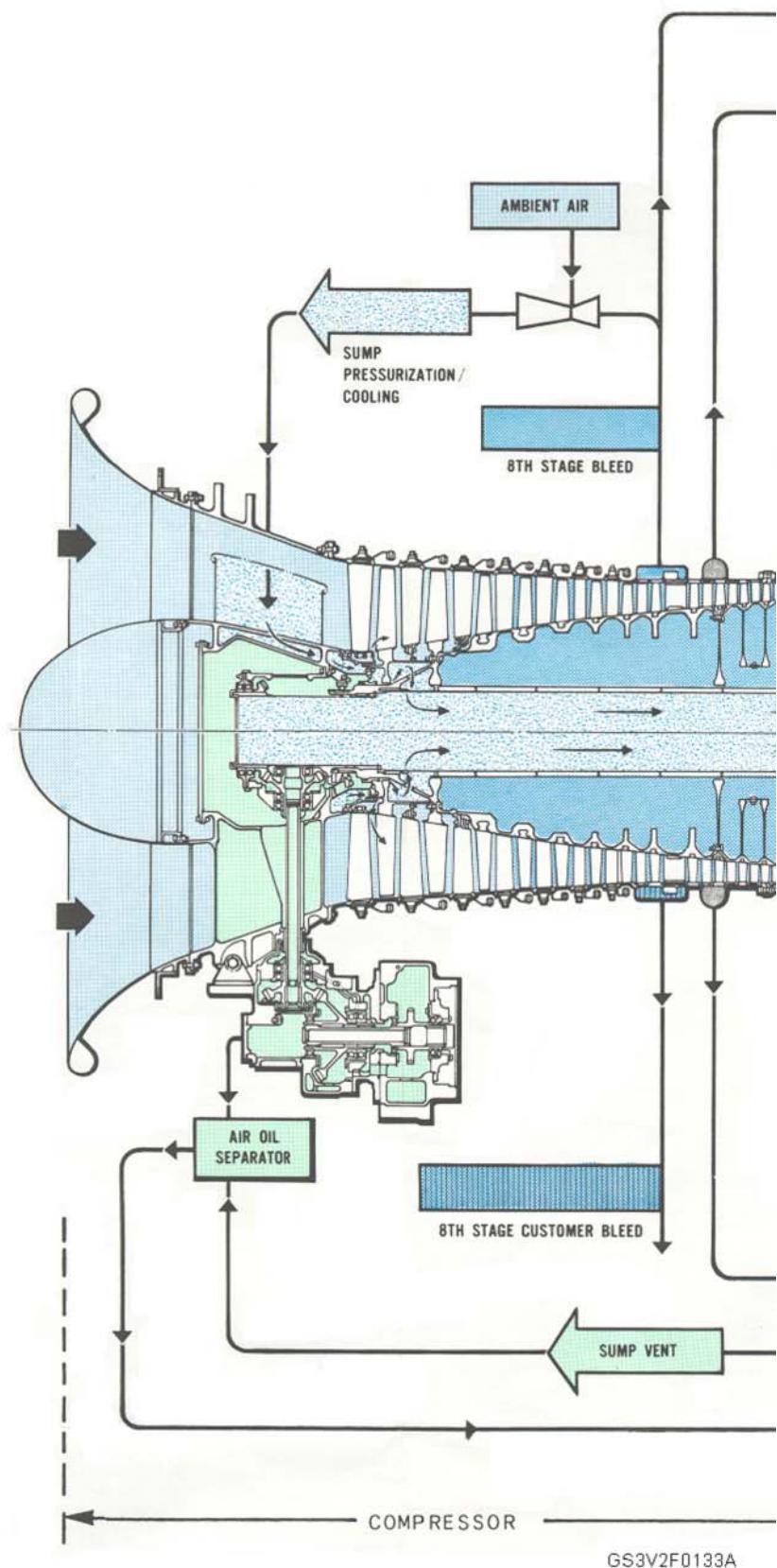


Figure 1-33A.—LM2500 GTE airflow.

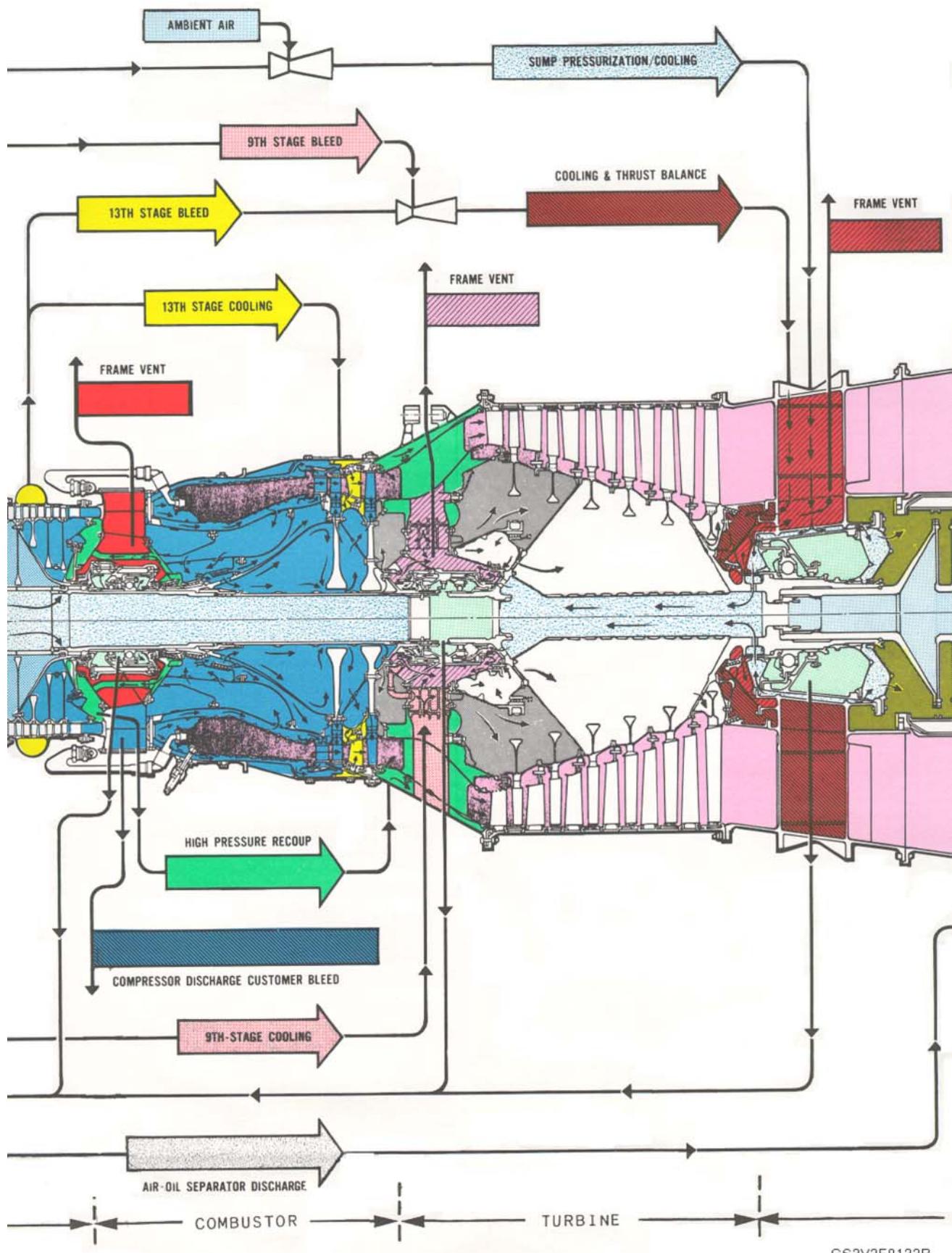


Figure 1-33B.—LM2500 GTE airflow—Continued..

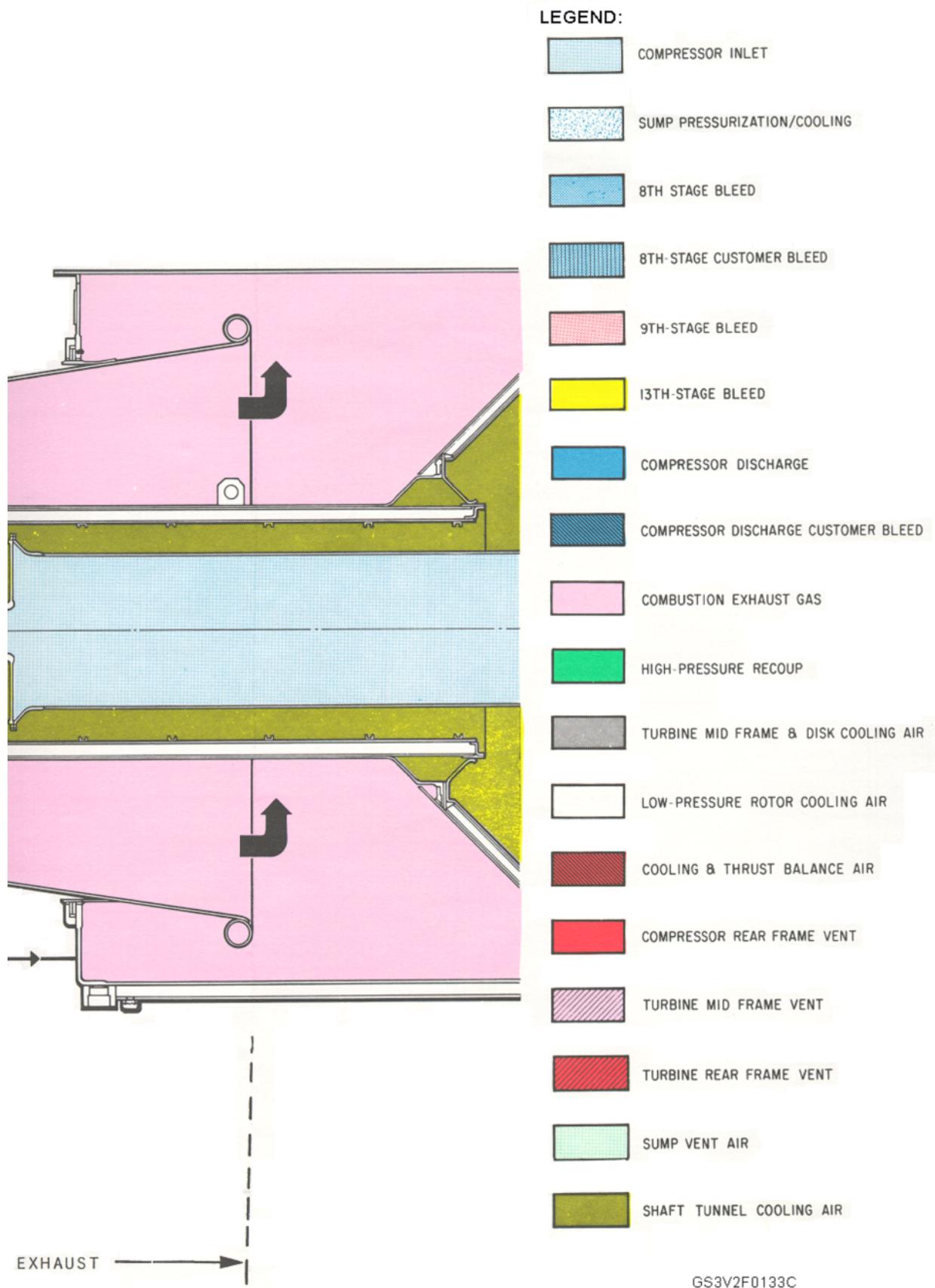


Figure 1-33C.—LM2500 GTE airflow—Continued.



## CHAPTER 2

# LM2500 GAS TURBINE ENGINE

As a gas turbine technician, you need to know the basic construction and function of the main propulsion power plant on your ship. The LM2500 GTE has been selected as the power plant for the CG-, DD-, FFG-, and AOE-6-class ships. The greater your understanding of the construction of the engine, the better you will be able to operate and maintain the engine.

In chapter 1 of this TRAMAN you learned the basic theory of how a GTE operates and the variety of engine types available. In this chapter we will discuss the LM2500 GTE in particular since this engine is the one you will most often work on. We will occasionally point out some similarities between the LM2500 GTE and the

Allison 501-K17 GTE, which is covered in detail in chapter 3 of this TRAMAN.

The LM2500 GTE is manufactured by the General Electric Company and is a marine version of the engine used in a variety of aircraft. It is the main propulsion plant for many gas turbine-powered ships. The engine is rated at approximately 20,000 brake horsepower; it has a power turbine speed ( $N_p$ ) of 3,600 rpm on the CG-, DD-, and FFG-class ships and 3,253 rpm on the ship.

The gas turbine equipment is composed of a base enclosure assembly and a gas turbine assembly. The gas turbine assembly (fig. 2-1) has a GG, a PT, a high-speed flexible coupling shaft,

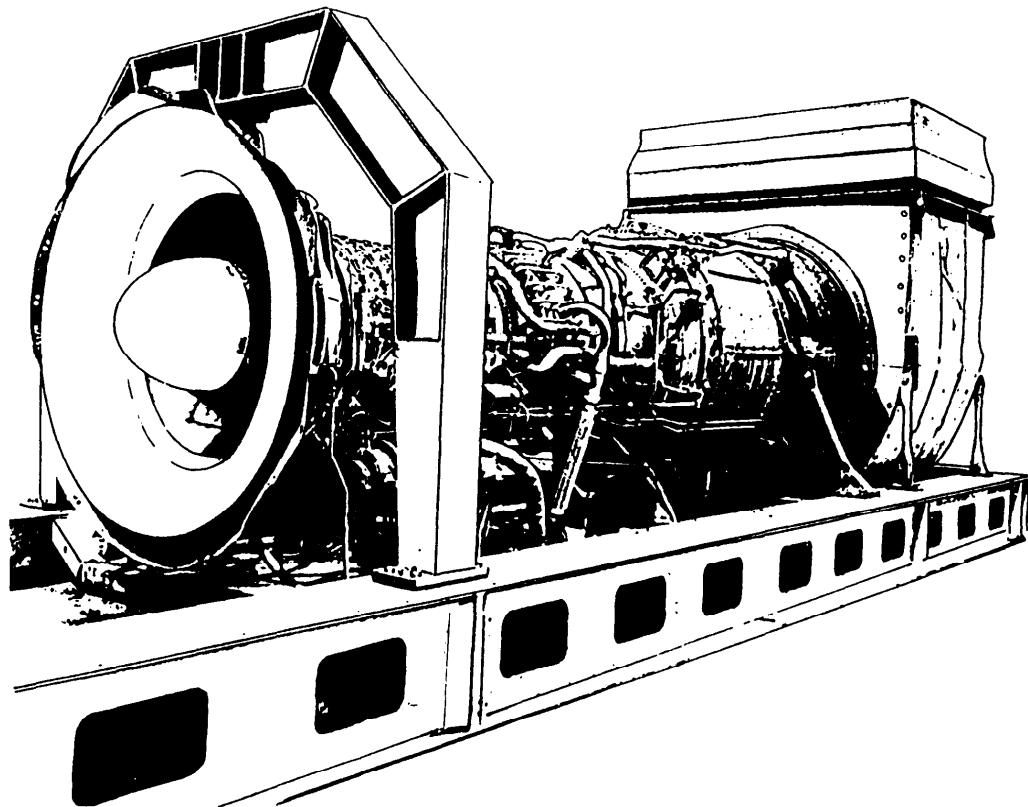
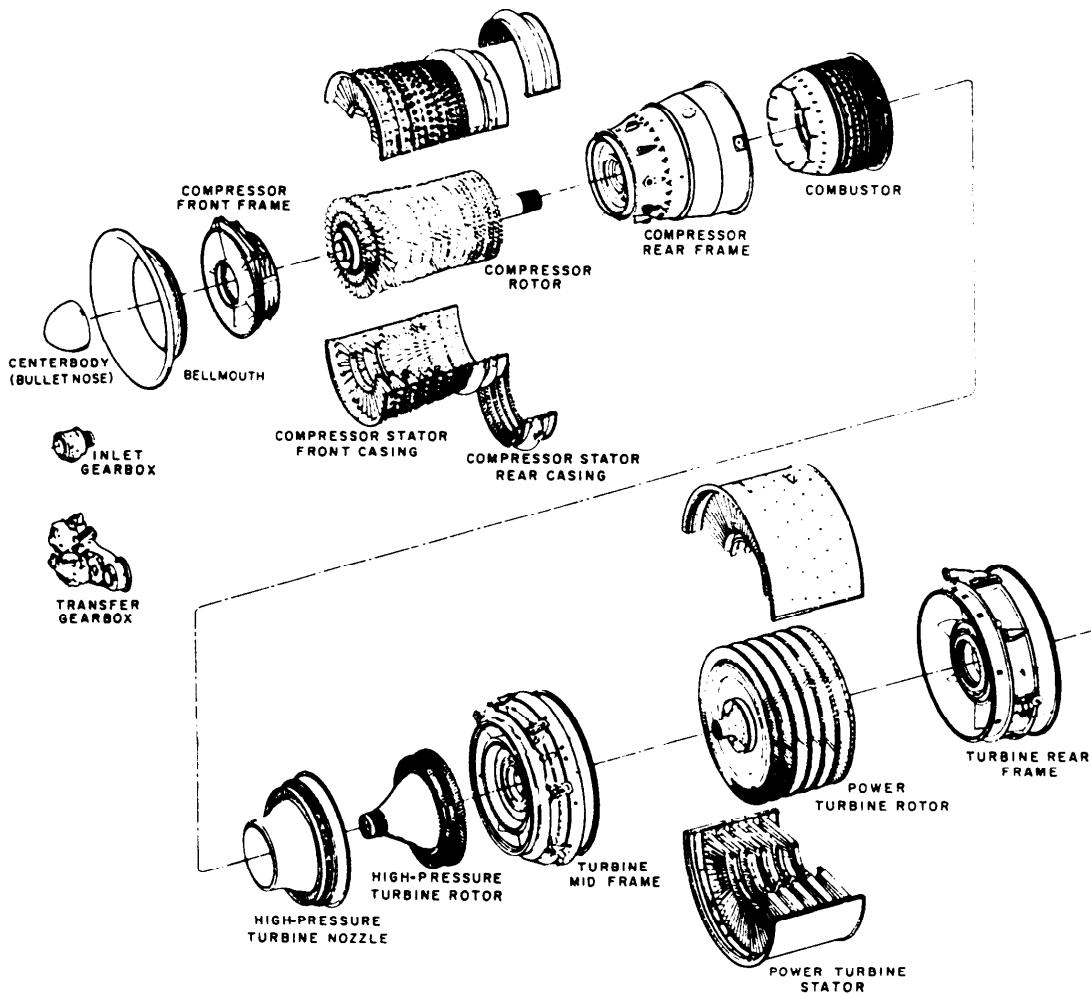


Figure 2-1.—Gas turbine assembly.



**Figure 2-2.—Gas turbine assembly (exploded view).**

inlet and exhaust components, and a lube oil storage and conditioning assembly (LOSCA).

The primary function of the GTE is to generate power and to transmit it through a high-speed flexible coupling shaft to the ship's reduction gearbox and propeller shafting.

**NOTE:** Figure 2-2 provides an exploded view of the LM2500 GTE. Refer to it during your study of the construction of this engine. The sections that follow describe the various components of the GTE.

### **BASE/ENCLOSURE ASSEMBLY**

The base/enclosure assembly (fig. 2-3) provides a thermally and acoustically insulated

structure for the gas turbine assembly and connections for electrical, fire-extinguishing, air, and liquid services.

The base/enclosure assembly has an enclosure (about 26 feet long, 8 feet high, and 9 feet wide), a shock-mounted base, a GTE mounting system, an intake and exhaust system, a fire detection and extinguishing system, an enclosure heater, a lighting system, and a GTE water wash system. The base/enclosure assembly is maintained in the installed position as a permanent part of the ship. This is opposed to the GTE assembly, which can be removed for major repair, overhaul, or replacement. Module doors provide access for routine maintenance. The number and location of the module doors varies on the different class ships. Removable side panels are installed on all modules.

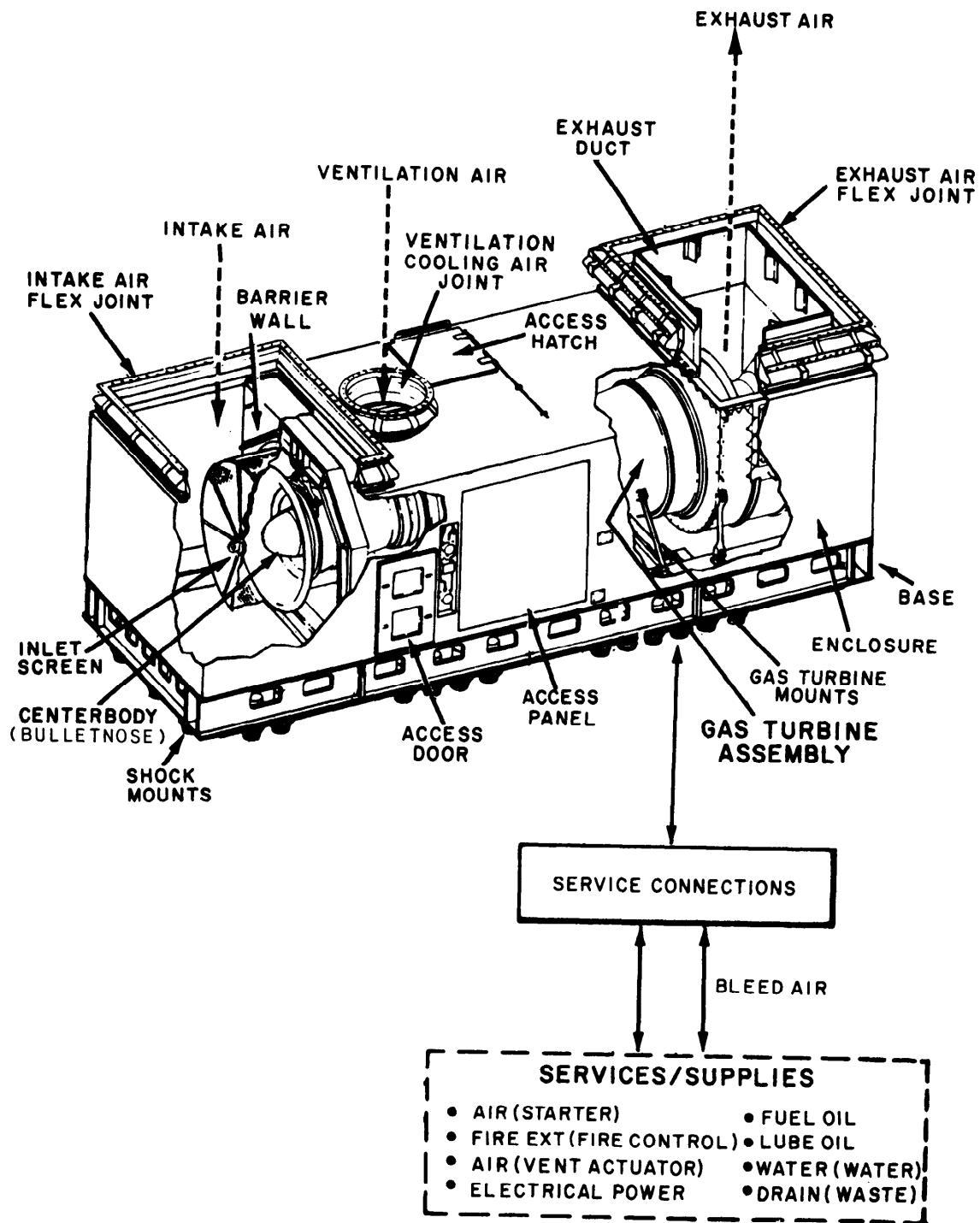


Figure 2-3.—Base/enclosure assembly.

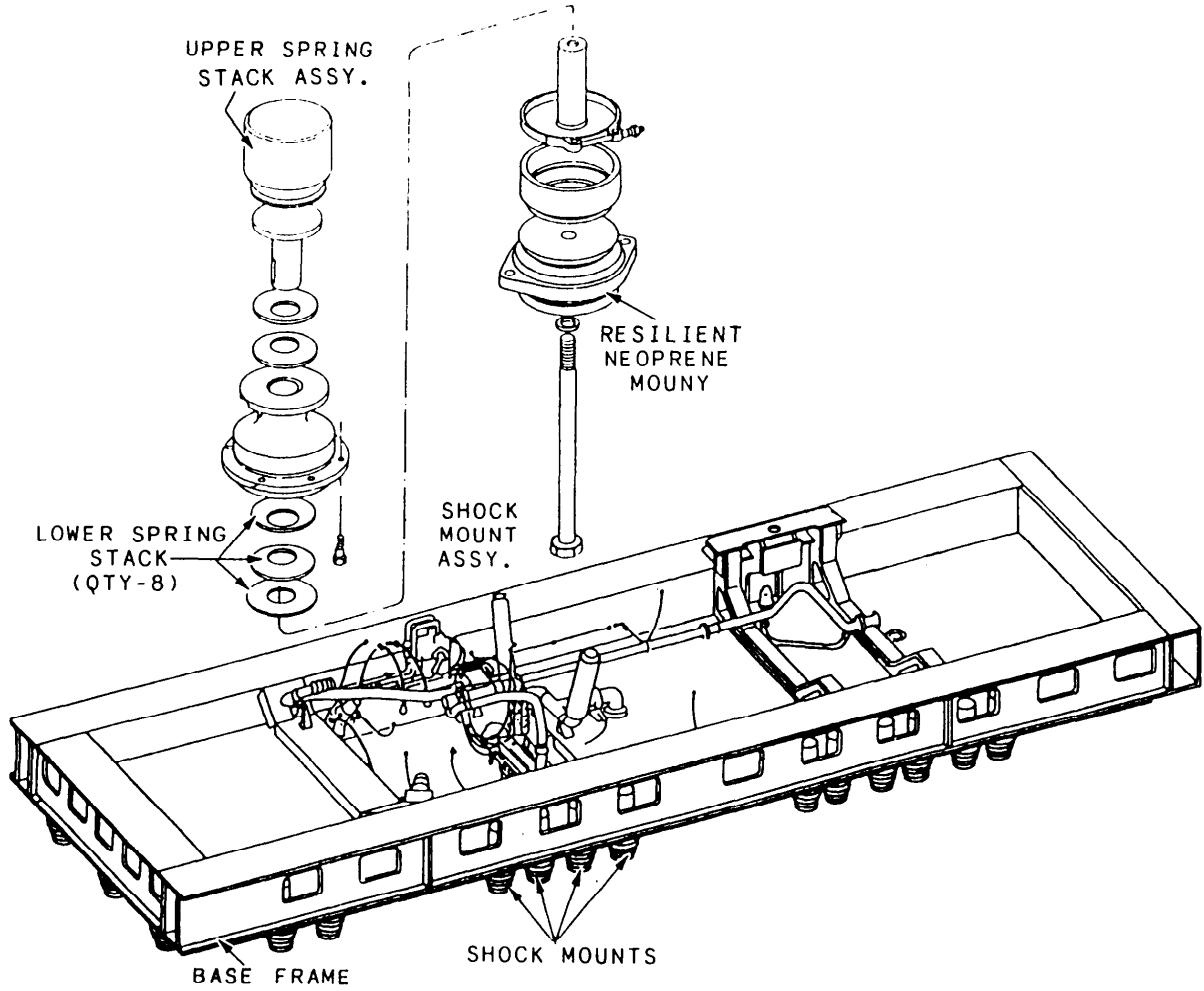


Figure 2-4.—LM2500 GTE base frame and shock mounts (exploded view).

## BASE ASSEMBLY

The base assembly (fig. 2-4) has a fabricated steel frame of steel double I-beams to provide a stable platform for the GTE. It contains suitable mounts and links to secure the GTE. Thirty-two shock mounts under the base secure the entire base/enclosure assembly to the ship's foundation. The shock mounts have two stacks of spring washers aligned above, and attached to, a resilient neoprene shock mount. They weaken shock loads by absorbing most of the abrupt up and down movements of the ship's foundation. The base also provides for connection of electrical, air, carbon dioxide ( $\text{CO}_2$ ) or Halon, and liquid services. This area is known as the base penetration plate. More detailed descriptions of the functions of the components that enter the enclosure are provided throughout this chapter.

The GTE and the exhaust duct are attached to the base by 11 supports (fig. 2-5) that secure the GTE vertically, laterally, and axially. The support to the base attachment points are shimmed to align the GTE. The forward end of the GTE is supported by a large yoke and two supports attached at the compressor front frame (points A and G on fig. 2-5). The aft end is attached by four supports—three on the right side and one on the left (shown on fig. 2-5 at points B, C, and F). The exhaust duct is secured by two supports (point E) on each side and one support (point D) and a thrust pin (point H) underneath. Figure 2-5 also shows an exploded view of each support point corresponding to its position on the base assembly.

**NOTE:** All GTE and enclosure references to left, right, front (forward), rear (aft), and clock

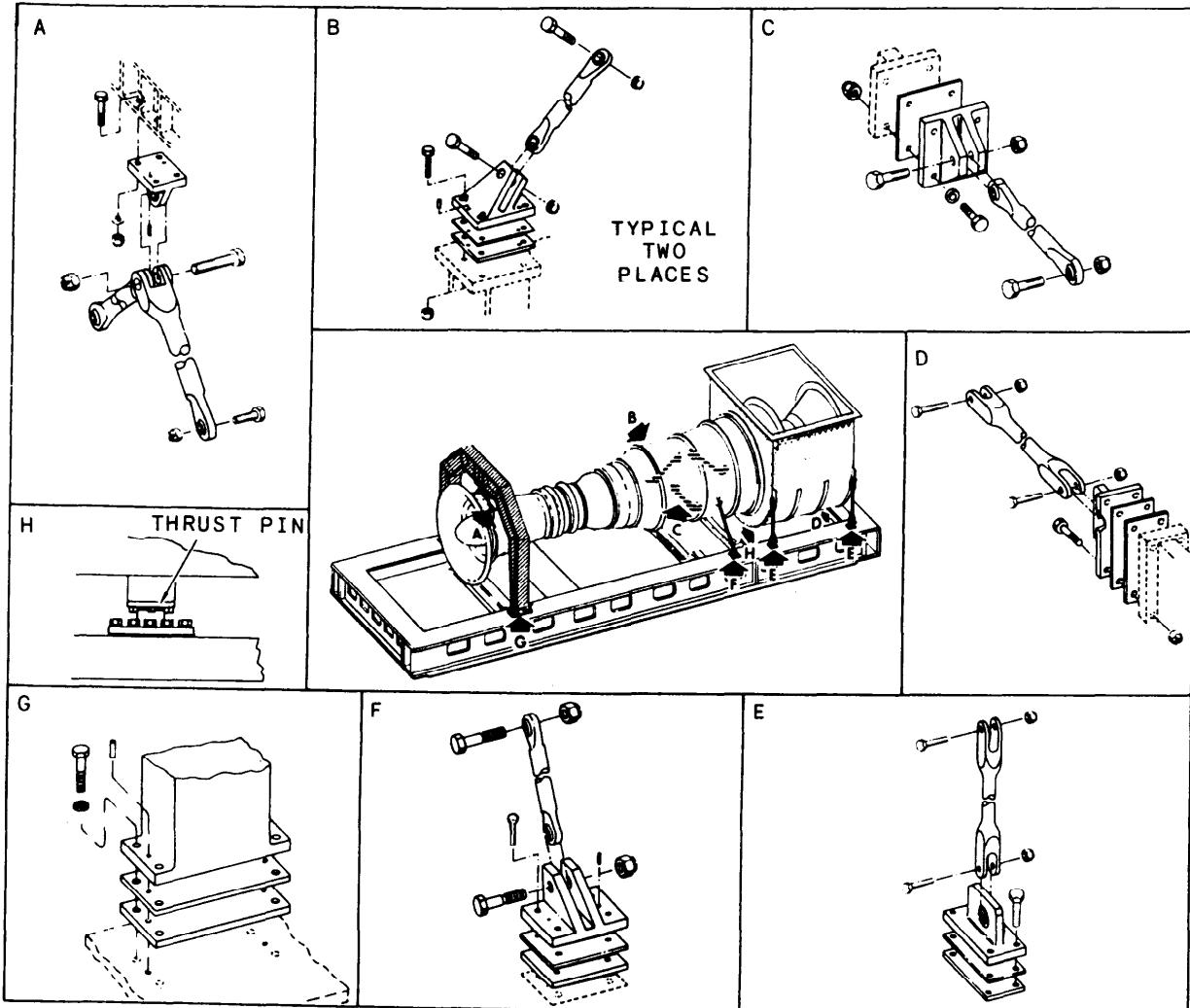


Figure 2-5.—Gas turbine assembly mounting.

positions apply when viewing the GTE from the rear (exhaust end) looking forward.

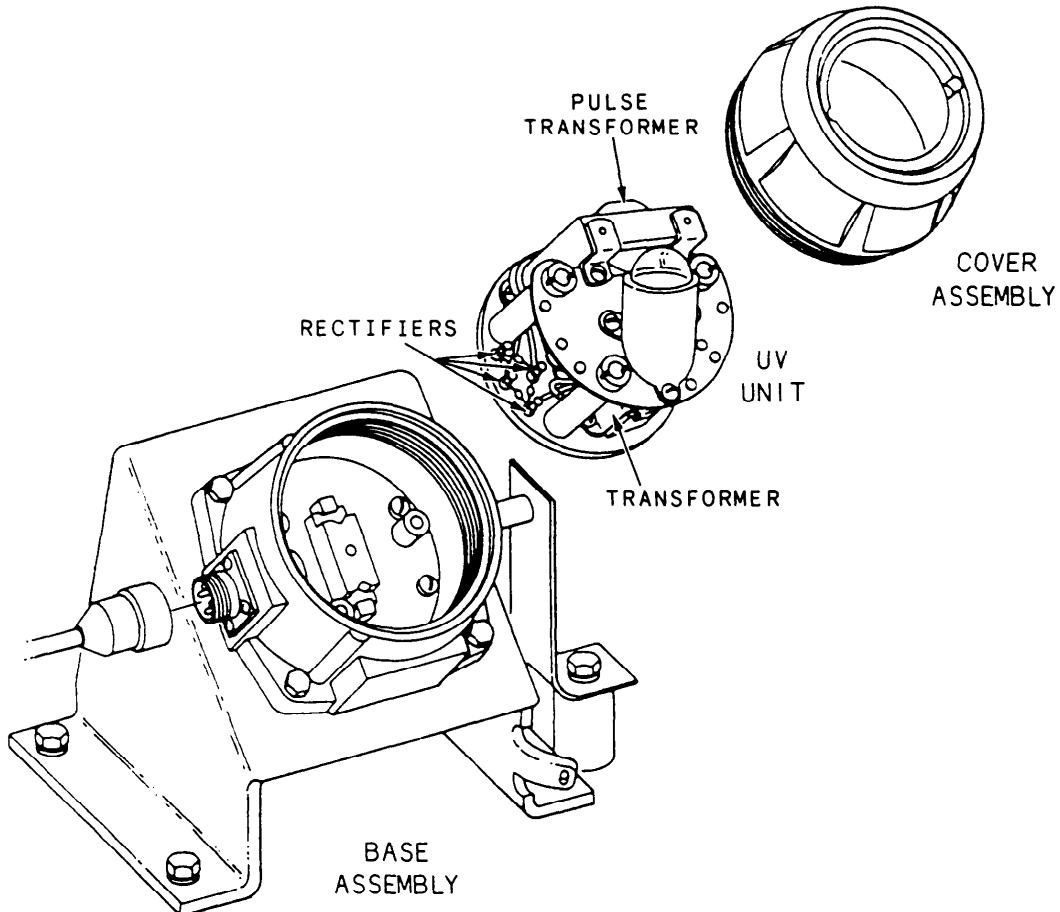
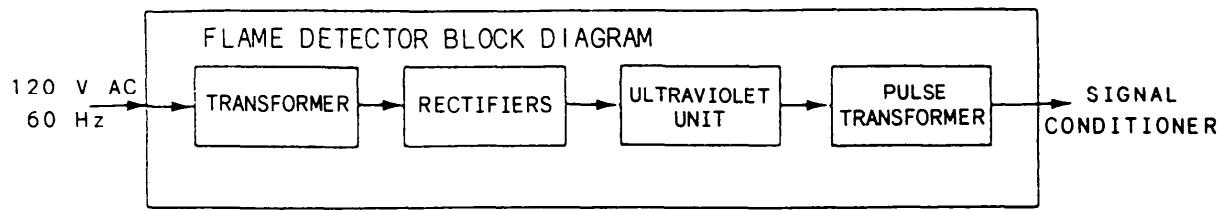
## ENCLOSURE

Refer to figure 2-3 as we discuss the enclosure. It is a soundproof, fire-resistant housing in which the GTE operates. The enclosure provides thermal and acoustical insulation, inlet and exhaust ducting, and a controlled environment for the GTE. Flexible coupling joints are provided at the air inlet and exhaust ducts which allow a flow path/interface between the enclosure and the ship's ducting. The enclosure is of double-wall construction. (**NOTE:** For personnel safety, testing was conducted to ensure the enclosure is

explosionproof and fireproof. The inner wall is constructed of perforated metal and can withstand a temperature of 2000°F for 15 minutes.) With ventilation air being supplied to the enclosure, the temperature of the outer wall normally does not exceed 150°F. The right and left propulsion GTE modules are functionally identical. The only difference between the enclosures of the different class ships is their access to the engine.

## Lighting

Enclosure illumination is provided by nine explosionproof light fixtures—eight on the ceiling and one on the base. With the exception of the CGs module illumination is the



**Figure 2-6.—Block diagram and an exploded view of a UV flame detector.**

same on each class. The lights are turned on with a rotary switch mounted on the exterior wall of the enclosure near the port side access door. The switch has four positions: off, base light, ceiling lights, and base and ceiling lights. The CGs and have two additional explosionproof light fixtures in the intake plenum. These two lights can be turned on and off by a push-button switch mounted on the front of the module adjacent to the inlet plenum observation window.

### **Heater**

The heater is ceiling mounted in the enclosure. It maintains the air temperature above 60°F when the GTE is not operating to ensure suitable fuel viscosity is maintained for engine starting. The heater is an electrically powered (440-volt ac, 3-phase) and thermostatically controlled, forced-air, 8-kilowatt space heater and blower motor. The thermostat cuts on the heater at 60° to 70°F

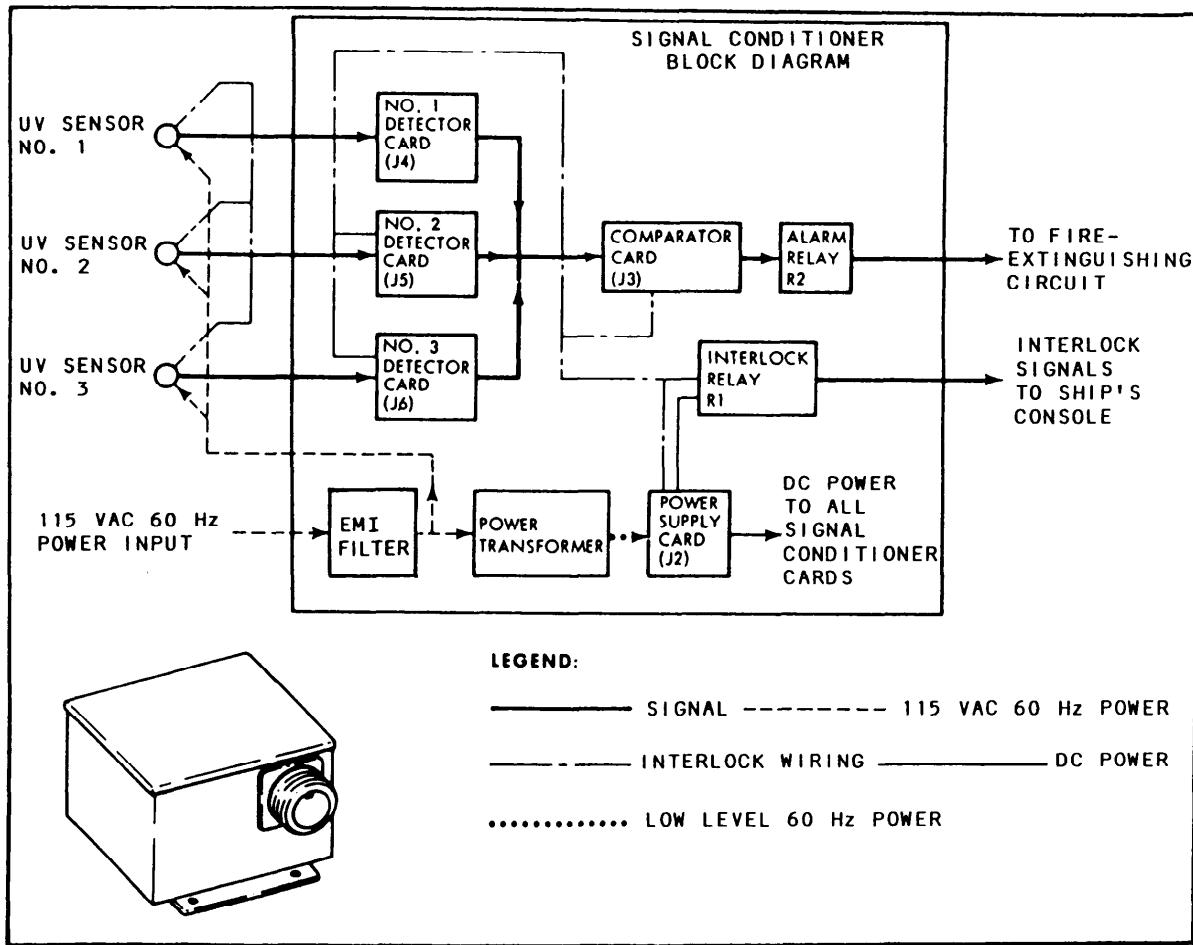


Figure 2-7.—Signal conditioner block diagram and typical signal conditioner unit.

and shuts it off when inlet air temperature reaches 85° to 95°F. The thermostat turns on the blower motor at 125°F and secures it at 145°F.

#### FIRE DETECTION AND EXTINGUISHING SYSTEMS

All LM2500 GTE modules have some method for detecting and extinguishing a fire in the enclosure. The sensors used to detect a fire are identical on all classes. The detection system has three ultraviolet (UV) flame detectors, a flame detector signal conditioner, and two resistance temperature elements (RTEs) used as temperature switches. The use of these sensors and the fire-extinguishing systems vary with ship classes.

Figure 2-6 shows a block diagram and an exploded view of a UV flame detector. This detector senses the presence of fire in the enclosure and generates a photoelectric signal. This signal

is transmitted to the signal conditioner to alert the operator of fire in the module. On the LM2500 GTE of the twin-shaft ships and on the Allison 501-K17, it also activates the fire stop sequence and releases fire-extinguishing agents to extinguish the fire.

The signal conditioner (fig. 2-7) is contained in a metal box. The box is attached to the underside of the base enclosure on the LM2500 GTE. On the Allison 501-K17 GTE, the unit is located in the alarm terminal box on the generator end of the base. Identical detector cards (one for each UV sensor) are located in the signal conditioner. The detector card amplifies, rectifies, and filters the current pulses from the UV sensor. This provides an output voltage level proportional to the UV light level at the UV sensor. The signal conditioner processes the input from the UV flame detector and completes the alarm control circuitry outside of the gas

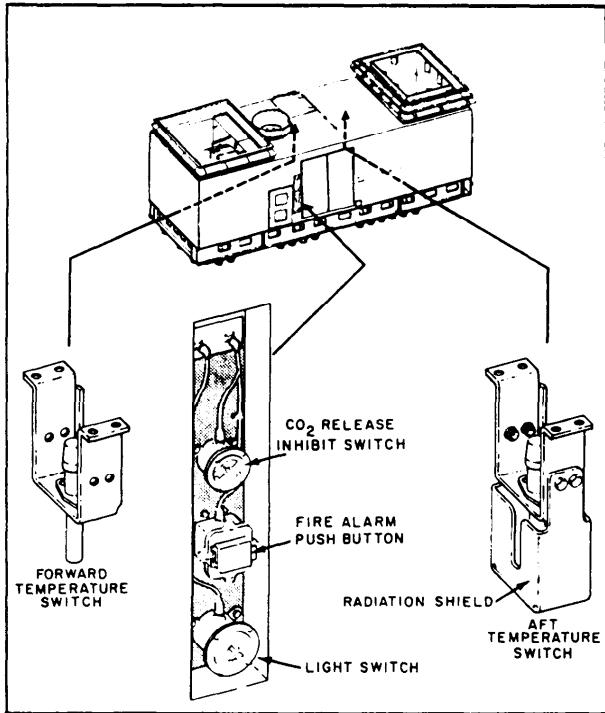


Figure 2-8.—Fire system temperature switches and manual switches.

turbine module (GTM), which results in the alarm indication.

The two temperature switches are mounted on the enclosure ceiling and generate an alarm signal if the temperature reaches a preset level (fig. 2-8). The output of the RTEs, which generate a fire signal only, is an input to the free standing electronic enclosure (FSEE).

### CG-, DD-, and Class Ships

Since we discussed the components of the fire detection system in the previous section, we will not discuss them here. The alarm system also has a manual fire alarm push button (shown in fig. 2-8) besides the electrical signal generated by either the temperature switch or the flame detector signal conditioner. The extinguishing system has two CO<sub>2</sub> discharge nozzles. When manually activated, the CO<sub>2</sub> fire-extinguishing agent is discharged into the enclosure. It also has an extinguish release/inhibit switch and a CO<sub>2</sub> release/inhibit switch mounted to the outside of the enclosure, next to the side access door.

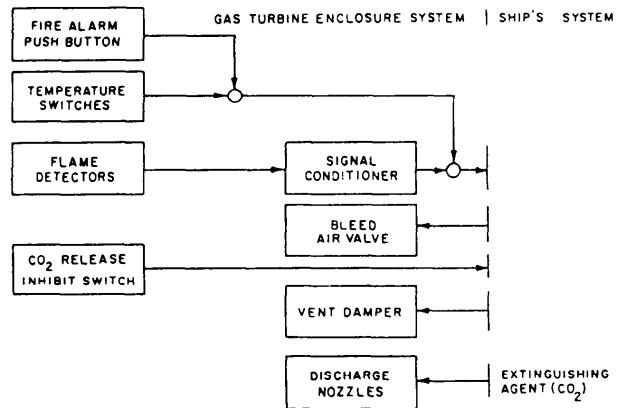


Figure 2-9.—CG, DD, and fire stop sequence flow chart.

Two CO<sub>2</sub> discharge nozzles are located inside the enclosure. They are mounted on the crossbeam under the compressor front frame. One is for initial discharge (primary) and the other for extended discharge (secondary). The fire extinguish release/inhibit switch is mounted above the fire alarm push button. It is a two-position switch (ACTIVE/INACTIVE). When in the INACTIVE position, this switch prevents discharge of the CO<sub>2</sub> extinguishing agent.

Figure 2-9 is a signal flow chart of the fire stop sequence. Fire is sensed by the flame detectors or temperature switches. The fire may also be discovered by watch station personnel who would operate the manual CO<sub>2</sub> release switch. In either situation, the sequence of events are the same after the fire is discovered. Electrical contacts close to activate the fire-extinguishing system and the following concurrent actions occur:

1. The fire alarm signal sounds.
2. The system conducts a self-check to see if battle override has been selected at the propulsion local control console (PLCC) or the propulsion auxiliary control console (PACC) or if the module cooling system has failed. Either event will terminate the fire stop sequence.
3. The GTE fuel shutdown valves close, shutting down the GTE.
4. The fuel supply to the GTM is shut off in the ship's service system.

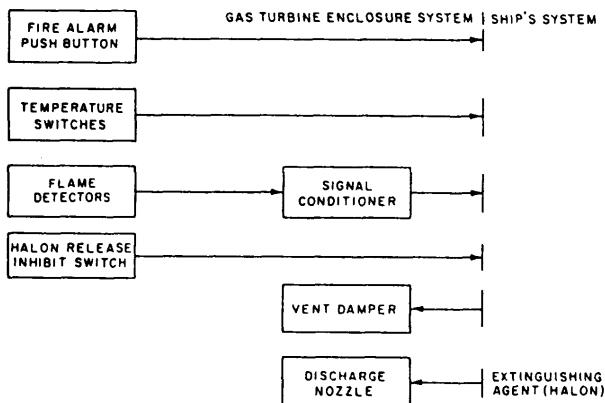


Figure 2-10.—FFG fire system block diagram.

5. The module cooling air fan is shut down.
6. The module vent damper is closed.
7. The bleed air valve is closed.
8. The enclosure lights flash (only if lights were previously on).
9. After a delay of 20 seconds, the initial CO<sub>2</sub> discharge occurs.

To prevent CO<sub>2</sub> discharge, position the release inhibit switch to the INACTIVE position during the 20-second time delay. The initial discharge delivers 150 pounds of CO<sub>2</sub> at a rate of 50 lb/min. If required, the extended CO<sub>2</sub> discharge is manually activated. The extended discharge delivers 200 pounds of CO<sub>2</sub> at the rate of 10 lb/min.

### FFG-Class Ship

Like the other ship classes already discussed, the fire detection system of the FFG-class ship has three flame detectors, a flame detector signal conditioner, and two temperature switches. The manual alarm system has a fire alarm push button. The extinguishing system has a single Halon discharge nozzle, connecting tubing, and an extinguish release inhibit switch.

The UV flame detectors of the FFG-class ship are identical to the type on the other class of GTE-powered ships, but provide only an alarm. The RTE fire sensor will also sound that same alarm, indicating a fire is present.

The manual fire alarm push button is mounted on the outside of the enclosure, next to the side access door. When activated, a contact closure signal is provided to the ship's system which

sounds an alarm at the propulsion control console (PCC) to notify the engineering officer of the watch (EOOW). Fire may also be sensed by the flame detectors (fig. 2-10) or either of the two temperature switches may detect enclosure temperature above preset limits.

The Halon discharge nozzle is located inside the enclosure. It is mounted on the underside of the crossbeam under the compressor front frame. This one nozzle provides both initial (primary) and standby (reserve) Halon discharge. The fire extinguish inhibit switch is mounted above the fire alarm push button on the outside of the module. When in the ACTIVE position, this switch will allow automatic or manual discharge of the Halon. When in the INACTIVE position, this switch provides a signal to the ship's system that is used to prevent discharge of the Halon. However, this switch does not override manual activation locally.

You can extinguish a fire in either enclosure by filling the enclosure with Halon. The PCC has a FLAME DET ALARM/HALON FLOOD push button for each enclosure. To prevent an enclosure from being flooded with Halon while personnel are inside, place the fire extinguish inhibit switch in the INACTIVE position.

Activation of the FLAME DET ALARM/HALON FLOOD switch on the PCC will provide the initial Halon discharge of 60 pounds at a rate of 1.45 lb/sec. An additional 60 pounds, with the same rate of discharge, is available on standby (manually activated).

### AIR INTAKE SYSTEM

The air intake system for the LM2500 GTE provides the large quantity of air with a minimum pressure drop that is needed for proper engine operation. The design of the ducting varies with the ship class. However, the function of the systems are the same. The intake system reduces the flow distortion, pressure drop, and salt ingestion. The intake system also provides duct silencing, a supply of cooling air, anti-icing protection, and mounting for moisture separation pads, and allows for engine removal by a system of rails on the duct walls. Blow-in doors located on the ship's upper level protect the GTE from air starvation if inlet blockage occurs.

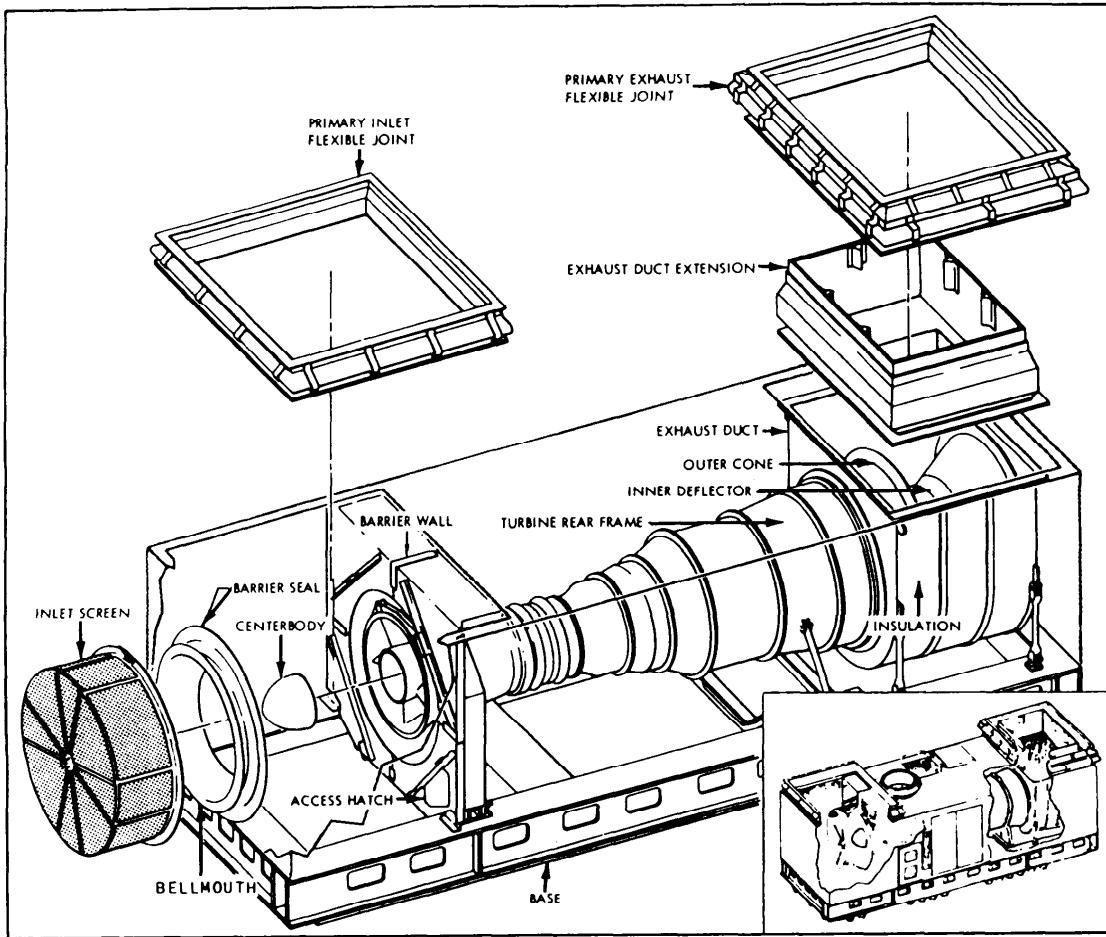


Figure 2-11.—GTE air inlet and exhaust.

Figure 2-11 shows the air inlet and exhaust components of a GTE. We will discuss the exhaust system after we describe the intake system.

The intake section of the enclosure is composed of five parts:

1. A primary inlet flexible joint, which connects the ship's ducting with the enclosure. It has an upper and lower flange and a fiber-filled flexible boot.

2. A barrier wall, which has four stainless steel panels bolted together. It prevents exhaust and ventilation air from being drawn into the intake. It has a removable access hatch for maintenance/operator personnel access to the inlet plenum.

3. A wire mesh inlet screen (foreign object damage (FOD) screen), which is bolted to the barrier wall and prevents foreign objects from entering the engine.

4. An inlet duct, which is bell-shaped and attached to the front frame of the compressor. The duct, or bellmouth, smoothes the airflow entering the turbine. A flexible seal is attached between the inlet duct and the barrier wall.

5. A dome-shaped fairing, called the centerbody, which is attached to the compressor front frame hub to aid in smoothing the airflow.

## CG, DD, AND INLET DUCT SYSTEMS

The inlet duct systems for the CG-, DD-class ships are very similar. The major difference is the sand separators used on the ships. Since only the four 993 class ships have the sand separators installed, we will not discuss this unique feature.

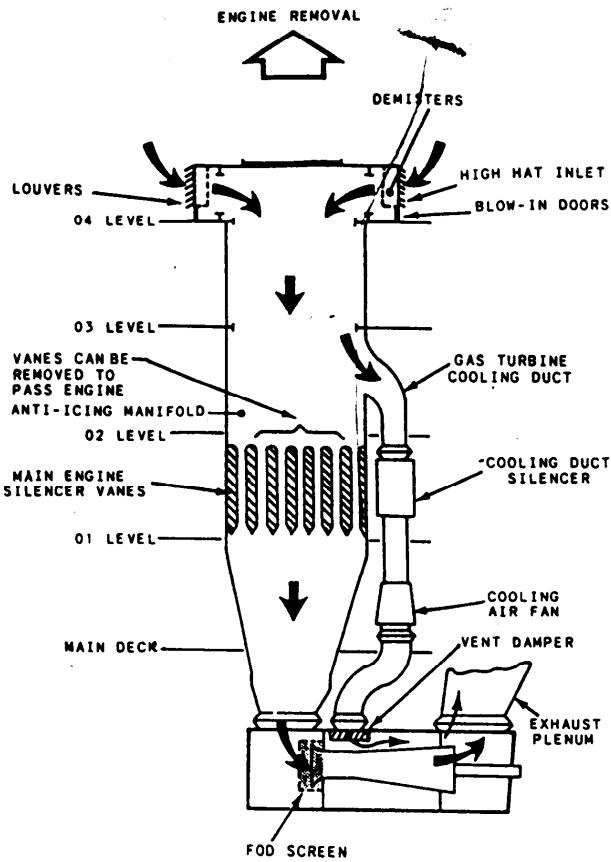


Figure 2-12.—CG, DD, intake duct system.

## Overall Flow Description

Refer to figure 2-12 while you are studying this section on the inlet duct systems. It shows the CG, DD, (minus the sand separators) intake duct system. Intake air enters the main duct through the demisters (moisture separators) located in the sides of the high hat inlet. The air flows down the main duct and passes through silencers located about midway down the duct. It then flows through a flexible coupling into the engine inlet plenum. Cooling air taken off the main duct ahead of the silencers flows through the cooling duct, cooling duct silencers, and cooling air fan. It then enters the engine enclosure through a vent damper. The air circulates around the engine and exits the enclosure through the exhaust plenum. If the moisture separation system becomes blocked, the blow-in doors automatically open to supply the engine with combustion and cooling air. Under these conditions, no demisting protection exists.

## High Hat Assembly

The high hat assembly (fig. 2-13) is located on the 04 level of the ship. It houses all the components of the moisture separation system.

**MOISTURE SEPARATION SYSTEM.**—The moisture separation system includes the

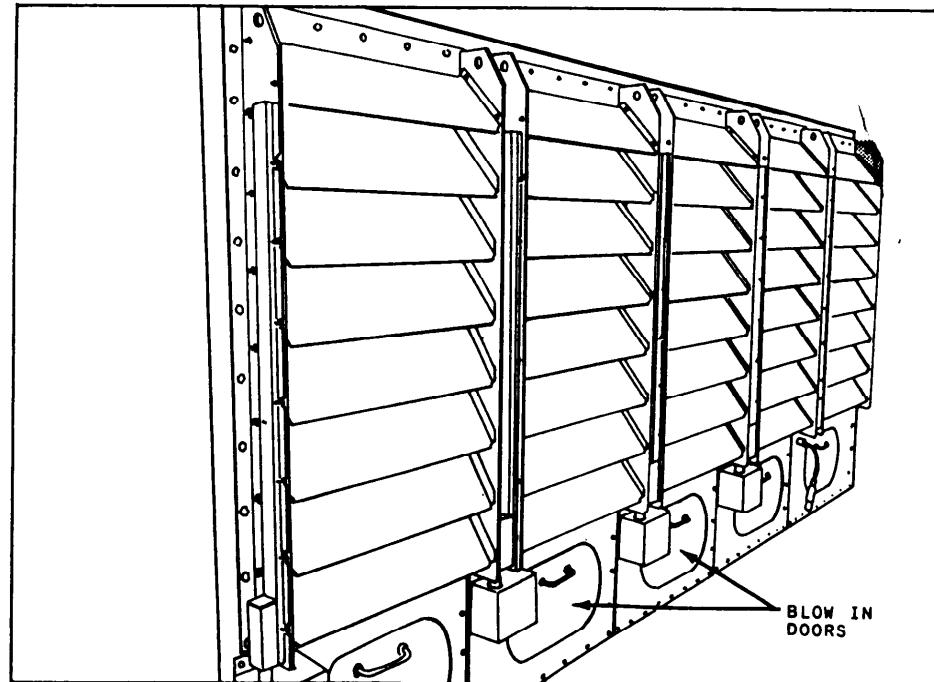


Figure 2-13.—High hat assembly.

inlet louvers and the demister panels. The inlet louvers are arranged in sections. They are located in the sides of the high hat assembly. The design and arrangement of the louvers are such that they will shed sea spray. The louvers are electrically heated to prevent icing. These heaters type and are located on the back of the louver surface. The heaters are controlled from the engine control consoles. The demisters are the two-stage, mesh-pad type and are mounted vertically behind the louvers. Water, separated from the inlet air as it passes through the demisters, is collected in scuppers and drained overboard. The demisters will remove 70 percent of the particles that are 1.7 to 5 microns in size and 90 percent of the particles that are 5 microns and larger.

**BLOW-IN DOORS.**—The blow-in doors are located just below the inlet louver. Their function is to bypass the moisture separation system. They provide an unrestricted inlet airflow to the engines if the moisture separation system becomes blocked. They are designed to open by solenoid-operated latch mechanisms, and will open if the inlet airflow becomes too restricted for normal engine operation.

On the DD-class ships, a controller is located in each engine room to provide for manual or automatic operation of the doors. This is done by a selector switch and a push button on the controller door. On the CG-class ship this controller is in the helo hangar. The push button on the CG-class is located on the high hat assembly. In manual operation, you can only open the doors by depressing the push button. In automatic operation the doors open by operation of a pressure switch. The switch operates on low duct pressure. This pressure switch also provides a DUCT PRESSURE LOW signal to propulsion auxiliary machinery control equipment (PAMCE) and propulsion local control equipment (PLOE). The pressure switch operates when duct pressure falls below 8 inches of water. If the doors open, the doors must be manually reset closed.

## Ducting

See figure 2-12 as we discuss the ducting. It allows the air to travel from the high hat assembly to the inlet of the compressor. The components of the ducting include the silencers, the anti-icing piping, the cooling air duct, and the engine removal system.

**SILENCERS.**—The main engine intake duct silencers are located about halfway down the duct. The silencers are vertical vane assemblies constructed of sound-deadening material. The intake ducts are encased in perforated stainless steel sheet. The vane assemblies are arranged in modules which are removable to aid in the removal of the GTEs through the intake duct.

**ANTI-ICING SYSTEM.**—This system prevents the formation of ice in the intake duct. High-temperature bleed air from the GTEs is piped to a manifold. This manifold is located inside the duct between the cooling air extraction port and the silencers. From the manifold the bleed air is discharged into the inlet airstream. The bleed air is mixed with the inlet air, raising the temperature enough to prevent the formation of ice. When enabled from the PAMCE or the PLOE, an electromechanical control system regulates bleed air flow to maintain the inlet air temperature at about 38°F. This prevents the formation of ice. A temperature sensor in the stack provides an ANTI-ICING INSUFFICIENT signal. This alarm activates when the anti-icing system has been enabled and the temperature drops below 36°F.

**COOLING AIR DUCT.**—Main engine cooling air is extracted from the main intake duct. It is taken at a point between the blow-in doors and the main duct silencers. It is then ducted to the engine enclosure. The cooling air duct contains a silencer and a cooling air fan. The cooling system will be discussed in more depth later in this chapter.

**ENGINE REMOVAL SYSTEM.**—Sometimes a main propulsion GTE must be removed from the ship for maintenance/overhaul. At the time of engine removal, a set of channel-shaped maintenance rails is installed in the engine enclosure. These are put adjacent to each side of the engine. A set of rollers, which fit into the rails, is attached to each side of the engine. The removable maintenance rails extend into the enclosure inlet plenum. They then turn 90 degrees, from horizontal to vertical attitude. They mate with permanently installed rails that extend up the intake duct. In the FFG-class ship, the uptake rails must be installed each time the engine is removed. The engine is removed through the intake duct. In the inlet plenum, three sets of maintenance rails interface with three sets of permanently installed rails in the ship's intake

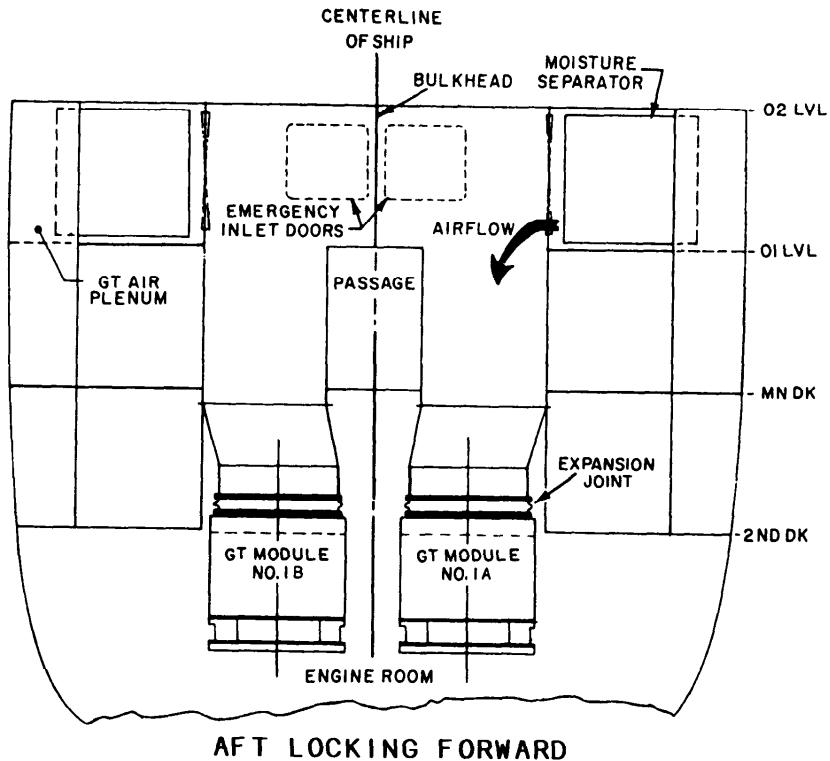


Figure 2-14.—FFG air intake system.

duct. The permanently installed rails extend through the high hat section. These serve to guide the engine as it is lifted vertically from the ship.

Removal of the engine is accomplished in two operations due to space constraints. The GG is separated from the PT while still in the enclosure. Then it is removed from the ship, followed by removal of the PT.

### FFG INLET DUCT SYSTEM

Refer to figure 2-14 as we discuss the FFG inlet duct system. The GTE uptake spaces and intake system house three separate ducting systems per GTE. They are for combustion air, module cooling air, and exhaust gas elimination. Atmospheric air for the combustion and cooling air ducting normally enters through the intake plenums. These are located on each side of the ship's structure. The air is then carried through ducting to the GTMs in the engine room below. Ducting connections to the GTMs are made via expansion joints on top of each GTM. The combustion air intake ducts also provide the access for removal and replacement of the engine GG and PT sections.

Besides the ducting, the GTE uptake and intake system includes moisture separator assemblies, emergency inlet doors, and cooling air fans (not shown). Also included are cooling air bypass dampers and provisions for anti-icing upstream and downstream of the moisture separators (not shown).

### Demister Panels

The demister panels (or moisture separators) are of knit wire mesh construction mounted in a supporting frame. They remove moisture droplets containing sea salt and prevent other foreign objects from entering the intake and cooling air ducts. In operation, the moisture droplets adhere to the wire mesh while the air passes through. The moisture droplets coalesce into larger drops and fall free of the airstream. They then drain into troughs which are piped to the plumbing drains system. Each combustion air intake duct has eight demister panels. Each cooling air intake duct has four panels.

### Blow-In Doors

Emergency inlet (blow-in) doors are provided in the combustion air and cooling air ducts to each

engine. One emergency inlet door is located between the uptake space and each combustion and cooling air duct. If the moisture separators start to ice or are partially blocked for any reason, the emergency inlet doors will open. These open automatically to provide inlet air from the uptake space and permit continued limited power engine operation. The doors are pneumatically operated, electrically actuated, and automatically controlled by differential pressure switches. Each combustion air emergency inlet door opens automatically at a differential pressure of 9.0 inches of water (in. H<sub>2</sub>O). The cooling air emergency inlet doors open automatically at 3.75 to 4.25 in. H<sub>2</sub>O differential pressure. You can actuate each door manually using the air solenoid override at the door control panel. If a loss of air pressure occurs, you can open or close the doors manually using a wrench at the door assembly.

### **Anti-Icing System**

An anti-icing system uses bleed air from the GTE. It is used to prevent the formation of ice in the intake system. Anti-icing nozzles are located upstream and downstream of the moisture separators.

The system has a sensor located in the inlet ducting and a signal conditioner. Icing conditions exist when the ambient air temperature is below 41°F and humidity above 70 percent. The signal conditioner transmits a signal to the anti-icing system when these conditions occur. This signal provides an alarm indication at the control console and provides an enable signal for initiation of the anti-icing system.

Bleed air from each GG is piped to its associated intake system for anti-icing purposes. The piping to each intake system contains a 250/38 psig regulating valve to reduce the bleed air pressure. The bleed air supplied to the intake system provides anti-icing air for the moisture separators, the GG bellmouth, and the enclosure cooling fan. Bleed air also supplies the cooling air bypass damper and the enclosure cooling air damper.

The anti-icing pressure regulating valve is actuated from either the PCC or the local operating panel (LOP). Valve status indication is provided at both control stations.

### **Intake Monitoring and Control**

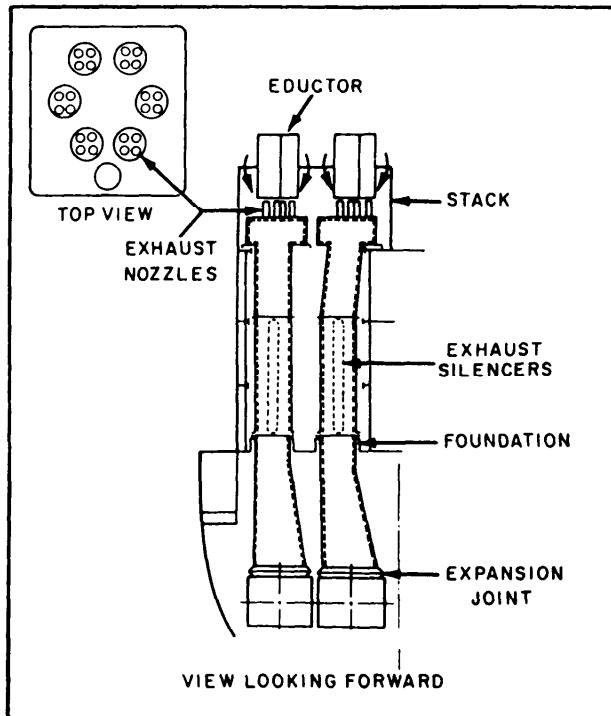
Outside air temperature is sensed by a resistance temperature detector (RTD). It is

mounted in each intake plenum upstream of the moisture separators. The temperature is displayed on the PCC demand display and on an edgewise meter on the LOP. The temperature signal is used by the propulsion control system (PCS) for gas turbine enclosure ventilation damper logic. It is also used for automatic GTE power correction when operating in programmed control. A differential pressure sensor measures the pressure difference between the intake duct and outside atmospheric pressure. If the differential pressure exceeds 7.5 in. H<sub>2</sub>O, the combustion air intake LP alarm is activated on the PCC in the central control station (CCS). This parameter can also be demand displayed on the PCC.

## **EXHAUST SYSTEMS**

The exhaust system (see fig. 2-11) routes the engine exhaust gases to the atmosphere. It is designed to prevent re-ingestion of exhaust gases into the intakes and to minimize heating of topside equipment. This system also minimizes the sound and the heat sensing of the ship by hostile vessels and aircraft. Re-ingestion of the exhaust gases is prevented by having the exhaust stack higher than the air inlet ducts. Sound level is reduced by exhaust duct wall insulation. On some ship classes a silencer is installed to assist in noise reduction. The exhaust gas temperature is reduced when the module cooling air combines with the hot engine gasses as they leave the GTM. Exhaust gas temperature may be further reduced by an IR suppression system.

The exhaust duct is attached to the base and turbine. An inner deflector is bolted to the turbine rear frame hub and protects the high-speed flexible coupling shaft from the exhaust gases. An outer cone is bolted to the turbine rear frame outer flange to direct exhaust gases smoothly into the duct. The exhaust extension differs in construction between the FFG- and the CG-, and DD-class ships, but serves the same purpose. On the FFG-class ship the exhaust extension is bolted to the exhaust duct through which the engine gases enter the exhaust duct. It creates an eductor effect which allows for enclosure ventilation air to exit through the space between the extension and the flexible joint. The primary exhaust flexible joint connects the ship's ducting to the enclosure.



**Figure 2-15.—DD exhaust duct systems.**

## DD AND CG EXHAUST DUCT SYSTEMS

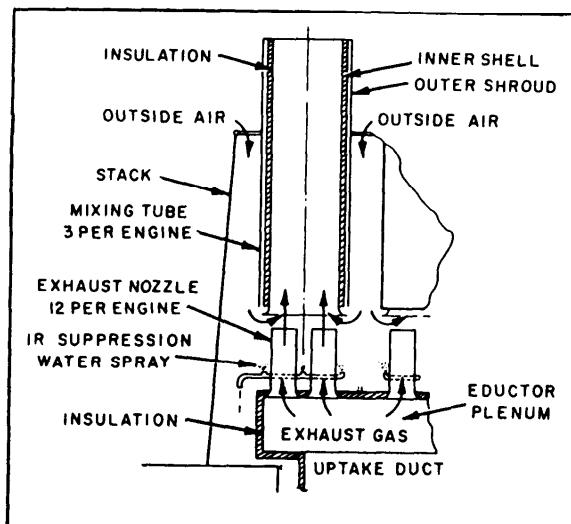
These ship classes have replaced the outmoted IR suppression system with the boundary layer infrared suppression system (BLISS), figure 2-17. Figure 2-15 shows a cross-sectional view of the DD exhaust duct system.

### Silencers

A single vane type of silencer is located in the center of the exhaust duct. It has sound-deadening material encased in perforated stainless steel sheet. This material, along with the duct wall insulation, reduces the sound level enough to meet acceptable airborne noise requirements.

### Eductors

Figure 2-16 is a cross-sectional view of an eductor. The exhaust eductors are located at the top of each propulsion engine exhaust duct. It is positioned so the gas flow from the exhaust nozzle will draw outside air into the exhaust stream to reduce exhaust gas temperature.



**Figure 2-16.—DD and DDG exhaust eductor.**

It is positioned so the gas flow from the exhaust nozzles will draw outside air into the exhaust stream. It also draws IR suppression spray into the exhaust as it enters the mixing tube.

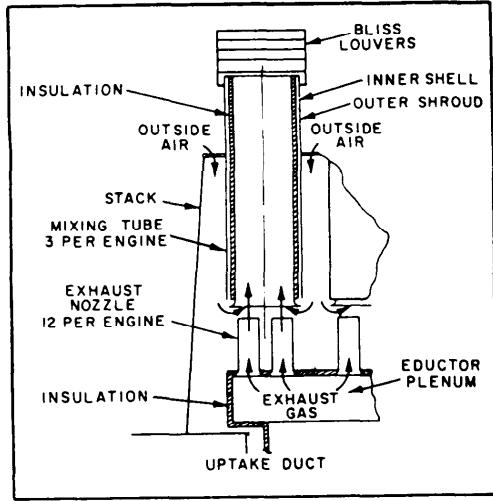


Figure 2-17.—CG exhaust eductor.

## FFG EXHAUST DUCT SYSTEM

The FFG exhaust (uptake) system (fig. 2-18) conducts the GTE combustion exhaust gases and the enclosure exhaust air to the atmosphere. The exhaust trunk extends from the exhaust expansion joint at the enclosure, up through the ship. It terminates in the atmosphere above the top of the stack. The enclosure cooling air exhaust is drawn into the exhaust trunk through an eductor effect, explained previously. An RTE is mounted in the exhaust trunk. It provides a signal to the propulsion control system for the demand display of the exhaust temperature at the PCC.

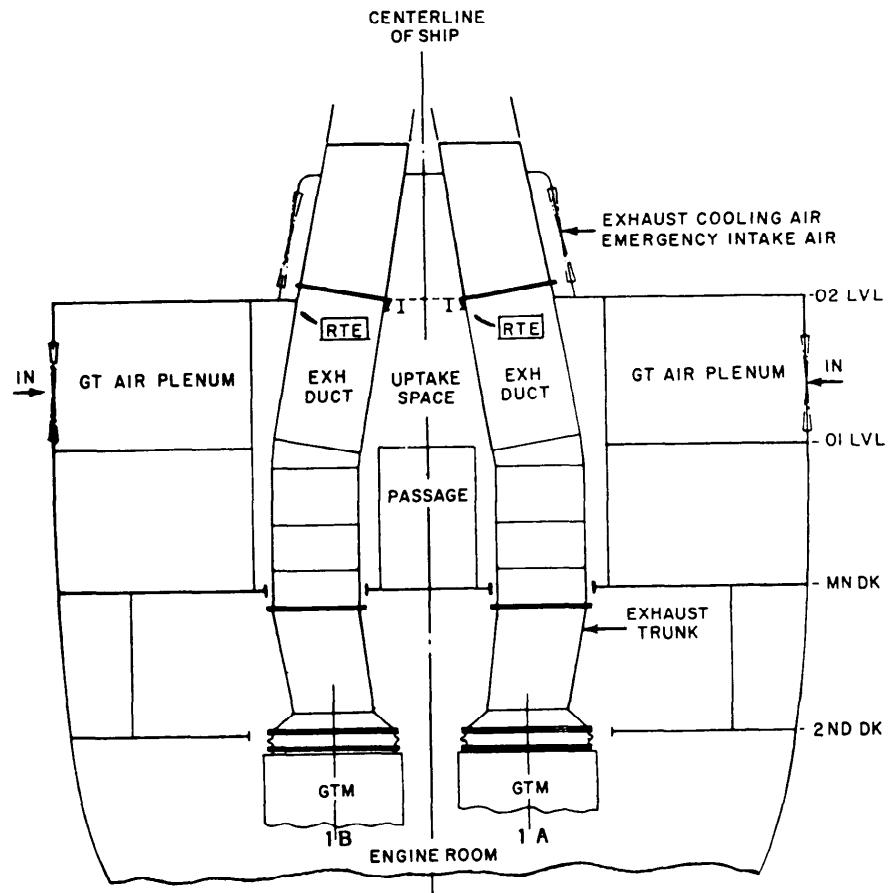


Figure 2-18.—FFG exhaust system.

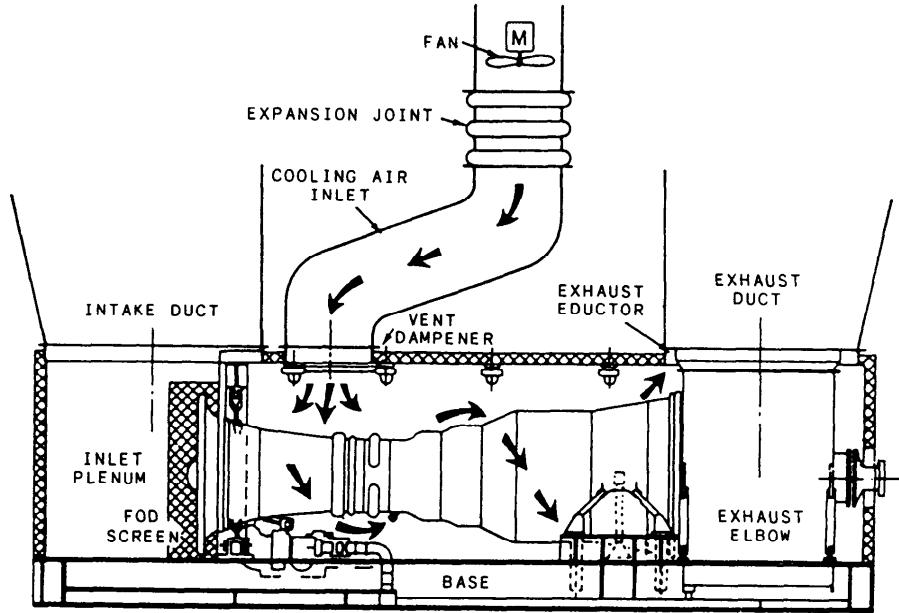


Figure 2-19.—Gas turbine module cooling.

## MODULE COOLING SYSTEMS

Navy GTEs are not rated for operation in ambient temperatures above 130°F. A module cooling system must be used to prevent module temperatures from exceeding 130°F. The LM2500 GTE module uses a combination of fan-forced ventilating air and exhaust gas eduction to cool the GTM (fig. 2-19). The location and operation of the cooling fan system differ among ship classes, but the ducting is connected to a flexible joint common to all enclosures. Cooling air is taken into the cooling duct and pressurized by the fan. It is then discharged at the electro-pneumatically controlled ventilation damper on the top of the module. This vent damper also will isolate the enclosure in case of fire or when the engine is secured. Once the air enters the module, a natural swirling effect takes place around the engine. The cooling air moves to the back of the module where it is removed by the exhaust eductor. A temperature monitor is located on the enclosure ceiling just forward of the exit area. This monitor provides an alarm indication to the control consoles if the enclosure temperature exceeds a set limit. Although the cooling systems of the different class ships perform the same function, they are constructed differently. The following sections of this chapter describe these differences.

## CG, DD, COOLING SYSTEM

In this system, main engine cooling air is extracted from the main intake duct at a point between the blow-in doors and the main duct silencers. It is then ducted to the engine enclosure. The cooling air duct contains a silencer and a cooling air fan (see fig. 2-12). The silencer has a double-walled cylinder. The cooling is activated either manually or automatically from the PACC and the PLCC (automatically from the Shaft Control Unit (SCU) on the DDG-51 class); the cooling system must be running for engine operation. The space between is filled with sound-deadening material. Suspended in the center of the cylinder is a torpedo-shaped baffle. It is made of perforated stainless steel sheet filled with sound-deadening material. The silencer forms a section of the cooling air duct. The cooling air fan is located in the duct between the engine enclosure and the silencer. The fan is rated at 80 hp and 17,000 cubic feet per minute (ft<sup>3</sup>/min) airflow.

From the cooling fan, the air is ducted to the engine enclosure. It enters the enclosure through a ceiling-mounted vent damper. Then it circulates around the engine. The air exits the enclosure through the exhaust plenum. The cooling is activated either manually or automatically from the PACC or the PLCC and must be running for engine operation. The vent dampers are electro-pneumatically operated. They use air from the

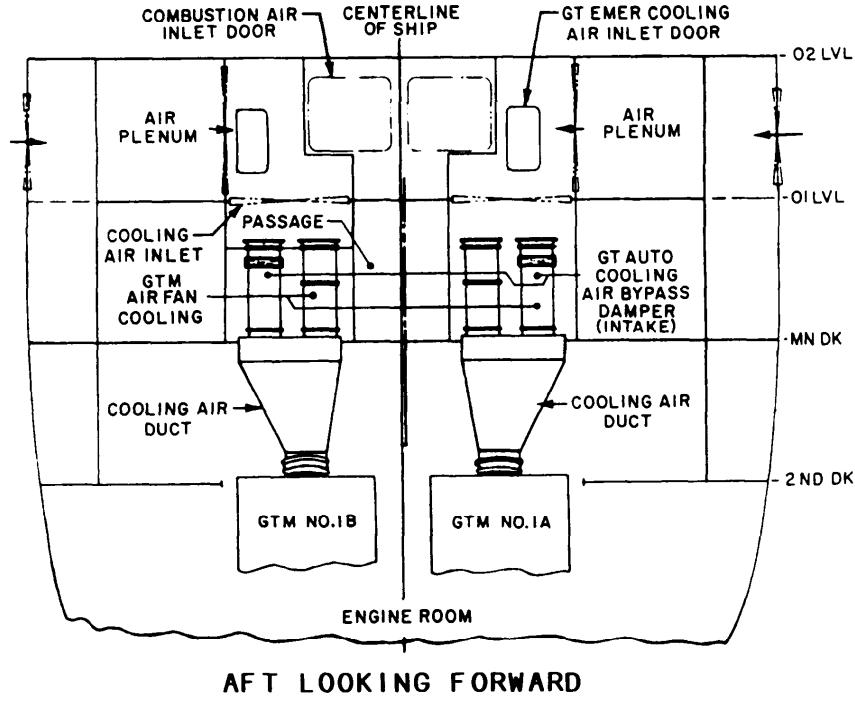


Figure 2-20.—FFG cooling system.

ship's service air system (SSAS). The vent dampers are operable either automatically or manually from the PACC or the PLCC.

#### FFG COOLING SYSTEM

In this system, the cooling air ducts to each engine are made up of two parallel sections (fig. 2-20). One section contains a cooling air fan and the other a cooling air bypass damper. The two sections join together before connecting to the GTM. At low engine power the cooling air fan in one leg supplies cooling air to the GTM. This acts to close the bypass damper in the other leg. As the engine power level passes 3,000 shaft horsepower (shp), the engine exhaust eductor creates enough draft for the bypass damper to open. Both parallel legs then permit cooling air to enter the GTM. The cooling air fan is shut off automatically at an engine power level of 3,000 shp by the PCS.

The PCS provides the control and status indications for the cooling air fans at the PCC and the LOP. Both locations have controls for manually starting the fans. They also have automatic control of the fans after the GTE has been started. The fan local motor controller provides the only controls for stopping the fan in the manual mode. The cooling air bypass dampers have position switches that show the status of the bypass damper at the PCC.

#### GAS TURBINE ENGINE ASSEMBLY

The LM2500 GTE is an axial-flow, split-shaft GTE with an annular-type combustion chamber. The gas turbine assembly aboard ship has a GG, a PT, a high-speed flexible coupling shaft, and inlet and exhaust components. The GG is composed of a FOD screen, a bellmouth, a 16-stage variable geometry compressor, an annular combustor, a two-stage high-pressure (HP) turbine, an accessory drive system, controls, and accessories. The accessory gearbox (AGB) is mounted on the GG. The PT is aerodynamically linked to the GG and is composed of a six-stage low-pressure (LP) turbine rotor, a low-pressure turbine stator, and a turbine rear frame. The high-speed flexible coupling shaft is connected to the power-turbine rotor and provides shaft power to the ship's drive system. The GTE inlet components consist of the inlet duct and the centerbody (see fig. 2-2). The GTE exhaust components consist of the exhaust duct, the outer cone, and the inner deflector (see fig. 2-11).

#### GAS GENERATOR ASSEMBLY

In this section we will individually describe the GG assembly components and their functions. These components are the FOD screen, bellmouth and bulletnose, compressor, combustor, HP turbine, and accessory drive.

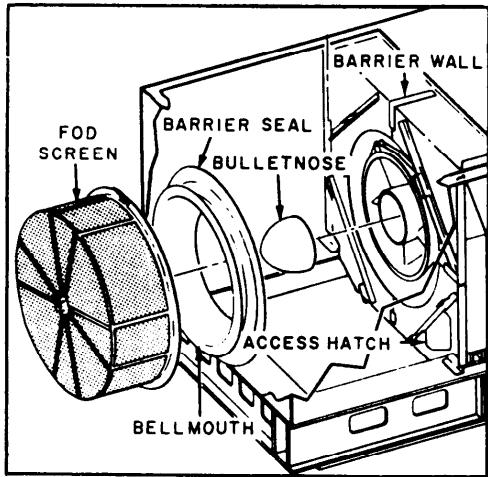


Figure 2-21.—LM2500 GTE inlet (FOD screen, centerbody (bulletnose), and bellmouth).

## FOD Screen

The FOD screen, or air inlet screen (fig. 2-21), is mounted on the module barrier wall. The purpose of this screen is to prevent foreign objects larger than 1/4 inch from entering the engine.

The screen will also prevent items from entering the engine if the blow-in doors open.

After major work, major intake cleaning, or anytime the ship is coming out of a shipyard environment, a special screen is used. It is a nylon screen that attaches over the metal FOD screen. The nylon screen will catch particles much smaller than the metal screen will. You must be careful not to exceed specified throttle limitations when using the nylon screen. Exceeding throttle limitations could starve the engine for air and cause a compressor stall. NAVSEA issues specific instructions for use of the nylon FOD screen.

## Bellmouth and Bulletnose

The bellmouth and bulletnose (centerbody) (see fig. 2-21) are mounted on the forward end of the compressor front frame. These components are used to direct air from the inlet plenum to the compressor. The surfaces of the two components have a smooth coat to reduce the turbulence of the airflow into the engine. The bellmouth also contains the water wash manifold. The water wash manifold is used to inject fresh water and/or a cleaning solution into the engine. This is done when the engine is being motored. This procedure is for maintenance purposes to clean deposits from the compressor. The water wash manifold is supplied by a common water wash system piped as a ship's system.

## Compressor Section

The LM2500 GTE compressor (fig. 2-22) is a 16-stage, HP ratio, axial-flow design. Major

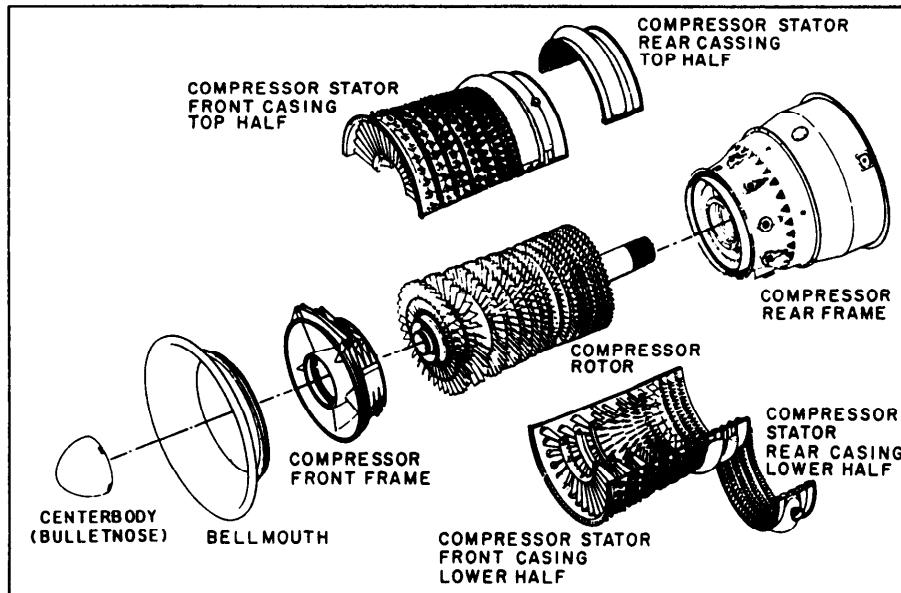


Figure 2-22.—LM2500 GTE compressor components.

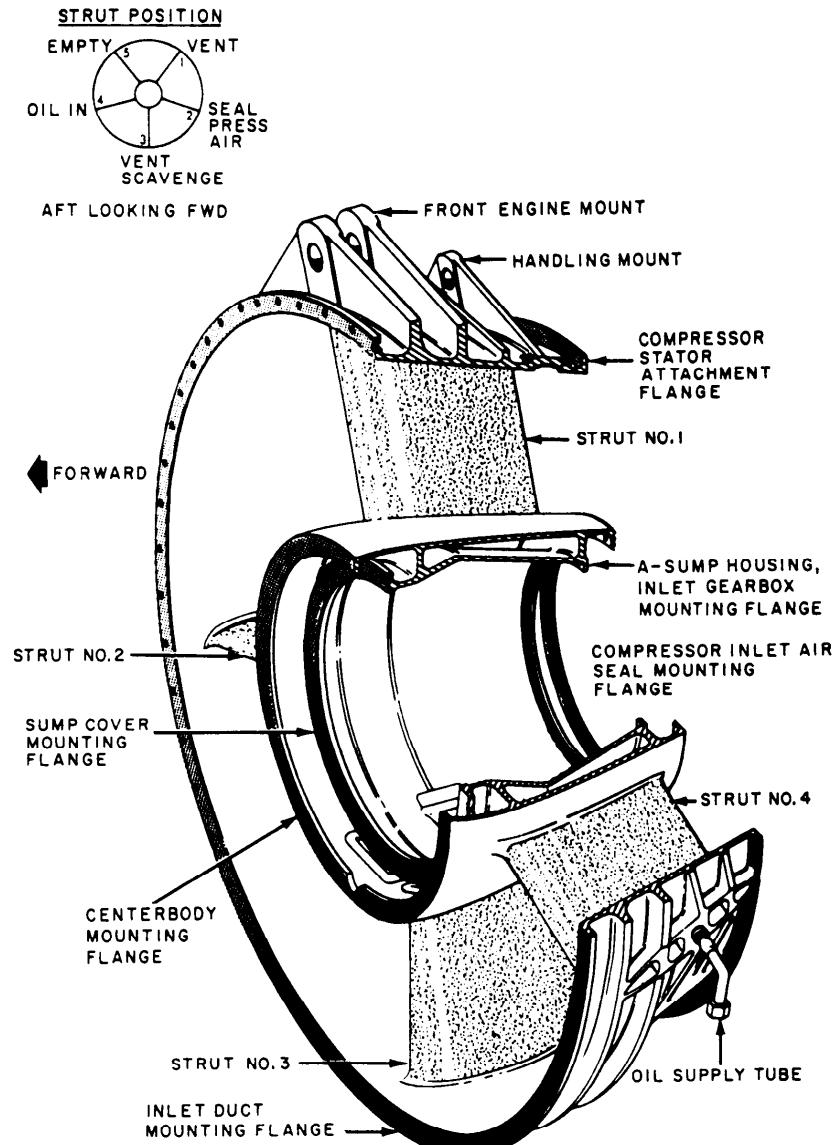


Figure 2-23.—Compressor front frame.

components are the compressor front frame, a compressor stator, a compressor rotor, and the compressor rear frame. The primary purpose of the compressor section is to compress air for combustion. A secondary purpose of the compressor section is to provide air for engine cooling, sump seal pressurization, and bleed air for ship's service use.

Air is drawn in through the front frame. Then it passes through successive stages of compressor rotor blades and compressor stator vanes. The air is compressed as it passes from stage to stage. After passing through 16 stages, the air has been compressed in the ratio of about 16 to 1. The

inlet guide vanes (IGVs) and first six stages of stator vanes are variable; their angular position is varied as a function of GG speed and compressor inlet temperature (CIT) by hydraulic fuel pressure from the main fuel control (MFC). This provides stall-free operation of the compressor throughout a wide range of speed and inlet temperature. Because these blades are able to be set at different angles, the term *variable geometry* applies to this compressor.

**FRONT FRAME.**—The compressor front frame (fig. 2-23) provides the forward attachment point for the GTE, supports the forward end of

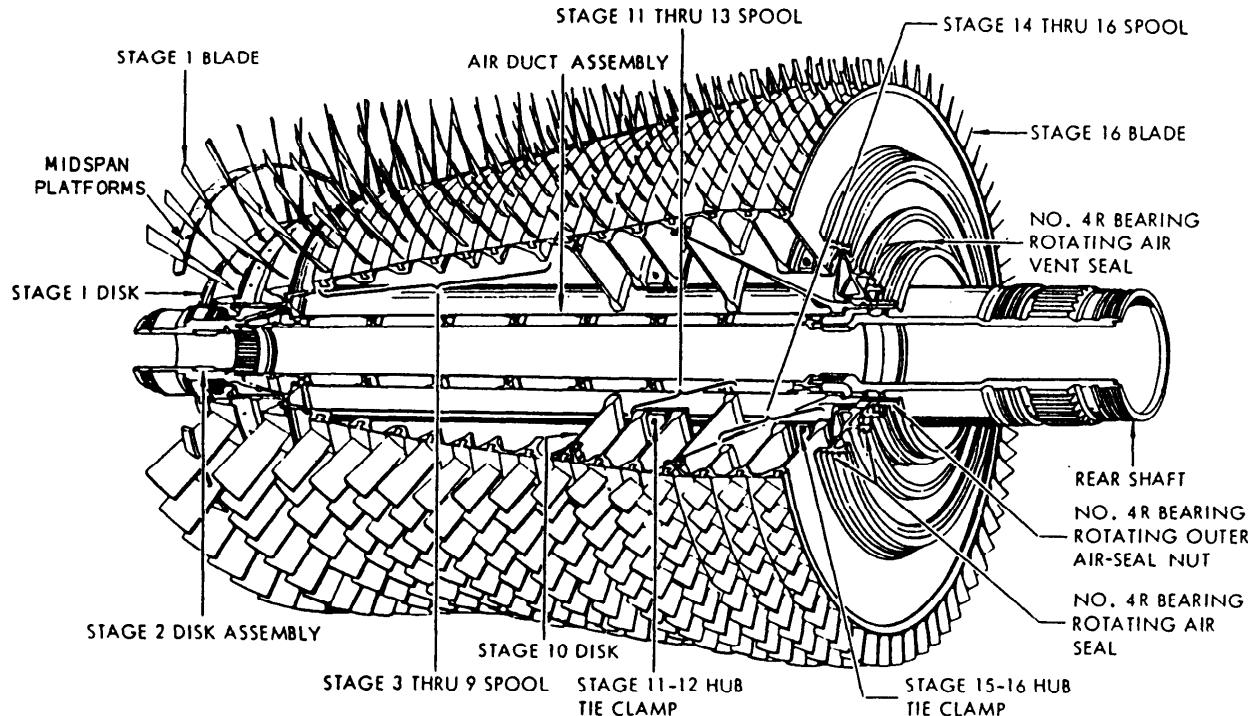


Figure 2-24.—Compressor rotor.

the compressor section, and forms a flow path for compressor inlet air. Five struts (see strut positions, fig. 2-23) between the hub and the outer case provide passages for lube oil, scavenge oil, seal pressurization air, and a vent for the A-sump components. The bearings of the engine are numbered 3 through 7. The No. 3 bearing, which supports the forward end of the compressor rotor and the inlet gearbox, are located in the A sump. The compressor inlet total pressure ( $P_{t2}$ ) probe and CIT sensor (not shown) are mounted in the outer case. The No. 3 strut (6 o'clock position) houses the radial drive shaft which transfers power from the inlet gearbox to the transfer gearbox (TGB) mounted on the bottom of the frame.

**ROTOR.**—The compressor rotor (fig. 2-24) is a spool/disk structure with circumferential dovetails. The use of spools makes it possible for several stages of blades to be carried on a single piece of rotor structure. The seven major structural elements and three main bolted joints are as follows:

- The first-stage disk, the second-stage disk (with integral front stub shaft), and the 3- through

9-spool stage are joined by a single bolted joint at stage 2.

- The 3- through 9-spool stage, the stage 10 disk, and the 11- through 13-spool stage are bolted at the stage 10 joint.
- The 11- through 13-spool (with its integral rear shaft) and the cantilevered 14- through 16-spool connect in a single bolted joint at stage 13.

An air duct, supported by the front and rear shafts, routes stage 8 air aft through the center of the rotor for pressurization of the B-sump seals. Close vane-to-rotor spool and blade-to-stator casing clearances are obtained with metal spray-rub coating. Thin squealer tips on the blades and vanes contact the sprayed material and abrasive action on the tips prevents excessive rub while obtaining minimum clearance. The first-stage blades have midspan platforms to reduce blade tip vibration.

**STATOR.**—The compressor stator has four sections bolted together. The top and bottom cases are manufactured in matched sets. For

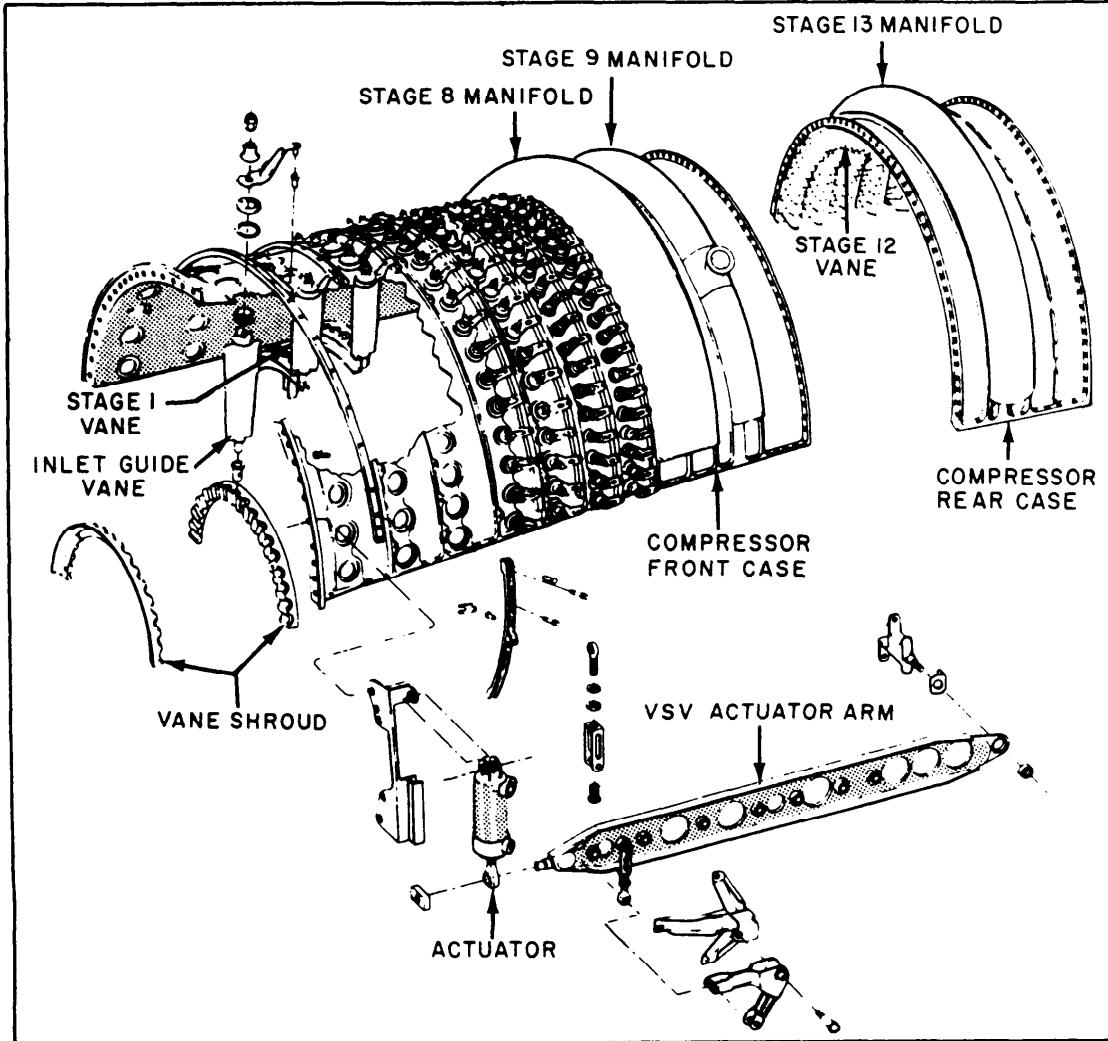
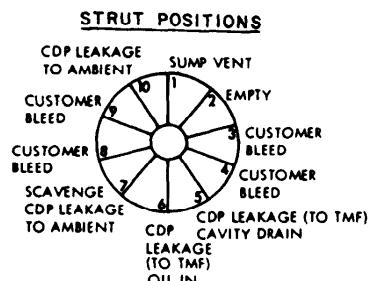


Figure 2-25.—Compressor stator.

clarity, figure 2-25 shows only the top two sections and the major components of the compressor stator. The front casing contains the IGVs and stages 1 through 11. The IGVs and the first six stages are variable to provide stall-free operation. The variable vanes are actuated by a pair of master levers (one on each side). The aft end of the master levers are attached to pivot posts at about the 10th stage on each side of the casing. Each of the lever's forward ends is positioned by a hydraulic actuator which uses fuel oil as the actuating medium. The operation of the IGVs and variable stator vanes (VSVs) are covered later in this chapter. The remaining vanes are stationary. The rear casing contains the 12th through the 16th stages, which are also stationary.

Three bleed manifolds are welded to the stator casings. Eighth-stage air, used for sump seal pressurization and cooling, is extracted from inside the annulus area at the tips of the hollow eighth-stage vanes. Ninth-stage air, used for PT cooling, PT forward seal pressurization, and PT balance piston cavity pressurization, is extracted from between the ninth-stage vanes through holes in the vane bases. Thirteenth-stage air, used for cooling the second-stage HP turbine nozzle, is extracted from between the thirteenth-stage vanes through holes in the vane bases.

**REAR FRAME.**—The compressor rear frame (fig. 2-26) has an outer case, a hub containing the B sump, and 10 struts attaching the hub to the outer case. The outer case supports the



AFT LOOKING FWD

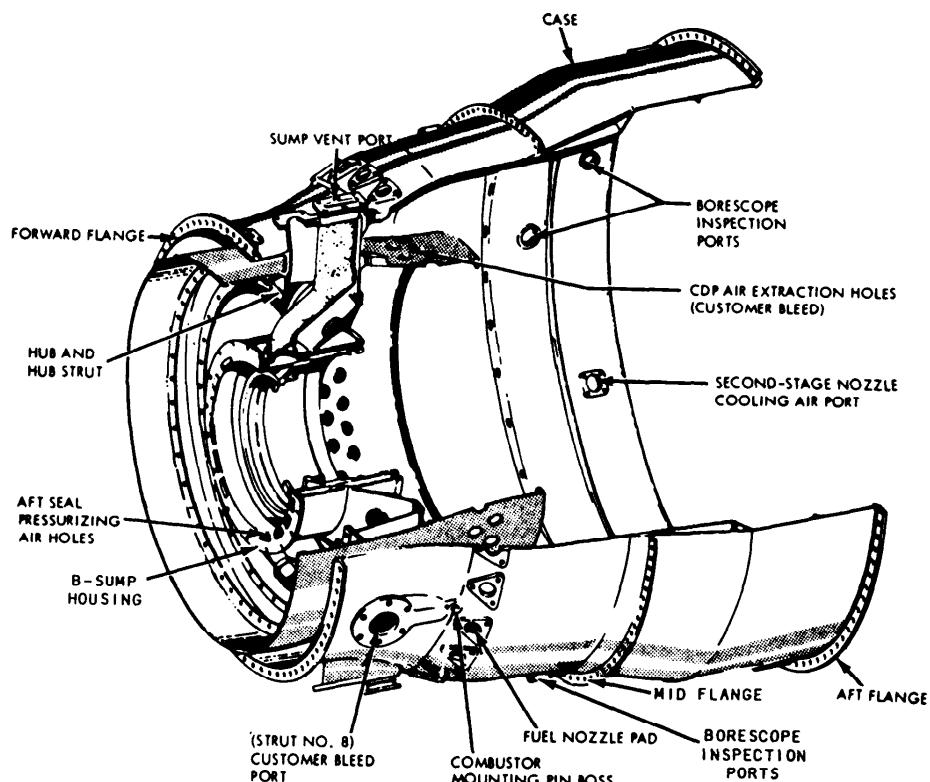


Figure 2-26.—Compressor rear frame.

combustor, the fuel manifold, 30 fuel nozzles, 2 spark igniters, and the first-stage HP turbine nozzle support. To provide the ship's bleed air system with compressor discharge air, an internal manifold within the frame extracts air upstream of the combustion area and routes it through struts 3, 4, 8, and 9. Compressor discharge air is also used for cooling the HP internal structures and the HP stage 1 and stage 2 blades. This will be addressed in more detail later. Six borescope ports, located in the case just forward of the mid flange, permit inspection of the

combustor, fuel nozzles, and the first-stage turbine nozzle.

Two borescope ports are provided in the aft portion of the case for inspection of the turbine blades and nozzles. The B sump contains the No. 4R and 4B bearings (R or no letter = roller, B = ball). The 4B bearing is the thrust bearing for the HP rotor system. The frame struts provide passage for lube oil, scavenge oil, sump vent, seal leakage (air leakage past the compressor discharge pressure (CDP) seals), and customer bleed air for masker, prairie, anti-icing, and engine starting services. The rear frame supports the aft end of

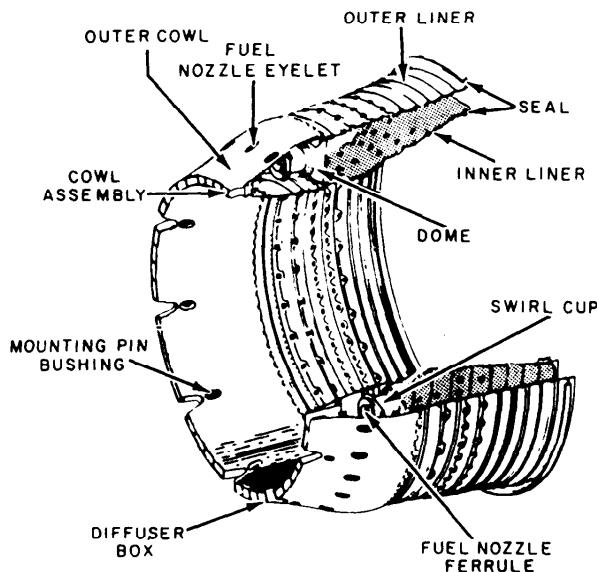


Figure 2-27.—LM2500 GTE combustor.

the compressor stator by the frame's forward flange, the aft end of the compressor rotor by the No. 4R and 4B bearings, and the forward end of the HP turbine rotor by the 4R and 4B bearings.

### Combustor Section

The LM2500 GTE combustor (fig. 2-27) is an annular type and has four major components riveted together—the cowl (diffuser) assembly, the dome, the inner liner, and the outer liner.

The cowl assembly and the compressor rear frame serve as a diffuser and distributor for the compressor discharge air. They furnish uniform airflow to the combustor throughout a large operating range. This provides uniform combustion and even-temperature distribution at the turbine. The combustor is mounted in the compressor rear frame on 10 equally spaced mounting pins in the forward (low temperature) section of the cowl assembly. These pins provide positive axial and radial location and assure centering of the cowl assembly in the diffuser passage. The mounting hardware is enclosed within the compressor rear frame struts so it will not affect airflow. Strength and stability of the cowl ring section are provided with a truss structure. The structure has 40 box sections welded to the cowl walls. The box sections also serve as aerodynamic diffuser elements. The cowl assembly leading edge fits within and around the compressor rear frame struts. This arrangement provides a short overall combustor system length.

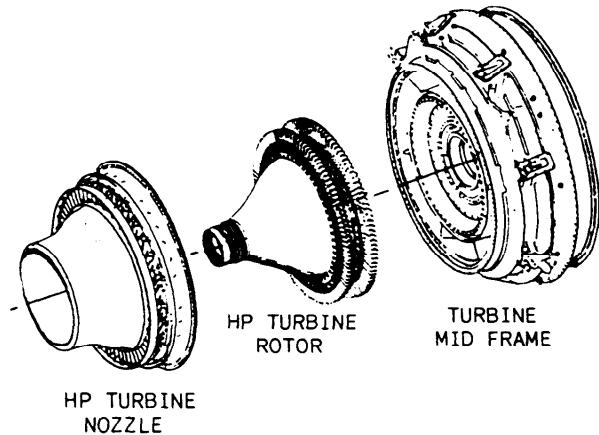


Figure 2-28.—HP turbine.

Thirty vortex-inducing axial swirl cups in the dome (one at each fuel nozzle tip) provide flame stabilization and mixing of the fuel and air. The interior surface of the dome is protected from the high temperature of combustion by a cooling-air film of the 16th-stage air. Accumulation of carbon on the fuel nozzle tips is minimized by venturi-shaped spools attached to the swirler.

The combustor liners are a series of overlapping rings joined by resistance-welded and brazed joints. They are protected from the high combustion heat by circumferential film cooling. Primary combustion and cooling air enters through closely spaced holes in each ring. These holes help to center the flame and admit the balance of the combustion air. Dilution holes on the outer and inner liners provide additional mixing to lower the gas temperature at the turbine inlet. Combustor/turbine nozzle air seals at the aft end of the liners prevent excessive air leakage and also provide for thermal growth.

About 30 percent of the total airflow is used in the combustion process. To understand this, you need to know that the ideal fuel/air ratio for combustion is about 15 to 1 (15 parts of air to 1 part of fuel). The rated airflow of the LM2500 GTE is 123 lb/sec or 442,800 lb/hour. At rated power, the engine burns about 9,000 pounds of fuel per hour. At the ideal fuel/air ratio of 15 to 1, only 135,000 pounds of air per hour, is required (30.5 percent of 442,800).

The remaining 70 percent of the airflow is used for cooling, seal pressurization, and ship's service use. This breaks down to 5.5 percent (maximum) used for ship's service and about 0.5 percent for seal pressurization. The rest is used for cooling, the majority of which reenters the mass flow cycle.

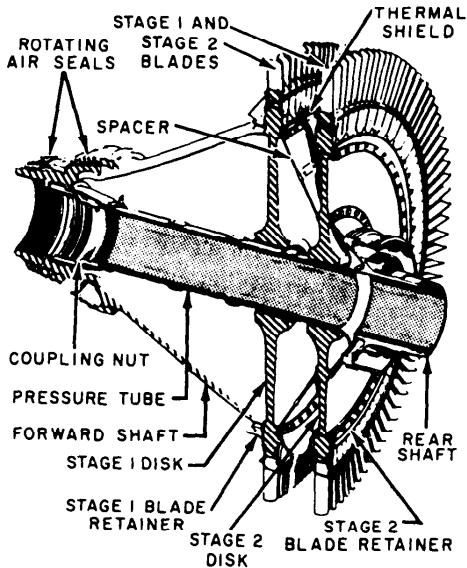


Figure 2-29.—HP turbine rotor.

### High-Pressure Turbine Section

The HP turbine section (fig. 2-28) has an HP turbine rotor, the first- and second-stage turbine nozzle assemblies, and the turbine mid frame. The turbine rotor extracts energy from the gas stream to drive the compressor rotor. The turbine rotor is mechanically coupled with the compressor rotor. The turbine nozzles direct the hot gas from the combustor onto the rotor blades at the best angle and velocity.

The turbine nozzles are contained in and supported by the compressor rear frame. The turbine mid frame, besides supporting the aft end of the turbine rotor, also supports the front end of the PT and contains the transition duct. The gas flows throughout this duct from the HP turbine section into the PT.

**ROTOR.**—The HP turbine rotor (fig. 2-29) has a conical forward shaft, two disks with blades and retainers, a conical rotor spacer, a thermal shield, and a rear shaft. The front end of the turbine rotor is supported at the compressor rotor rear shaft by the No. 4 bearings. The rear of the rotor is supported by the No. 5 bearing in the turbine mid frame (C sump).

Energy extracted from the hot combustion gases is transmitted to the compressor rotor through the turbine rotor forward shaft. Two air seals are on the forward end of the forward shaft. The front seal helps prevent CDP air from entering the sump. The other seal maintains CDP in the plenum formed by the rotor and combustor. This plenum is a balance chamber that provides a corrective force that minimizes the thrust load on the No. 4B bearing.

**High-Pressure Turbine Rotor Cooling.**—The HP turbine rotor is cooled by a continuous flow of compressor discharge air. This air passes through holes in the first-stage nozzle support and in the forward turbine shaft. The air cools the inside of the rotor and both disks before passing between the dovetails and out to the blades. Figure 2-30 shows the airflow path for HP turbine rotor cooling.

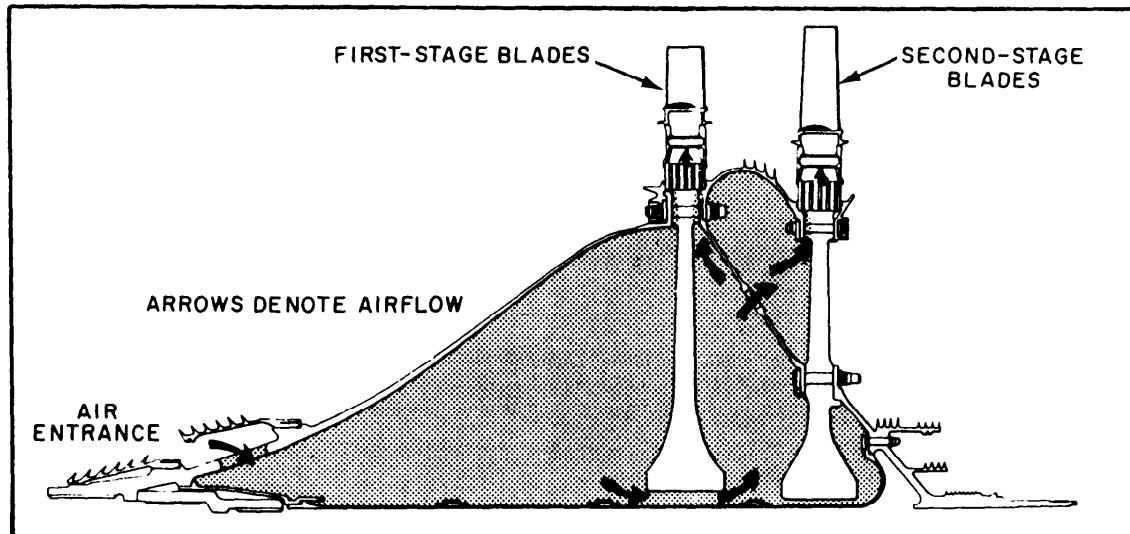


Figure 2-30.—HP turbine rotor cooling.

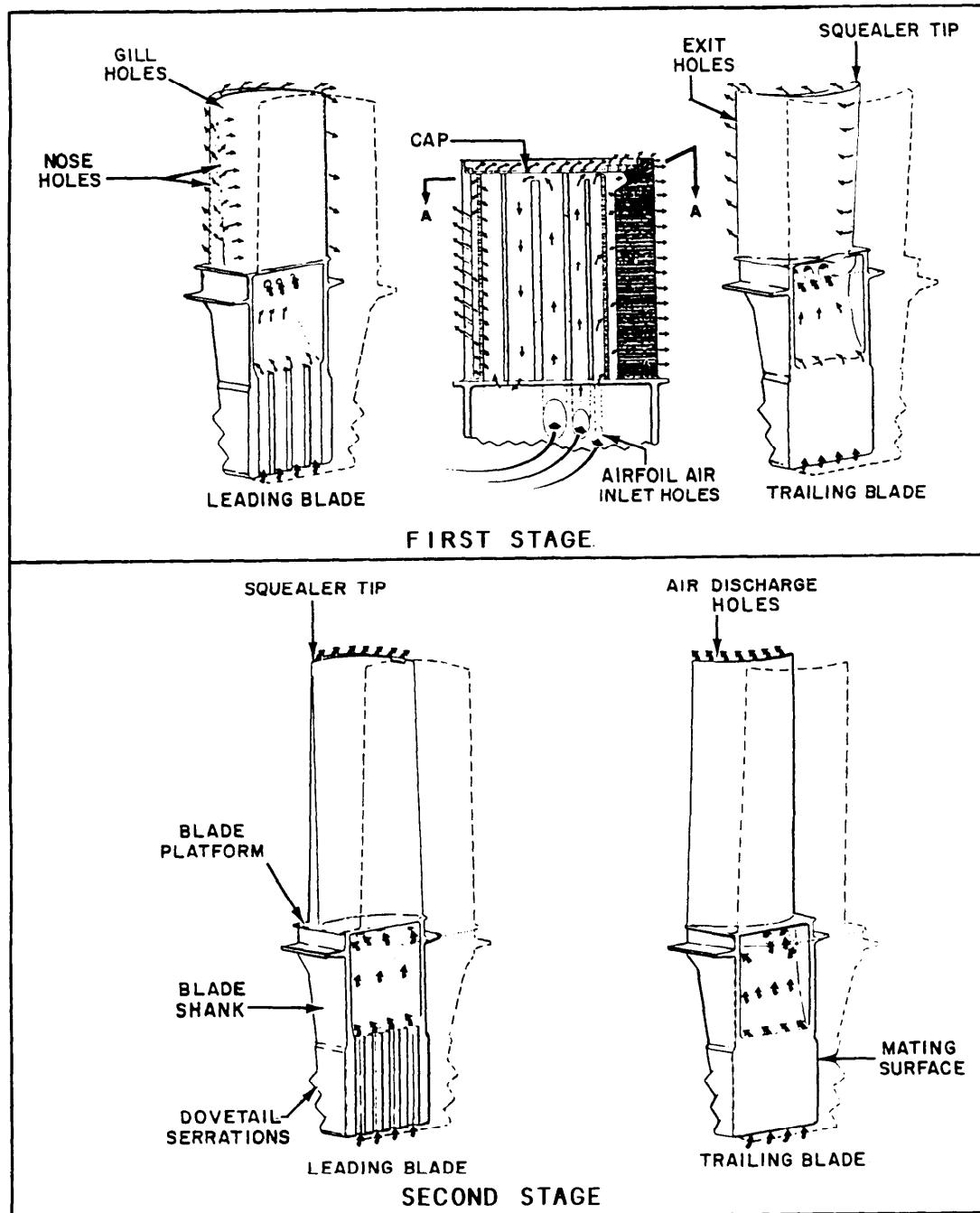


Figure 2-31.—HP turbine rotor blade cooling.

**High-Pressure Turbine Blade Cooling.**—Both stages of HP turbine blades are cooled by compressor discharge air (fig. 2-31). This air flows through the dovetail and through blade shanks into the blades. First-stage blades are cooled by internal convection and external film cooling. The convection cooling of the center area is done through a labyrinth within the blade. The

leading edge circuit provides internal convection cooling by airflow through the labyrinth and out through the leading edge nose and gill holes. Convection cooling of the trailing edge is provided by air flowing through the trailing edge exit holes. Second-stage blades are cooled by convection, with all the cooling air discharged at the blade tips.

### **FIRST-STAGE NOZZLE ASSEMBLY.—**

The first-stage nozzle assembly has the nozzle support, the nozzles, the inner seal, the outer seal, and baffles (fig. 2-32). The nozzles are coated to improve erosion and oxidation resistance. They are bolted to the first-stage nozzle support and receive axial support from the second-stage nozzle support. The nozzle assembly has 32 nozzle segments, each segment has two vanes. The vanes are cast and then welded into pairs (segments) to decrease the number of gas leakage paths. The

first-stage nozzles are cooled by air from the compressor's 16th stage. The first-stage nozzle support forms the inner flow path wall from the compressor rear frame to the nozzle segments. Additionally, it supports the nozzle segments. It is bolted to the aft end of the pressure balance seal support.

### **SECOND-STAGE NOZZLE ASSEMBLY.—**

The major parts of the second-stage nozzle assembly (fig. 2-33) are the nozzles, the nozzle

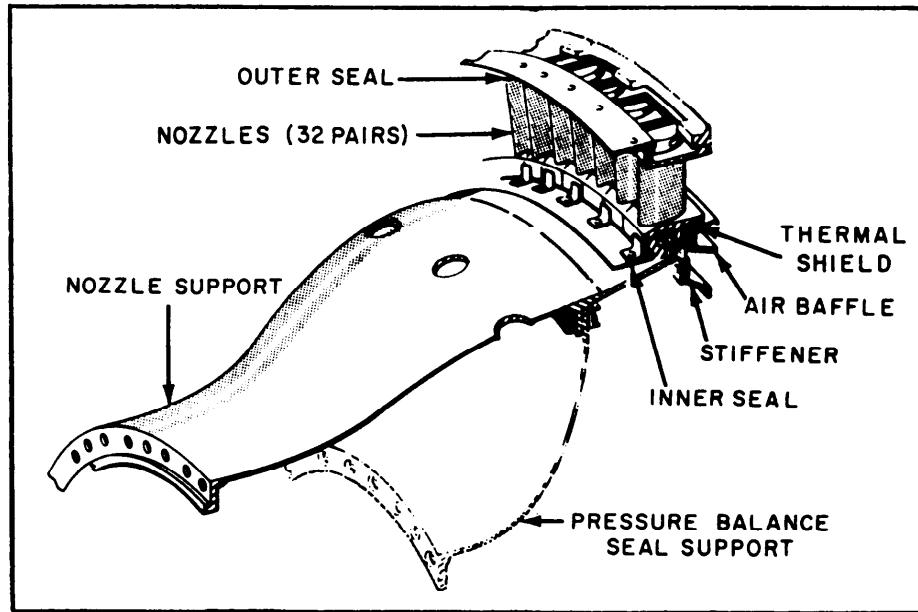


Figure 2-32.—First-stage HP turbine nozzle.

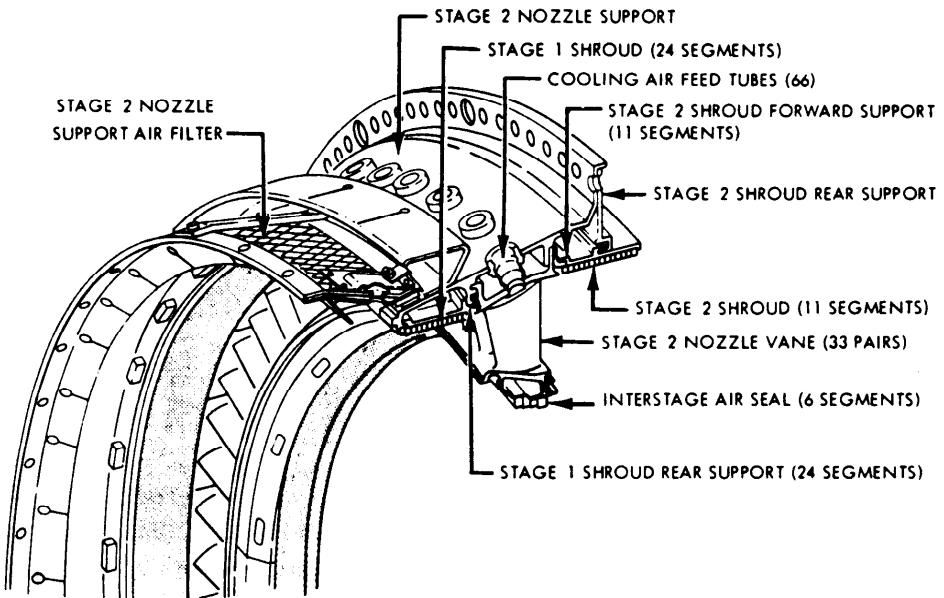
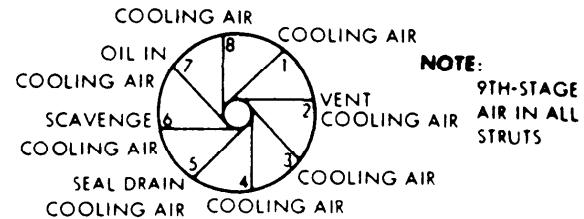


Figure 2-33.—Second-stage HP turbine nozzle.

support, the stage 1 and stage 2 turbine shrouds, and the interstage seal. The nozzle support is a conical section with a flange that is bolted between the flanges of the compressor rear frame and the turbine mid frame. The support provides for the mounting of the nozzles, the cooling air feeder tubes, and the stage 1 and stage 2 turbine shrouds. The nozzles are cast and then coated to improve erosion and oxidation resistance. The vanes (two per nozzle) direct the gas stream onto the second-stage turbine blades. The inner ends of the nozzles form a mounting circle for the interstage seal attachment. The turbine shrouds form a portion of the outer aerodynamic flow path through the turbine. They are located radially in line with the turbine blades and form a pressure seal to prevent excessive gas leakage over the blade tips. The first stage has 24 shroud segments; the second stage has 11 shroud segments. The interstage seal is composed of six segments bolted to the nozzles. Its purpose is to minimize gas leakage between the second-stage nozzle and the turbine rotor. The sealing surface is honeycomb and has four steps for maximum sealing. Since the honeycomb cools more rapidly than the four rotating sealing teeth, the honeycomb is pre-grooved to prevent contact under rapid or emergency shutdown conditions. The second-stage nozzle is air-cooled by convection. The nozzle vane center area and leading edge are cooled by 13th-stage air which enters through cooling air tubes. Some of the air is discharged through holes in the trailing edge; the remainder flows out through the bottom of the vanes and is used to cool the interstage seals and turbine blade shanks.

**MID FRAME.**—The turbine mid frame (fig. 2-34) supports two areas. It supports the aft end of the HP turbine rotor (No. 5 bearing); and the forward end of the PT rotor (No. 6 bearing). It is bolted between the aft flange of the compressor rear frame and the forward flange of the PT stator. The frame provides smooth diffuser flow passage for HP turbine exhaust gas into the PT. The frame hub is an open, drum-shaped, one-piece casting with flanges to support the C-sump housing, stationary seals, inner liner support, and PT first-stage nozzle support. The C sump contains the No. 5 and No. 6 bearings. Eight struts connect the hub to the outer case. The struts provide passage for C-sump lubrication and scavenge oil, cooling air, sump vent, and seal drain services.

### STRUT POSITIONS



### AFT LOOKING FORWARD

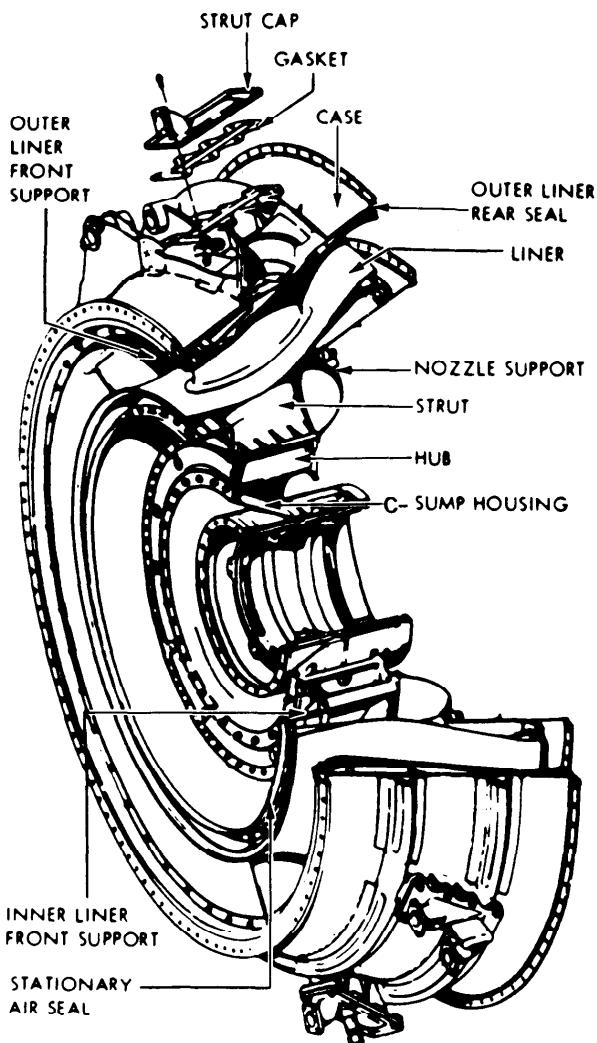
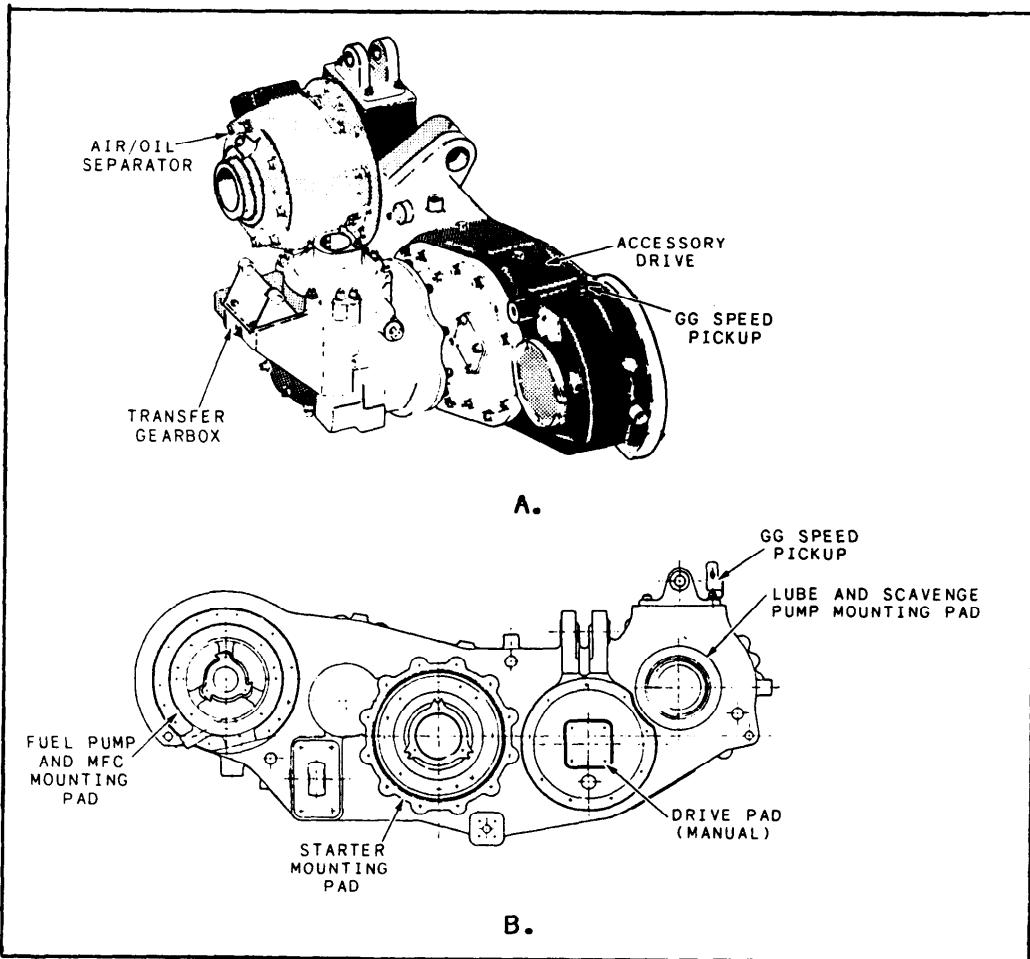


Figure 2-34.—Turbine mid frame.

The frame has ports for the HP turbine exhaust thermocouples and pressure probes (not shown). These ports also provide access for borescope inspection of the PT inlet area. The PT first-stage nozzle assembly is part of the frame.



**Figure 2-35.—Accessory drive section. A. Accessory gearbox. B. Aft view of accessory gearbox.**

The frame liner assembly has an inner and an outer liner held together with airfoil-shaped strut fairings butt-welded to both liners. This assembly guides the gas flow and shields the main structure from high temperature. The PT first-stage nozzle assembly is part of the turbine mid frame assembly. This assembly has 14 segments with 6 vanes each. The inner end is bolted to the nozzle support; the outer end is secured between the mid frame aft flange and the PT stator forward flange.

### Accessory Drive Section

The accessory drive section (fig. 2-35) has an inlet gearbox in the hub of the front frame, a radial drive shaft inside the 6 o'clock strut of the front frame, and a TGB bolted underneath the front frame. The fuel pump and MFC, the

pneumatic starter, and the lube and scavenge pump are mounted on the aft side of the TGB. It also provides mounting for the GG speed pickup. An air/oil separator on the front is a part of the gearbox.

Power to drive the accessories is extracted from the compressor rotor through a large-diameter hollow shaft which is spline-connected to the rotor front shaft. A set of bevel gears in the inlet gearbox transfers this power to the radial drive shaft. The radial drive shaft transmits the power to another set of bevel gears in the forward section of the TGB. Each bevel gear is supported by a duplex ball bearing and a roller bearing. A short horizontal drive shaft transmits the power to the accessory drive adapters in the TGB.

**TRANSFER GEARBOX.**—The TGB shown in figure 2-35, view A, has a two-piece aluminum

casing, an air/oil separator, gears, bearings, seals, oil nozzles, and accessory adapters. The accessories are the fuel pump, main fuel control (MFC), lube and scavenge pump, air/oil separator, and starter. All except the air/oil separator are mounted on the aft section (fig. 2-35, view B). The aft section of the TGB is the AGB. An access cover in the bottom of the casing allows easy removal and installation of the radial drive shaft. Also, an access cover is on the manual drive pad. This feature allows access to the jacking gears, which you can use to manually jack the engine over for maintenance.

The "plug-in" gear concept is used on all accessory adapters and idler gears in the aft section. This concept permits an entire gear, bearing, seal, and adapter assembly to be removed and replaced without disassembling the gearbox. Each spur gear is supported by a casing-mounted roller bearing on one end and an adapter-mounted ball bearing on the other end. The accessory drive spur gears are internally splined. Internal tubes and oil nozzles provide lubrication of the gears and bearings. Gearbox carbon-face seals are retained from the outside of the gearbox. You can replace them without disassembly of the gearbox. The TGB is assembled as a single unit and bolted to the engine externally. This feature allows you to replace the entire unit without removing the engine from the enclosure.

**INLET GEAR BOX.**—The inlet gearbox assembly (fig. 2-36) has a cast aluminum casing,

a shaft, a pair of bevel gears, bearings, and oil jets (not shown). Two duplex ball bearings and a roller bearing are mounted in the casing. The casing is bolted inside the front frame hub and has internal oil passages and jets to provide lubrication for the gears and bearings. The shaft, which rotates on a horizontal axis, is splined at the aft end to mate with the second-stage disk of the compressor rotor. The forward end of the shaft mounts the upper bevel gear and is supported by a duplex ball bearing. The lower bevel gear rotates on a vertical axis. It is supported at its upper end by a roller bearing and at its lower end by a duplex ball bearing. The lower end is also splined to mate with the radial drive shaft.

**RADIAL DRIVE SHAFT.**—The radial drive shaft, a hollow shaft externally splined on each end, mates with the bevel gears in the inlet and transfer gearboxes. Its function is to transmit power from the inlet gearbox to the forward section (bevel gearbox) of the TGB. The shaft contains a shear section (for overtorque protection) to prevent damage to the accessory drive system.

#### POWER TURBINE/LOW-PRESSURE SECTION

The PT is used to extract the remaining energy from the hot gas. This energy is used to power the ship for propulsion. The PT section (fig. 2-37) has a six-stage LP turbine rotor, a turbine stator, and a rear frame. The PT is a separate unit from

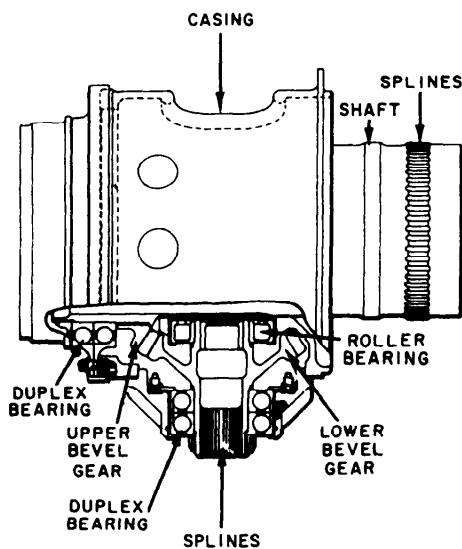


Figure 2-36.—Inlet gearbox.

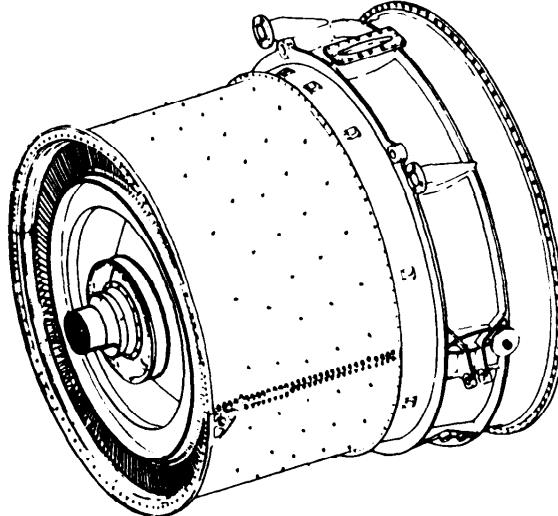


Figure 2-37.—LM2500 GTE power turbine.

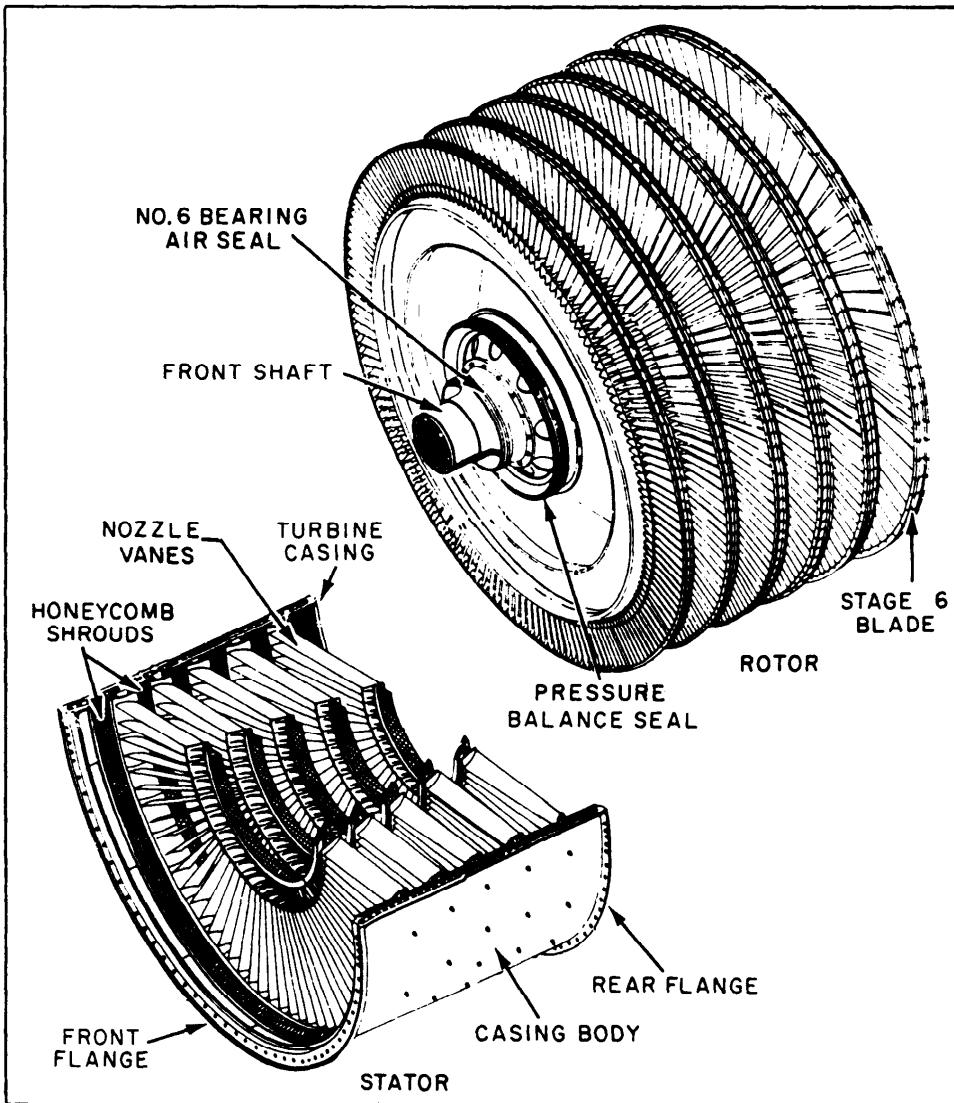


Figure 2-38.—LP turbine rotor and stator.

the GG. If the GG must be changed out, it is simply unbolted from the PT and removed. If PT replacement is required, the GG must be removed also.

### Rotor

The PT rotor (fig. 2-38) has six disks with integral disk spacers bolted together to form the rotor spool. Blades of all six stages contain interlocking tip shrouds for low vibration levels and are retained in the disks by dovetails. Replaceable rotating seals, secured between the disk spacers, mate with stationary seals to prevent excessive gas leakage between stages. The

first three stages of blades are coated for corrosion protection.

### Stator

The PT stator, also shown in figure 2-38, has two casing halves (only the lower half is shown), the stage 2 through 6 turbine nozzles, and six stages of blade shrouds. The first-stage nozzle is part of the turbine mid frame. Honeycomb shrouds, mounted in casing channels, mate with the shrouded blade tips to provide close-clearance seals. These stationary interstage seals are attached to the inner ends of the nozzle vanes to maintain low leakage between stages. Insulation

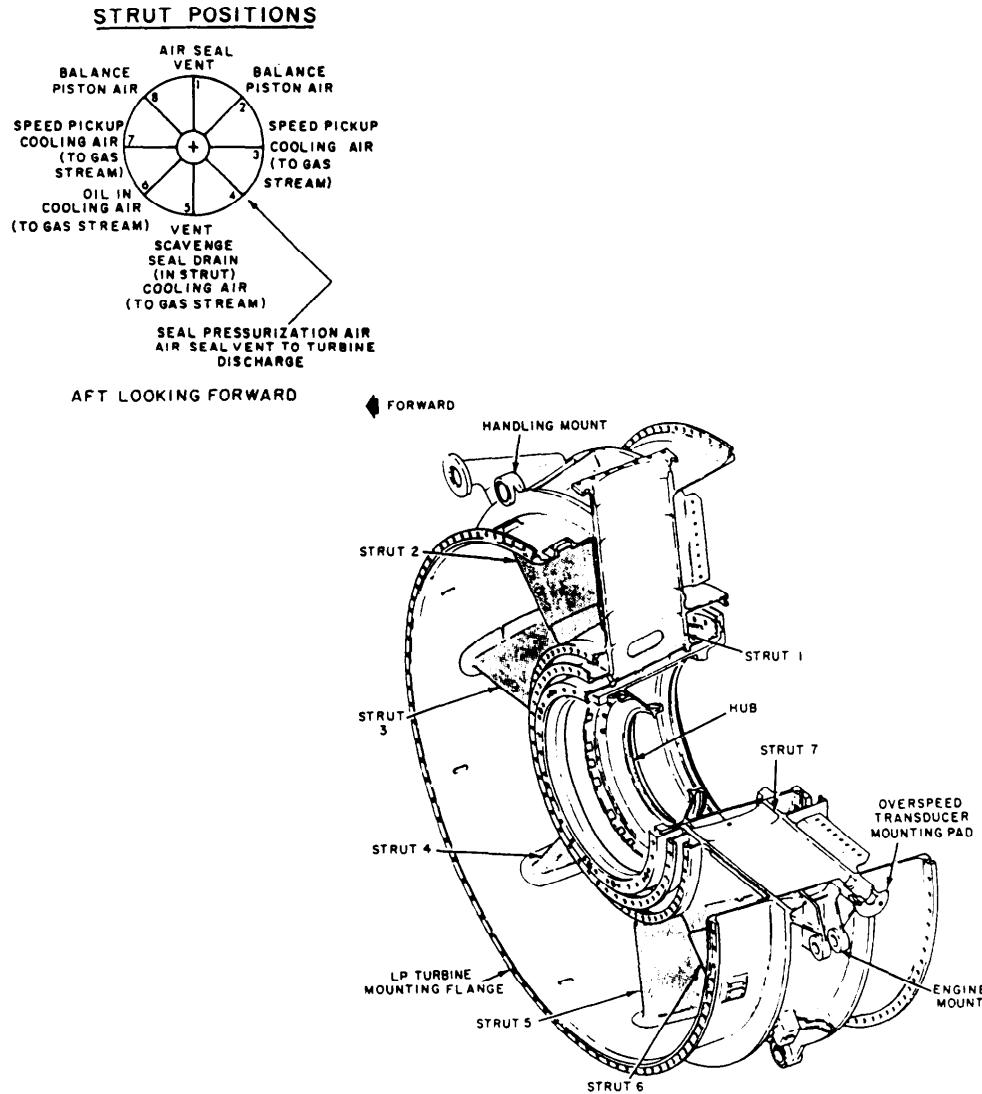


Figure 2-39.—PT rear frame.

is installed between nozzle shrouds and casing to protect the casing from the high temperature of the gas stream.

#### Rear Frame

The PT rear frame (fig. 2-39) has an outer casing, eight equally spaced radial struts, and a single-piece cast-steel hub. It forms the PT exhaust flow path and supports the aft end of the PT. It also supports the forward end of the high-speed flexible-coupling shaft. The turbine rear frame hub supports the inner deflector of the exhaust system. It also has a bearing housing for the No. 7B and No. 7R bearings. The No. 7B bearing is the thrust bearing for the PT. The hub and the

bearing housings have flanges to which air and oil seals are attached to form the D sump. The frame casing supports the outer cone of the exhaust system and provides attaching points for the GTE rear supports. The struts provide passage for lubrication and scavenging oil, C- and D-sump seal pressurization air, D-sump vent, cooling air, and PT balance piston air services. The two PT speed pickups also pass through the struts (No. 3 and No. 7).

#### HIGH-SPEED FLEXIBLE COUPLING SHAFT

The high-speed flexible-coupling shaft has a forward adapter, which mates with the PT, two

flexible couplings, a distance piece, and an aft adapter, which mates with the reduction gear high-speed pinion. The forward and aft adapters are connected to the distance piece by the flexible couplings. The flexible couplings allow for axial and radial deflection between the GTE and the ship's drive system during operation. Inside the aft adapter and the aft flexible coupling is an axial damper system which has a cylinder and piston assembly. The damper assembly prevents excessive cycling of the flexible couplings. Antideflection rings restrict radial deflection of the couplings during shock loads.

## ENGINE SYSTEMS

Engine control systems were discussed briefly in chapter 1 of this TRAMAN. They consist of the start air system, the fuel and speed-governing system, the synthetic lube oil system, the ignition

system, the water wash system, and the bleed air system. In this section, we will present a more detailed description of these systems for the LM2500 GTE.

## START AIR SYSTEM

The start air system provides compressed air to rotate the engine starter through the accessory drive. The starter rotates the GG for starting, motoring, and water washing. The system uses either engine bleed air or HP air on the CG-, DD-, class ships. The FFG-class ships use HP air as the primary start system and diesel-driven start air compressors (SACs) and engine bleed air as secondary start air systems.

The start air system (fig. 2-40) has a pneumatic turbine starter and a starter (air regulating) valve. The starter is mounted on the aft side of the TGB (AGB). The starter valve is line-mounted behind the starter. The starter drives the GG through the gearbox during the start cycle. It drives it until the GG reaches or exceeds self-sustaining speed.

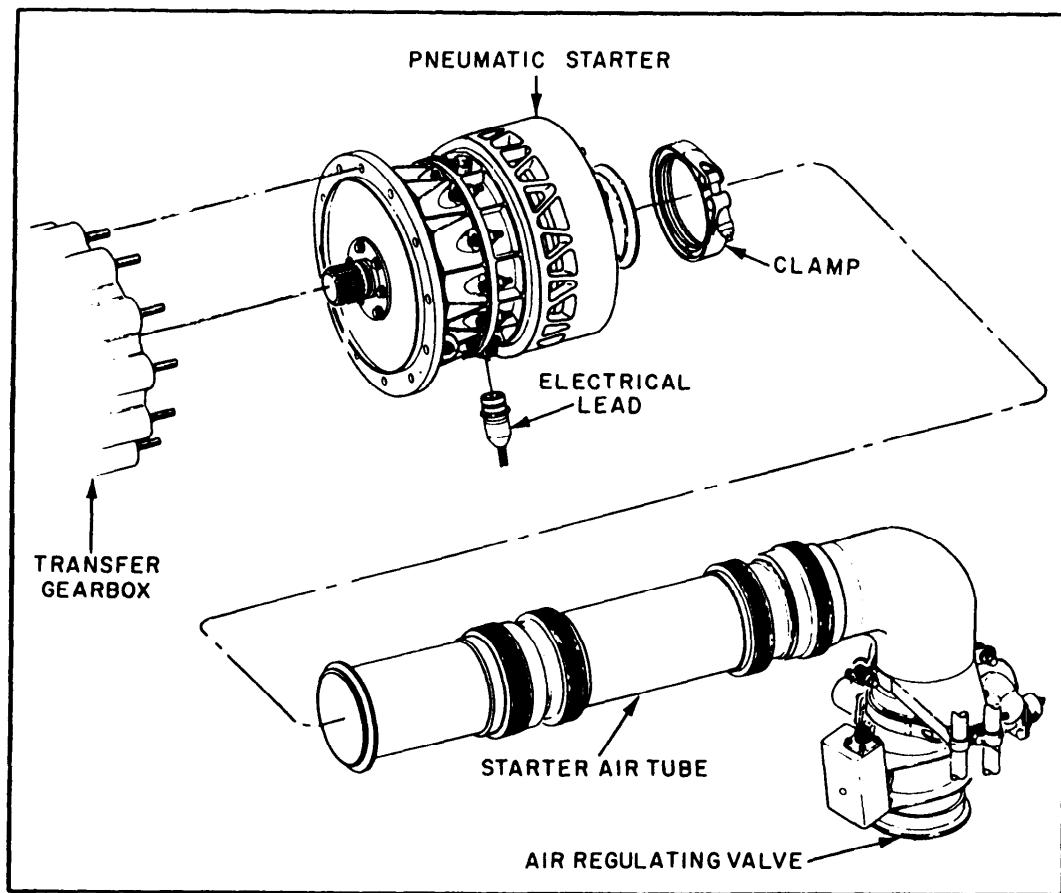


Figure 2-40.—LM2500 GTE start air system.

## Starter

The starter has an inlet assembly, a turbine assembly, and reduction gearing. It also includes a cutout switch, an overrunning clutch, and a splined output shaft. The turbine is a single-stage, axial-flow type. The reduction gearing is a compound planetary system with a rotating ring gear. The overrunning clutch is a pawl and ratchet type. This provides positive engagement during starting and overrunning when driven by the GG. The cutout switch is normally closed. It is actuated by a centrifugal governor which trips open the switch. This also illuminates a STARTER CUTOUT indicator light at the propulsion consoles. The output shaft has a shear section to prevent overtorque damage. The starter operating air pressure is 35 to 41 psig for starting and  $21 \pm 1$  psig for water washing. Air to the starter is piped from the starter air regulating valve. The starter exhausts directly into the module enclosure.

## Starter Air Valve

The starter valve is a normally closed pneumatic regulator and shutoff valve. It has a bleed-on regulator, a solenoid switch, and a pneumatic switch. It also incorporates a check valve, an actuator, and a butterfly valve. Air from the ship's start air system is supplied through an inlet fitting on the enclosure base to the starter valve at 0 to 75 psig. When 28-volt dc power is supplied to the solenoid from the FSEE, the valve opens. It regulates discharge air pressure (to the starter) at 35 to 41 psig at a flow rate of 0 to 3.5 lb/sec.

Regulation is accomplished by the balance between the pneumatic actuator and a torsion spring on the butterfly. When the 28-volt dc signal is removed, the butterfly is closed by the pneumatic actuator and the torsion spring. Valve position is displayed by a mechanical position indicator at the valve. The valve position switch provides a valve position signal to the propulsion console.

## FUEL AND SPEED-GOVERNING SYSTEM

The fuel and speed-governing system regulates and distributes fuel to the combustion section of the GG to control gas generator speed ( $N_{GG}$ ). The PT speed is not directly controlled, but is established by the gas stream energy level

produced by the GG. The PT overspeed protection is provided by an electronic overspeed switch that is located in the FSEE via signals from the two PT speed pickups. The fuel used by the LM2500 GTE is supplied by the fuel service system. For more information on your ship's fuel system, refer to the Engineering Operational Sequencing System (EOSS).

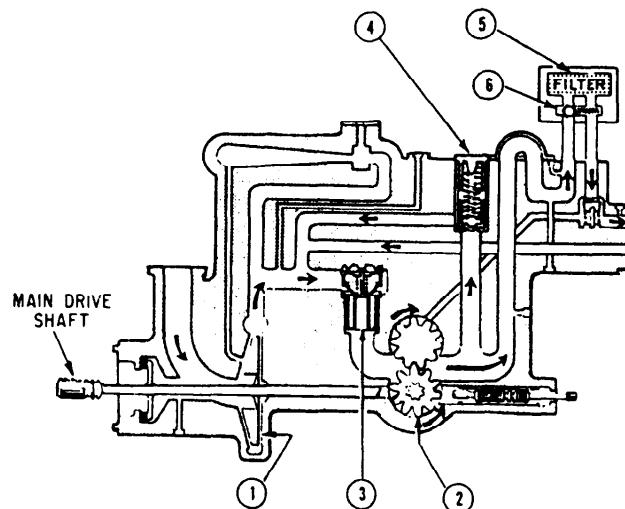
The fuel system of the LM2500 GTE has several components. These components are the fuel pump and filter, MFC, a pressurizing valve, two fuel shutdown valves, a purge valve, the fuel manifold and shroud, and 30 fuel nozzles. Also included are the CIT sensor, the VSVs, the VSV actuators, and the power lever angle (PLA) rotary actuator. We will discuss these components individually and explain how they relate to the system. Refer to figure 2-41, which shows the LM2500 GTE fuel system flow path, to help you follow our discussion.

## Fuel Pump and Filter

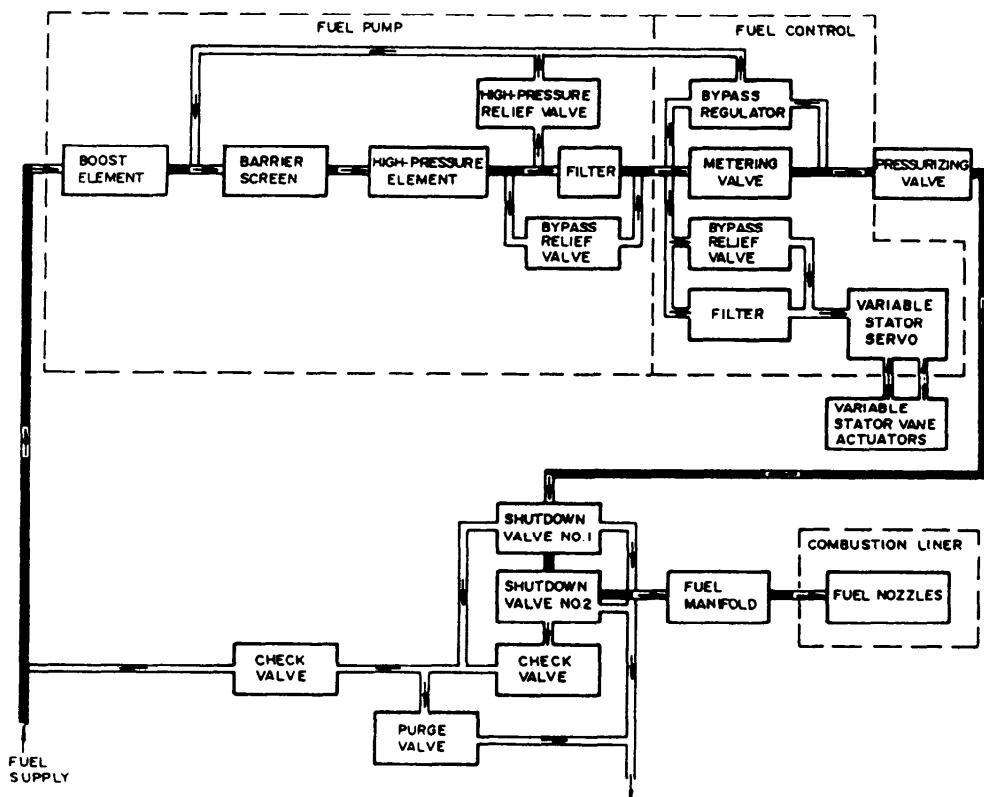
The fuel pump has two pumping elements, a centrifugal boost element (1) and an HP gear element (2). It provides mounting pads and flange ports for the fuel filter and the MFC. This feature reduces the amount of external piping required. The pump also provides a drive shaft for the MFC. This eliminates the need for a separate TGB drive pad.

To assure an adequate supply of fuel for GTE operation, the fuel pump has a higher flow capacity than the GTE uses. Within the MFC the pump discharge is divided into metered flow and bypass flow. This division maintains a preset pressure drop across the metering valve by use of a bypass valve. Bypass fuel is ported to the HP element inlet screen (3) of the fuel pump. If an abnormal condition occurs that causes pump outlet pressure to become too high, a relief valve (4) in the pump bypasses fuel back to the HP element inlet screen (3).

Fuel from the ship's supply enters the pump through the fuel inlet port and is boosted in pressure by the centrifugal boost element (1), discharging into a circumferential scroll. The flow passes through the strainer element (3) which has an integral bypass; it then passes into the HP positive displacement gear element (2). The combination of pumping elements is designed to provide improved fuel pump features so normal operation can be sustained without external boost pumps. The pump incorporates an HP relief valve (4). This valve cracks at or above 1,350 pounds



A.



B.

- |                              |                            |                        |
|------------------------------|----------------------------|------------------------|
| 1. Centrifugal boost element | 3. HP element inlet screen | 5. Fuel filter         |
| 2. HP gear element           | 4. HP relief valve         | 6. Bypass relief valve |

Figure 2-41.—LM2500 GTE fuel system. A. Cross-sectional view of the fuel pump. B. Fuel system block diagram,

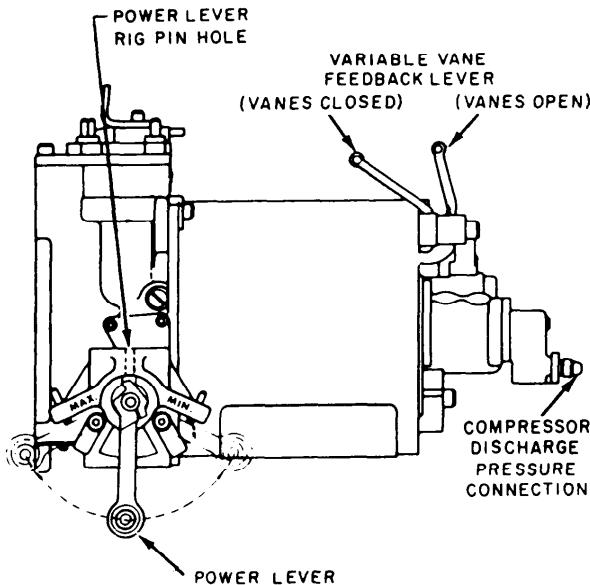


Figure 2-42.—Main fuel control.

per square inch absolute (psia); it reseats at or above 1,325 psia. These features protect the pump and downstream components against excessive system pressures.

The fuel filter (5) is an HP filter mounted on the fuel pump and flange-ported to eliminate external piping. The head houses a bypass relief valve (6); the bowl houses the filter element. The filter element is rated at 46 microns nominal and 74 microns absolute. It prevents larger contaminants from being carried into the MFC.

High-pressure fuel flows from the fuel pump through the flange port and enters the filter bowl. The fuel then flows from the outside of the filter element to the center, up into the head, out the flange return port, and back into the fuel pump. There, it is routed to the MFC. If the filter becomes clogged, the bypass relief valve opens at 35 pounds per square inch differential (psid). From the MFC the fuel goes to the fuel shutdown valves, the purge valve, the fuel manifold, and finally the fuel nozzles.

### Main Fuel Control

The MFC (fig. 2-42) is basically a speed governor which senses  $N_{GG}$  and power lever

position; it adjusts the fuel flow to maintain the desired speed set by the power lever. The MFC is a hydromechanical device which operates by use of fuel-operated servo valves. The MFC has two primary functions. One is to control GG speed (schedules acceleration fuel flow and deceleration fuel flow). The other controls stator vane angle (for stall-free, optimum performance over the operating range of the GTE).

The MFC controls GG speed as a function of power lever position. The power level is set electrically by a signal from the FSEE. Movement of the power lever changes speed demand. A flyweight governor senses GG speed. This adjusts the fuel flow as necessary to maintain the speed set by the power lever. Three fuel schedules are established by the control: acceleration, deceleration, and minimum fuel schedules. The acceleration schedule limits fuel flow necessary for acceleration to prevent overtemperature and stall. The deceleration schedule limits the rate of fuel flow decrease to prevent combustion flameout during deceleration. The minimum fuel schedule limits fuel flow for starting to prevent overtemperature. The MFC senses CIT, CDP, and  $N_{GG}$ , which biases the fuel schedules as a function of atmospheric and engine operating conditions.

The MFC schedules the VSVs as a function of GG speed and CIT. Actual position of the VSVs is sensed by the control via a position feedback cable. One end of the feedback cable is connected to the left master lever arm. The other end is connected to the feedback lever on the MFC.

### Pressurizing Valve

The pressurizing valve pressurizes the fuel system. It ensures adequate fuel control servo supply pressure and VSV actuation pressure. These pressures are essential for proper fuel and stator vane scheduling during GG operation at low fuel flow levels. The valve is a fuel pressure-operated, piston-type valve. The piston is held on its seat (closed) by spring force and fuel pressure (reference pressure) from the MFC. Servo pressure is 110 to 275 psig. The MFC discharge fuel (metered fuel for combustion) enters the pressurizing valve at the opposite side of the piston. When MFC discharge pressure is 80 to 130

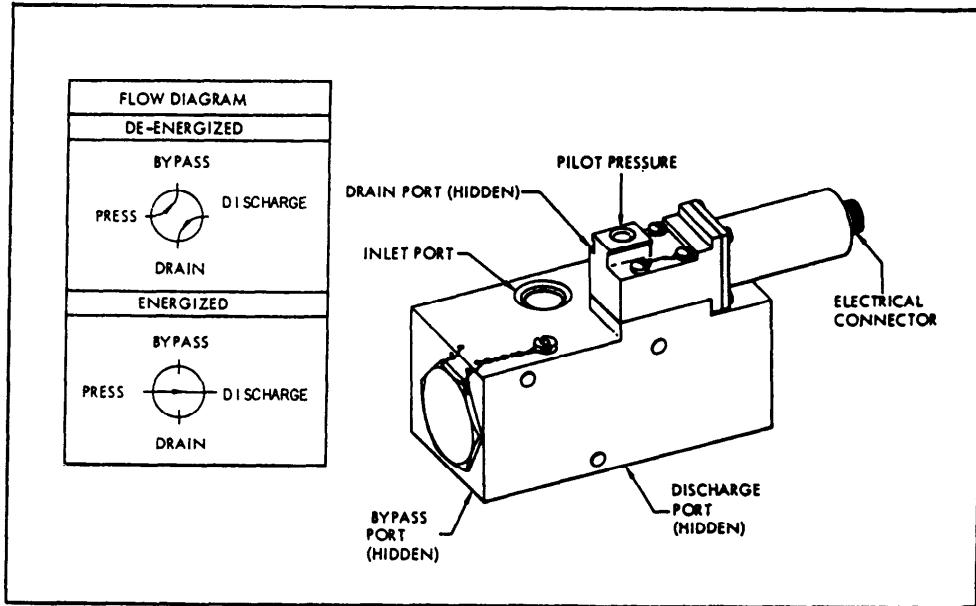


Figure 2-43.—Fuel shutdown valve.

psig greater than reference pressure, the valve opens. The upstream pressure (including servo supply and stator actuation) is 190 psig or greater before the pressurizing valve opens. This is adequate for proper operation.

### Fuel Shutdown Valves

The two fuel shutdown valves (fig. 2-43) are pilot-valve actuated and electrically controlled. The valves are piped hydraulically in series. They are electrically operated in parallel by control logic during an automatic sequence. The console operator can also operate them at the LOP, the PCC, or the PACC during a manual stop. Both valves must be energized to port metered fuel to the GG fuel manifold. De-energizing either valve will bypass the fuel back to the pump inlet. Normally, both valves are de-energized to shut down the engine. The second valve acts as a backup and will bypass fuel if the first should fail to function. You can operate the two valves independently from the LOP as a maintenance check.

Each shutdown valve has a pilot pressure bleed relief valve to prevent backflow through the valve during GTE motoring. A check valve which has a 2 psid cracking pressure is located in the bypass port of the No. 2 shutdown valve to prevent fuel

backflow into the No. 2 valve from the No. 1 valve bypass line.

### Purge Valve

The purge valve operates electrically. It is a normally-closed, on-off valve used to drain low-temperature fuel from the system before a GTE start. It is spring-loaded to the closed position; a solenoid opens the valve when it is energized. About 3 gallons of fuel are drained from the system during purging.

### Fuel Manifold System

The fuel manifold system is shrouded. (The manifold and the manifold-to-fuel nozzle connector tubes are tubes within a tube assembly.) If a fuel leak develops in the manifold system, the leakage collects inside the shroud. It is then drained through a drain line to a telltale drain under the enclosure base. Next it goes to a collection tank. Fuel leakage inside the enclosure from the manifold system is prevented and fire hazard is minimized by this system design.

### Fuel Nozzles

The LM2500 GTE uses 30 fuel nozzles to admit fuel to the combustor. The fuel nozzle

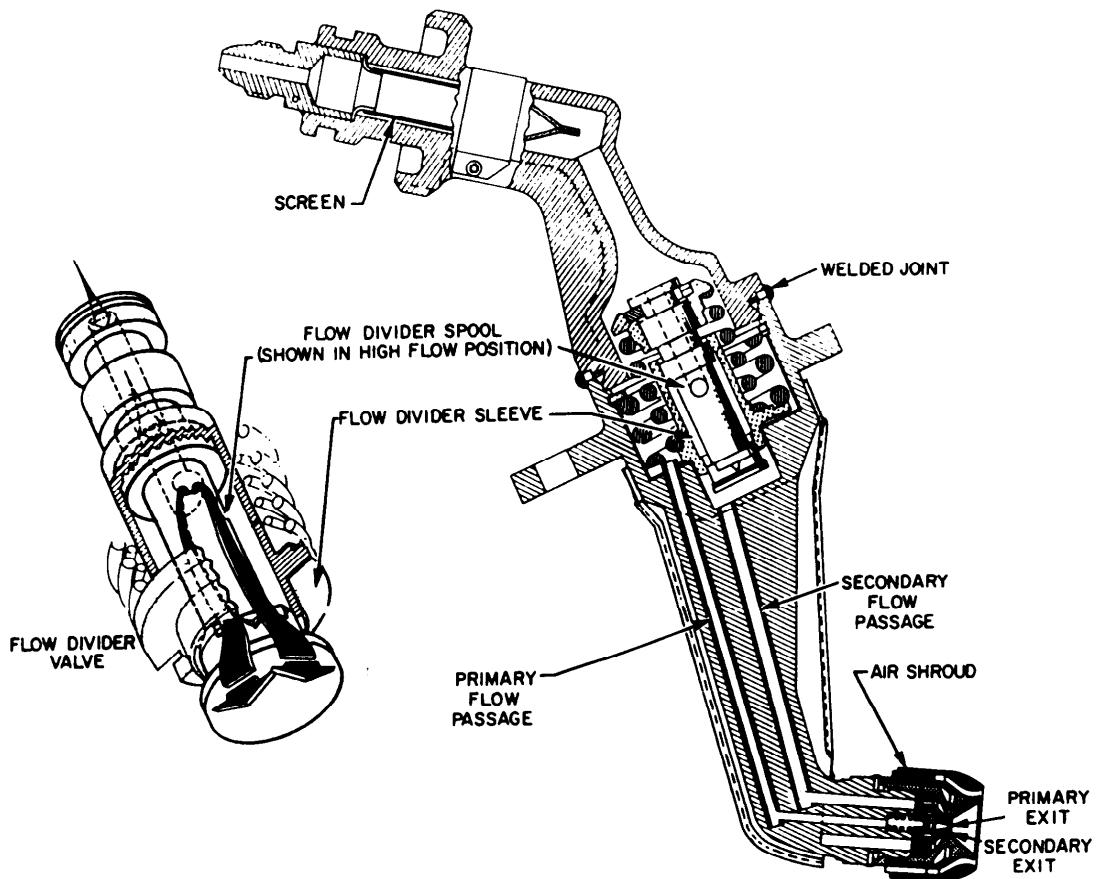


Figure 2-44.—Fuel nozzle.

(fig. 2-44) is a dual-orifice, swirl atomizer with an internal flow divider. The fuel nozzles produce the desired spray pattern over the full range of fuel flow. Fuel enters the nozzle through a single tube, flows through a 117-micron screen, and then the flow divider. When the nozzle is pressurized, primary fuel flows through a drilled passage and tube assembly in the nozzle shank. It then flows through the primary spin chamber and into the combustor. When fuel pressure to the nozzle rises to 330 to 350 psig, the flow divider opens and introduces secondary fuel flow. The secondary fuel flows through the flow divider, through a passage in the nozzle shank, into the secondary spin chamber, and mixes with the primary flow as it enters the combustor. An air shroud (swirl cup) around the nozzle tip scoops a small quantity of air from the main airstream to cool the nozzle tip. This retards the buildup of carbon deposits on its face.

### Compressor Inlet Temperature Sensor

The CIT sensor has a constant-volume, gas-filled probe and a metering valve. This sensor controls or meters fuel across an orifice. It is mounted at the 8 o'clock position in the compressor front frame. The sensing probe projects through the frame into the airstream. Since the temperature sensing probe has a constant volume, the gas pressure inside the probe is equal to the temperature. This pressure is connected to a sensing bellows, which, in turn, is connected to the metering valve. Fuel from the MFC enters the CIT sensor. There it is metered by the metering valve proportional to the temperature at the sensing probe. It is then used as a scheduling parameter by the MFC.

### Variable Stator Vanes

The VSVs are positioned by two hydraulic actuators operated by fuel pressure from the

MFC. The MFC has a variable vane scheduling, 3-dimensional (3-D) cam which is positioned by  $N_{GG}$  and CIT signals; it has a variable vane feedback mechanism which receives a vane position signal from a linkage connected to the VSV master lever; it also has a variable vane pilot valve positioned as a result of the comparison of the scheduling cam position and the feedback signal. Changes in engine speed rotate the scheduling cam; changes in CIT reposition the cam. Movement of the cam repositions the pilot valve. The pilot valve ports HP fuel (pump discharge pressure) to either the rod end (closing) or head end (opening) of the vane actuators; it vents the other end to bypass pressure. The variable vane actuating linkage mechanically transmits the actuator movement to the variable vanes and IGVs. A flexible cable is attached to the linkage. It transmits a feedback signal to the MFC. The feedback mechanism in the MFC repositions the pilot valve to terminate the actuator signal when the vanes reach the scheduled position.

### Variable Stator Vane Actuators

The VSV actuators (fig. 2-45) are single-ended, uncushioned hydraulic cylinders which are driven in either direction by HP fuel. The piston stroke is controlled by internal stops. The two actuators are mounted tangentially on the compressor stator

forward flange at the 3 o'clock and 9 o'clock positions. They are connected to the VSVs through master lever arms and actuation rings. The MFC schedules HP fuel to either the head-end port (opens VSVs) or the rod-end port (closes VSVs). Control parameters sensed by the MFC to schedule variable vane angle are  $N_{GG}$ , CIT, and stator vane angle via a feedback cable. The feedback cable is connected on one end to the left master lever arm and on the other end to the MFC.

### Power Lever Angle Rotary Actuator

The PLA rotary actuator is an electro-mechanical device that interfaces the PLA actuator electronics in the FSEE with the MFC of the GTE. It moves the internal components of the MFC to control fuel flow to the engine. It has a dc servomotor, a reducing gear, a slide potentiometer, a tachometer generator, mechanical linkage, and an electrical line filter. The PLA actuator is mounted on the fuel pump; it is connected to the fuel control power lever through a mechanical linkage. It is electrically connected to the FSEE.

Signals from the PLA actuator electronics, located in the FSEE, are converted by a servo-mechanism into mechanical action that positions the fuel-control power lever. Feedback of PLA and rate of change are sent to the FSEE. A

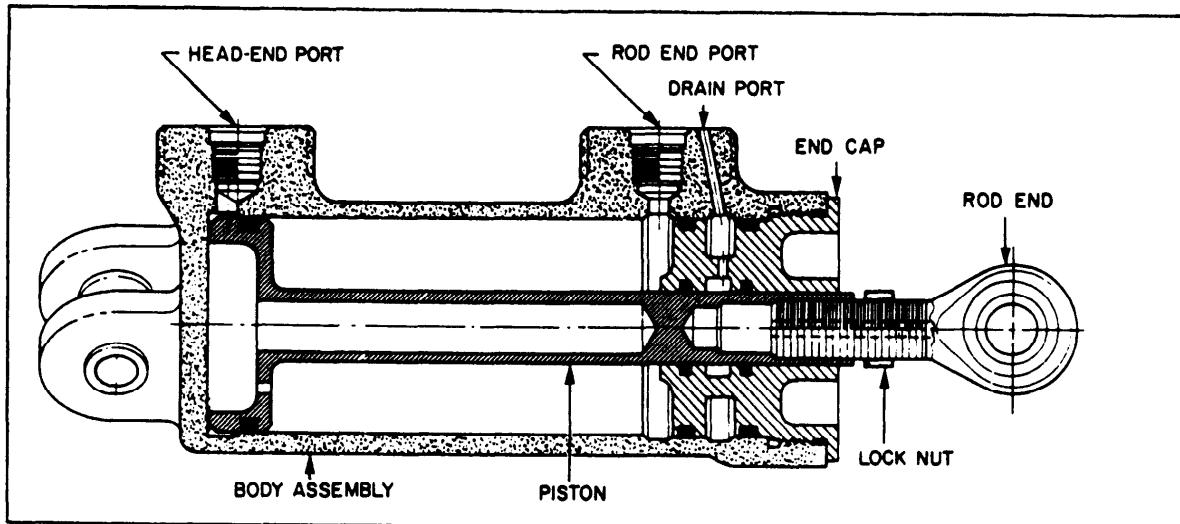


Figure 2-45.—VSV actuator, cross-sectional view.

positive mechanical rig feature allows locking of the PLA actuator output lever at a position of  $113.5^\circ \pm 1^\circ$ . This rig point is used in conjunction with a corresponding rig point on the fuel control. Its purpose is to establish mechanical synchronization between the PLA actuator and the fuel control.

## SYNTHETIC LUBE OIL SYSTEM

The synthetic lube oil system provides the GTE bearings, gears, and splines with adequate cool oil to prevent excessive friction and heat. The synthetic lube oil used in this application is MIL-L-23699. It is a dry sump system. It is divided into three subsystems with three functions identified as lube supply, lube scavenge, and sump vent.

The lube supply subsystem provides oil to the bearings. It contains the supply element of the lube and scavenge pump, the supply duplex filter, the supply check valve, and the C- and D-sump supply check valves. The lube scavenge subsystem removes the oil from the sumps. It contains the scavenge elements of the lube and scavenge pump. Oil from this pump goes to the LOSCA. The components of the LOSCA are the scavenge oil filter, the scavenge oil check valve, the oil cooler, and the oil tank. The third subsystem vents excessive air pressure to the atmosphere. It contains piping to the atmosphere, piping to the air/oil separator, and the air/oil separator. Figure 2-46 is a block diagram of the lube oil system. Please refer to this figure to help you understand the following paragraphs as we describe the system's components and the lube oil flow path.

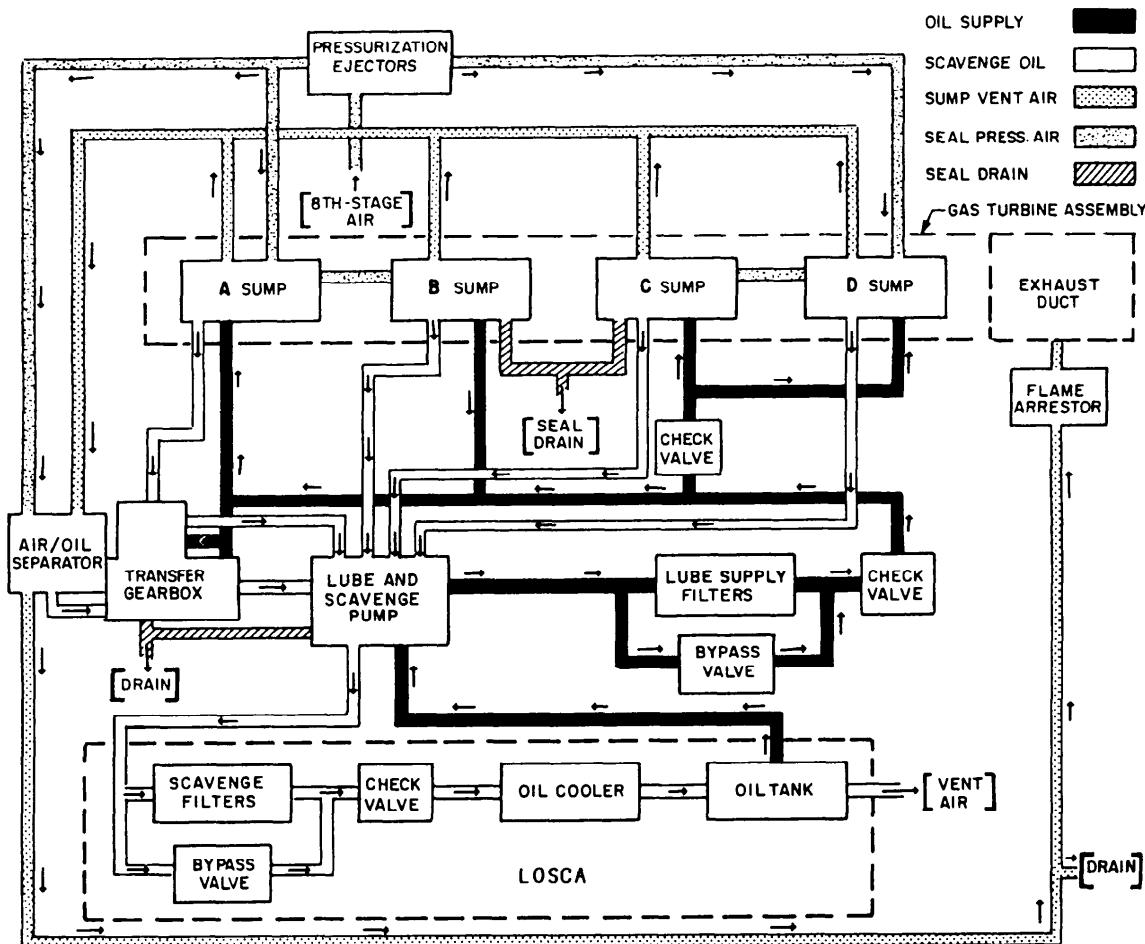


Figure 2-46.—Lube oil system block diagram.

## Lube Oil System Components

In this section we will describe the lube oil system components in the order of lube oil flow, from the LOSCA through the system and back to the LOSCA.

**OIL TANK.**—The oil tank is an integral part of the LOSCA. The early configuration of cast construction on the DD-class ship contains six sight glasses (view ports) for visual detection of oil level in the tank. Starting with the second glass from the bottom, they are spaced at 5-gallon intervals. On the later configuration of fabricated construction (fig. 2-47), three sight glasses are provided for low level, 19-gallon level, and full level positions. An oil level switch on the DD-class ship monitors oil level from within the tank and transmits an electrical

signal when the oil level is too high or too low. An oil level sensor on the FFG-class ship monitors oil level from within the tank and transmits a continuous electrical signal for remote readout of lube oil level. The oil tank is considered full when oil is visible at the 24-gallon sight glass.

Instrumentation valves, a filter differential pressure transducer, a filter differential pressure gauge, a level sensor, and an oil temperature switch are mounted on the tank. A gravity fill cap is installed on the tank cover fill port. The fill port has a strainer to prevent foreign material from entering the tank. Baffles are located in the bottom of the tank to minimize oil sloshing. A deaerator is inside the tank at the scavenge inlet (which separates air from the scavenge oil). You can drain the oil tank by positioning a lever located in the assembly base.

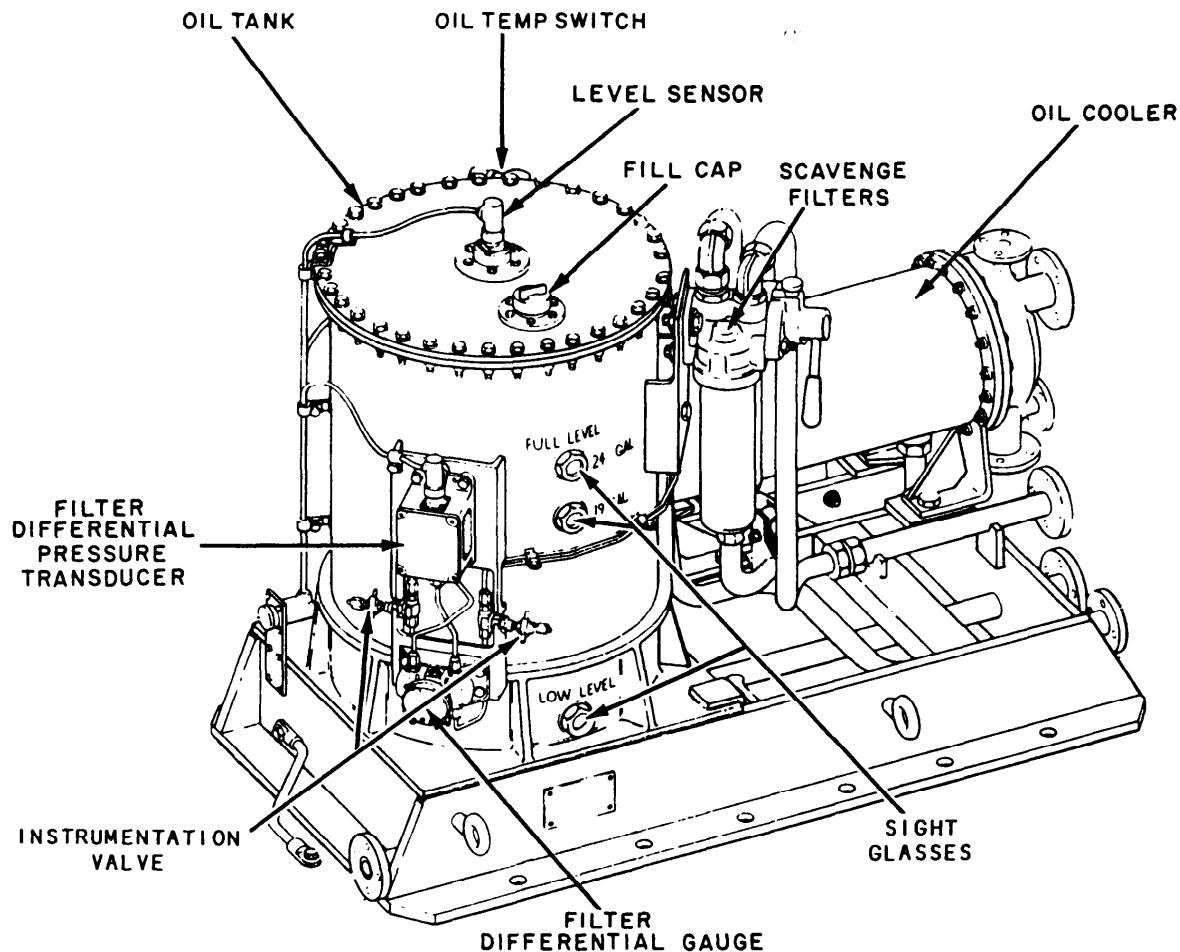


Figure 2-47.—LOSCA.

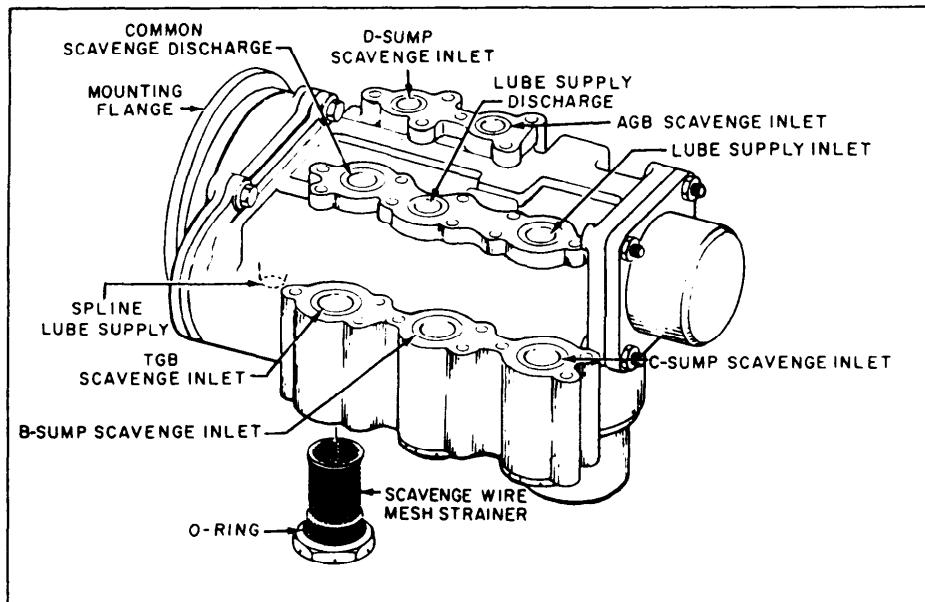


Figure 2-48.—Lube and scavenge pump.

**LUBE AND SCAVENGE PUMP.**—The lube and scavenge pump (fig. 2-48) is a six-element, positive-displacement vane pump. Each element has a wire mesh strainer. One element is used for lube supply and five are used for lube scavenging.

The lube supply element supplies oil to the seven main bearings that support the GG assembly and the PT assembly. These bearings are located in the sumps as follows:

- Bearing No. 3R in the A sump
- Bearings No. 4R and 4B in the B sump
- Bearings No. 5R and 6R in the C sump
- Bearings No. 7B and 7R in the D sump

Scavenge oil enters the pump through the five scavenge oil ports, passes through an inlet screen in each port, and enters the scavenge elements. The outputs of the five scavenge elements are connected inside the pump and discharge through a common scavenge discharge port. This scavenge discharge is routed to the duplex filter mounted on the lube storage and conditioning assembly oil tank.

The five scavenge elements of the lube and scavenge pump scavenge oil from the B, C, and D sumps and from the TGB and AGB (A sump). There are five RTDs located in the scavenge oil

system lines in the immediate vicinity of the pump. They sense oil temperatures for the A, B, C, and D sumps and for the TGB; they also provide a signal to the off-engine electronic controls.

**LUBE SUPPLY FILTER.**—The lube supply filter (fig. 2-49) is a duplex filter assembly with provision for manual selection of either element. It is mounted on the outboard rail of the engine subframe. It is the same type that is used for the scavenge oil filter. Oil to the GTE enters the inlet port, flows through the selected element (outside to inside), and exits through the filter outlet port. A bypass (relief) valve in the filter opens to allow oil to bypass the filter if the filter becomes clogged. To make a filter selection, raise the spring-loaded locking pin, move the selector handle until it is in front of the element NOT being used, and release the locking pin. Make certain you engage the pin in the locking slot. A drain plug in the bottom of each filter bowl permits oil to be drained from the element before it is removed for cleaning.

**LUBE SUPPLY CHECK VALVE.**—The lube supply check valve is on the downstream side of the supply filter. It prevents oil in the tank from draining into the sumps when the GTE is shut down. It opens and flows at a rate of 20 gpm with a maximum differential pressure of 15 psid.

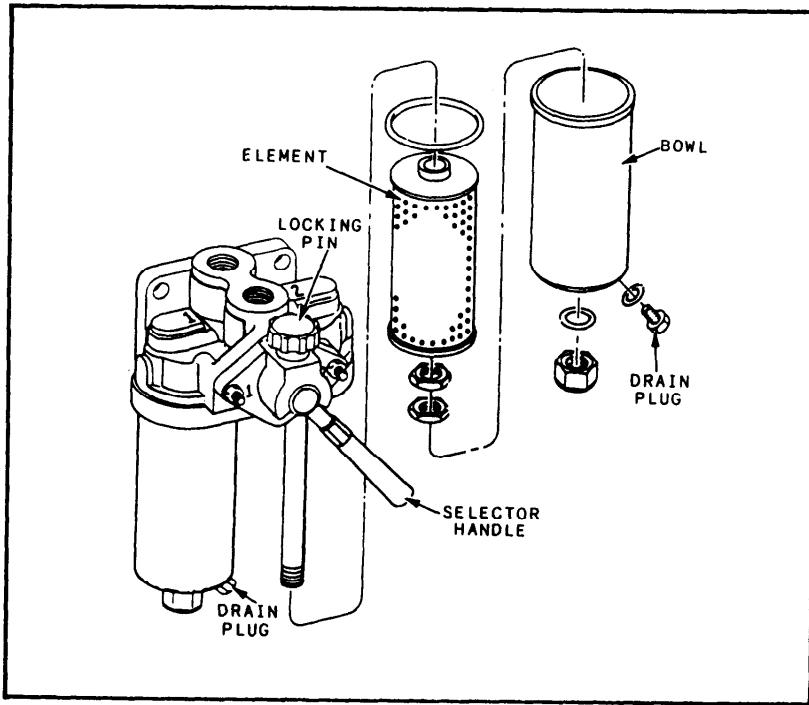


Figure 2-49.—Lube supply filter.

**C- AND D-SUMP CHECK VALVE.**—This check valve is in the lube supply line to the C and D sumps. It isolates the C and D sumps from the GG lube oil system when an external lube supply and scavenge system is used for the PT. Both the C- and D-sump oil supply lines and scavenge lines have fittings to connect an external lube system for the PT. During normal engine operation, the lube oil pump supplies lube oil to the C and D sumps. The check valve opens at 2 psid.

**SCAVENGE OIL FILTER.**—The duplex scavenge oil filter differs from the lube supply filter only in its mounting position. The scavenge filter is located on and is part of the LOSCA. See figure 2-47.

**SCAVENGE OIL CHECK VALVE.**—The check valve is between the scavenge filter and the oil cooler (heat exchanger). It prevents oil in the scavenge lines from draining back into the sumps and gearbox while the engine is shut down. It functions the same as the lube supply check valve.

**OIL COOLER.**—The oil cooler is a shell-tube assembly (see fig. 2-47). The coolant is main reduction gear (MRG) lube oil (2190 TEP). The

coolant passes from the MRG lube oil cooler through temperature control valves and through the inside of the tubes. The synthetic lube oil passes around the outside of the tubes. The oil is discharged from the oil cooler back to the oil tank. To gain direct access to the inside of the coolant tubes for cleaning, remove the end domes.

**AIR/OIL SEPARATOR.**—The air/oil separator has a fabricated sheet metal impeller with a cast aluminum housing. It prevents excessive oil loss from venting oil vapor overboard. All sumps are vented to the air/oil separator. The sump air is vented to the exhaust duct after passing through the separator. Oil is collected on the inside of the impeller as the oil-laden sump air passes through the separator. Small holes in the segments of the impeller allow the collected oil to be discharged to the separator outer housing. Vanes on the housing wall are used to collect and direct the oil to the separator outlet where it is returned to the gearbox. To prevent oil and oil vapors from escaping past the end of the impeller, the separator has two labyrinth seals, with the cavity between the two seals pressurized with eighth-stage ejector air.

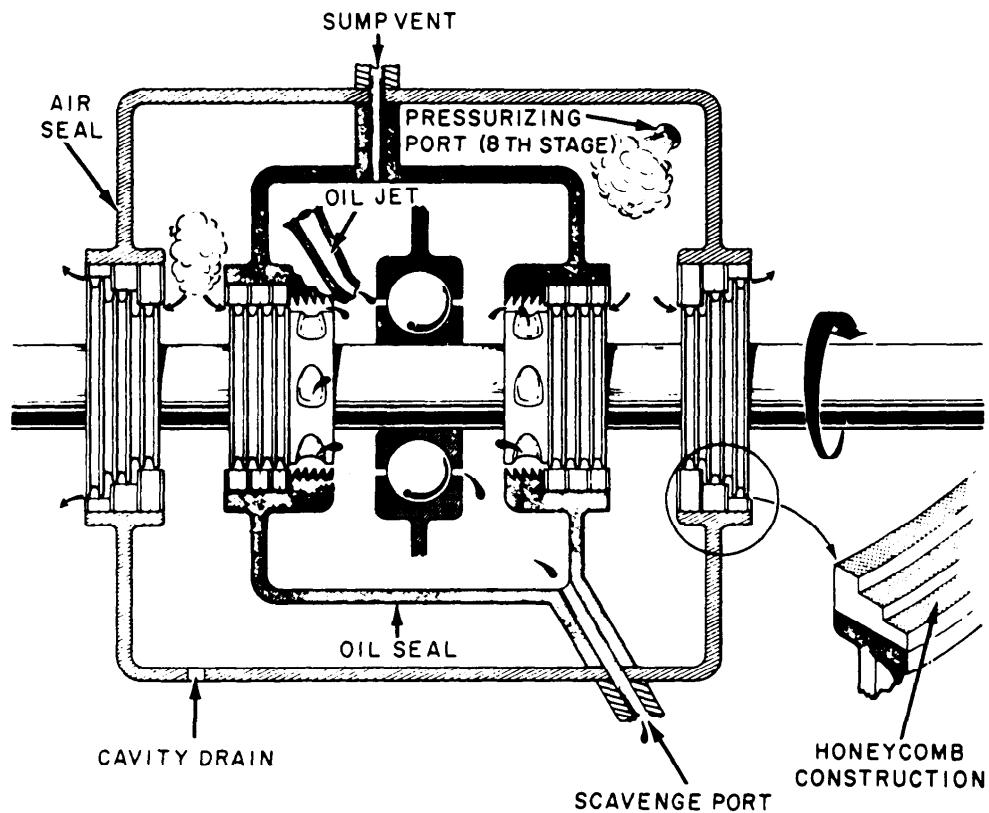


Figure 2-50.—Bearing sump.

### Lube Oil Flow

Lube oil is gravity fed from the oil tank in the LOSCA through the ship's piping to an inlet fitting in the enclosure base. It is then fed to the inlet of the supply element of the lube and scavenge pump. From the supply element of the pump, the oil passes through the supply duplex filter. It then goes through a check valve and into a supply manifold. From the supply manifold, the oil is distributed to the four sumps and the TGB. Each end of the sump has a labyrinth/windback oil seal and a labyrinth air seal (fig. 2-50). This is to prevent oil leakage from the sumps. The cavity between the two seals is pressurized by eighth-stage air ejectors. The pressure in the cavity is always greater than the pressure inside the sump. Air flowing from the cavity, across the oil seal, prevents oil from leaking across the seal.

The scavenge oil is drawn in from the sumps and TGB by the five scavenge elements of the pump. It passes through the pump, through an

outlet fitting on the enclosure base, and is returned to the LOSCA.

At the LOSCA the oil passes through the scavenge filters to the scavenge check valve. The oil then goes through the oil cooler where it is cooled by the MRG (2190 TEP) lube oil. The cooled oil is then routed to the oil tank for storage and deaerating.

### IGNITION SYSTEM

The ignition system provides ignition to start combustion in the engine. It has ignition excitors and two spark igniters located in the combustor. The system is actuated by an electronic signal during the engine start sequence. It is generated either manually by the operator or by the electronic timing controls. The engine must reach a speed of 1,200 rpm prior to ignition; then, if performing a manual start, you must energize the igniters before opening the fuel valves. When you start the engine in the automatic mode, the fuel valves will not open unless the igniters are already functioning. This prevents excess fuel

from entering the combustion chamber and causing excessive start temperatures. The igniters are secured by an electronic signal at 4,500 rpm. By this time combustion has occurred and the engine has reached self-sustaining speed.

### Ignition Exciters

The ignition exciters are the capacitor discharge type. They are located on the right side of the front frame. They are attached to special mounts that absorb shock and vibration. The exciters operate on 115-volt ac, 60-Hz input. The power is transformed, rectified, and discharged in the form of capacitor discharge energy pulses. It then flows through the coaxial shielded leads to the spark igniters.

When the starting switch is closed, shipboard 60-Hz power is applied to the exciter circuits. The exciter has input, rectifier, discharge, and output circuits. The input circuit includes a filter that prevents feedback of radio-frequency interference (RFI) (generated within the exciter). The filter also prevents introduction of electromagnetic interference (EMI) (generated externally). The input circuit also includes a power transformer that provides step-up voltage for the rectifier circuit. The full-wave rectifier circuit includes diodes that rectify the high-voltage ac. This circuit also includes capacitors that are arranged in a voltage doubler configuration. Tank capacitors store the dc voltage developed in the rectifier circuit. They store this voltage until the potential developed reaches the breakdown point of spark gaps in the discharge circuit. The discharge circuit contains the spark gaps, high-frequency (HF) capacitor, resistors, and HF transformer. When the spark

gaps break down, a current (caused by a partial discharge of the tank capacitors) through the HF transformer and in conjunction with the HF capacitor causes a series resonant condition to exist. It also causes HF oscillations to occur in the output circuit. These HF oscillations cause ionization of a recessed spark gap of the igniter plug. A low-resistance path now exists for total discharge of the tank capacitor, producing a high-energy spark used to ignite the fuel within the combustor. The spark rate is determined by the total rectifier circuit resistance. This controls the resistive capacitive (RC) time constant in the charging circuit.

### Spark Igniters

The spark igniters (fig. 2-51) are the surface gap type. They have internal passages for air cooling and air vents. These passages prevent the accumulation of carbon in interior passages. The igniter has a seating flange with attached copper gaskets for sealing purposes. Grooves in the outer surface of the tip and axial holes cool the outer and inner electrodes with compressor bleed air.

The surface gap will ionize at 8,500 volts when dry and 15,000 volts when wet. A discharge of 2 joules of energy exists across the gap.

### CAUTION

This energy level is lethal. You should never contact the output from the spark exciter, the leads, or the igniter. You must use a grounding probe to ground the ignition system when maintenance is performed.

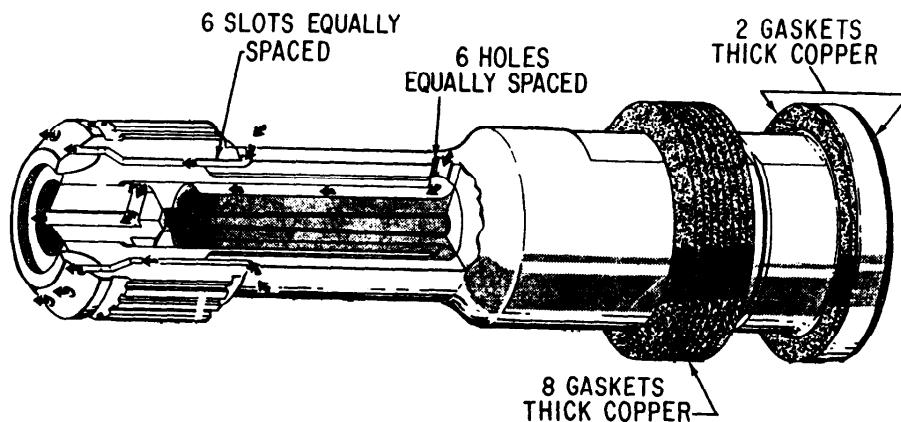


Figure 2-51.—Spark igniter.

## Ignition Leads

The ignition leads are low-loss connections between the ignition excitors and the spark igniters. They are coaxial leads with metallic shielding that incorporates copper inner braid, sealed flexible conduit, and nickel outer braid.

## WATER WASH SYSTEM

The purpose of the water wash system is to remove contaminants from the inlet and compressor sections. The system has a water wash/rinse supply tank and piping attached to the outside of the base enclosure. A flexible hose is attached from the inside base enclosure floor to the GG inlet duct at the 6 o'clock position. The inlet duct is made with an internal passageway or manifold which distributes water wash fluid to outlet spray orifices. The outlet spray orifices eject the water wash fluid into the airstream flowing through the inlet duct.

## BLEED AIR SYSTEM

Air extracted from the compressor for cooling, seal pressurization, pressure balance to reduce rotor thrust loads, and ship's service (secondary) air is called bleed air. For this application, air is bled from the 8th, 9th, 13th, and 16th stages. Only 16th-stage air (known as CDP) is used for the ship's bleed air system. Refer to figure 1-33 (At the end of chapter 1), which shows the LM2500 GTE airflow, to help you understand the following discussion.

## Eighth-Stage Air

Eighth-stage air is bled from the compressor through hollow eighth-stage stator vanes into an

external manifold. From the manifold, the air is piped forward and aft to ejector nozzles. Each ejector contains a venturi through which the eighth-stage air passes; it draws enclosure air into the ejector. This air mixes with the eighth-stage air, reduces the downstream pressure and temperature, and increases the volume. Air from the forward ejector is piped into the front frame hub; there it pressurizes and cools the A sump. Some of the A-sump air passes through holes in the compressor rotor front shaft, through the rotor air duct, and through holes in the rotor aft shaft; there it pressurizes and cools the B sump. Air from the rear ejector is piped into the turbine rear frame hub; it is used to pressurize and cool the D sump. Part of the air entering the D sump bleeds into the flexible-coupling shaft tunnel for cooling and passes out the aft end of the exhaust duct. Some of the D-sump air passes through holes in the PT aft shaft, rotor air tube, and holes in the rotor front shaft; there it pressurizes and cools the C sump.

## Ninth-Stage Air

Ninth-stage air is bled from the compressor through holes in the ninth-stage vane bases and compressor casing into an external manifold. There it is piped to the turbine mid frame and turbine rear frame. Air enters the turbine mid frame through all the struts. Some of the air exits through holes in the frame hub to cool the frame inner liner. The rest of the air enters tubes in the C-sump air seals; after it crosses these seals, the air passes through and cools the PT rotor. It then exits into the PT exhaust gas. The air to the turbine rear frame enters the frame through struts 2 and 8. It passes into an area between the

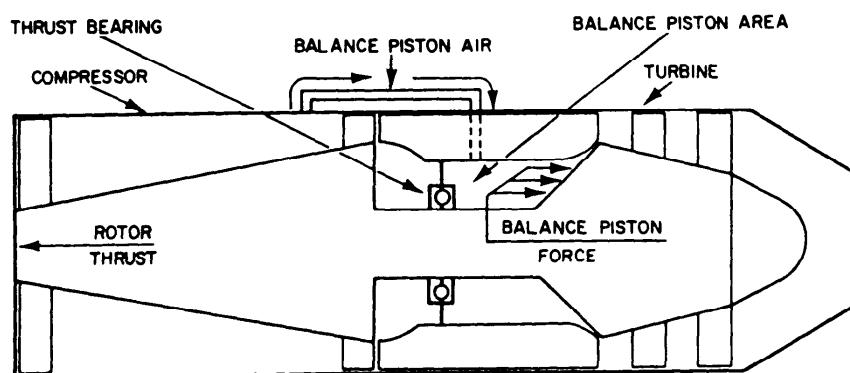


Figure 2-52.—Balance piston principle.

forward air seals. At this point it is called balance piston air.

### Balance Piston Air

On the LM2500 GTE, balance piston air (or pressure balance air) is ninth-stage air that is bled into a balance chamber to reduce the aft loading on the No. 7B bearing. This air applies force to the face of a rotor disk in the direction opposite the thrust load to reduce the axial load applied to the thrust bearing by the rotor thrust. This increases the thrust-bearing life. The balance piston principle is shown in figure 2-52.

### Thirteenth-Stage Air

Thirteenth-stage air is bled from the compressor through holes in the thirteenth-stage vane bases and compressor casing into an external manifold. The air is piped through the compressor rear frame casing and into the HP turbine shrouds. The air then flows through and cools the second-stage turbine nozzle. Some of the air exits through nozzle-trailing edge holes. The remaining air is used for cooling the interstage seal, the aft side of the first-stage blade shanks, and the front side of the second-stage shanks.

### Sixteenth-Stage Air

Sixteenth-stage compressor discharge bleed air is bled through holes in the inner wall of the compressor rear frame and out through Nos. 3, 4, 8, and 9 frame struts. It is then piped to the bleed air valve. The bleed air valve operates electrically to provide air to the ship's bleed air system. High-pressure turbine rotor and blade cooling air is extracted internally through the aft stationary air seal and holes in the forward end of the rotor front shaft. The remaining compressor discharge bleed air is used for cooling the combustion liner and first-stage HP turbine nozzle vanes.

## ENGINE INSTRUMENTATION

The GT assembly is instrumented with sensors that provide for remote monitoring of the engine, module, and LOSCA. Temperature, vibration, and speed sensors give an electrical output signal directly. However, pressure sensors use base-mounted transducers to convert a pressure level

to a corresponding electric signal. The sensor information is transmitted to the controls, either directly or through the FSEE. The controls use the sensor information for GTE monitoring, alarming, and control sequencing. A majority of these sensors, along with their location/function, are described in the following paragraphs.

- Compressor Inlet Total Pressure ( $P_{t_2}$ )—Pressure is sensed by a total pressure probe mounted in the compressor front frame at the 12 o'clock position. Pressure is piped to a transducer mounted on the bottom of the enclosure base. The electrical output signal from the transducer is sent to the FSEE signal conditioner and torque computer electronics. Output signals from the FSEE are sent to the controls.
  - Power Turbine Inlet Total Pressure ( $P_{t_{5.4}}$ )—Pressure is sensed by five total pressure probes located circumferentially in the turbine mid frame. Pressure is piped to a transducer mounted on the bottom of the enclosure base. The electrical output signal from the transducer is sent to the FSEE signal conditioner and torque computer electronics. An output signal from the FSEE is sent to the controls.
  - Compressor Inlet Temperature ( $T_2$ )—Temperature is sensed by a platinum RTD penetrating the enclosure inlet barrier wall at the lower left corner. The signal from the RTD is sent to the FSEE signal conditioner and torque computer electronics. An output signal from the FSEE is sent to the controls.
- NOTE: Only  $P_{t_2}$ ,  $P_{t_{5.4}}$ , and  $T_2$  (which are torque computer inputs) are signal conditioned in the FSEE. Signals from the following instrumentation go to the controls where they are signal conditioned and used for monitoring, control, alarm, and shutdown as noted.
- Power Turbine Speed ( $N_{pt}$ )— $N_{pt}$  is sensed by two magnetic pickups in the turbine rear frame. The signal from the magnetic pickups is sent to the controls to the FSEE signal conditioner and torque computer electronics. The controls use the signal for PT speed meter displays and PT overspeed alarm generation.
  - Gas Generator Speed ( $N_{GG}$ )—Gas generator speed is sensed by a single magnetic pickup located on the top left side of the aft TGB (AGB).

- Gas Turbine Vibration—Vibration is sensed by two velocity pickups. One pickup is mounted on the compressor rear frame forward flange at the 12 o'clock position; one is mounted on the turbine rear frame forward flange at the 12 o'clock position.
- Compressor discharge static pressure ( $P_{s3}$ )—Pressure is sensed from a pressure tap on the  $P_{s3}$  sensing line to the MFC and is piped to a base-mounted transducer.
- Fuel manifold pressure—Pressure is sensed from a pressure tap on the fuel manifold downstream from the No. 2 fuel shutdown valve. The pressure is piped to a base-mounted transducer.
- Fuel pump filter differential pressure—Pressure is sensed from two pressure taps in the fuel pump body at the filter inlet and discharge ports. Pressure is piped to a base-mounted transducer and a base-mounted gauge.
- Lube supply pressure (pump discharge)—Pressure is sensed from a tap on the supply manifold downstream from the supply check valve. Pressure is piped to a base-mounted transducer.
- Lube supply filter differential pressure—Pressure is sensed from taps in the filter head at the inlet and discharge ports. Pressure is piped to a base-mounted transducer and a base-mounted gauge.
- Lube scavenge filter differential pressure—Pressure is sensed from taps in the filter head and piped to a transducer. Both filter and transducer are mounted on the LOSCA.
- Lube scavenge temperature—A-, B-, C-, and D-sump and the AGB-sump temperatures are sensed by platinum RTDs installed in each scavenge line near the inlet ports of the pump.
- Lube scavenge pressure—The pressure is sensed by a transducer in the lube scavenge return line near the LOSCA.
- Lube cooler outlet temperature—Temperature is sensed by a platinum RTD installed in the cooler discharge line at the LOSCA storage-tank inlet port.
- Fuel inlet temperature—Temperature is sensed by a platinum RTD installed in the fuel inlet line inside the gas turbine enclosure.
- Power turbine inlet gas temperature ( $T_{5,4}$ )—Temperature is sensed by 11 dual-element chromel-alumel thermocouples installed circumferentially in the turbine mid frame. They are electrically paralleled to produce a single output signal.
- Enclosure cooling air out temperature—Temperature is sensed by a platinum RTD mounted on the enclosure ceiling on the centerline and just forward of the exit area.
- MFC power lever position—A 0.5 to 10-volt dc signal from the PLA actuator position feedback potentiometer is sent to the FSEE.

## FREE STANDING ELECTRONIC ENCLOSURE

The FSEE is the major electrical interface to the LM2500 GTE. It is a metal cabinet located outside of the gas turbine enclosure that contains most of the electronics necessary for control of the propulsion turbines. Each FSEE controls two LM2500 GTEs. Therefore, there will be one FSEE per engine room.

Since the FSEEs are similar on all ship classes, we will discuss the basic FSEE, pointing out the differences as necessary. The major differences are the input power supply and the start/stop sequencer (on the FFG class). Another difference is the use of an acceleration limiting circuit in the FSEE of all classes but the FFG class.

The start/stop sequencer in the FFG-class FSEE provides for independent manual and automatic remote control of startup, operation, and shutdown of the GTE. The system also monitors various parameters to ensure safe GTE operation. The same capabilities are provided for on the CG-, and DD-class ships, but from a separate system called the engineering control and surveillance system (ECSS). In the following discussion, we concern ourselves with the operation of the FSEE which, with the exceptions already discussed above, are similar to all classes. The FSEEs used on the CG-, and DD-class ships (fig. 2-53) have fewer components. This is because the start/stop sequencing on these ships is done in the PLCC. Only one circuit card rack is used; it holds the circuit cards for both GTs.

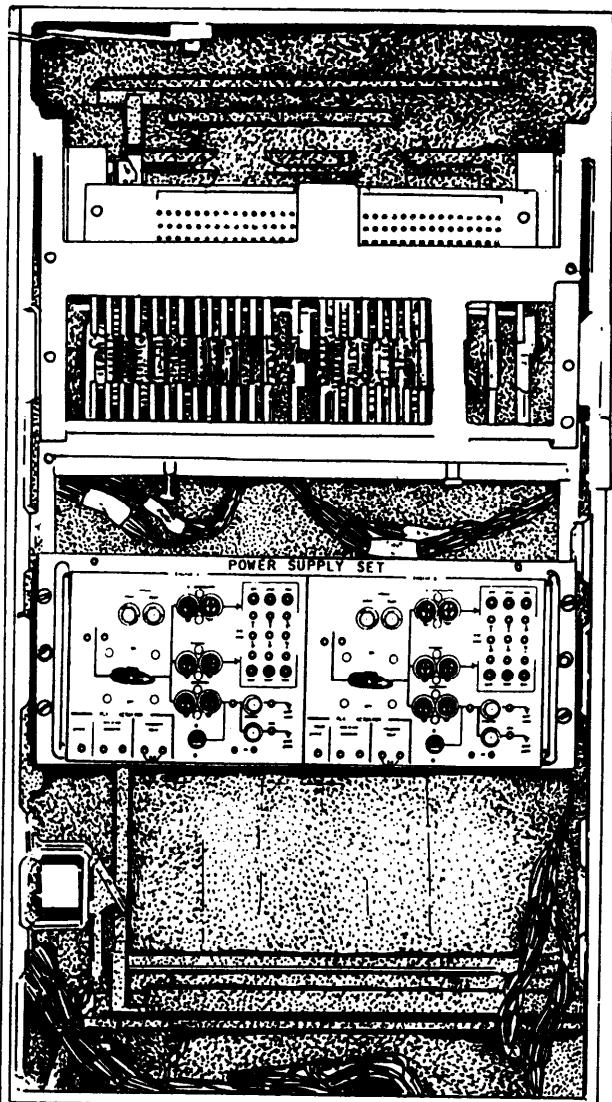


Figure 2-53.—FSEE on the CG-, DD-class ships.

One common card, the M card, is used by both GTs on these classes but is not used on FFG FSEEs. The FSEE on the FFG-class ship (fig. 2-54) has two card racks (one per engine) and two power supplies.

The FSEE circuitry is divided into two identical sections—one for each turbine. The electronic circuitry is in the form of pull-out cards and a power supply rack; the cards may be referred to as either printed-circuit boards (PCBs) or printed-wiring boards (PWBs). Functionally, the electronics for either turbine can be divided into five subsystems: signal conditioning circuitry, torque computer, overspeed switch control, power supply, and the PLA actuator electronics. The

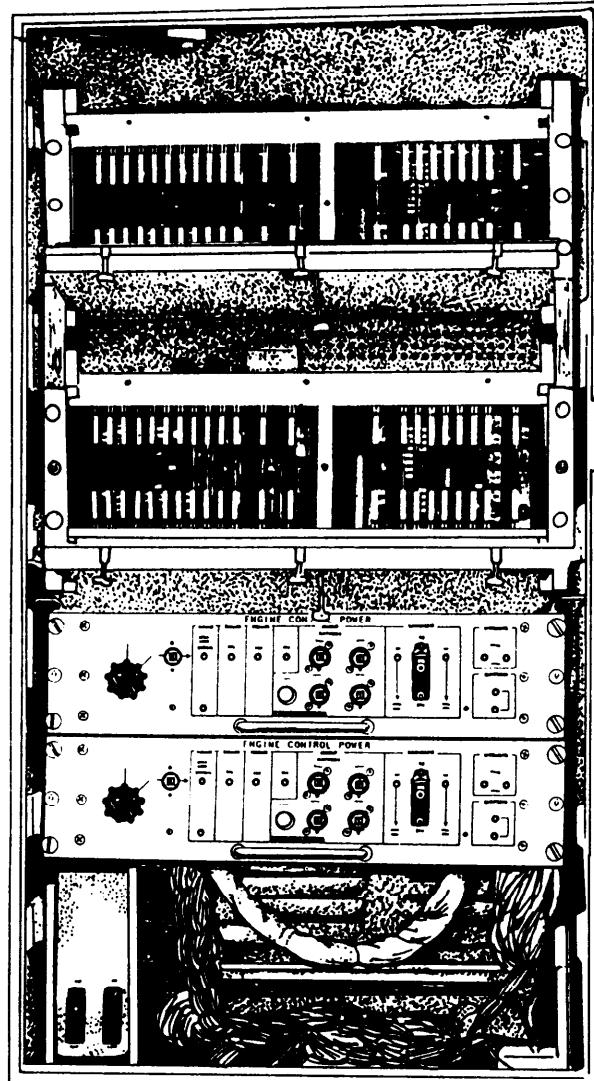


Figure 2-54.—FSEE on the FFG-class ship.

FSEE also generates some signals (uplink) for display on the GTE control consoles.

#### SIGNAL CONDITIONING ELECTRONICS

The signal conditioning electronics are contained on one PWB—the E card. Five transducer signals and one internal signal are processed in these circuits. These are  $P_{t2}$ ,  $P_{t5.4}$ ,  $T_2$ , and two  $N_{pt}$  speed signals (one from each PT speed pickup). Four of these signals are provided as inputs to the torque computer. In addition, five signals are buffered and transmitted uplink to the GTE control console. Two pressure signals,  $P_{t2}$  and  $P_{t5.4}$  are received in the form of 4 to 20

milliamp signals. They are converted to 0- to 5-volt signals for the torque computer. They are also processed into 0- to 10-volt signals for external use. The only temperature signal processed by the FSEE is  $T_2$ . This signal comes from a platinum RTD. The electronics changes the RTD signal to a 0- to 5-volt and a 0- to 10-volt signal for the torque computer and uplink, respectively.

A dual tachometer system is mounted on the PT. This has a spur gear with 83 teeth which rotate past two sensors. The output of each sensor is a pulse train whose frequency is directly proportional to the speed of the turbine. The purpose for the two-speed signals is reliability. One is the normal (channel A) signal, the other (channel B) is a backup in case the first fails. The speed signal is converted to voltages proportional to speed for purposes of torque computer monitoring.

## TORQUE COMPUTER

The torque computer is a special-purpose computer used to calculate engine torque. It has seven PCBs (PWBs) whose only function is to calculate the torque output of the PT. Five inputs are necessary to the computer for the calculations. Four are 0- to 5-volt analog inputs from the signal conditioning circuitry— $P_{t5.4}$ ,  $T_2$ , and  $N_{p,t}$ . The fifth is a discrete (ON/OFF) input to indicate whether bleed air is being diverted from the GG. If the bleed air valve is open (ON), it will affect the efficiency of the engine and the torque output.

The torque computer is similar to many general-purpose computers of this size. The computer performs internal calculations and compares them to internally stored data tables. From the tables, selected values are taken to be used in further calculations to determine the final value of torque. The torque calculated is accurate to within 3,000 ft-lb.

When the turbine is at idle, the computer output is a torque value of about 5,000 ft-lb. This set point is the basic value used to allow the electronics to operate accurately over a broad range of operating conditions.

The output of the torque computer is a 0- to 5-volt signal, which is the input to the PLA

actuator electronics and a 0- to 10-volt signal for uplink and display. Torque range is 5,000 to 50,000 ft-lb. The computer also calculates horsepower as a function of PT speed and torque for shipboard monitoring.

## OVERSPEED SWITCH CONTROL

The overspeed switch control circuits function to shut down the engine if a PT overspeed, PT underspeed, or a loss of control power to the control circuits occurs. Two PCBs (PWBs) (the D cards) of identical type are required per engine for overspeed protection. Speed signal channels A and B go to their own respective D cards. Each card receives its signal from its own speed pickup and controls both fuel valves. (Remember, there are two fuel solenoid valves piped in series, but wired in parallel.) This allows for two independent speed channels and two independent overspeed trips. The outputs of the overspeed switch circuits are overspeed voltages, loss-of-speed signal voltages, and a voltage for the fuel shutdown valves. The following two test functions are provided:

1. Overspeed test function. Each board has a test generator with an output frequency above the highest PT speed to ensure a proper test. When you depress the test button, the overspeed indicator on the GTE control console lights and the fuel shutdown valves de-energize (close).

2. Speed limit test function. When you depress the speed limit test push button, the electronics lowers the speed limit to 75 percent of the normal speed limit and permits testing the speed limit circuitry without overspeeding the PT.

If the PT speed signals should become disconnected or lost ( $N_{p,t} < 100$  rpm), the overspeed switch opens. Both signals must be lost before the fuel shutdown valves actuate.

To start the GTE, a method of bypassing the loss of speed signal ( $N_{p,t} < 100$  rpm) shutoff is provided. With the throttle position at a nominal 30 degrees or below, a signal is generated that causes the loss of speed-signal function to be bypassed. The throttle must remain below 30 degrees until the PT exceeds 100 rpm. The signal loss bypass function is deactivated whenever the throttle is above a nominal 30 degrees.

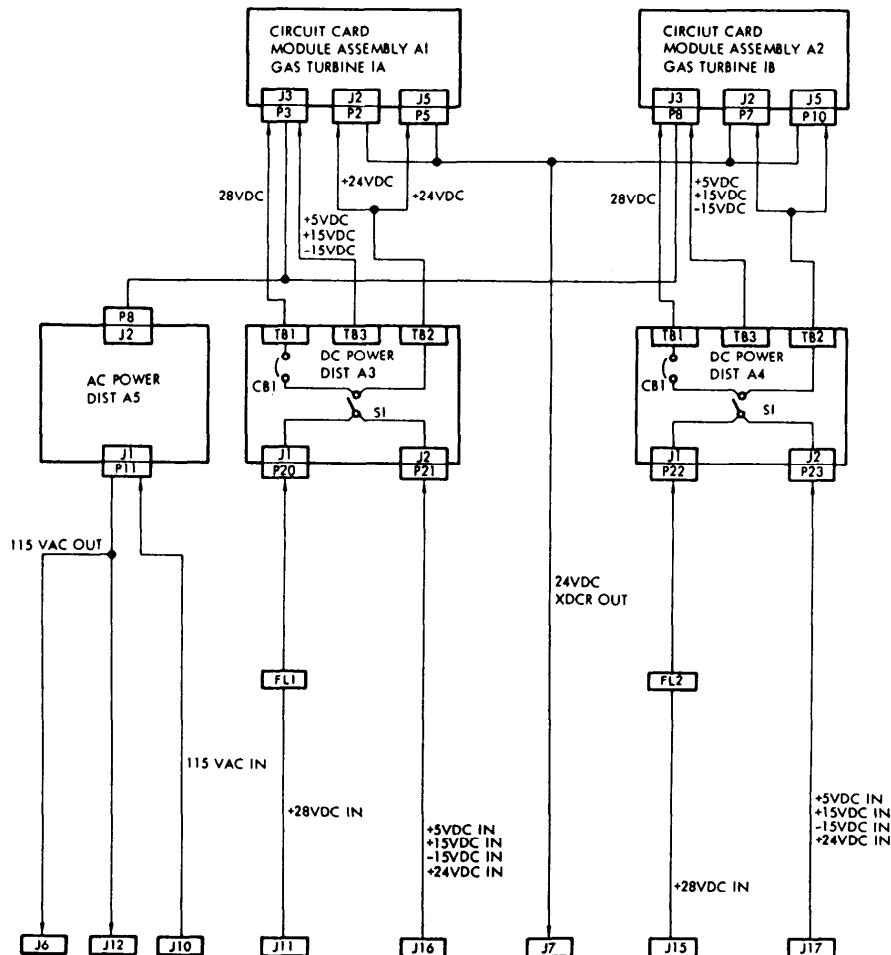


Figure 2-55.—Simplified FFG FSEE power distribution.

## POWER SUPPLY

The two different models of the FSEE use two different power distribution sets. A major difference between the two model FSEEs is that the FFG FSEE uses a 115-volt ac input and only distributes power, while the other model FSEE generates all FSEE voltages from a 28-volt dc input. The following is a basic overview of the power distribution of the two different FSEEs. For a detailed functional description of these FSEEs, refer to Volume 1, Part 1, of the LM2500 Technical Manual, S9234-AD-MMO-010.

### FFG FSEE Power Distribution

The power requirements for the FFG FSEE (fig. 2-55) are supplied by the ship power supplies. It requires +5 volt dc, +15 volt dc, -15 volt dc, +24 volt dc, + 28 volt dc, and +115 volt ac inputs to operate the various GTE systems. Power

is routed through the FSEE via interconnecting cables. The dc power is routed to dc power distribution assemblies A3 and A4. The A3 and A4 assemblies are identical and distribute all dc power for the FSEE circuits. The A3 assembly distributes dc power to circuit card module assembly A1 for the 1A GTE, and the A4 assembly distributes dc power to circuit card module assembly A2 for the 1B GTE.

The 115-volt, 60-Hz ac power is routed to ac power distributor assembly A5. The A5 assembly filters and distributes the ac power to the flame detectors, ice detectors, and ignition excitors of both engines.

### CG, DD, and FSEE Power Distribution

This model FSEE also has the power circuitry for two GTEs. The power requirements for all the FSEE equipment are supplied by a 28-volt

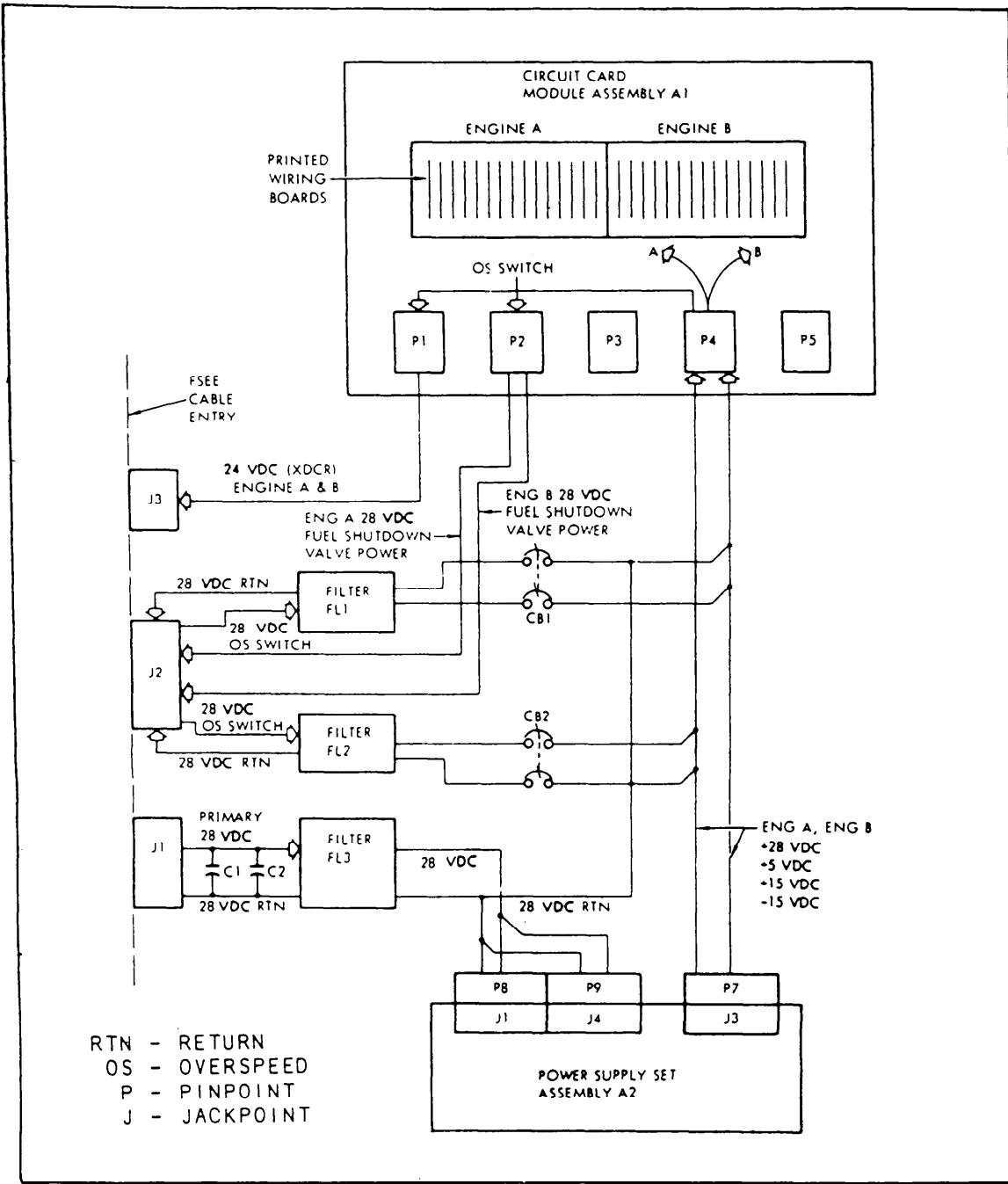


Figure 2-56.—Simplified CG, and DD FSEE power distribution.

dc power bus to power supply set assembly A2 (fig. 2-56). High-frequency line noise on the three power inputs are filtered by line filters FL1, FL2, and FL3. The A2 assembly distributes power to the circuit card module assembly A1 and has dual redundant power supplies. Each pair of

redundant power supplies feed engine A and engine B and are controlled by separate rotary switches, S1 and S2 (not shown), in the power supply set. The engine A and engine B PWBs in the A1 assembly are supplied by separate +28 volt dc and regulated +5, +15, and - 15 dc voltages.

All the voltages, except for the 24-volt dc transducer (xdr) power, are distributed directly from the A2 assembly. The 24-volt dc power source for the  $P_{T2}$  and  $P_{T5.4}$  pressure transducers for both engines are distributed from the A1 assembly.

## PLA ACTUATOR ELECTRONICS

The main functions of this subsystem are to condition the command signal, compare it to the feedbacks from the actuator, and provide the signal to drive the PLA actuator to the commanded position. In conjunction with the main functions, this subsystem provides monitoring of certain system parameters for the protection of the GTE and power train. The PLA actuator electronics are identical in both model FSEEs. The major difference between the actuator electronics of both models is location. In the FSEE on the CG-, and DD-class ships, the PLA actuator electronics are located in the A2 power supply set. In the FSEE on the FFG-class ships, they are located in the A3 and A4 dc power distribution assemblies.

The PLA electronics are composed of three PCBs (PBWs) per engine in the FSEE. These are the A, B, and C cards. The PLA actuator sends two signals back to the electronics. They are position feedback (potentiometer) and rate feedback (tachometer). Besides the command signal, these two signals provide most of the information necessary for the electronics to place the MFC at the correct position.

The potentiometer receives its reference voltages from the PLA actuator electronics. The potentiometer slider takes a voltage proportionate to the actuator position from the potentiometer; this voltage signal is connected to the control circuit. The voltage signal is used to compare with the command signal and to generate an uplink signal representative of actuator position. Also, the position feedback is used within an idle position detection circuit; this circuit detects when the MFC is within 2 degrees of the normal idle position and generates an uplink signal to indicate when the MFC is at idle.

Rate feedback is developed by the tachometer attached to the motor shaft. The purpose of the rate feedback is to control the response of the PLA actuator during changes of MFC lever position. When a large difference exists between the commanded position and the actual position of the PLA actuator, the drive signal to the servomotor is large. A large drive signal causes

rapid acceleration of the motor, which could allow the motor to overshoot the desired PLA actuator position. Tachometer feedback reduces this problem. If the feedback signal was not present, the desired position would be passed. This would force the system to backtrack by turning the motor in the other direction; it would eventually seesaw past the desired position a number of times before it settled at the correct position. The tachometer feedback anticipates the overshooting of the correct position and acts as a braking system for the motor. This is the same function that a compensating system in a hydraulic governor provides.

### Slider Potentiometer

The slider potentiometer provides a position feedback signal, which is proportional to the position of the PLA actuator shaft and MFC lever. It is a linear nonwire-wound variable resistance whose potentiometer slider position is controlled by the actuator output shaft. Two gears between the output shaft and the potentiometer increase the potentiometer's range of rotational movement by a factor of 2.27. The normal operating range of the actuator is about 100 degrees and the potentiometer 227 degrees. The potentiometer reference voltages are supplied from electronics in the FSEE.

### Servomotor

The dc servomotor is driven by the PLA actuator drive signal from the PLA actuator electronics. The drive signal is developed by the electronics in the FSEE. It is amplified and connected through the fail-to-idle relay. The motor's direction of rotation is determined by the polarity of the drive signal; its velocity is proportional to the drive signal amplitude. For an input range of -23 to +23 volts, the motor output shaft speed range is 0 to 900 rpm in either direction. The PLA actuator is reduced by a gear ratio of 55.64 to 1. This allows a speed range of 0° to 16 rpm (0 to 96°/second). It is also capable of running into mechanical stops at full voltage and velocity and remain stalled without damage to the motor.

### Tachometer

The tachometer is a dc generator that is directly coupled to the motor shaft and outputs a dc voltage proportional to the motor speed. The

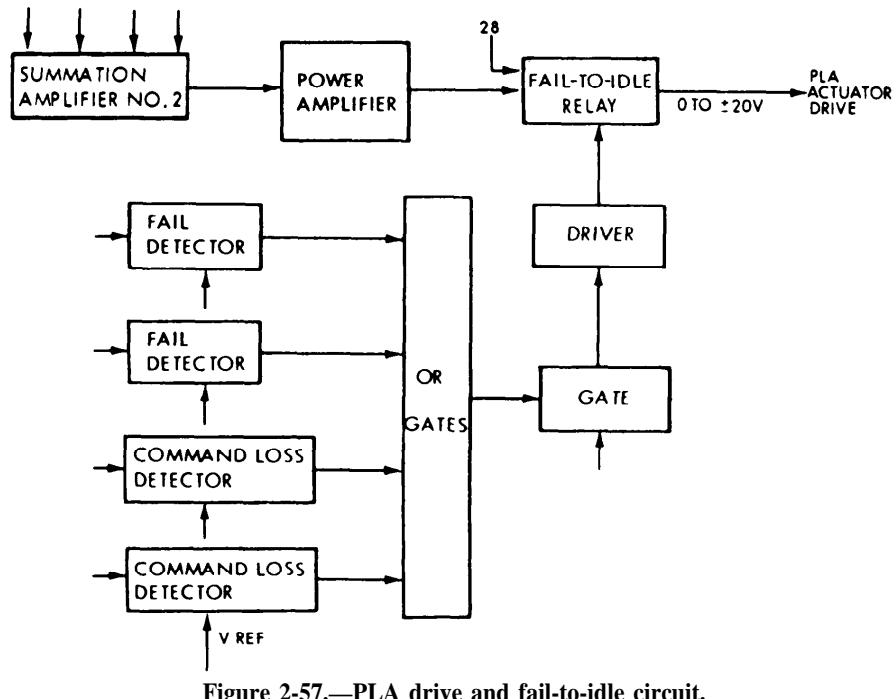


Figure 2-57.—PLA drive and fail-to-idle circuit.

polarity of the signal is dependent on the shaft's direction of rotation. The tachometer output range is 0 to 2.7 volts dc nominal for a shaft input of 0 to 840 rpm.

### PLA Actuator Drive

The PLA actuator drive and fail-to-idle circuit (fig. 2-57) provides the power to drive the actuator motor. It also provides the fail-to-idle signal that drives the motor during FSEE malfunctions.

In normal operation, the output of summation amplifier No. 2 is amplified by the power amplifier in the power distribution assembly. The output of this amplifier is sent through the fail-to-idle relay. This signal, in turn, is sent to the PLA actuator. A fail-to-idle signal is sent to the relay from either the fail or command loss detector (discussed under the system fail protection topic). If this occurs, the amplifier output is disconnected by the gate; a 28-volt dc signal is inserted to drive the motor. The polarity of this signal is such that it drives the PLA to the idle stop.

### Protective Functions

The protective functions of the PLA actuator electronics are torque limit control, speed limit control, acceleration limit control, PLA command rate limit control, and system fail protection.

**TORQUE LIMIT CONTROL.**—The PLA actuator contains the circuitry that monitors for an overtorque condition. Torque is calculated for either one or two engines in the operation on the FFGs or split plant or full power on the CG-, and DD-class ships. If the torque signal received from the torque computer exceeds the limit, the limiting circuit goes into action to drive the MFC back, thereby reducing the torque output of the turbine(s).

**SPEED LIMIT CONTROL.**—The speed limit control circuitry starts limiting when turbine speed reaches 3,672 rpm. The purpose of the speed limit control is to keep the turbine speed below 3,852 rpm. The circuit receives a speed signal from the signal conditioning card. This signal goes through an anticipation (to anticipate speed) amplifier; this amplifier detects the rate of increase of the speed (acceleration). This acceleration signal and the speed signal together are compared to a limit

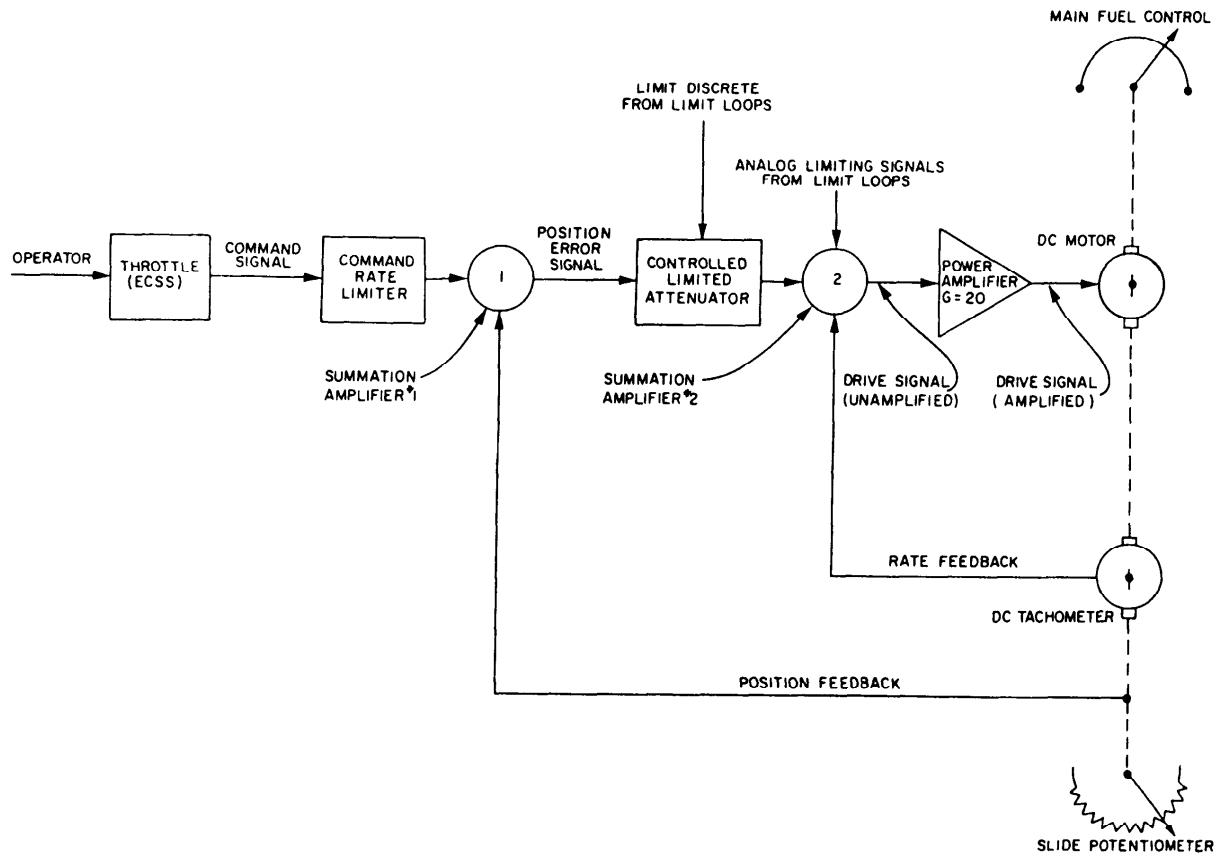


Figure 2-58.—Gas turbine simplified control loops.

voltage. If that voltage is exceeded, the speed limiting circuit goes into action to limit the PT speed or acceleration.

**ACCELERATION LIMIT CONTROL.**—A separate circuit also receives the PT speed signal where the rate of speed change (acceleration) is monitored. If the acceleration exceeds 332 rpm/second, this circuit lowers the PLA actuator drive signal to lower the PT acceleration.

**PLA COMMAND RATE LIMIT CONTROL.**—The position of the MFC lever is proportionally controlled by the command signal. The rate of change of the lever position is normally limited to predetermined increasing and decreasing rates by the command rate limiter.

**SYSTEM FAIL PROTECTION.**—The PLA actuator generates two signals when certain abnormal conditions are detected. One is an uplink signal to indicate a system failure; the other energizes the fail-to-idle relay to open the path

of the PLA actuator's drive signal and inserts a fixed voltage to drive the MFC to idle.

If the command signal exceeds a maximum of +12 volts dc or falls below a minimum of +0.3 volt dc, a command loss condition exists. Both the fail-to-idle relay energizing voltage and the system fail signal are generated.

A malfunction is considered to exist if the unamplified drive signal to the rotary actuator exceeds +2.7 volts or below -2.7 volts for 1 second or longer. Again both the fail-to-idle relay energizing voltage and the system fail signal are generated.

If the MFC is at idle and an overtorque condition exists or if either of the 15-volt power supplies fail, a system fail signal is generated.

### PLA Actuator Theory of Operation

In the following discussion, please refer to figure 2-58 to help you trace the command signal from the throttle to the MFC.

The command signal is developed by an operator at a throttle. When it reaches the PLA electronics, it first goes through a command rate limiting circuit. This circuit does not let the command signal (into summation amplifier No. 1) exceed a rate of change of 2.1 volts ( $22.5^\circ$ )/second increasing or 9.0 volts ( $89^\circ$ )/second decreasing. At summation amplifier No. 1, the command signal is compared to the position feedback signal. The difference is called the position error signal.

The position error signal is passed through the controlled limited attenuator. Here the signal is passed unchanged or is attenuated (decreased in amplitude). Whether attenuation occurs or not depends on the limit discrete signal. This signal is generated from within the limit loops when the torque or speed limit is exceeded. The attenuator attenuates the position error signal when the limit discrete signal is present. The attenuation of the position error signal lowers its effect on the PLA actuator.

**NOTE:** When the torque or speed limits are exceeded, the limit discrete and the analog limiting signals are simultaneously generated. The limit discrete signal lets the analog signal have more effect by diminishing the drive signal before the analog limiting signal is added to it at summation point No. 2.

The position error signal out of the attenuator, the speed (PLA actuator rate) feedback, and the analog limiting signal from the limit loops is added into summation point No. 2. There they are algebraically summed to generate the unamplified drive signal for the servomotor. The tachometer feedback signal lowers the drive signal whenever the PLA actuator moves fast. When the PLA actuator is moving slowly, the tachometer feedback is low and its effect is minimal on the drive signal.

The analog limiting signal is generated in the limiting electronics when the torque, speed, acceleration, or PLA actuator rate limit is reached. This signal is proportional to the amount of PT torque, speed, acceleration, or PLA actuator rate present over their respective limit. It drives the MFC in the direction necessary to remove the PT from the limit condition.

The corrected drive signal is sent through a power amplifier where it is amplified by a gain of 20. The signal then goes through the fail-to-idle relay to the servomotor. The fail-to-idle relay connects the drive signal to the PLA actuator

through normally closed contacts; it may gate a fixed voltage, through normally open contacts, to drive the PLA actuator to idle if one of the conditions discussed previously exists.

The limiting functions of the PLA actuator electronics have a passive role during normal operation of the PT. Only when a limit is exceeded or, as in the case of speed limiting, seems like it is going to be exceeded, do the limiting circuits become active.

The inputs to the limiting circuits are PT speed and PT torque. The speed signal comes from one of two PT speed transducers through a signal conditioning circuit. The torque signal is calculated by the torque computer in the FSEE.

If more than one event (overspeed or over-torque) occurs simultaneously, the analog signals from the speed acceleration and torque limiting circuits are brought to the same point. At this point, the largest of the signals gates to summation point No. 2 in the control loops. The analog signal from the rate limit can be applied to summation point No. 2 regardless of other inputs.

The operation of the control circuits in the PLA actuator electronics can be altered by the battle override function. During testing and emergency operation of the ship, authorized personnel can activate this function at the control consoles. In the battle override mode, the fail-to-idle relay will not operate. This will prevent the PLA being forced to idle. The analog limit signal used by the limit loops to lower PLA actuator position is inhibited. ( **NOTE:** Depressing the engine synchronizing switch located within the FSEE will activate battle override as long as the switch is depressed.)

## FSEE CIRCUITRY TESTS

The electronics within the FSEE covers various internal tests to check if circuits are working properly. The tests are for the torque computer, the speed limit circuit, and the overspeed switch. These tests only test the FSEE circuitry. For a total system test, refer to the applicable maintenance requirement card (MRC) of the Planned Maintenance System (PMS).

- Torque computer test. On this test, the torque computer uses several fixed parameter values to calculate a torque value. If the value exceeds the reference set point, an indicator light on the control console signals that the torque test passed.

- Speed limit test. This test lowers the speed limit loop reference voltage by 25 percent. To test this loop using the turbines, the PT would only have to be run to 75 percent of real limit point. (NOTE: Follow the PMS procedure to test speed limiting.)

- Overspeed test. Four push buttons are located in the FSEE, one each for channels A and B on each turbine. When you depress a push button for testing the circuit, a frequency generator in each PWB introduces a signal simulating a high-speed signal. This signal causes the fuel valves to close and the overspeed light to illuminate.

## START/STOP SEQUENCER

The start/stop sequencer is installed in the FSEE on FFG-class ships. It provides signal conditioning, monitoring, and logic circuits required for safe GT starting and stopping. Nine circuit cards are used for this feature. Three cards (the X, Y, and Z cards) are signal conditioners. Four of the cards are logic cards (the AB, AD, AE, and AC cards). The other two cards are a transmitter card (AA) and a thermocouple amplifier card (V).

The start/stop sequencer provides the following functions:

- Signal conditioning of gas turbine parameters
- Monitoring of vital parameters
- Sensing out-of-limits instrumentation signals
- Signal conditioning output status signals
- Initiating automatic control signals
- Receiving and processing operator commands

The start sequencer has three sequence modes available. These modes are auto, manual, and auxiliary (or test). In the auto mode, when commanded by a signal from the PCC, an automatic start-up of the GTE can be performed. This auto start sequence using a programmed time sequence monitors and controls the engine starting. Parameters monitored include  $N_{GG}$ ,  $T_{5.4}$ , fuel manifold pressure, and lube oil supply

pressure. If these parameters are not within limit during start-up, the sequencer will initiate an immediate automatic shutdown.

In the manual mode, an operator is required to initiate the starter on, fuel on, and ignition on commands. When the sequencer receives a manual start command, it provides the time sequence and engine parameters for the operator's information. The conditions that would cause shutdowns in the automatic mode provide only an alarm in the manual mode.

In the auxiliary (or test) mode, an operator can test the engine start components without activating the fuel and ignition at the same time. In this mode, the operator can check the fuel system without causing a start of the engine. The operator does this by manually motoring an engine, and at 1,200 rpm, energizing the fuel valves. Then the operator checks the operation of the fuel system components. This is done by the operator monitoring the fuel supply temperature, pressure, fuel flow, and fuel manifold pressure. In this way, the operator checks the operation of the fuel pump, MFC, and fuel shutoff valves. The operator checks the fuel shutdown valves upon completion of the test by de-energizing the valves. A fuel valve test mode also allows you to test the valves to ensure proper operation of the valves. Also, you can test the ignition system using the auxiliary mode. The ignition test will cause the igniters to be on as long as you depress the igniter push button.

## SUMMARY

In this chapter and the previous one, we discussed how the LM2500 GTE is constructed and the function of its various parts. We described the operations of its many systems, including the flow of air into the combustion section, the mix of fuel and air, and how the fuel system and ignitor system cause combustion. We described the operation of the lube oil system and looked at a description of its function and how the engine is controlled electronically by the FSEE. We briefly covered the control systems for the different class ships. We discussed the ECSS and start/stop sequencer control.

We will describe the actual start, operation, and stopping of the LM2500 GTE in chapters 6,

7, and 8 of this manual. After reading this chapter and chapters 6, 7, and 8, you will be able to understand how the overall engine operation is controlled from the engine room or from a central control point aboard ship.

You should now be familiar enough with the engine and its operational systems to be able to follow instructions concerning basic maintenance procedures and understand the importance of the numerous parameters that control the engine.

## CHAPTER 3

# SHIP'S SERVICE GAS TURBINE GENERATOR SETS

Until now our discussion has centered on the propulsion uses of GTEs. This means we have covered only part of the job tasks of GSs. On the larger gas turbine ships, such as the DD, and CG classes, GSs must maintain the ship's service gas turbine generator sets (SSGTGSs). These ships use four different gas turbine generator sets (GTGSs). The model 104 is found on the DD-class ships, the model 119 on ships, and the model 139 on CG-class ships. The model 170 GTGS is found only on the USS *Paul F. Foster* (DD-964). It is very similar to the model 104. Except for the 51 class ships, all of the GTGSs use the Allison 501-K17 GTE as a prime mover. The 51 class ship uses the Allison 501-K34, a modified version of the K17. In this chapter we refer to the Allison 501-K17 (K34) as the GTE, the engine, or the prime mover. Although the engine is the same on all sets, many differences exist between the units. Models 104 and 170 GTGSs are 2000-kW GTGSs; models 119 and 139 are 2500-kW GTGSs. Models 104, 119, and 170 have solid-state local operating control panels (LOCOPs) that use analog meters; the model 139 incorporates a digital LOCOP with light-emitting diodes (LEDs) used to display operating parameters. Models 119 and 139 use a brushless exciter that replaces the brushes and slip rings found on the 104 and 170. Many other differences exist between these GTGSs. We will discuss most of these in detail in this chapter. Model 170 incorporates features from each of the other three models. It will not be discussed separately in this chapter.

Normally the GTGS is not attended while it is in operation. It is controlled either at the switchboard (SWBD) or the electric plant control console (EPCC). The EPCC operators are the watches that monitor the electric plant. They are responsible for taking action to prevent loss of the electrical load during a generator casualty. Neither control station can monitor all the parameters of the operating GTGS. For this reason, a monitor who makes hourly rounds of

the equipment is usually required to log parameters not otherwise observed. Most often these monitors are GSs in the junior paygrades (E-5 and below). You will need to be able to quickly identify any impending casualty to the GTGS to prevent loss of the ship's electrical power. To do this, you must first understand how the set is constructed, how its systems function, and how to operate it.

After reading this chapter and completing the associated nonresident training course (NRTC), you should be ready to begin qualification as an engine-room equipment monitor and as an EPCC operator. You should also be able to identify and describe a majority of the GTE and generator components. You should be able to understand the operations of the various engine systems and the generator control and monitoring equipment. You should understand the procedures for starting, stopping, and motoring a gas turbine generator (GTG) locally or from the SWBD. You should also be able to understand frequency and voltage control functions.

The EOSS gives you the correct procedures for operating this vital piece of machinery. Always use the EOSS when actually operating any engineering equipment. Using the EOSS will prevent you from missing any steps/procedures that could result in damage to a valuable piece of ship's equipment.

**NOTE:** Directions in this chapter relate to an observer standing at the exhaust end of the GTGS looking toward the generator (aft looking forward).

### GENERAL DESCRIPTION OF THE GENERATOR SET

Ship's service electric power is provided by three 2500-kW GTGSs on the CG-class ships. On the DD-class ships, ship's service electric power is provided by three 2000-kW

GTGSs except the USS *Paul F. Foster*. This ship has a fourth GTGS (model 170), which is a modified model 104. For detailed information on this GTGS, refer to NAVSEA technical manual, *Description, Operation and Installation, Model 104 Gas Turbine Generator Set, S9234-BC-MMO-010*, change B.

Under normal operating conditions, any two generators can supply the entire ship's demand. The third GTGS can be set up in auto-standby. It will then come on the line automatically in case either on-line GTGS fails.

The No. 1 GTGS and the No. 2 GTGS are located in the No. 1 and No. 2 engine rooms,

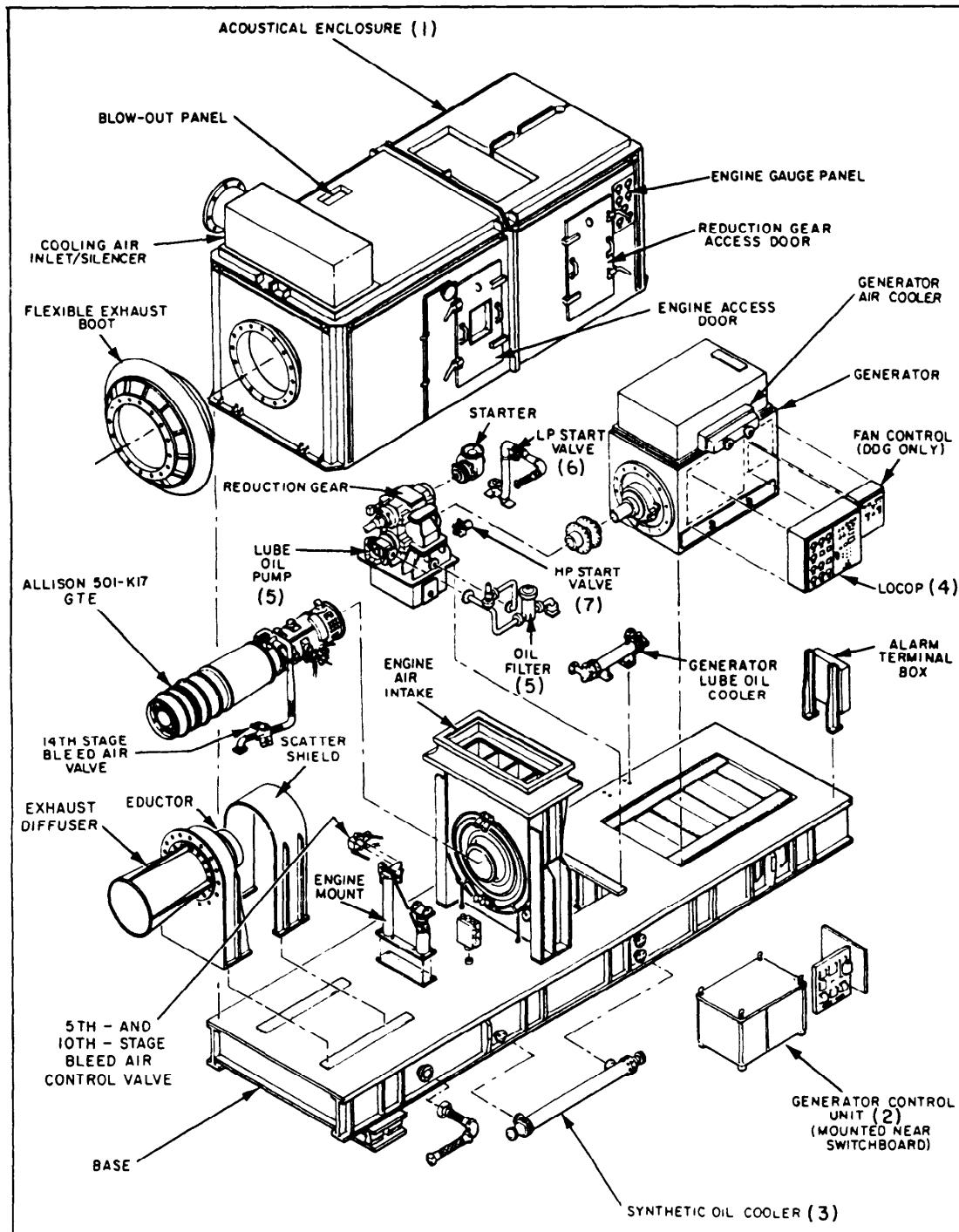


Figure 3-1.—Model 104 GTGS.

respectively, on the second platform level. They are located opposite the main engines. The No. 3 GTGS is located in the No. 3 generator room at the first platform level. This arrangement separates each GTGS by at least three watertight bulkheads. This reduces the chance of total loss of electric power because of battle damage. Figure 3-1 shows the equipment layout of a GTGS. Refer to the numbers listed in parentheses after each description to locate the component in figure 3-1.

Each GTGS is a module consisting of a GTE, a reduction gear assembly, and a generator. These are all mounted on a common base with associated engine controls and monitoring devices. Each GTGS is about 25 feet long, 7 feet wide, and 9 feet high. The GTE and reduction gear assembly are housed in an acoustical enclosure (1). Each generator has a remotely mounted generator control unit (2). The lube oil cooler (3) for each gas turbine/reduction gear system is mounted under the module base.

The GTGSs can be started and monitored locally at the LOCOP (4) mounted on the generator housing or remotely from the SWBD or EPCC in CCS. The LOCOP contains the electronic controls that sequence and monitor the operation of the GTE. Control of generator voltage, frequency, and the generator circuit breaker is available at either the EPCC or the SWBD.

Each GTGS has its own seawater cooling system and lube oil system (5). The module is cooled by air supplied from the intake system through an electric fan. Two fans are used on the CG classes. The module receives starting air from the bleed (low-pressure) (6) and high-pressure (7) air systems, signal air from the ship's service air system (SSAS), cooling and emergency cooling water from the seawater service system, fuel from the engine room's fuel oil (FO) service system, carbon dioxide (CO<sub>2</sub>) from the fire extinguishing system, and gas turbine cleaning/rinsing solution from the water wash system. Figure 3-2 shows the interrelations of

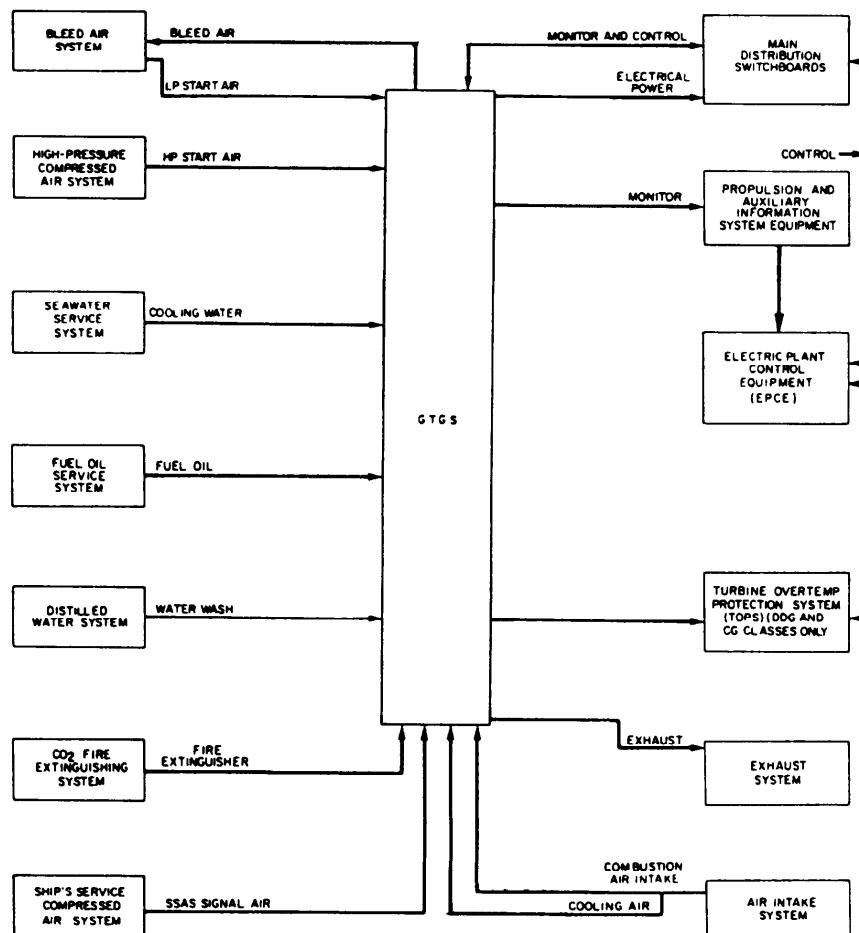


Figure 3-2.—GTGS interrelation with ship's systems.

these systems to the GTGS. These and other services interface connections are made at the module (fig. 3-3).

### GAS TURBINE GENERATOR SET MODULE COMPONENTS AND SYSTEMS

The module components and systems support the operation of the engine, reduction gear, and generator. These components and systems include the base, the enclosure, the cooling air flow and temperature monitoring systems, the water wash system, the fire detection and extinguishing system, the intake and exhaust systems, the GTGS fire detection and CO<sub>2</sub> system, and the seawater service system.

#### BASE

The GTGS base is a steel frame attached to the ship's structure through 5000-pound capacity, shock/vibration isolating mounts. Twelve mounts are used for the model 104 GTGS; fourteen are used for the models 119 and 139 GTGSs. The base

supports the entire GTGS system except for these two components. They are the generator exciter/voltage regulator unit (including the electronic governor) and an externally mounted oil cooler for the GTE and the reduction gear lube oil systems.

#### ENCLOSURE

The engine and the reduction gear assembly are housed in an acoustical enclosure (fig. 3-4). The enclosure reduces the noise level within the machinery space and ducts cooling air for the GTE. Barrier walls and the air inlet plenum within the enclosure separate the engine compartment from the reduction gear compartment.

#### Blow-In and Blow-Out Panels

Figure 3-4 shows the blow-in and blow-out panels on the enclosure. They prevent damage to the GTGS due to high or low external pressure. The panels are spring-loaded in the closed position. The blow-in panel is located in the left wall of the enclosure. It is near the aft end and

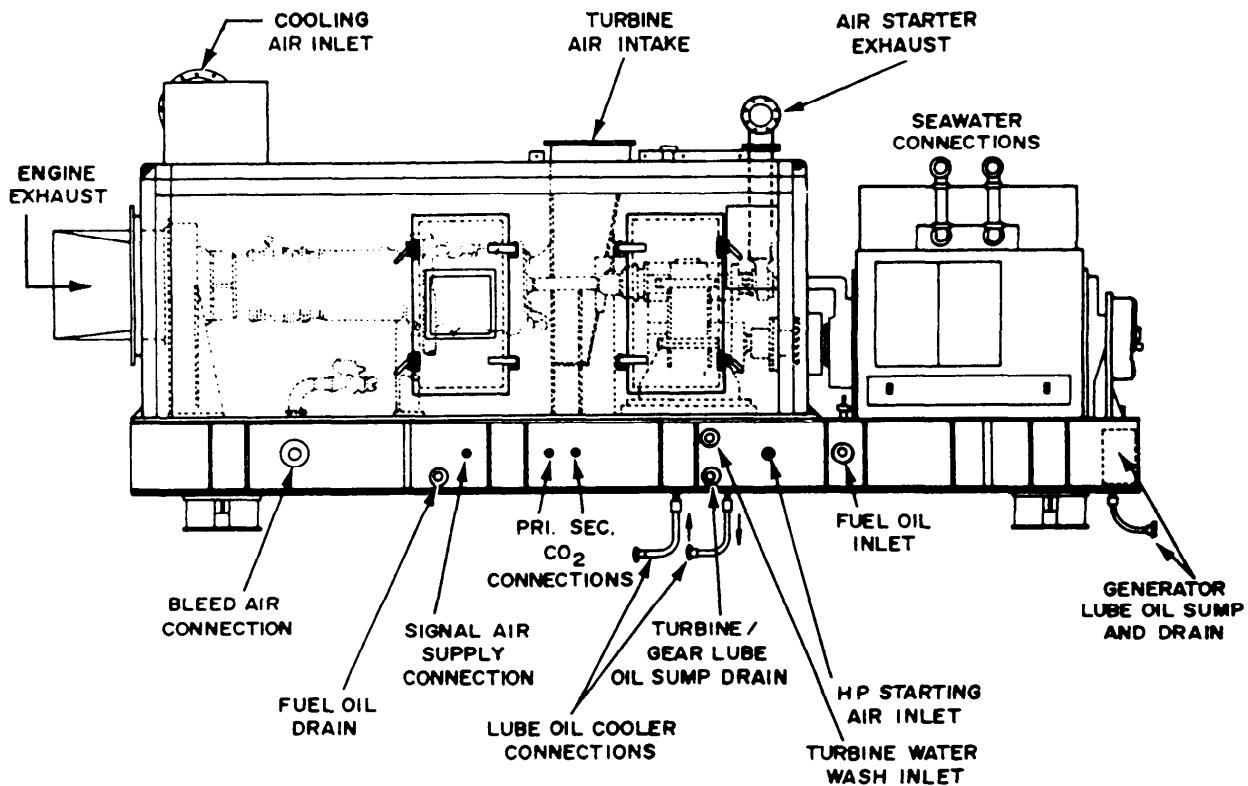


Figure 3-3.—GTGS ship's system interface connections.

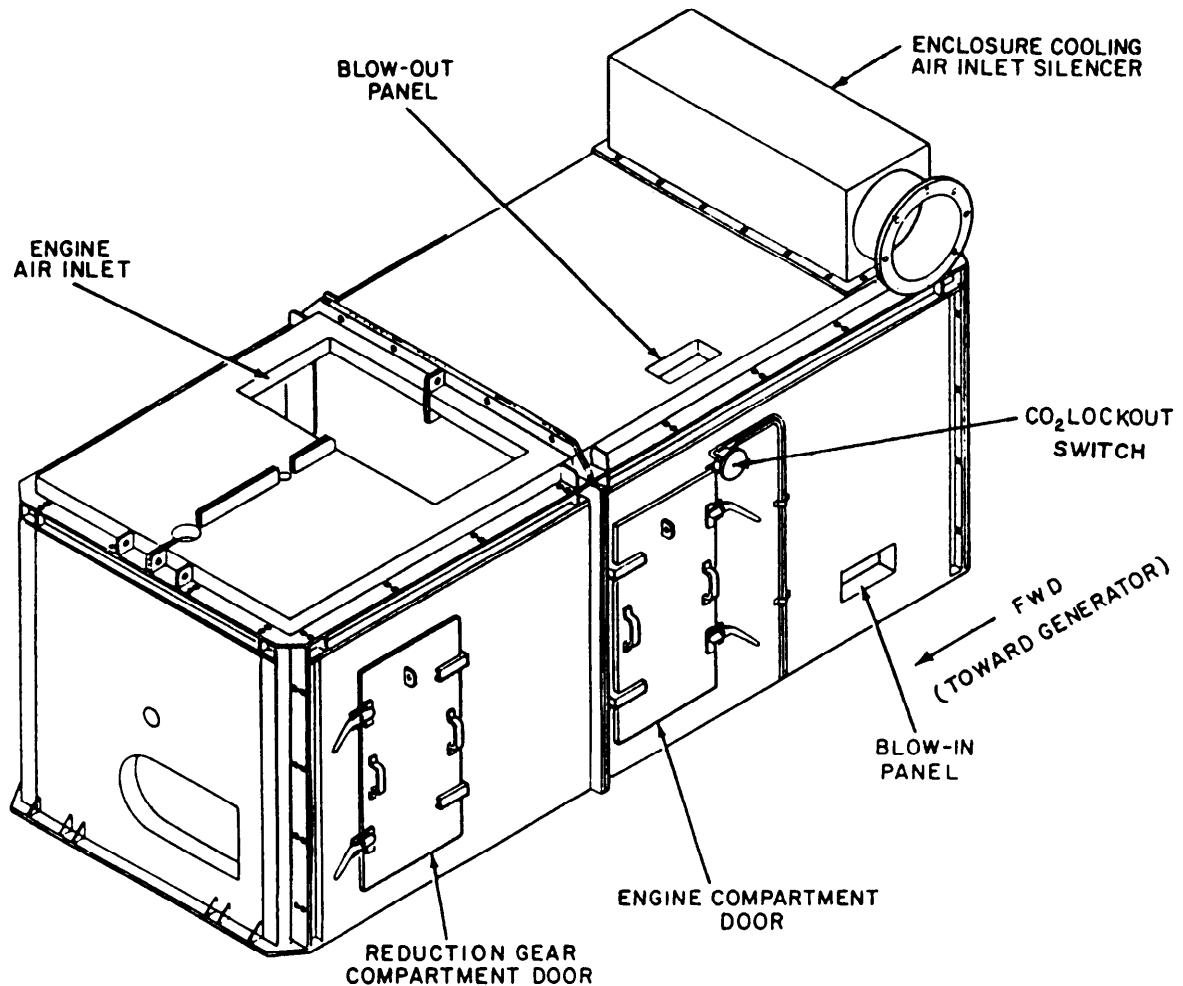


Figure 3-4.—GTGS enclosure-left side view.

just above the base. The blow-out panel is located in the enclosure roof panel on the left side. It is forward of the cooling air inlet silencer.

#### Module Cooling Air Flow and Temperature Monitoring

Cooling air is extracted from the GTE combustion air intake duct and flows through a louvered cooling air modulator on the model 104. Then it flows through an axial fan (two on CGs) and a fire damper. It is ducted into the enclosure, entering the enclosure through a silencer mounted on the aft (exhaust) end of the enclosure roof. Ceiling-mounted baffles in the enclosure direct the cooling air to the forward (compressor) end of the engine enclosure. The air circulates around the engine and exits through a gap between the engine exhaust nozzle and the

exhaust. The flow of exhaust gas past this gap pulls the cooling air out of the enclosure and into the uptake. The cooling fan(s) is only activated if this natural flow is not enough to keep the enclosure air temperature below 195°F.

**DD MODULE TEMPERATURE MONITORING.**—Two temperature switches, a thermostat, and an RTD are associated with the cooling air system. These components are all located inside the acoustical enclosure. One switch controls the cooling air fan, turning the fan on when the air temperature in the enclosure is 195°F and off when it is 175°F. The second switch activates the ENCLOSURE TEMP HIGH alarm indicator at the electric plant control equipment (EPCE). It also activates the summary alarm at the associated switchboard. The alarms are activated when the enclosure temperature reaches

200°F. The RTD provides a continuous enclosure temperature signal to both the LOCOP and propulsion and auxiliary machinery information system equipment (PAMISE). The signal in the PAMISE is used for data logging and the demand display indicators (DDIs). The thermostat controls the operation of the louvered cooling air modulator.

**CG CLASS MODULE TEMPERATURE MONITORING.**—Two temperature switches, a thermostat, a manual rotary selector switch, and an RTD are associated with the cooling air system. The manual rotary selector switch is located on the LOCOP. It is a four-position switch: FAN A, FAN B, MANUAL, and OFF. When the selector switch is positioned on FAN A or FAN B, this selects the lead fan. The temperature switches work with the rotary switch to determine which is the lead fan or for manual operation. With the rotary switch in the FAN A position, fan A will act as lead fan. When the GTG is started, fan A will start at an enclosure temperature of 170°F.

If the temperature continues to rise, standby fan B will start at 190°F. It will continue to run until the temperature drops to 180°F. When you secure the GTG, the lead fan will continue to run until the temperature drops to a point below 140°F.

When the LOCOP switch is positioned on MANUAL, you can select a fan by using the LOCOP push-button indicators. The fan selected will operate until it is stopped manually.

The RTD on the model 139 operates like the RTD on the model 104 except that the RTD in the enclosure provides a temperature signal to the EPCC that activates the ENCLOSURE TEMP HIGH alarm indicator at the EPCC.

## WATER WASH SYSTEM

Figure 3-5 shows the components of the water wash system and the CO<sub>2</sub> system. The CO<sub>2</sub> system is discussed later in this chapter. The water wash system is used to clean the compressor section of the GTE. Two spray nozzles spray chemical cleaner or fresh water into the engine inlet while

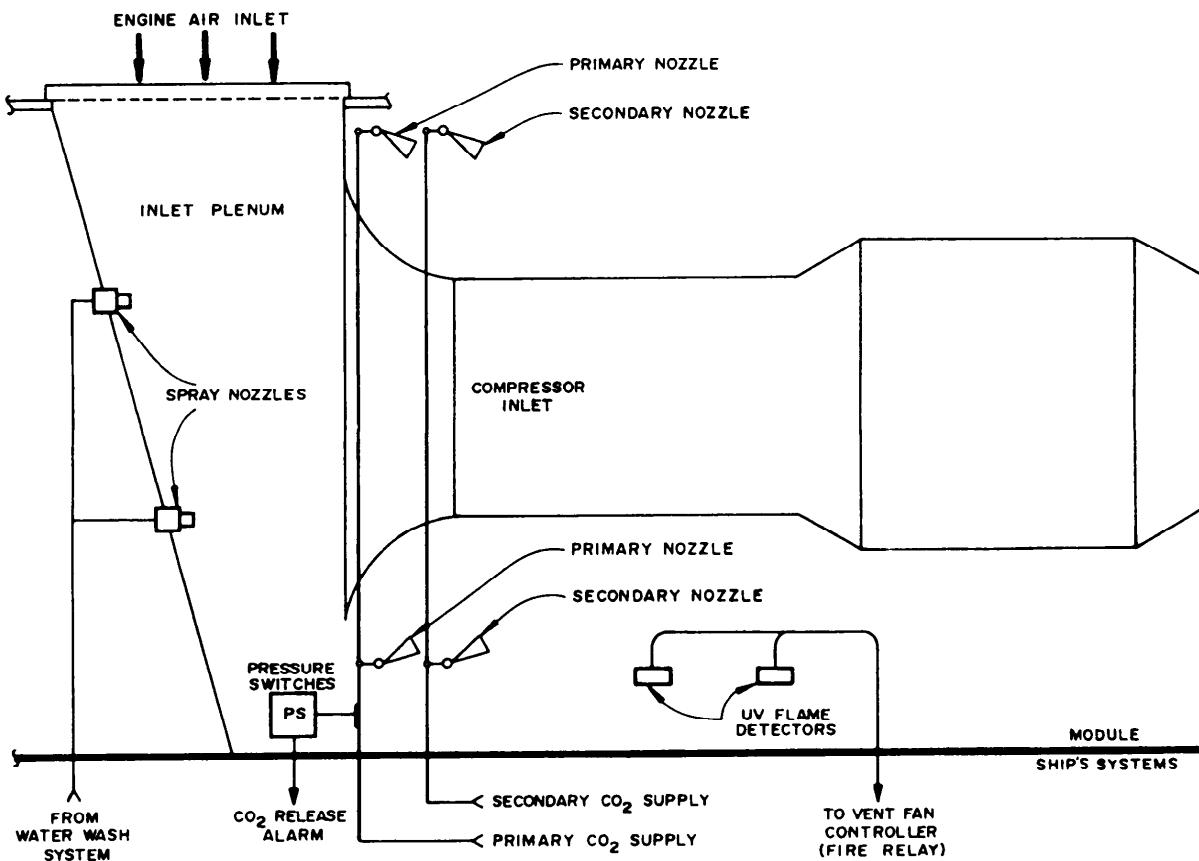


Figure 3-5.—GTGS water wash and CO<sub>2</sub> systems.

the engine is motoring. The nozzles are mounted in the forward wall of the inlet plenum. Except for the spray nozzles and the solenoid-operated signal air valve (not shown) located under the module, all components of the water wash system are ship's systems.

## FIRE DETECTION AND EXTINGUISHING SYSTEMS

Figure 3-5 also shows the fire detection and extinguishing system. This system has two UV flame detectors, a signal conditioner (not shown), and four CO<sub>2</sub> discharge nozzles. The flame detectors are mounted on the engine side of the inlet plenum wall. The CO<sub>2</sub> discharge nozzles are

mounted in pairs above and below the air inlet housing. Each pair has one primary and one secondary discharge nozzle. The CO<sub>2</sub> is piped to the module from the primary and secondary CO<sub>2</sub> tank banks. When the flame detector detects a fire, an electrical signal from the vent fan controller activates the primary CO<sub>2</sub> system. If failure of the primary system occurs, or the primary is not enough to extinguish the fire, the secondary system can be manually activated at the module or outside the space.

## INTAKE, COOLING, AND EXHAUST SYSTEMS

The intake, cooling, and exhaust systems (fig. 3-6) provide the flow path for combustion and

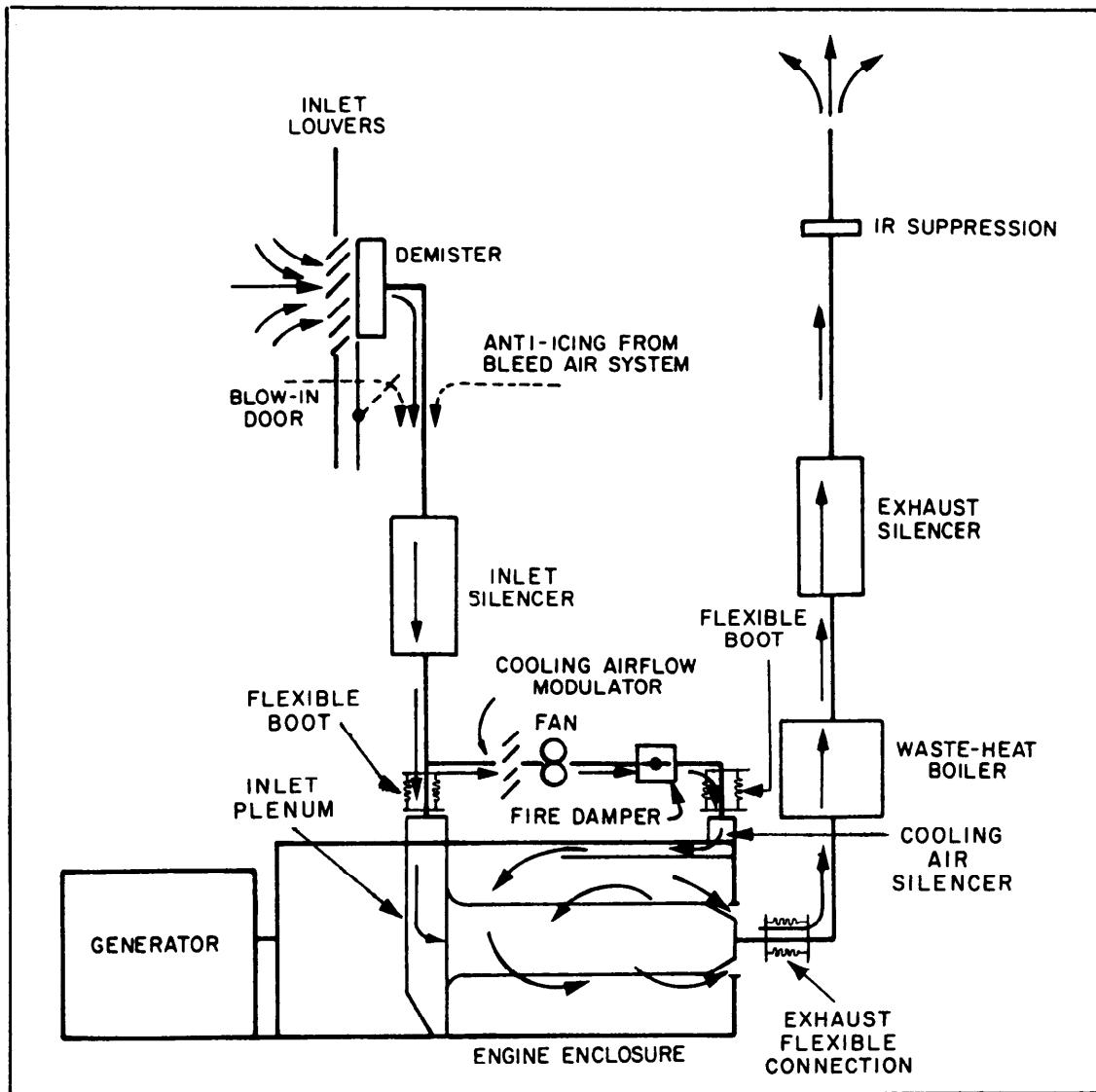


Figure 3-6.—GTGS intake, cooling, and exhaust systems.

cooling air to and from the GTE. The inlet systems have inlet louvers, demisters, blow-in doors, silencers, cooling airflow modulators, fans, and a fire damper. The exhaust systems contain silencers and IR suppression systems. The exhaust gas is routed through waste heat boilers (WHBs) before entering the exhaust stack.

## Intake Duct

The intake ducts are rectangular structures attached to the enclosure by a flexible rubber boot. Both combustion and cooling air enters through a common duct, but separate before entering the enclosure. The ducts for the No. 1 and No. 2 engines are located on the inboard side of the exhaust stacks. Air enters the ducts through louvers mounted in the side of the stack. It flows through mesh pad demisters and silencers into the module inlet plenum and into the engine inlet. The cooling air splits off just before the flexible boot on top of the inlet plenum. It is routed to the aft end of the enclosure through another flexible boot.

The intake air plenum for the No. 3 GTGS is located on the 01 level, starboard side, aft of the missile launcher area. Air enters a vertical bellmouth and flows into the No. 3 generator. This plenum serves as a green water trap. It allows any large quantities of water to drain through slots in the deck combing. The air then flows through demisters into the No. 3 generator intake room. The bulkhead between these two compartments has the blow-in doors. Combustion and cooling air flow through separate ducts from the intake room to the module.

**LOUVERS.**—The intake duct inlets for the No. 1 and No. 2 engines have louvers similar to the main engine inlet louvers. Like the main engine louvers, they are designed and arranged to shed sea spray. Because of the vertical flow inlet design, the No. 3 engine duct inlet has no louvers.

**DEMISTERS.**—The demisters are mesh pads. They are similar to those in the main engine inlet. They are arranged vertically behind the louvers. Moisture separated from the air collects in scuppers under the demisters and is drained overboard.

**BLOW-IN DOORS.**—A single blow-in door is located in each inlet below the demisters. Their purpose is to bypass the demisters if they become clogged. This permits enough combustion and

cooling airflow to the engine for normal operation. A controller provides for manual or automatic operation by a selector switch on the controller door. When in manual, you can use a push button to energize a solenoid and release the blow-in door. When in automatic, the solenoid is energized by action of a pressure switch. This switch is set to operate at about 8 inches of water ( $\text{in.H}_2\text{O}$ ) differential pressure. Indication and alarm of DUCT PRESS LO are given at the propulsion local operating equipment (PLOE) and the propulsion and auxiliary machinery control equipment (PAMCE) consoles. Once open, the doors must be closed manually.

**SILENCERS.**—The vane-type silencers have sound-deadening material encased in a perforated, stainless steel sheet. They are mounted vertically in the duct between the demisters and the cooling air duct.

**ANTI-ICING.**—The anti-icing system is similar to that in the main engine inlet ducts. Hot bleed air from the engine is discharged into the inlet duct. There it mixes with the inlet air and raises the temperature above the freezing point. Bleed air flow is regulated as a function of upstream temperature versus a fixed temperature. This maintains an inlet temperature of about 38°F when anti-icing is selected. This temperature is enough to prevent the formation of ice. It also melts any ice, sleet, or snow entrained in the air.

## Module Cooling System

The module cooling system has a duct, a flow modulator, an axial fan (two fans on the model 139), a fire damper, an air silencer, and a ceiling-mounted baffle within the module.

**FLOW MODULATOR.**—The flow modulator is located in the cooling duct between the engine intake duct and the fan. It controls the flow of air to the module enclosure based on the enclosure air temperature. When the enclosure temperature increases to 180°F, the high-temperature set point contacts of the module-mounted thermostat will close. This causes the flow modulator motor to rotate the modulating blade-type vanes to the full-open position. When the enclosure temperature decreases to 170°F, the low-temperature set point contacts will close. This causes the flow modulator motor to rotate the modulating vanes back to the half-open position. The modulator is not used on the model 139 GTGS.

**COOLING FAN(S).**—The fan(s) is located in the cooling air duct between the flow modulator and the fire damper. The fan(s) draws air from the intake duct through the flow modulator. It blows the air through the fire damper to the module enclosure. The air enters the module through the silencer. It passes across the ceiling-mounted baffle within the enclosure and then circulates around the engine. It exits through a gap between the engine exhaust nozzle and the exhaust eductor where it mixes with the engine exhaust.

**COOLING FAN CONTROLLER.**—The fan controller has a circuit to cycle the fan on and off automatically based on the enclosure temperature. It also has circuitry to perform a GTGS system fire stop, which is described later in this chapter. It is provided with a NORMAL/ALTERNATE power supply selector switch. The NORMAL source for the controller is the generator bus; the ALTERNATE source is one of the other SWBDs. The fan will cycle on when a temperature switch within the module enclosure senses a temperature of 175°F. It cycles off when the temperature decreases to 160°F. The model 139 also cycles on and off based on the enclosure temperature. This function is controlled by the LOCOP; however, no separate fan controller is used.

**FIRE DAMPER.**—The fire damper is located in the cooling air duct between the fan and module enclosure. It closes off the flow of cooling air to the module when a fire is present within the module. During normal operation, the fire damper is in the full-open position. A fire detected by either of the two UV detectors within the enclosure will cause the fire stop circuit within the fan controller to close a set of contacts. This energizes the fire damper motor and rotates the damper to the closed position. The fire damper is reset manually.

### Exhaust Duct System

The exhaust ducts are round, insulated, stainless steel structures. Each duct has a silencer and an IR suppression system. The model 139 uses a BLISS-type IR suppression system similar to the ones used on the CG main engines. Because of their smaller size and lower gas flow rate, they do not require eductors as do the main exhaust ducts. The exhaust ducts from the No. 1 and No. 2 engines run parallel to the main engine ducts in the exhaust stacks. The duct from the No. 3

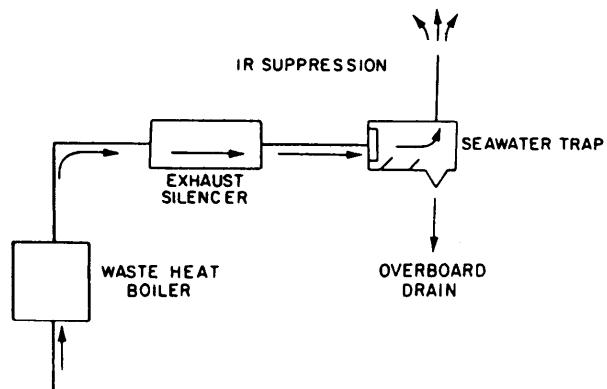


Figure 3-7.—No. 3 exhaust configuration.

engine (fig. 3-7) traverses the ship and discharges from the aft, port side on the 01 level. Because of the location of the No. 3 exhaust, a seawater trap is provided to trap and drain this water overboard.

**SILENCERS.**—The silencers have sound-deadening material. They are encased in a perforated stainless steel sheet cylinder. This is suspended in the center of the exhaust duct. This unit with the duct wall insulation provides the required sound reduction to meet airborne noise requirements.

**BOUDARY LAYER INFRARED SUPPRESSION.**—The purpose of the IR suppression system is to reduce the exhaust gas temperature before it is discharged to the atmosphere. This minimizes heat sensing of the ship by other vessels and aircraft.

**GREEN WATER TRAP.**—Figure 3-7 shows the location of the green water (seawater) trap. Because of the low location of the No. 3 engine exhaust duct exit relative to sea level, green water can enter the duct exit during high sea states. To stop the seawater from flowing down through the exhaust system, a tank is located in the duct near the exit. Any water that enters the duct is trapped in the tank and drained overboard.

## **GTGS FIRE STOP AND CO<sub>2</sub> SYSTEM**

Two UV detectors are used to sense a fire condition in the engine enclosure. Only the engine enclosure is protected by the installed CO<sub>2</sub> system. The UV sensors and signal conditioners used on the GTGS are similar to the type used on the LM2500 GTE. The two sensors are mounted in the enclosure near the compressor inlet. The signal conditioners are mounted in the alarm terminal box located on the generator end of the base. The fire stop logic is controlled by the module cooling fan controller.

### **Model 104 Fire Stop Logic**

When a fire is detected by the UV sensors in the module of the model 104 GTGS, a signal is sent to the fire shutdown relays. The following actions then occur:

1. A 5-second delay occurs. This prevents any stray signals from causing a fire stop. The fire condition must exist for these 5 seconds.
2. After the 5-second delay, the following actions occur:
  - a. Primary CO<sub>2</sub> is released.
  - b. A stop command is sent to the LOCOP.
  - c. The module fire damper is closed.
  - d. The cooling fan is stopped.
  - e. Ship's service LP air is ported to the 5th- and 10th-stage bleed air valves to keep them closed.
  - f. Fire alarms are activated at the damage control console (DCC), EPCC, and the summary alarm at the SWBD.
3. The stop command to the LOCOP closes the fuel valve. When the GTGS rpm drops below 12,780 rpm, the 14th-stage bleed air valve closes.
4. Door interlocks are provided to prevent CO<sub>2</sub> discharge if the engine section module doors are open.

### **Model 139 Fire Stop Logic**

The model 139 fire stop is also controlled by the cooling fan controller. The fire stop sequence

is different from that on the model 104. The following actions occur if a fire is detected by the UV sensors:

1. The cooling fan(s) stop(s), if running.
2. A 20-second delay is activated if the fire signal remains for 1.5 seconds or longer.
3. After 20 seconds the following actions occur:
  - a. A stop command is sent to the LOCOP.
  - b. Ship's service LP air is ported to the 5th- and 10th-stage bleed air valves to keep them closed.
  - c. The fire dampers are closed.
  - d. Primary CO<sub>2</sub> is released.
  - e. Fire alarms are activated at the DCC, EPCC, and the SWBD.
4. The LOCOP stop command closes the engine fuel valve. When the engine drops to 12,780 rpm, the 14th-stage bleed air valve closes.

### **CO<sub>2</sub> System**

The primary CO<sub>2</sub> system has two 50-pound CO<sub>2</sub> cylinders (one master and one slave), two pressure switches, and two high-volume, low-velocity nozzles. The CO<sub>2</sub> cylinders are mounted in racks adjacent to the module. The pressure switches are located in the piping system. One is outside and the other is inside the enclosure. The nozzles are mounted on the air intake assembly. Figure 3-5 shows the CO<sub>2</sub> system components and their location on the GTGS.

Normally, the primary bank is activated by fire stop logic. You can also activate the primary bank manually at the bank or remotely from the pull box. When the two pressure switches are activated by CO<sub>2</sub> pressure in the header, a CO<sub>2</sub> release alarm is initiated locally and at the DCC. The summary alarm at the SWBD is also activated. Once started, CO<sub>2</sub> discharge cannot be stopped. The primary discharge occurs at the rate of 200 lb/min until the primary cylinders are exhausted.

The secondary system has three 50-pound CO<sub>2</sub> cylinders (one master and two slave) and two high-volume, low-velocity nozzles. These are connected by a common piping system. The secondary bank

must be released manually at the bank. The secondary system is not equipped with monitors or alarms. Once released, CO<sub>2</sub> discharge cannot be stopped. The secondary discharge is at the rate of 67 lb/min.

## SEAWATER SERVICE SYSTEM

Each GTGS has an independent seawater service system for the lube oil coolers and generator air cooler. Power for the pumps is taken from the generator side of the main circuit breaker. Thus, the electric pumps start automatically as the generator's voltage exceeds excitation voltage. Figure 3-8 is a flow diagram of this service system. A solenoid-operated pilot valve automatically opens the diaphragm-actuated, hydraulically operated stop valve when LP contacts close in the pressure switch in the normal service line. Cooling water is drawn from the sea chest. It flows through a strainer and then the generator air cooler and lube oil cooler. It passes through the reduction gear/engine lube oil cooler. The seawater flow requirements are different for

the three coolers. Therefore, each unit has a bypass valve to adjust the amount of seawater flowing through the cooler. This amount is based on the temperature of the oil or air being cooled.

If the electric pump system fails, emergency cooling water is supplied by the ship's seawater service system. This is accomplished by activation of the pressure switch that senses pump discharge pressure. If the GTGS is running and pump discharge pressure drops below the pressure switch set point, the solenoid-operated pilot valve will energize, opening the diaphragm-actuated stop valve and circulating the emergency seawater supply through the coolers. Seawater is discharged overboard through an emergency stop valve.

## GTE ASSEMBLY

The Allison 501-K17 is a single-shaft, axial-flow GTE. It has a 14-stage axial-flow compressor, a can-annular combustor, and a 4-stage axial-flow turbine directly coupled to the

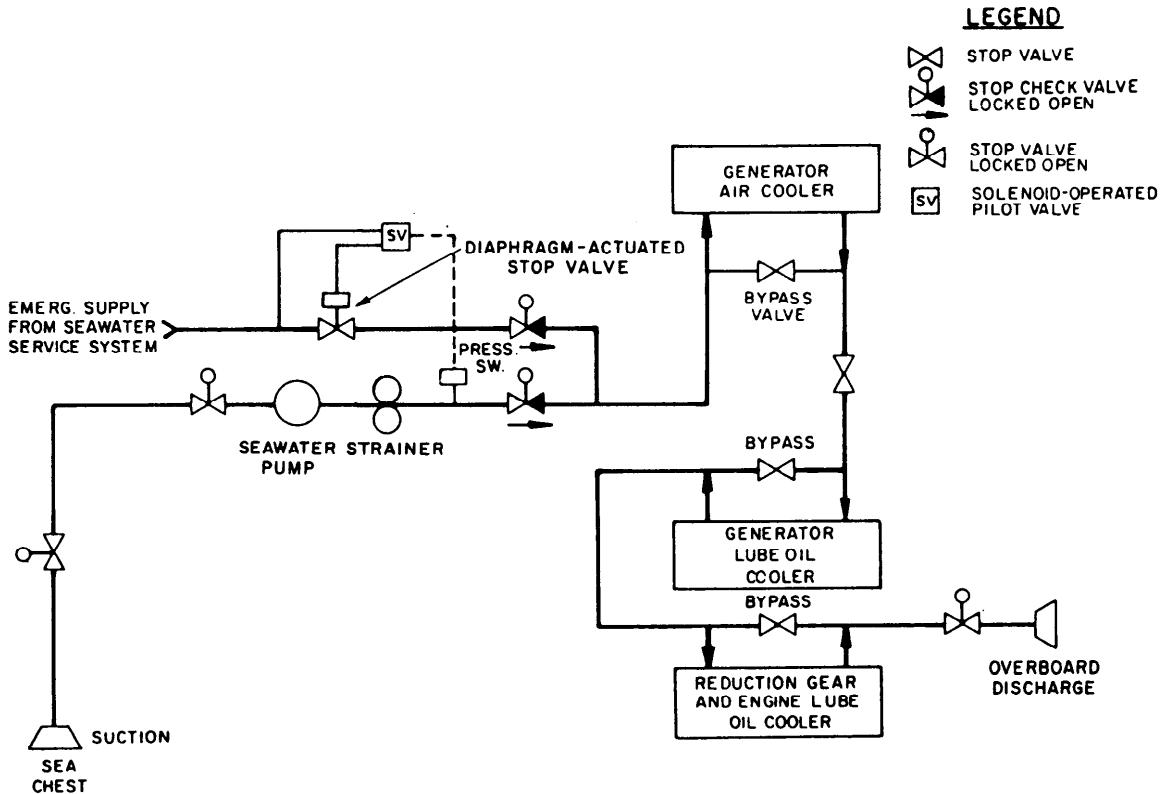


Figure 3-8.—Generator seawater service system.

compressor (fig. 3-9). The GTE drives the generator through a reduction gear. The reduction gear is mounted in front of the GTE. It is connected to the compressor front shaft by a power take-off (PTO) shaft assembly. The GTE is mounted on a suspension system at its approximate center of gravity. It is adjusted so minimum stress is placed on the bolted flanges of the PTO housing. Engine to reduction gear misalignment is, therefore, minimized when movement occurs because of shock or thermal growth changes. The direction of rotation of the engine is counterclockwise when viewed from the exhaust end.

In this section we will describe the Allison 501-K17 air intake system; the compressor, combustor, and turbine section; and the accessory drive section.

## AIR INTAKE

The air intake has a one-piece cast aluminum inlet housing. This forms the airflow path to the compressor. Figure 3-10 shows the air inlet housing, the compressor IGV assembly, and the compressor front frame assembly. The housing has an outer case, a center hub, and eight struts connecting the hub to the outer case. The hub contains the compressor front bearing. This supports the forward end of the compressor rotor, the bearing labyrinth seal, and the bevel gears. The bottom strut contains the radial drive shaft. The shaft transfers power from the compressor rotor to the AGB, which is used to drive the accessories. The outer case has a pad on the bottom that provides the mounting for the AGB. The turbine breather is mounted on the top. The

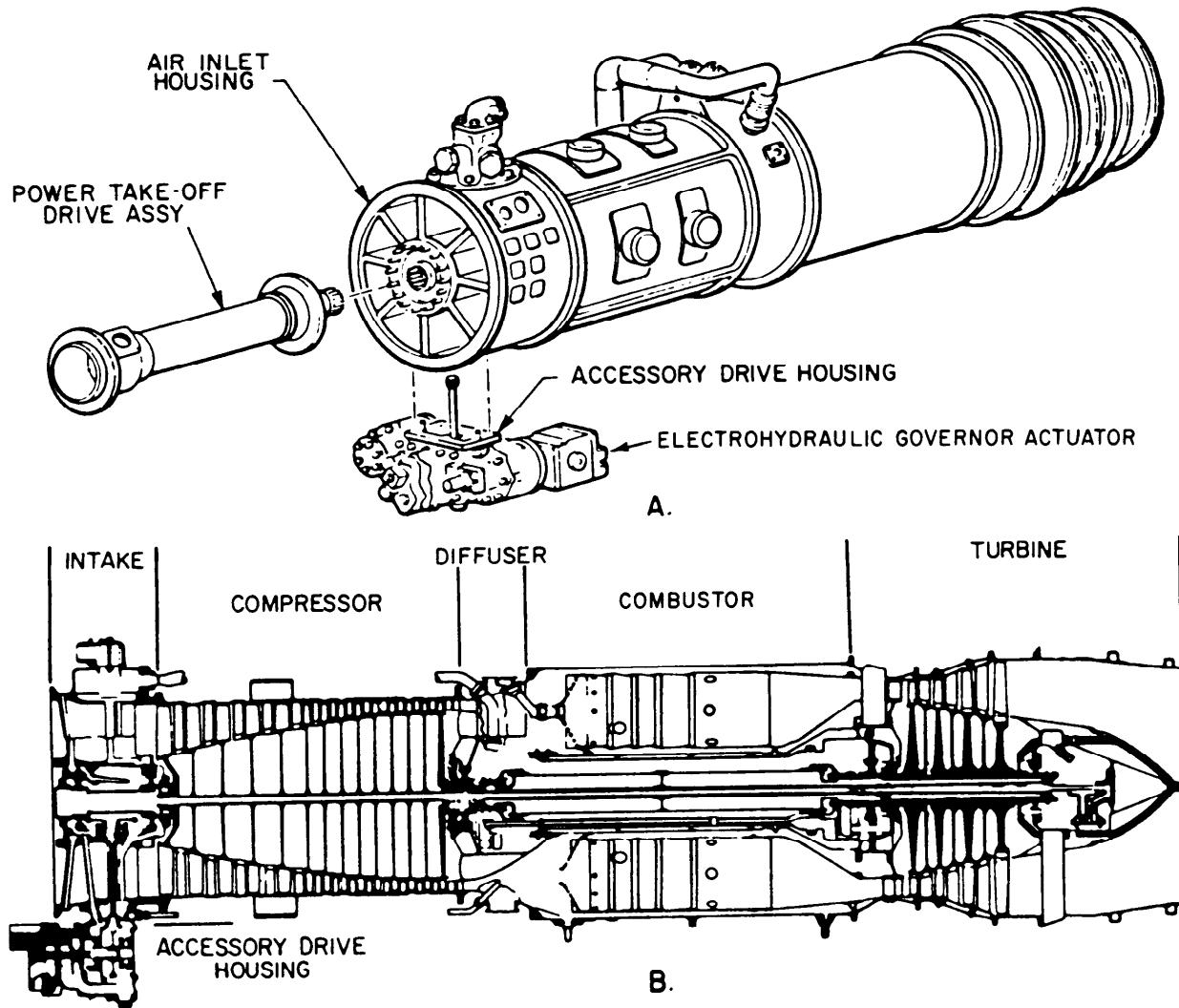


Figure 3-9.—Allison 501-K17 GTE. A. Overall view. B. Cutaway view.

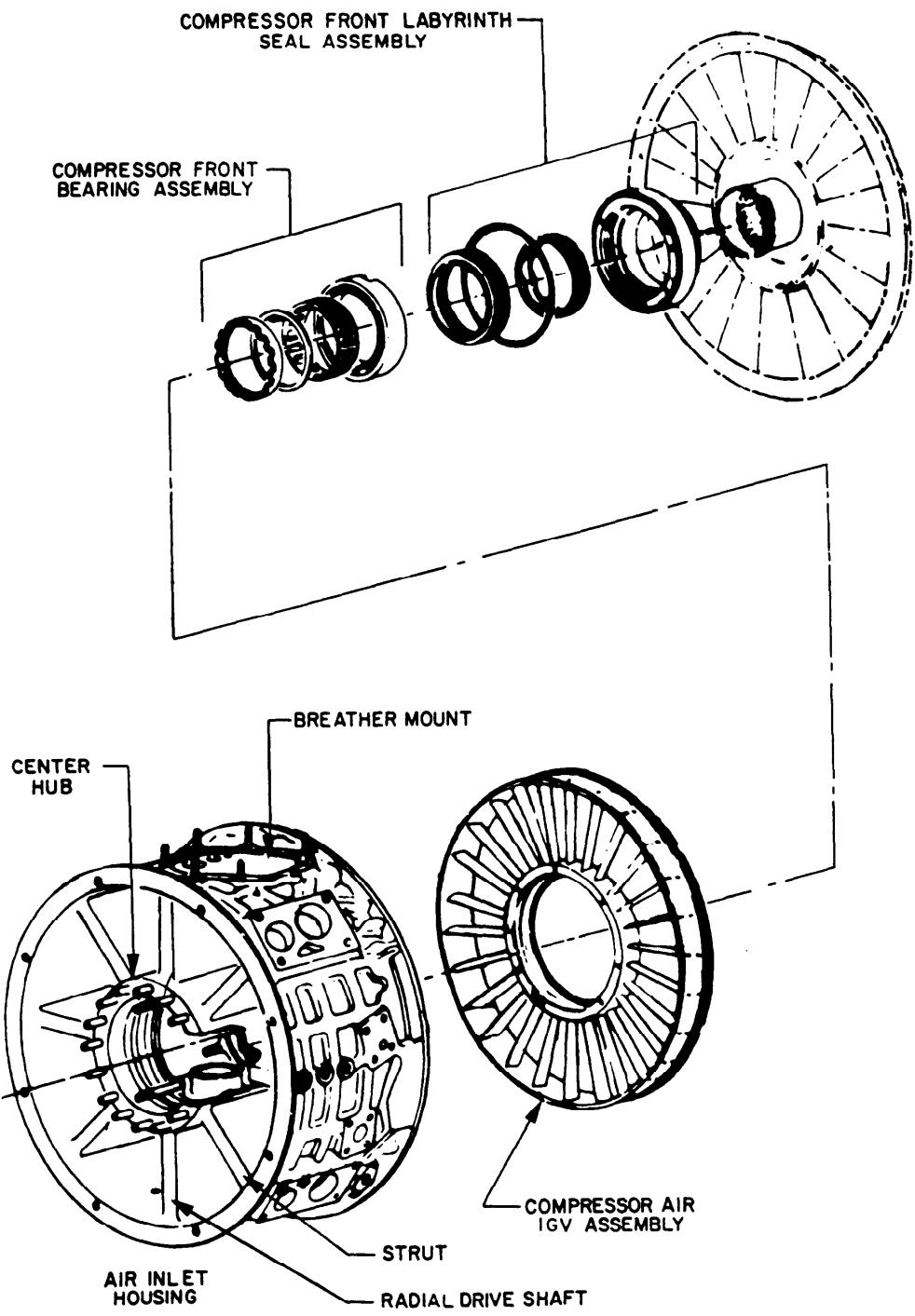


Figure 3-10.—Air inlet housing, IGV assembly, and compressor front frame assembly.

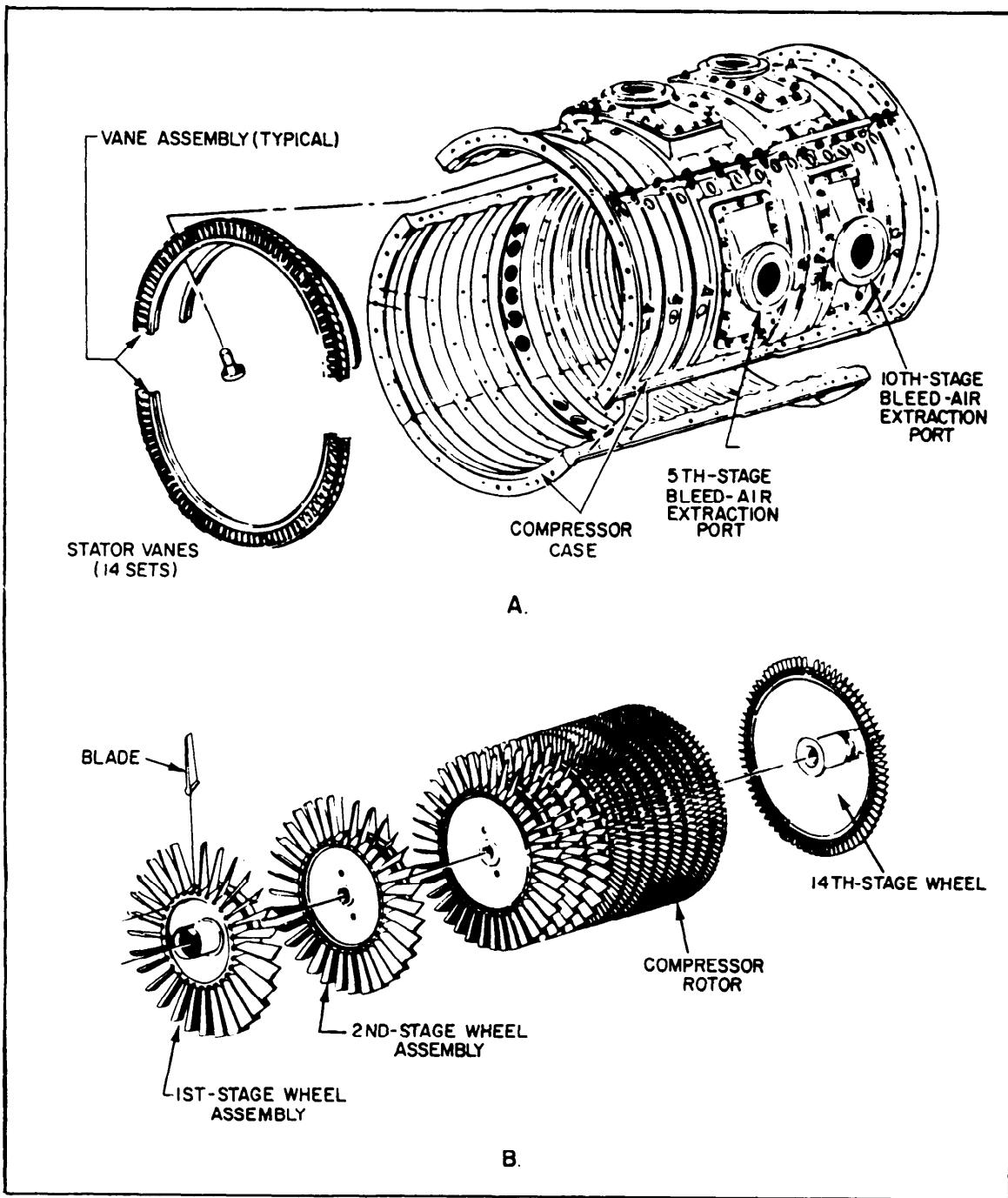


Figure 3-11.—Allison 501-K17 compressor. A. Stator. B. Rotor.

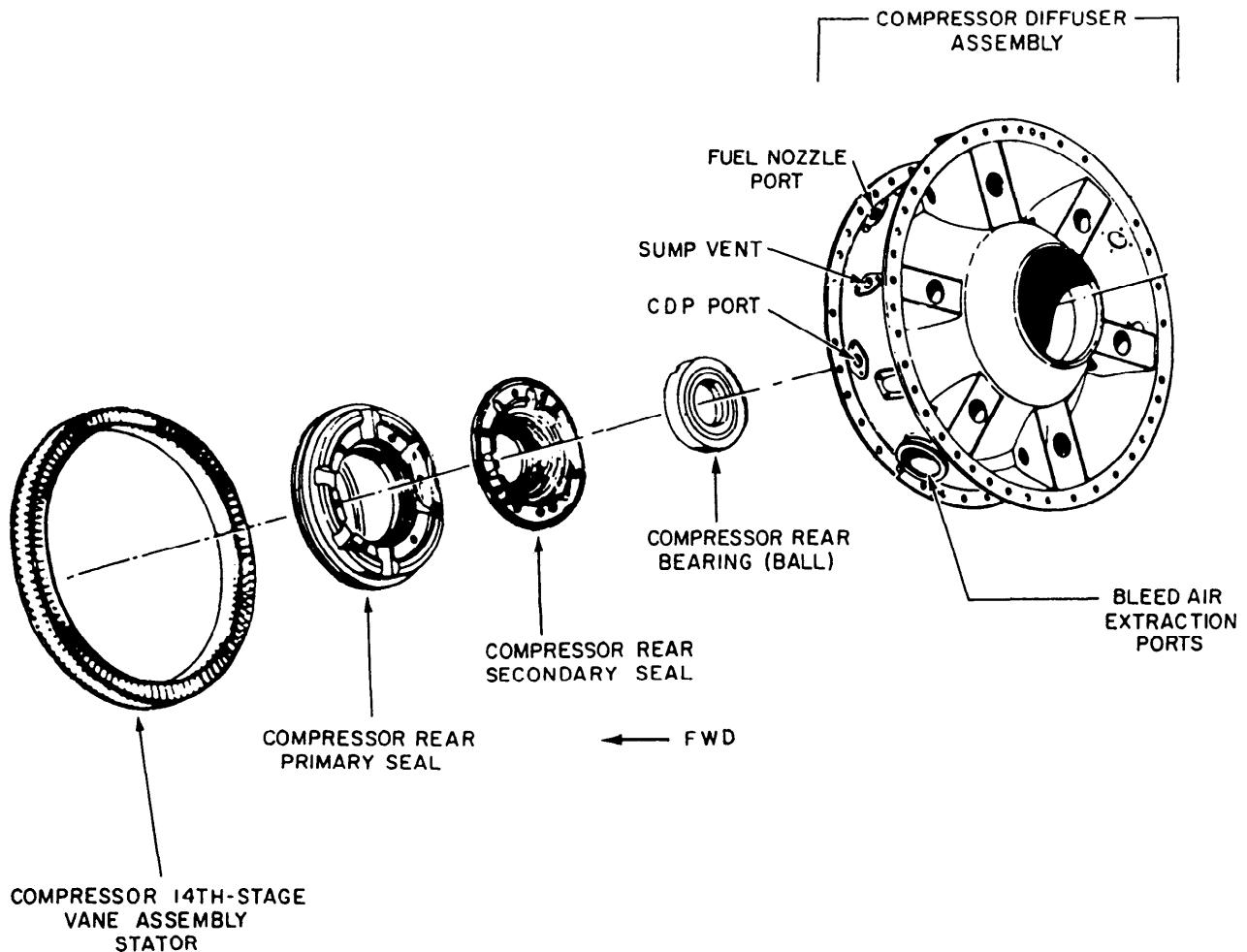


Figure 3-12.—Allison 501-K17 diffuser and 14th-stage stator vane assembly.

housing also has passages for directing anti-icing air to the strut leading edges and the IGV assembly. This assembly is located in the after side of the inlet housing. However, in this application, engine anti-icing is no longer used.

### COMPRESSOR SECTION

The compressor section has a compressor stator (fig. 3-11, view A), a compressor rotor (fig. 3-11, view B), and a diffuser (fig. 3-12). The air inlet housing described in the preceding paragraph is also part of the compressor section. The compressor case is made up of four sections bolted together along horizontal split lines. The case contains the 14 stages of stator vanes and the exit

guide vanes. The rotor is made up of 14 individual wheels. The wheels contain the 14 stages of blades and are pressed and bolted together as one assembly.

The diffuser is of welded steel construction. It is used to slow the compressor discharge air before entering the combustor. The diffuser supports the compressor rear bearing/thrust bearing, the compressor seal (two-stage) stationary members, and six fuel nozzles. It provides three bleed air extraction ports to which a manifold is attached. This allows bleed air extraction (up to 10 percent of total engine airflow) to the ship's bleed air system. Bleed air is also extracted for use in keeping the 5th- and 10th-stage bleed valves closed during normal operation.

## COMBUSTION SECTION

The combustion section has six individual combustion chambers (burner cans) (fig. 3-13). They are equally spaced in an annulus formed by a one-piece outer casing and a two-piece inner casing. Six crossover tubes connect the burner cans. These provide flame dispersal during starting. The burner cans are held by the fuel nozzles, spark igniters (two chambers), and liner supports (four chambers). The burner cans are of welded construction.

The outer casing encloses the burner cans and provides the supporting structure between the diffuser and turbine. The casing has two drain valves to drain unburned fuel after shutdown or after a false start. They may be called either burner drain valves (model 104) or combustor drain valves (model 139). These valves open when combustion pressure drops below 1 to 5 psig. They close above 2 to 5 psig on increasing pressure.

The two-piece inner casing has an inner casing and inner casing liner. These are separated by an air space and bolted together at the front. The inner casing liner has a bellows to take up thermal expansion and contraction. It is bolted to the

turbine inlet casing at the rear. The aft end of the inner casing is bolted to the turbine inlet casing. The front end is supported by a sleeve in the diffuser.

About 25 percent of the compressor discharge air entering the combustion section passes to the burner cans. Combustion takes place in the six combustion liners. Air initially enters the liners through vanes at the front of the liners that swirl the airflow. The swirling air mixes with the fuel sprayed into the liners by the fuel nozzles. The mixture is ignited during start by the spark igniters located in two of the liners (these are described later in this chapter). After a start, a steady flame is established by the constant addition of fuel and air.

Holes along the body of the liners allow cooling air to enter the liners. This air provides a buffer between the liner and the hot flames. Two reverse flow baffles ensure the liners direct air from some of the cooling air holes toward the front of each liner. This cools the forward portion of the liners and provides additional turbulence (for better combustion) of the fuel and air mixture. The hot gases produced in the liners exist through a transition section into the turbine.

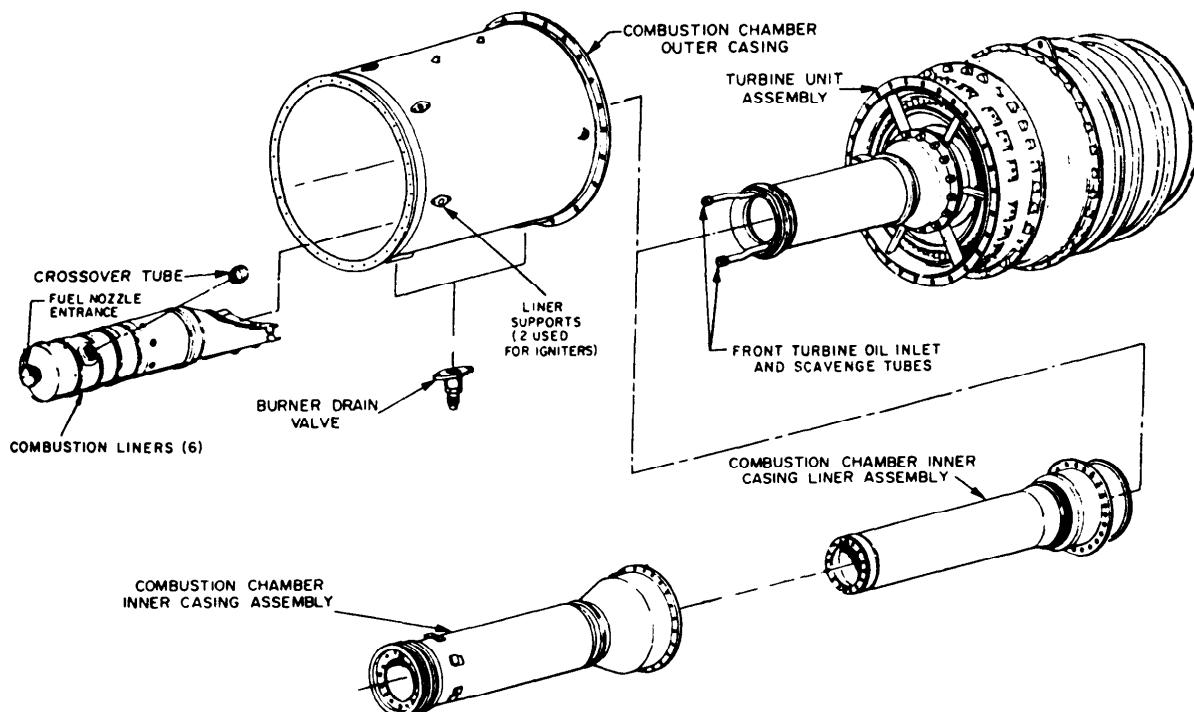


Figure 3-13.—Allision 501-K17 combustion section.

## TURBINE SECTION

The turbine section (fig. 3-14) has several parts: the turbine inlet casing and front bearing support, turbine rotor, turbine vanes (not shown) and rear labyrinth seals, turbine vane casing, turbine rear bearing support, and the turbine rear scavenge pump.

The turbine inlet casing and front bearing support house the first-stage vanes, the front turbine roller bearing, 18 turbine inlet temperature thermocouples, and the front labyrinth seal. The

front bearing support is bolted to the inlet housing.

The second-, third-, and fourth-stage vanes are mounted in the vane casing. The vane casing is a one-piece structure bolted between the aft flange of the inlet casing and the forward flange of the turbine rear bearing support.

The turbine rear bearing support contains the rear roller bearing. It also provides the sump for the rear bearing scavenge oil and mounting for the turbine rear scavenge oil pump.

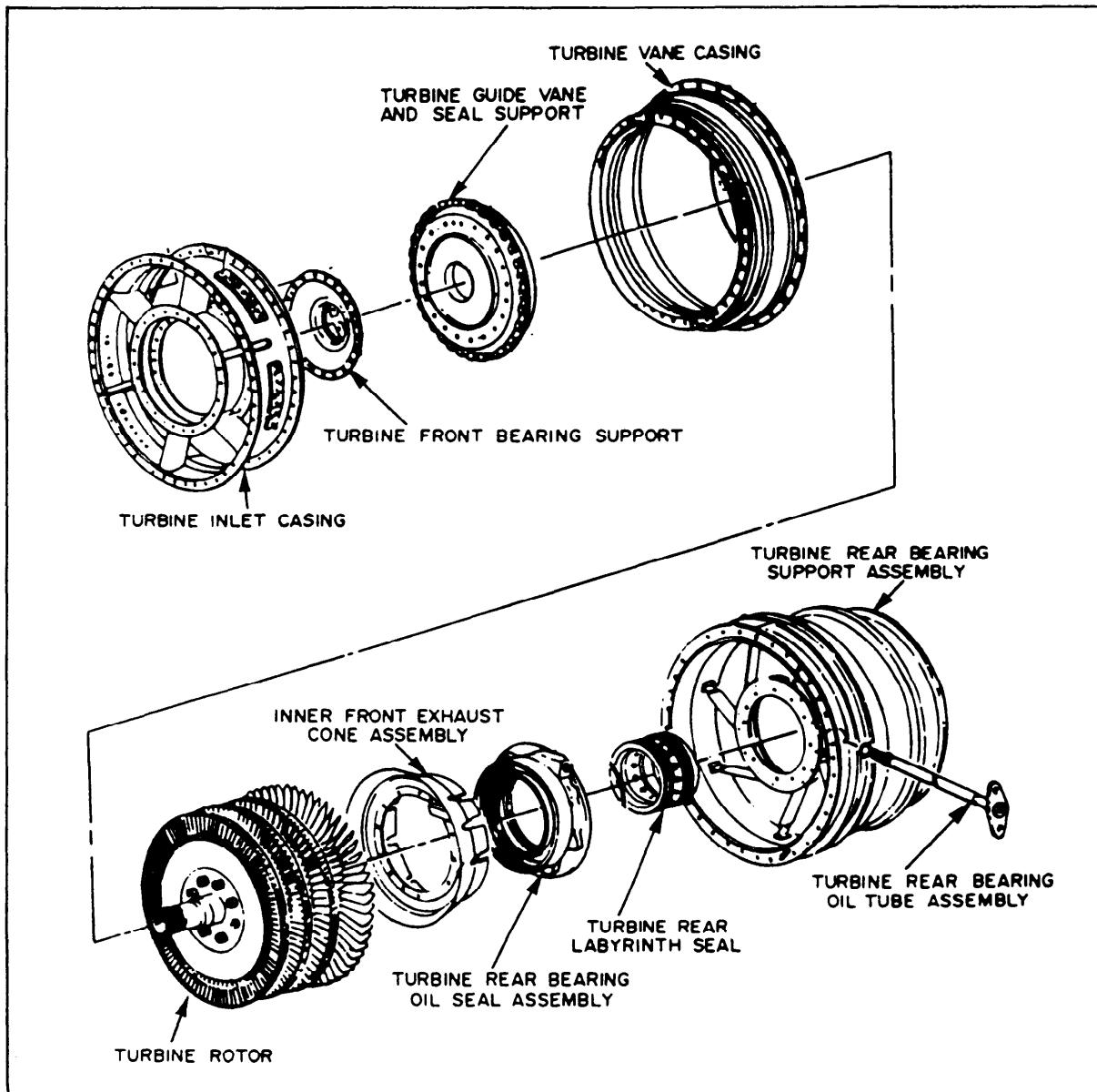


Figure 3-14.—Allison 501-K17 turbine section.

The turbine rotor has four wheels containing the turbine blades and is supported at each end by roller bearings. The turbine rotor extracts energy from the hot exhaust gas. It converts this energy into shaft horsepower to drive the compressor through a coupling shaft that runs through the combustion chamber inner casing liner assembly and the generator through the PTO shaft and reduction gear. This is different from the LM2500 GTE. It uses one turbine to drive its compressor and a separate turbine to drive its load.

## ACCESSORY DRIVE SECTION

The accessory drive housing (fig. 3-15) provides mounting pads on the front and rear faces. The pads on the rear face are for the fuel

pump, governor actuator, and external scavange oil pump. Pads on the front face are for the speed-sensitive valve, main oil pump, and oil filter (this requires no gearing). The components themselves are discussed later in this chapter. The accessory drive is driven by the compressor rotor extension shaft. This is accomplished by bevel gears that drive a radial drive shaft, located in the inlet housing. The radial drive shaft is splined into one bevel gear through the bottommost strut of the inlet housing. A pinion on the other end of the shaft drives the gears in the accessory drive housing.

## ENGINE SYSTEMS

As previously mentioned, the model 104 and the model 139 both use the same GTE. However,

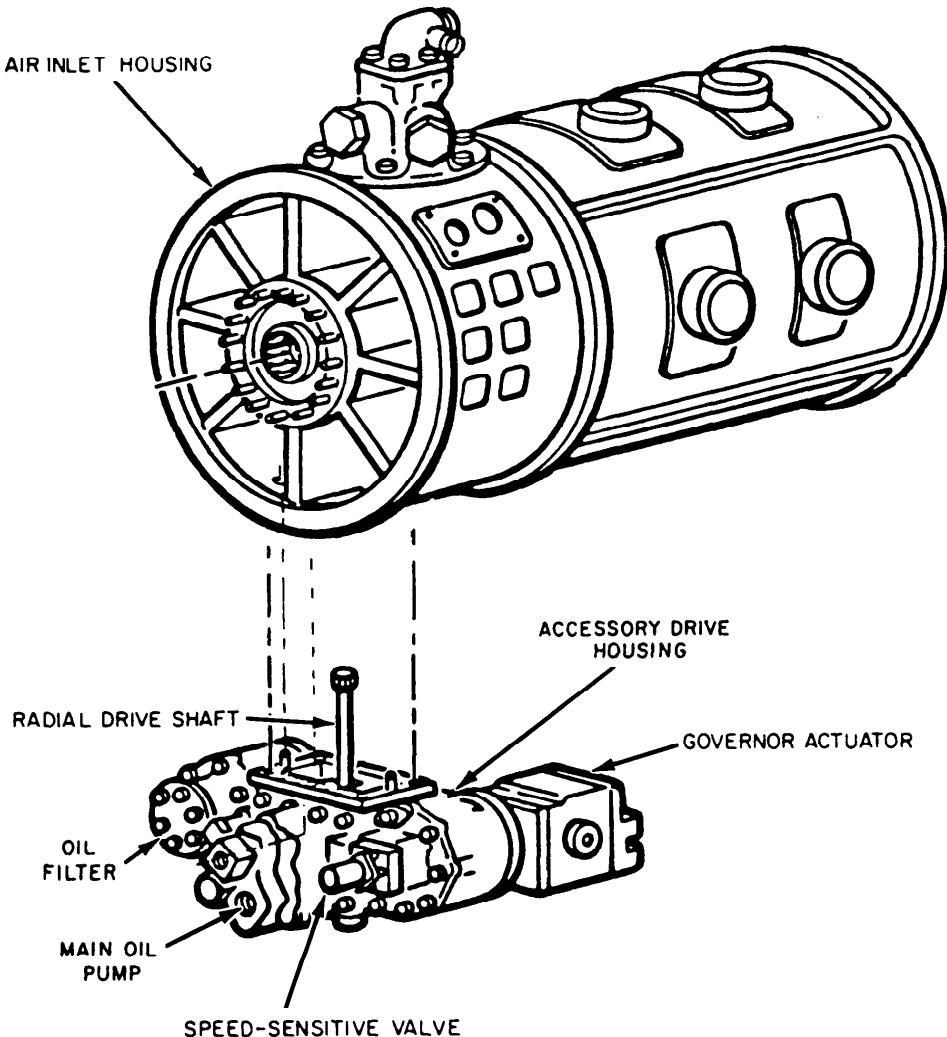


Figure 3-15.—Allison 501-K17 accessory drive housing.

some differences exist in the support systems of each model. In this section we will describe these systems and point out their differences. We will describe the ignition system, the bleed air system, the engine fuel system, the reduction gear/engine lube oil system, and the air start system.

## IGNITION SYSTEM

The ignition system is identical for the two types of GTGSs. The ignition system (fig. 3-16) has an ignition exciter, two high-tension leads, and two spark igniters. The system operates on + 28 volts dc. However, proper operation can be obtained over a range of + 14 to + 28 volts dc (for MOD 139, +22 to +28 Vdc). Power is supplied to the system through an electronic speed switch actuated relay. This energizes the system at 2200 rpm and de-energizes at 8400 rpm during the starting cycle.

### Ignition Exciter

The ignition exciter is a sealed unit mounted on the right side of the compressor. It is a high-voltage, capacitor-discharge type of exciter. It is capable of firing two spark igniters at the same time.

### Spark Igniters

The two spark igniters are mounted in the outer combustion case. One extends into the No. 2 can and the other into the No. 5 can. The igniters receive the electrical output from the ignition exciter. They discharge this electrical energy during starting to ignite the fuel-air mixture in the combustion cans. Two high-voltage leads connect the spark igniters to the ignition exciter.

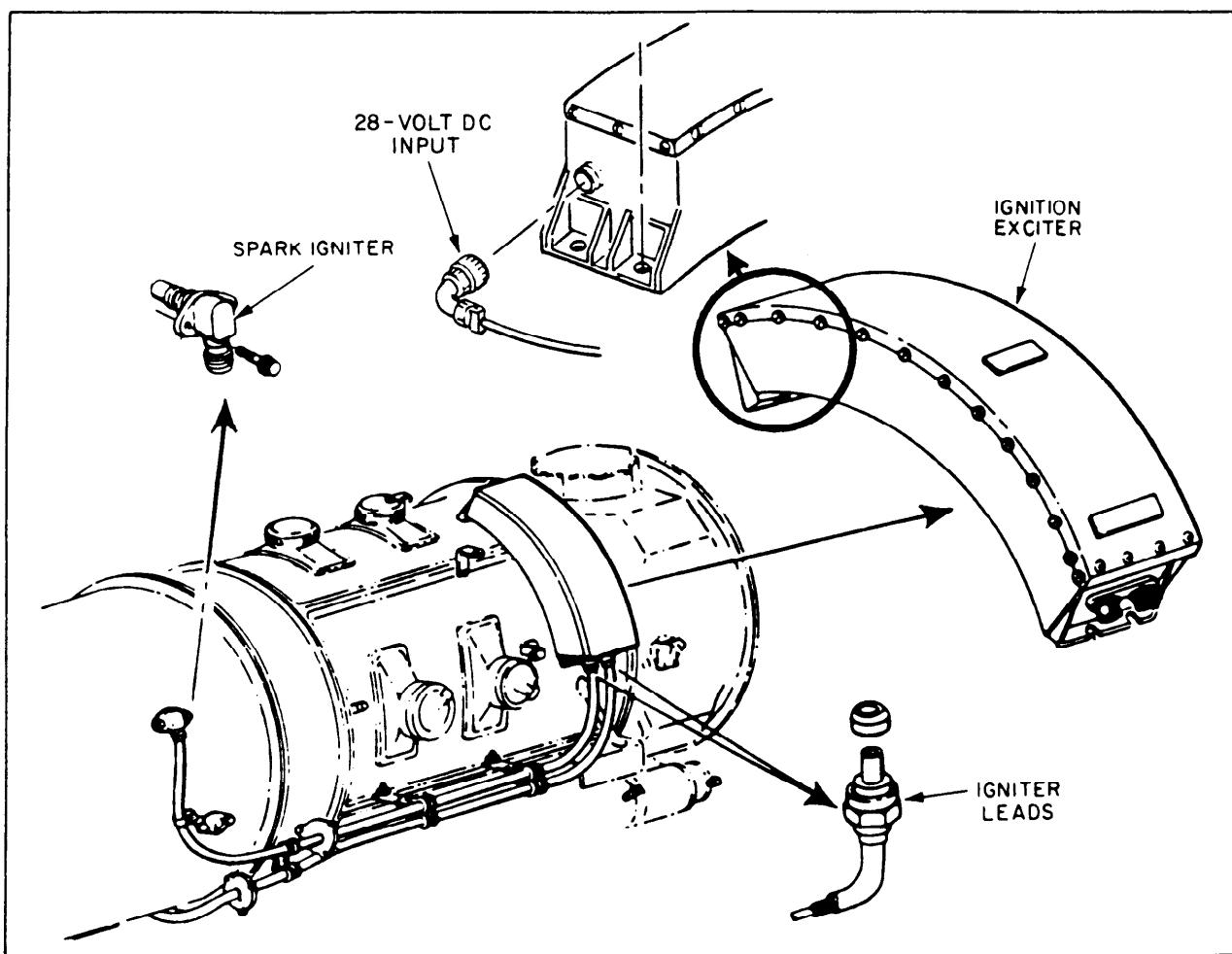


Figure 3-16.—Ignition system components.

## BLEED AIR SYSTEM

The bleed air system (fig. 3-17) on the model 104 and model 139 are nearly identical. The major difference is found in the 14th-stage bleed air valve. A fast-acting 14th-stage bleed air valve is used on the model 139. This allows the engine to respond quickly to transient load conditions brought about by failure of one of two GTGSs operated in parallel. This GTGS loss is partially compensated for by the quick closing (in about 150 to 200 milliseconds) of the 14th-stage bleed air valve on the surviving GTGS. The quick-closing feature is controlled by the externally mounted turbine overtemperature protection system (TOPS). This system is not covered in this chapter.

The bleed air system consists of two independent systems—the 14th-stage system and the 5th- and 10th-stage system. The 5th- and 10th-stage bleed air system unloads the compressor during starts. This reduces the possibility of compressor surge during the starting cycle. The 14th-stage bleed air system extracts air from the compressor for the ship's bleed air system. Airflow up to 2.37 lb/sec at 55 to 60 psig may be extracted. This is about 8 percent of compressor airflow.

### Fourteenth-Stage Bleed Air

Fourteenth-stage compressor discharge air is extracted from ports on the compressor diffuser. A manifold surrounds the diffuser to collect the discharge air. This air is piped through a bleed

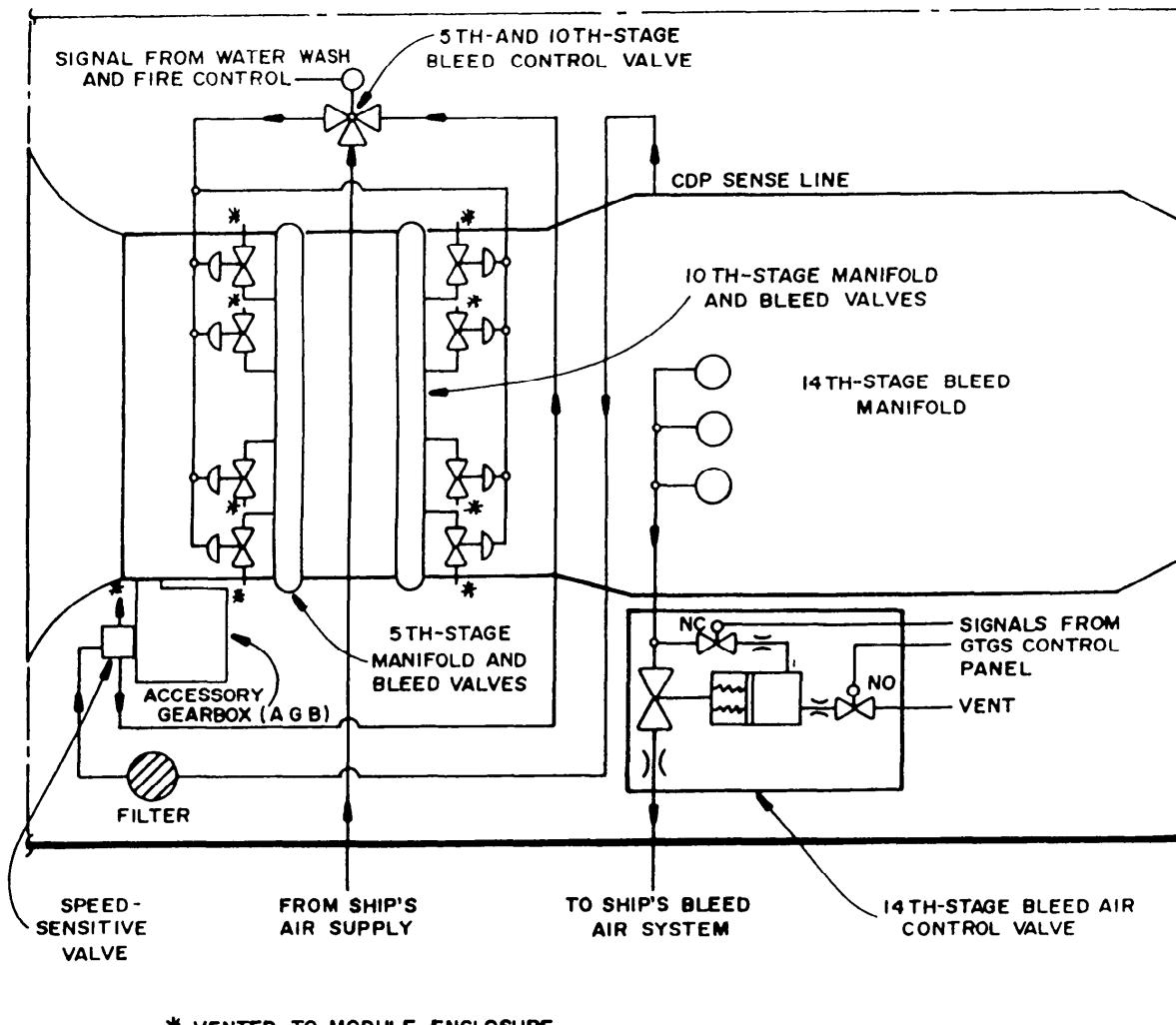


Figure 3-17.—Allison 501-K17 bleed air system.

air control valve and into the ship's bleed air system. The control valve receives signals from the LOCOP for operation. If the TIT reaches 1870°F, the bleed air control valve will close to maximize the amount of cooling air to the turbine and maintain the TIT in the range of 1850°F to 1870°F. A manual switch, 14TH-STAGE BLEED, is located on the LOCOP. It allows you to enable the bleed air control circuit. When this switch is in the ON position, the bleed valve will open at 12,780 rpm. It is then fully automatic with respect to TIT. The 14th-stage bleed air valve will also close when the engine speed drops below 12,780 rpm.

The model 139 LOCOP bleed air selector switch also has a remote position. When the switch is placed in remote, the control of the 14th-stage bleed air valve is transferred to a control panel in CCS.

### Fifth- and Tenth-Stage Bleed Air

This system has eight pneumatically operated bleed air valves, a speed-sensitive valve, a filter, and a three-way, solenoid-operated valve. Four bleed air valves are mounted on each of the 5th-stage and the 10th-stage bleed manifolds. These valves are piston-type valves, with 5th- and 10th-stage air pressure on the inboard side of the valve. Either atmospheric pressure or 14th-stage air pressure is routed to the outboard side.

The speed-sensitive valve is engine driven. It is mounted on the left forward side of the AGB. The valve has three ports. One port receives 14th-stage air via a pipe from the diffuser. A second port is piped to the outboard side of the 5th- and 10th-stage bleed air valves. The third port is vented to the atmosphere. During operation at engine speeds below 12,780 rpm, a pilot valve in the speed-sensitive valve blocks 14th-stage air. This allows the outboard side of the 5th- and 10th-stage bleed air valves to be vented to the atmosphere (through the third port on the speed-sensitive valve). Since 5th- and 10th-stage air pressure is greater than atmospheric pressure, the valves open and vent air from the compressor. At engine speeds above 12,780 rpm, the pilot valve closes the vent port. This allows 14th-stage air to be ported to the outboard side of the 5th- and 10th-stage bleed air valves. Since 14th-stage air pressure is greater than 5th- and 10th-stage air pressure, the valves close and bleed air is stopped.

The filter is located in the 14th-stage air line from the diffuser to the speed-sensitive valve. It prevents contaminants in the air from clogging the valve.

The solenoid valve is located in the line between the speed-sensitive valve and the bleed air valves. When activated, it routes ship's service air to hold the 5th- and 10th-stage bleed air valves closed. It is used during a fire stop or while the engine is water washed.

## ENGINE FUEL SYSTEM

The fuel system meters and distributes fuel to the engine. This system is used to maintain a constant generator rotor speed under varying load conditions. Components of the fuel system are both engine mounted and off-engine mounted.

The engine-mounted components on the model 104 GTGS (fig. 3-18) include the following parts: a dual-element fuel pump (1), an LP fuel filter (2), an HP fuel filter (3), a pressure relief valve (4), a liquid fuel valve (LFV) (5), an electrohydraulic (electric) governor (EG) actuator (6), a fuel shutoff valve (7), a manifold drain valve (8), fuel nozzles (9), and burner/combustor drain valves (10).

Off-engine mounted components of the model 104 are a temperature-biased compressor inlet temperature (CIT)/compressor discharge pressure (CDP) sensor (11), the governor control unit (GCU) (not shown), and a start temperature limit control valve (12). The model 104 uses the Woodward 2301 governor control system.

The model 139 fuel system (fig. 3-19) is slightly different from the model 104 fuel system. Both models incorporate an engine-mounted fuel divider (1), two manifold drain valves (one manifold drain valve on the model 104) (2), dual-entry fuel nozzles (3), and two fuel manifolds (4). Refer to your ship's technical manuals for the system used on your ship.

The governor system on the model 139 is the Woodward 9900-302 governor control system. For this adaption the engine is fitted with an electrical CIT sensor, mounted in the air inlet housing, a magnetic speed pickup, and a LFV-mounted linear variable displacement transformer (LVDT) (5).

### Model 104 Fuel System Flow Path

The following paragraph describes the fuel flow path through the fuel system of the model 104. Refer to figure 3-18 as we describe the operation.

Fuel from a gravity feed tank enters the enclosure through an external emergency shutoff valve and flows into the inlet of the fuel pump.

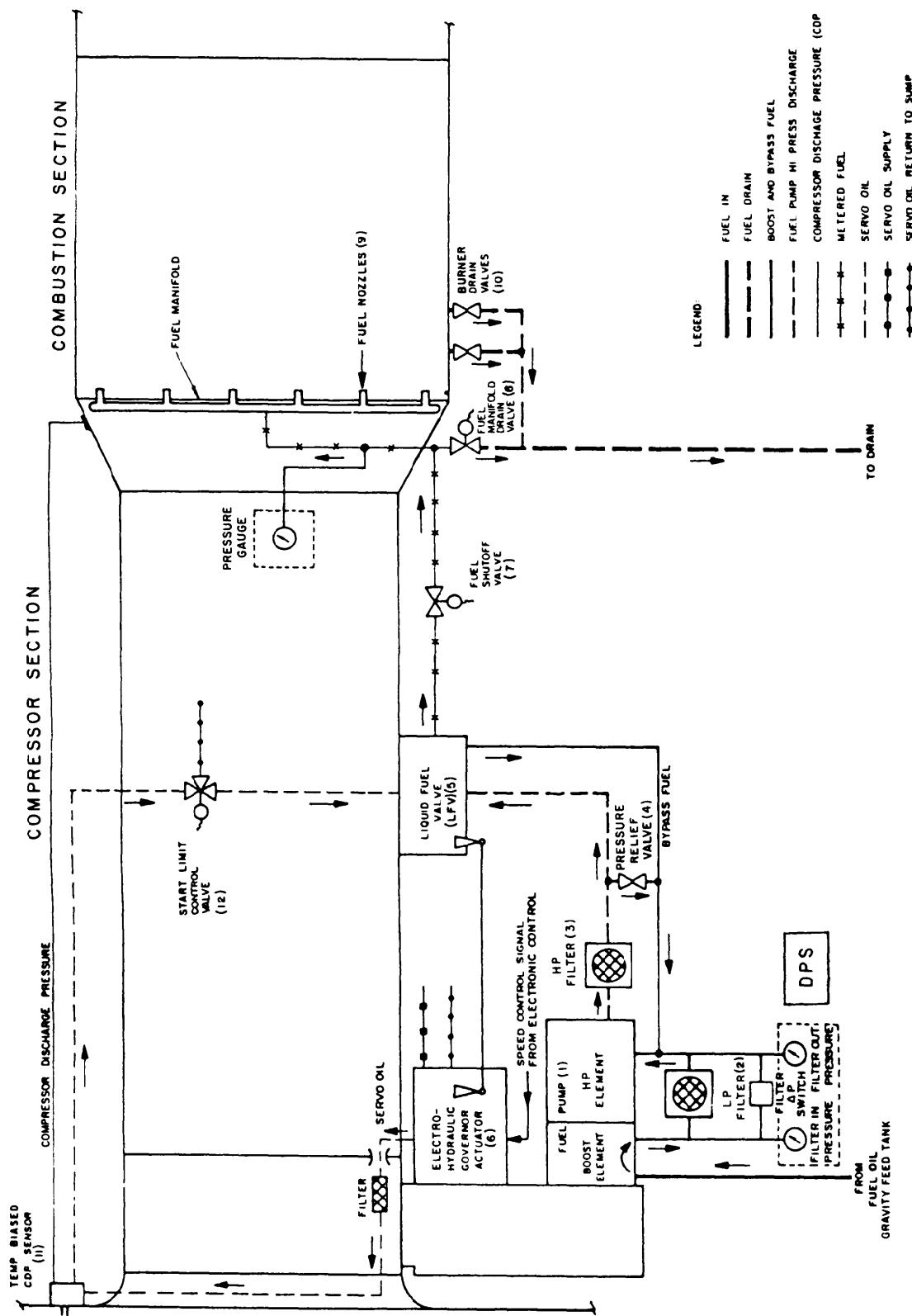


Figure 3-18.—Model 104 fuel system flow diagram.

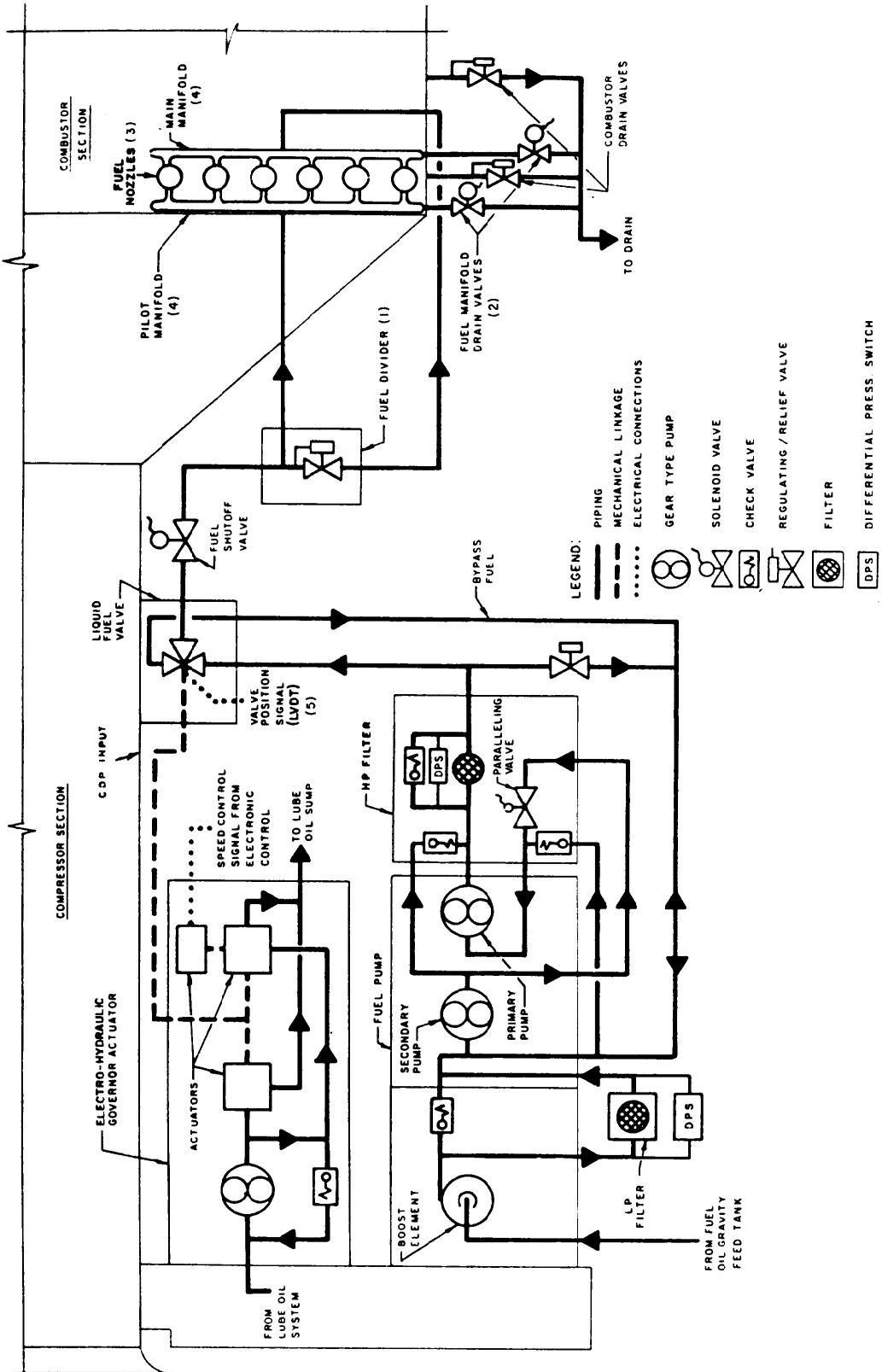


Figure 3-19.—Model 139 fuel system flow diagram.

It passes through the pump boost element, through the LP filter, and into the HP elements. From the pump's HP elements, the fuel passes through the HP filter and into the LFV. Metered fuel from the LFV passes through the fuel shutoff valve. It then flows through the flow divider and into the fuel manifolds and fuel nozzles. It is discharged into the combustion chambers by the fuel nozzles. The fuel pump delivers more fuel than is required. So the LFV bypasses the excess fuel back to the inlet side of the pump's HP elements.

### Model 139 Fuel System Flow Path

Fuel system operation of the model 139 is similar to the model 104 (refer to fig. 3-19). After the fuel shutoff valve, the fuel goes to the fuel divider. Some of the fuel goes directly to the pilot manifold. At 150 psig, fuel is also diverted to the main fuel manifold. Two manifold drain valves are also used to drain both manifolds at shutdown. Remember, some model 104 units have been modified to use this flow divider and dual-entry fuel nozzles.

### Fuel Pump

To help you understand the following discussion of the various fuel system components,

refer to figure 3-20 and the flow diagrams of the model 104 and model 139 fuel systems. The fuel pump is an engine-driven, dual-element pump. It is mounted on the aft right side of the AGB. The boost element has an impeller-type centrifugal pump and bypass valve. The HP element has a dual-element (primary and secondary) gear-type pump.

In operation, fuel enters the boost pump and then flows externally through the LP filter. It then returns to the HP elements through passages in the HP filter assembly. (It is not actually going through the filter element at this point.) The bypass valve (not shown) opens only if the boost pump fails. This allows fuel to flow directly to the HP filters through the LP filter. Fuel normally flows in series through the primary and secondary elements of the two HP elements. However, the two HP elements are placed in parallel from about 2200 to 8400 rpm by a solenoid-operated paralleling valve. The valve is located in the fuel pump assembly. From the HP element of the pump, fuel flows through internal passages to the HP filter.

### Low-Pressure Filter

The LP filter is a paper cartridge type. It is located in the fuel line between the boost pump

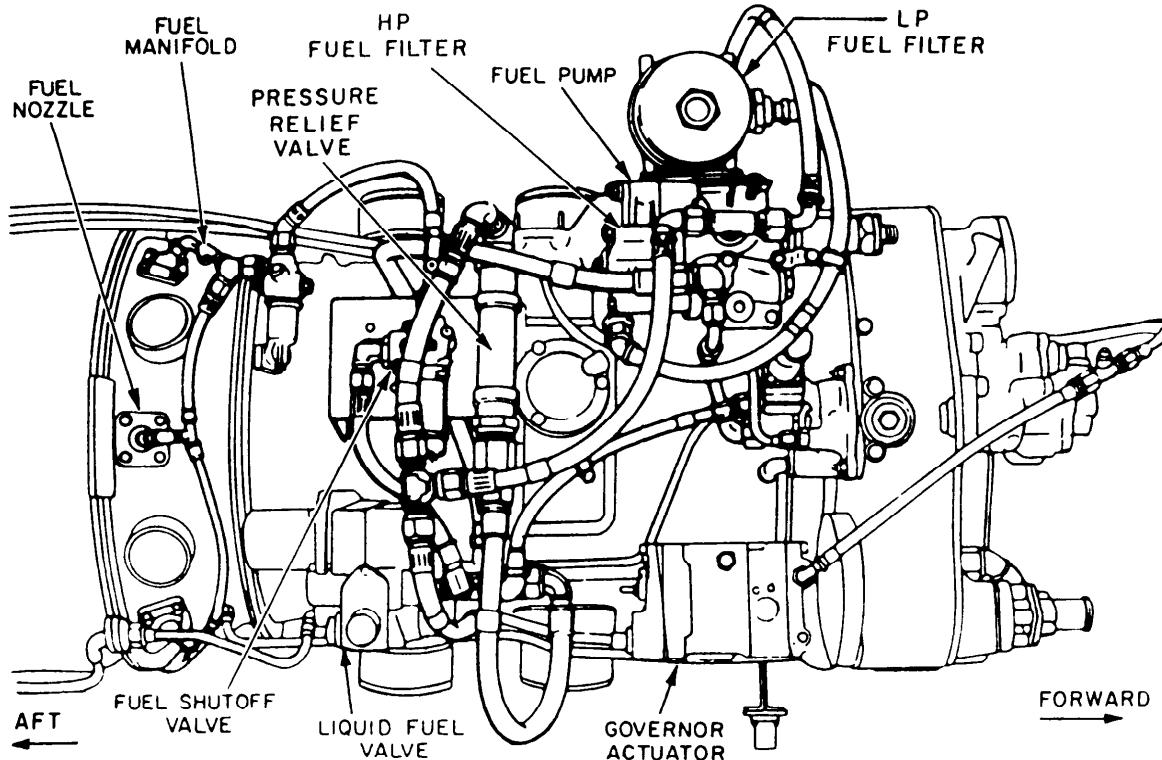


Figure 3-20.—Fuel system components-bottom view of engine.

outlet and the HP element inlet. Relief valves are incorporated in the filter head to bypass the fuel if the filter becomes clogged. The LP filter inlet and outlet pressures are shown on the engine gauge panel.

### High-Pressure Filter

The HP filter assembly is mounted on the bottom of the fuel pump. It has a filter, bypass valve, two check valves, and a solenoid-operated paralleling valve. The filter is a 33-micron disk type. It is removable for servicing. The bypass valve opens to permit continuous flow if the filter becomes clogged. If one HP gear element fails, the check valves permit engine operation from the other element.

### Pressure Relief Valve

The pressure relief valve is closed during normal engine operation. If the pump discharge pressure reaches  $500 \pm 10$  psig above the bypass line pressure, the relief valve opens. This permits excess fuel to return to the pump inlet.

### Model 104 Liquid Fuel Valve

The LFV is mounted on the left, lower side of the engine. It is mechanically and hydraulically connected to the EG actuator. The hydraulic connection is through the CIT/CDP sensor and the start temperature limit control valve. The LFV has a metering valve, an acceleration limiter, and a bypass valve. It meters the required fuel for all engine operating conditions. The EG actuator linkage and the acceleration limiter (internal part of the fuel valve) control the metering valve position. This, in turn, allows control of the fuel flow.

The acceleration limiter schedules fuel flow during start as a function of CIT and CDP. During start and rapid acceleration, the limiter overrides the governor input. This prevents compressor surge (stall) and excessive TIT. The limiter linkage (internal) is actuated by servo oil pressure from the EG actuator. This is regulated by the CIT/CDP sensor.

To accurately meter fuel flow, you have to maintain a constant pressure drop across the metering valve. This is done when the bypass valve opens and returns excess fuel from the pump outlet to the pump inlet.

### Model 139 Liquid Fuel Valve

Like the model 104, the model 139 LFV is mounted on the left side of the engine. It is mechanically connected to the EG actuator. It has a fuel metering valve and a fuel valve position

sensor. It meters the required fuel for all engine operating conditions.

The LFV is directly controlled by the governor actuator. During start and running of the engine, the LFV is positioned by the governor to limit the amount of fuel to the fuel nozzles. The governor control circuit receives inputs of engine speed, CIT, fuel valve position, and TIT. The CDP pressure is provided to the LFV directly. The control circuit sets the LFV through the governor actuator. This provides the proper amount of fuel to the engine for all engine power and acceleration settings.

The fuel valve position sensor is an LVDT. It is mechanically linked to the LFV metering sleeve and senses fuel valve position. The linkage moves the sleeve to the actuator. As it does this, the amount of excitation voltage at the LVDT output is changed. The output of the LVDT is proportional to the position of the fuel metering sleeve. A comparator compares inputs from the electronic control unit (ECU) and the LVDT. This is done to correctly position the fuel valve.

Excess fuel from the pump is returned to the secondary pump suction by the bypass valve. Like the model 104 LFV, this is done to maintain constant pressure at the metering valve.

### Electrohydraulic Governor Actuator

The EG actuator is engine driven. It is mounted on the left side of the AGB. Its output shaft is mechanically linked to the LFV. It receives signals from the EG control box and positions the LFV. The LFV, in turn, meters fuel to the engine. The governor actuator incorporates normal control by the EG system and backup control by a centrifugal governor. Each is independently able to position the output shaft to maintain engine speed.

An integral oil pump provides servo oil pressure for governor operation as well as other functions. Engine lube oil pressure from the AGB is supplied to the actuator pump through an external line. During normal operation, an output signal from the EG control box produces a force on an armature magnet. The magnet is attached to a pilot valve plunger and moves the plunger up or down. The pilot valve plunger directs servo oil pressure to change the position of the output shaft. If the electrical signal to the governor actuator is interrupted, it may attempt to overspeed the engine. If this happens, the pilot valve plunger and terminal shaft will be positioned toward the maximum fuel flow position. When the engine speed exceeds a preset limit (about 14,300 rpm), the centrifugal governor will assume

control of the engine. Flyweights, opposed by spring force, position the pilot valve plunger as a function of engine speed. The pilot valve plunger directs servo oil pressure to position the output shaft. The centrifugal governor is set to regulate engine speed at 480 to 580 engine rpm above the normal EG operating speed. It has been factory adjusted between 14,300 to 14,400 rpm. This equals between 62 and 62.5 Hz generator output.

#### **Compressor Inlet Temperature/ Compressor Discharge Pressure Sensor**

The CIT/CDP sensor (fig. 3-18, item 11) senses both CIT and CDP. It regulates servo oil from the EG to the acceleration limiter in the LFV in relation to CIT and CDP. The acceleration limiter, in turn, schedules fuel flow as a function of servo oil pressure. During the start cycle (above 2200 rpm) and during rapid accelerations, the acceleration limiter overrides the input from the EG. This limits the maximum fuel flow and prevents compressor stall and/or excessive TIT. Below 2200 rpm, the regulated oil pressure from the CIT/CDP sensor is blocked by the start temperature limit control valve. This assures the turbine starts on the minimum fuel flow at lightoff. The CIT/CDP sensor is mounted on the inlet air plenum. The temperature sensing element protrudes into the inlet airstream.

#### **Fuel Shutoff Valve**

The fuel shutoff valve is a normally closed, solenoid-operated valve. It is located in the line between the LFV and the fuel manifold. All fuel to the fuel nozzles must pass through this valve. During the start cycle, the valve is opened (energized) by the electronic speed switch circuit at 2200 rpm. The valve is closed (de-energized) by the control circuits to shut down the engine.

#### **Models 104 and 139 Flow Divider, Fuel Manifold, and Fuel Nozzles**

Fuel flow from the fuel shutoff valve is directed to the manifolds by a flow divider. The divider has an internal pressure-actuated valve. During start-up, the flow divider allows fuel to be supplied to only the pilot manifold. When fuel pressure reaches about 150 psig, the valve opens. This allows fuel to be supplied to the main manifold.

Two fuel manifolds, pilot and main, supply fuel to the six fuel nozzles. Both manifolds are Teflon-lined hoses with braided steel armor. Each manifold is fitted with a solenoid-operated drain valve at its low point. The pilot manifold receives fuel from the flow divider during start-up and

normal operation. It distributes the fuel to the pilot connection on each of the nozzles. After fuel pressure to the flow divider reaches about 150 psig, fuel is supplied to the main connection of each fuel nozzle. The six nozzles are positioned to extend into their respective combustion liners. Fuel from the pilot manifold flows through the center hole in the tip of each nozzle. This forms a spray pattern in the combustion liner. Main manifold fuel is supplied to the holes in the periphery of the nozzle tip. From there it is sprayed into the combustion liner and mixed with compressor air for combustion.

#### **Fuel Manifold Drain Valve**

The fuel manifold drain valves are spring-loaded, normally closed, solenoid-operated valves located at the bottom of the manifold (figs. 3-18 and 3-19). They drain fuel from the manifolds to the waste oil drain tank during coastdown. The valves are open (energized) only during the 2-minute period determined by the coastdown timer. On the model 139 these valves are also open any time the engine is below 2200 rpm.

#### **Start Limit Control Valve**

The start limit control valve is a normally open, three-way, solenoid-operated valve. It is located in the regulated servo oil supply line between the CIT/CDP sensor and the LFV (fig. 3-18, item 12). Below 2200 rpm in the start cycle, the valve is energized. This blocks the regulated oil supply and ports the oil from the acceleration limiter (part of the liquid fuel valve) to drain. This causes the fuel valve to remain against the minimum fuel flow stop until the engine reaches 2200 rpm. Between 2,200 and 12,780 rpm, the valve is normally de-energized (open). However, if TIT exceeds 1500°F, the valve is intermittently energized/de-energized until temperature drops below 1500°F. Above 12,780 rpm, the valve is electrically locked out of the system (de-energized).

#### **LUBE OIL SYSTEM**

The lube oil systems on the model 104 and model 139 are almost identical. The engine receives synthetic lube oil (MIL-L-23699) from the GTGS reduction gear lube oil system.

The engine and reduction gear lube systems share a common supply tank, filter, and cooler. The supply tank is the reduction gear sump, while the filter is base mounted inside the reduction gear section of the enclosure. The oil cooler is mounted remotely under the module. Please follow figure 3-21 to help you understand

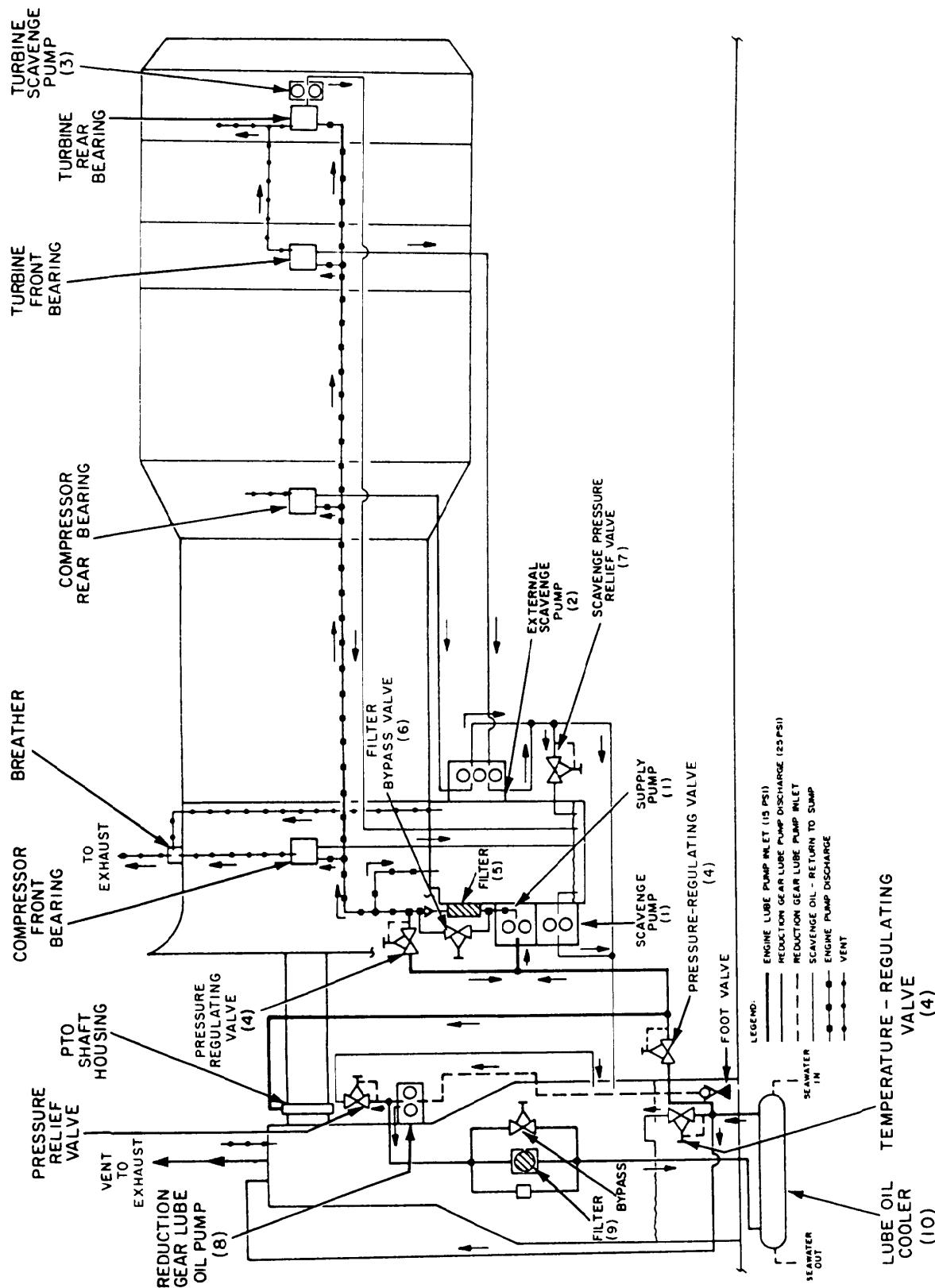


Figure 3-21.—GTGS synthetic lube oil system flow diagram.

the following discussion on oil flow through the system.

The engine lube oil system is an LP, dry sump system. It consists of a combination lube supply and scavenge pump (1), an external scavenge pump (2), a turbine scavenge pump (3), pressure-regulating valves (4), an oil filter and check valve (5), a filter bypass valve (6), and a scavenge pressure relief valve (7).

In operation, oil from the reduction gear sump (supply tank) is picked up by the reduction gear lube oil pump. It then flows through the supply filter and the oil cooler. Oil from the cooler supplies both the reduction gear and engine lube oil systems. Oil to the engine flows through a pressure regulating valve and into the inlet of the engine supply pump. From the engine supply pump, the oil flows through a filter and check valve. It then flows through drilled and cored passages and internal and external lines to areas of the engine needing lubrication.

Scavenge oil is collected by the scavenge element of the main lube and scavenge pump, the external scavenge pump, and the turbine scavenge pump. Oil from the turbine scavenge pump flows through drilled passages and internal lines to the AGB. There it is picked up by the scavenge element of the main pump. Flow from the external scavenge pump joins the flow from the main scavenge pump (through external lines) and is returned to the reduction gear sump. The magnetic drain plugs (not shown) are on the bottom of the AGB and the discharge of the main scavenge pump. These collect any steel particles in the oil.

### Main Pressure and Scavenge Oil Pump

The main pressure (supply) and scavenge oil pump assembly is mounted on the front of the AGB. It has two gear-type pumps, one for the supply system and one for the scavenge system. It also has a pressure-regulating valve. Oil is pumped by the pressure (supply) element of the pump to the following components: the compressor extension shaft bearing, the PTO shaft mid-bearing, the AGB, the four main bearings of the engine, and the EG actuator.

The scavenge element picks up scavenge oil in the AGB. The oil is gravity drained from the compressor extension shaft bearing and the compressor front bearing. The scavenge element returns the scavenge oil, along with the oil from other scavenge pumps, to the reduction gear

sump. An indicating type of magnetic plug is located in the scavenge side of the pump.

### Oil Filter

An oil filter is mounted on the front of the AGB. It has a pleated-type element and incorporates a Teflon-seated, poppet-type check valve. This valve prevents oil from draining out of the engine when the engine is shut down. A bypass valve, located in the AGB front cover, opens at a specific pressure differential. This bypasses the filter if it becomes clogged.

### External Scavenge Pump

The external scavenge pump is a three-gear, dual-element pump. It is mounted on the aft side of the AGB. It scavenges the oil from the compressor rear bearing sump and from the turbine forward bearing sump. The oil from the pump is combined with the scavenge oil from the main scavenge pump. It is then returned to the reduction gear sump.

### Turbine Scavenge Pump

The turbine scavenge pump is a gear-type pump. It is mounted in the rear turbine bearing support assembly. A splined coupling drives the pump from the turbine-to-compressor tie bolt. The pump scavenges oil from the turbine rear bearing and returns it to the accessory drive housing. It is covered by a thermal insulation blanket and the exhaust inner cone.

### Vent System

The air inlet housing cavity and AGB are vented. This is through an external line from the AGB to a breather mounted on top of the air inlet housing. Air used to send the compressor rear bearing sump is vented through the two horizontal struts of the compressor diffuser. The combustor inner casing is vented to atmosphere through two horizontal struts in the turbine inlet casing. The combustion inner casing liner provides a passage for venting along the shaft. This flows through holes in the turbine coupling shaft. From there it flows to and pressurizes the turbine rear bearing labyrinth seal at the rear face of the turbine fourth-stage wheel, finally entering the exhaust gas stream.

## AIR START SYSTEM

The engine air start system (fig. 3-22) has an air turbine starter, a starter exhaust system, and two independent air supply systems. Each system has its own control valve. Air from the LP starter air control valve enters the starter inlet through a 3-inch line. Air from the HP starter air control valve enters the inlet through a 1 1/2-inch line. Exhaust air from the starter is discharged through a 6-inch line into the engine module cooling air duct downstream of the fire damper.

### Low-Pressure Air Start System

Air from the ship's bleed air system enters the starter LP air control valve. The control valve is a normally closed, solenoid-operated regulating valve. It regulates airflow to the starter at 45 psig.

### High-Pressure Air Start System

Air from the HP air flasks enters the starter HP control valve. The control valve is a normally

closed, solenoid-operated regulating valve. It regulates airflow to the starter to  $450 \pm 50$  psig. A bypass line with an orifice and a pilot valve provides for smooth engagement of the starter teeth. An HP start signal will cause the pilot valve to open. This allows air to flow through the orifice to the starter at less than 50 psig to engage the starter teeth. After about one-quarter second, the pilot valve will cause the air control valve to open. Full pressure is then applied to the starter for rotation. A manual needle bypass valve is provided for manual HP starting.

### Air Starter Motor

The Bendix air turbine starter is mounted on the generator side of the reduction gear high-speed input shaft. It is directly coupled to the engine through the reduction gear high-speed pinion and PTO shaft during the start cycle.

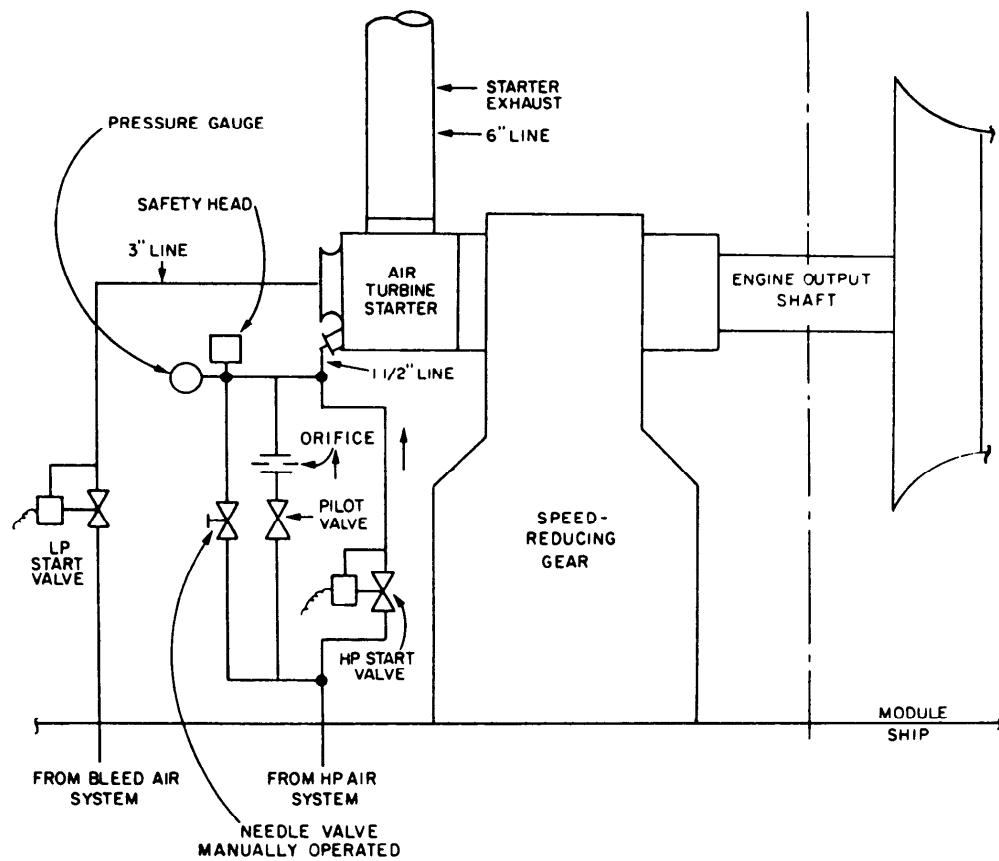


Figure 3-22.—GTGS air start system.

## GTGS REDUCTION GEAR AND LUBE OIL SYSTEM

The reduction gears used to couple the engine to the generator on the four models of GTGSs are identical. The reduction gear is a single-reduction, single-helical gear type of speed reducer. The reduction ratio is 7.678 to 1. The gear is an over-under, vertically offset, parallel shaft design. It uses a three-piece housing split horizontally at the center lines of the high-speed shaft and the low-speed shaft. The gear elements are supported in sleeve bearings. The starter is mounted on the gear case and drives the high-speed shaft. The oil pump is located on the engine side of the low-speed shaft. The reduction gear is coupled to the generator by a diaphragm-type flexible coupling.

Refer to figure 3-21 to help you understand the following discussion of the reduction gear's lube oil system. The lube oil system is a wet sump, force-feed system. The sump has a capacity of 60 gallons. It is an integral part of the reduction gear assembly. It also serves as the supply tank for the GTE lube oil system. Oil from the sump is picked up by the reduction gear supply pump (8). The pump is rated at 40 gpm at 1800 rpm. From the pump, the oil passes through a 25-micron base-mounted filter (9) and through a remotely mounted oil cooler (10). It is then distributed to the reduction gear, PTO assembly, and the engine.

Pressure at this point is regulated at 25 psig by excess flow returning to the reduction gear sump. Oil to the engine and PTO assembly is regulated to 15 psig.

Oil to the PTO assembly is directed by a nozzle onto the shaft coupling. It is then returned by gravity to the sump. The shaft mid-bearing is lubricated by a spray nozzle on the front of the compressor extension shaft housing. Oil to the reduction gear assembly, 30 gpm at 25 psig, lubricates the reduction gears and bearings. It returns by gravity to the sump.

## POWER TAKE-OFF ASSEMBLY

The PTO assembly (fig. 3-23) has a PTO shaft, shaft adapter, tapered coupling, mid-bearing assembly, housing, and speed sensor pickup. The assembly transmits the torque produced by the engine to the reduction gear. It also provides the means to measure the engine speed using a magnetic pickup mounted on the housing over the shaft exciter wheel teeth.

## POWER TAKE-OFF SHAFT AND ADAPTER

The PTO shaft is a solid steel shaft. It is bolted to the shaft adapter at the forward end and splined to the compressor extension shaft at the aft end.

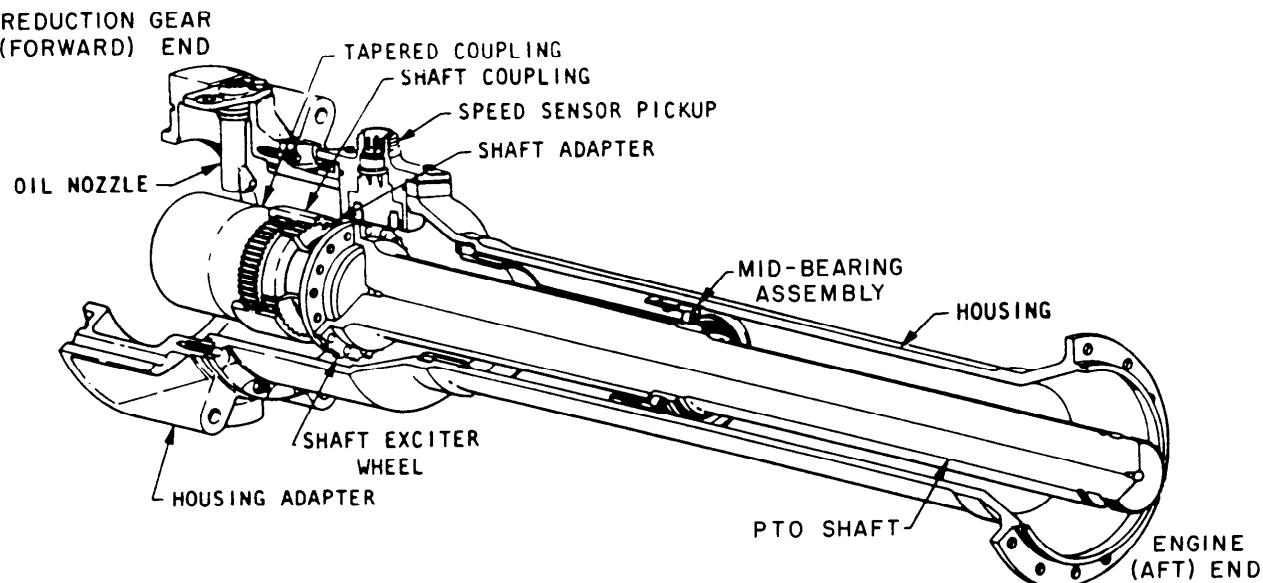


Figure 3-23.—PTO assembly.

Forty equally spaced teeth are machined on the flange at the forward end of the shaft. These provide excitation for the speed sensor.

## HOUSING

The housing encloses the shaft, supports the forward end of the engine, and contains the mid-bearing assembly. The housing also provides the mounting for the speed sensor assembly and an oil nozzle that lubricates the splines of the tapered coupling and shaft adapter. The mid-bearing assembly prevents the shaft from whipping.

## ENGINE INSTRUMENTATION

Besides the instruments that measure pressure and temperature of the engine's support systems and enclosure, several sensors monitor the engine itself. These are the thermocouples, vibration sensor, and magnetic speed pickup.

The thermocouples are wired in parallel to provide an average TIT signal. This is amplified by the turbine speed temperature box in the LOCOP. This signal provides TIT indication and input to engine emergency shutdown functions. The speed temperature box uses the magnetic speed pickup signal for speed sensing and control during start. An alarm and automatic shutdown are provided for overspeed or underspeed. The speed temp box also transmits a speed and temperature signal for remote display of engine speed and temperature on the DDIs.

## THERMOCOUPLE

Eighteen dual-element, Chromel-Alumel thermocouple probes are mounted on the turbine inlet casing. The probes extend into the outlet of the combustion liners at the turbine inlet. Each of the probe elements is independent of the other, thereby providing two independent sampling circuits. The thermocouple probe housing leading edges are air cooled to prolong probe life. To accomplish this, cooling air enters the probe cavity leading edge through a hole below the probe shoulder. It flows through the probe and is discharged through two small openings in the bottom of the probe.

A thermocouple harness assembly has a right and a left section. It is enclosed in channels that are rigidly mounted on the turbine inlet case forward flange. The harness incorporates separate leads for each thermocouple probe. A terminal

block serves as the junction for two thermocouple harnesses and the amplifier leads. It has eight terminal connections and four terminals for each of the two harnesses.

## VIBRATION TRANSDUCER

Engine vibration is measured by a displacement type of vibration transducer. It is mounted on the turbine rear bearing support at the 12 o'clock position. It provides a signal to a meter on the LOCOP.

## SPEED PICKUP

Engine speed is measured by a magnetic pickup. This is mounted in the PTO shaft housing over the shaft exciter teeth. Passage of the exciter teeth under the magnetic pickup produces electrical impulses. These impulses are used by the speed temp box for speed sensing. This, in turn, is used for start sequencing, over- and underspeed protection, and speed monitoring.

## SPEED GOVERNING SYSTEM

The Allison 501-K17 is a constant speed engine. It is designed to maintain a speed (13,821 engine rpm) that will output a steady 60 Hz from the generator. Dependable 60-Hz power is required to keep electronic equipment and motors operating properly. The Allison 501-K17 uses an EG to maintain this constant speed. Two different electronic control systems are used on the GTGSs. Most model 104 GTGSs use the Woodward 2301 control system. The model 139 GTGS and some model 104 GTGSs use the Woodward 9900-302 control system. Both model GTGSs use the Woodward EGB-2P electrohydraulic actuator.

Both systems normally operate on the EG. The EG will maintain the frequency set by the operator. Once the frequency is set and the load is balanced between GTGSs in parallel, the governor system will maintain the set frequency and load balance.

If failure of the EG control occurs, a mechanical flyweight governor will regulate the engine speed. The mechanical governor is set at a slightly higher speed than the EG. It will maintain a frequency of about 62 Hz. This mechanical governor prevents overspeed of the engine during an EG failure. It is set by a screw adjustment on the EG.

## OPERATING MODES

The governor system of both the model 104 and the model 139 have two basic operating modes, NORMAL (isochronous) and DROOP.

### Isochronous Mode

This mode provides constant speed operation, regardless of load. When generators are operated in parallel and in the isochronous mode, the governor system maintains a constant speed. It also controls the load division between paralleled generators. The isochronous mode is selected when the EPCC selector or the SWBD selector is in the NORMAL position. The load sharing function is automatically enabled when a generator operating in the NORMAL mode is paralleled with another generator.

### Droop Mode

In this mode, the governor system still regulates engine speed, but the speed will decrease slightly with an increase in load. Sometimes the generator is paralleled with a constant frequency bus (such as shore power) while in the droop mode. In this case, the governor cannot control speed since it is held constant by the bus frequency. Instead, it will control the load carried by the generator. In this way, the droop mode provides load control of a generator paralleled with shore power. It also can unload a generator paralleled with another GTGS without disturbing system frequency. When the selector is in the DROOP position, droop mode is selected at the EPCC or the SWBD.

## MODEL 104 GOVERNOR SYSTEM

The engine speed governor on the model 104 GTGS is the Woodward 2301 electrohydraulic control system. It has a backup centrifugal governor override. Three major components within the system are a motor-operated potentiometer, an ECU, and an EG actuator. The motor-operated potentiometer is located at the ECU. The ECU is mounted in the GCU. The primary function of the GCU is to provide generator field excitation and voltage control in either the automatic or manual mode. The GCU is a solid-state electronic package. It processes input commands and feedback signals to generate a signal to position the engine-mounted EG actuator. The actuator positions its output shaft

in response to the control signal. This shaft controls the engine's LFV through a mechanical linkage. If the engine speed increases to a preset limit because of a failure in the electronic control, then the centrifugal governor section of the actuator will automatically assume control of the output shaft. Engine speed will then be controlled at a point slightly above the normal operating speed.

### Motor-Operated Potentiometer

The operating point of the governor is set by the motor-operated potentiometer. The individual frequency adjust controls at the EPCC or the SWBD are used to adjust the potentiometer. These controls adjust the position of the motor-operated potentiometer to a higher or lower position. If generators are operated in parallel from the EPCC, with the system frequency controls enabled, the motor-operated potentiometer returns to a calibrated 60-Hz position. You can make adjustments by using the SYSTEM FREQUENCY ADJUST control at the EPCC. This control will position a master frequency trimmer in the EPCC. It sends equal adjust signals directly to each generator's ECU. The frequency of the bus can be changed without disturbing the load balance between operating units. During automatic paralleling operations, the APD will adjust the oncoming generator for synchronization. This adjust signal is also a direct input into the ECU. It is in effect only during automatic paralleling conditioning. Figure 3-24 is a governor interface diagram.

### Electronic Control Unit

The ECU of the Woodward 2301 governor system is modular in design. It is composed of the motor-operated potentiometer, the master frequency trimmer, the APD, an amplifier, the fuel control actuator, two power supplies, an accessory box, two filters, and a load sensor. The following paragraphs describe the function of these subunits and are keyed to figure 3-25, a functional diagram of the Woodward 2301 governor.

The motor-operated potentiometer (1) supplies a reference to the amplifier. When the electric plant operates in the manual, manual permissive, or droop mode, frequency adjust commands will cause the motor to rotate in the raise or lower direction. This changes the reference correspondingly. When operating in the automatic

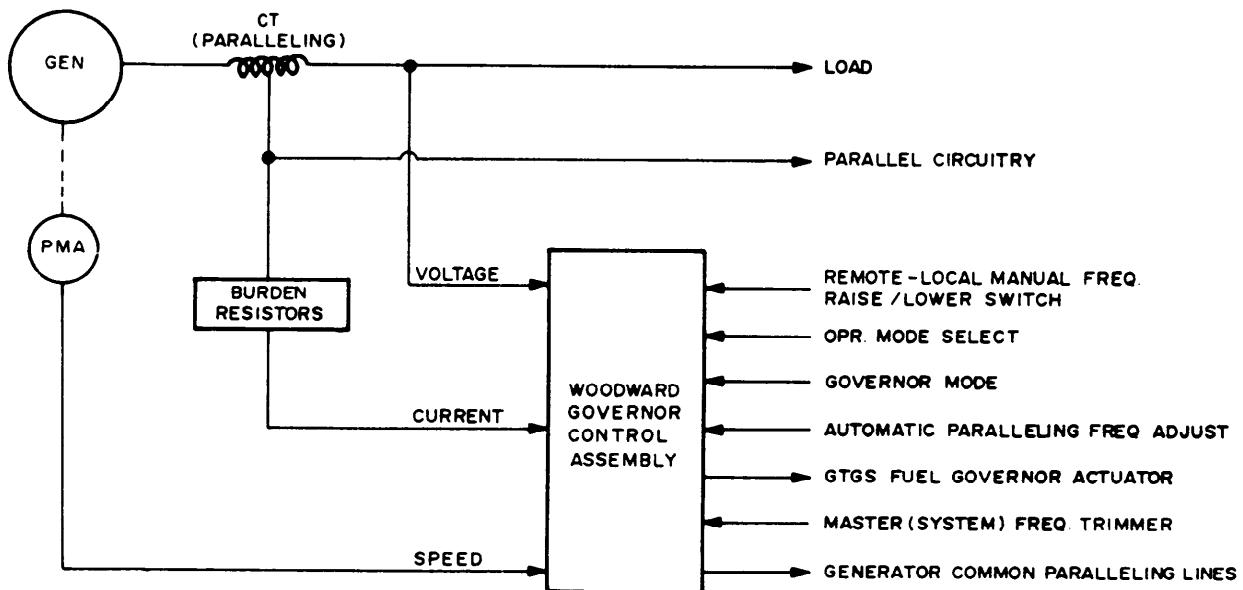


Figure 3-24.—Woodward 2301 governor interface diagram.

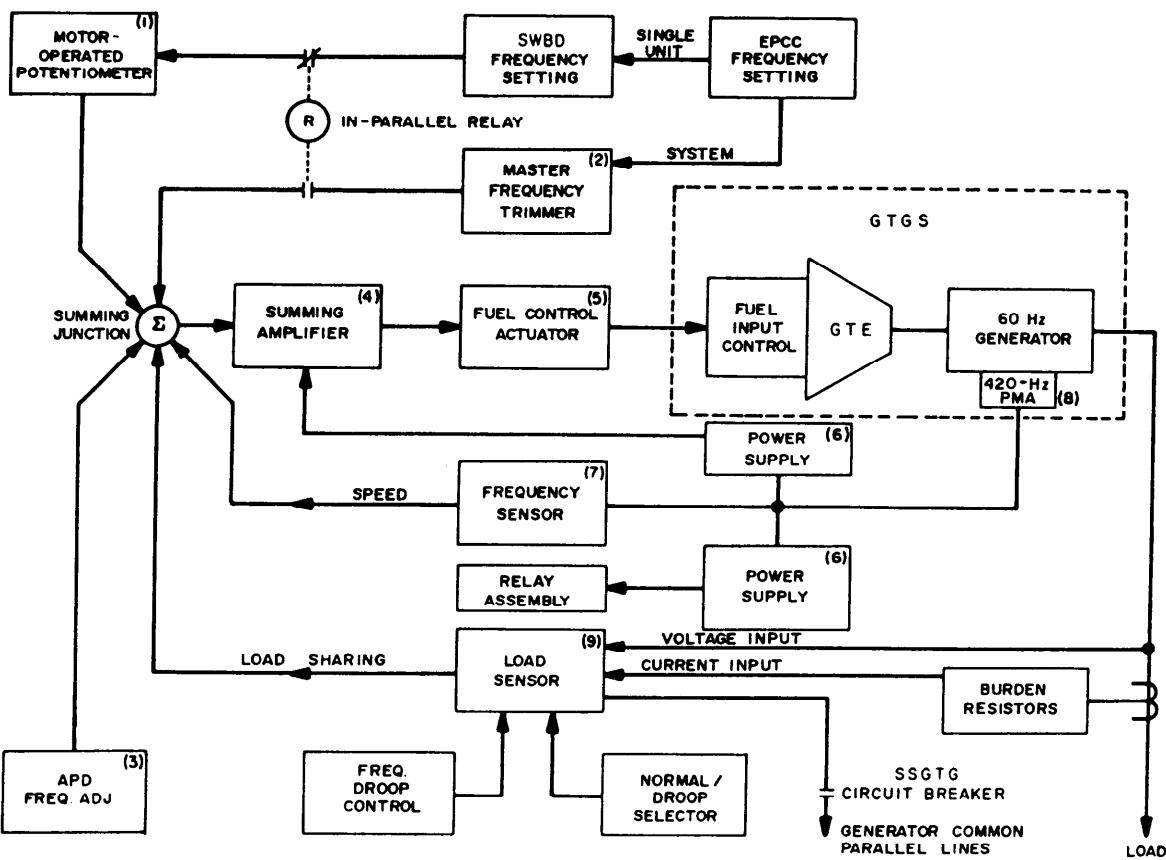


Figure 3-25.—Woodward 2301 governor functional diagram.

mode, the motor automatically drives to and remains at 60 Hz. This position is established by the motor's limit switches. External adjustments to the governor system are done by additional inputs to the amplifier. These inputs come from either the master frequency trimmer (2) or the APD (3). The master frequency trimmer in the EPCC provides frequency control to any two or all three generators when operating in parallel on either the model 104 or the model 139 GTGS. You may use the EPCC panel SYSTEM FREQ RAISE/LOWER switch to demand a change of frequency for the paralleled units. This control inputs 115 volts ac into a reversible motorized potentiometer assembly. The potentiometer output is a dc signal. Its amplitude is proportional to the correction demanded in the generator output frequency. The polarity dictates the direction of change.

The summing amplifier (4) provides the current to the fuel control actuator (5). This current is varied in response to the inputs to the amplifier. This includes the reference, frequency feedback, and load sensing. Input changes because of load, speed, or reference cause the amplifier current to reposition the actuator output shaft. This increases or decreases fuel flow. Amplifier current then stabilizes at a new setting that satisfies all inputs. The amplifier is reverse acting. That is, the larger the input (error signal), the smaller the output current to the actuator. The actuator output shaft is designed to work so a decrease in current causes it to drive the LFV toward the maximum fuel position. If the amplifier fails and the current goes to zero, the actuator will be positioned in the maximum fuel position. (The centrifugal governor assumes control if engine speed increases to the preset limit.)

The PMA input to the control unit provides voltage for the two power supplies (6) and a frequency feedback signal to the frequency sensor (7). One power supply feeds the amplifier; the second provides power for the motor-operated potentiometer. The frequency sensor converts the PMA output (8) (about 120 volts ac at 420 Hz) to a proportional dc voltage. This is used for the frequency feedback input to the amplifier.

The load sensor module (9) controls load sharing in parallel isochronous operation. It is used to generate the droop characteristics during droop operation. Power generated by the generator is measured by transformers. They supply voltage to a bridge circuit. For load sharing, the bridges of each paralleled generator

are connected so an unbalance because of uneven loads causes an input to each governor amplifier. This forces proportional fuel adjustments until the loads are balanced between the two units. This also balances the bridge circuits. The amplifier input is again returned to algebraic zero volts dc. Sudden shifts in load demand cause pulses to be developed in the load sensor. This upsets the algebraic zero voltage of the governor amplifier. This results in quicker response to load changes. Polarity of the pulse is also sensed to determine the direction of load changes.

During droop mode some of the load sensor output opposes the action of the amplifier speed reference. The input to the amplifier will be decreased by an amount proportional to load, resulting in droop.

If the generator is not paralleled with another source, this droop will result in a decrease in frequency. The decrease is proportional to the increase in load. If the generator is paralleled with an infinite bus (such as shore power), droop provides load control. When paralleled with an infinite bus, the speed of the engine is held constant by the bus. The governor system, in this situation, cannot control speed. Any attempt to increase or decrease speed will only result in an increase or decrease in load. Without the droop characteristics, the governor system would attempt to adjust the frequency to satisfy the reference exactly causing the load to increase beyond generator capacity or decrease until the flow of power reverses. The droop input, however, will modify the speed reference. The governor will reach a stable operating point even though the frequency does not match the reference. This operating point is set by the speed reference and droop input (since frequency is constant). It determines the load on the generator. Under this condition, the load on the generator will remain constant for any reference setting.

### Electrohydraulic Governor Actuator

The EG actuator is engine driven and is mounted on the left side of the AGB. The actuators output shaft is mechanically linked to the LFV. The actuator receives signals from the GCU and positions the LFV, which, in turn, meters fuel flow to the engine. The actuator incorporates normal (electronic) control by the GCU and backup (mechanical) control by a centrifugal governor. Both systems are independently capable of positioning the actuator output shaft.

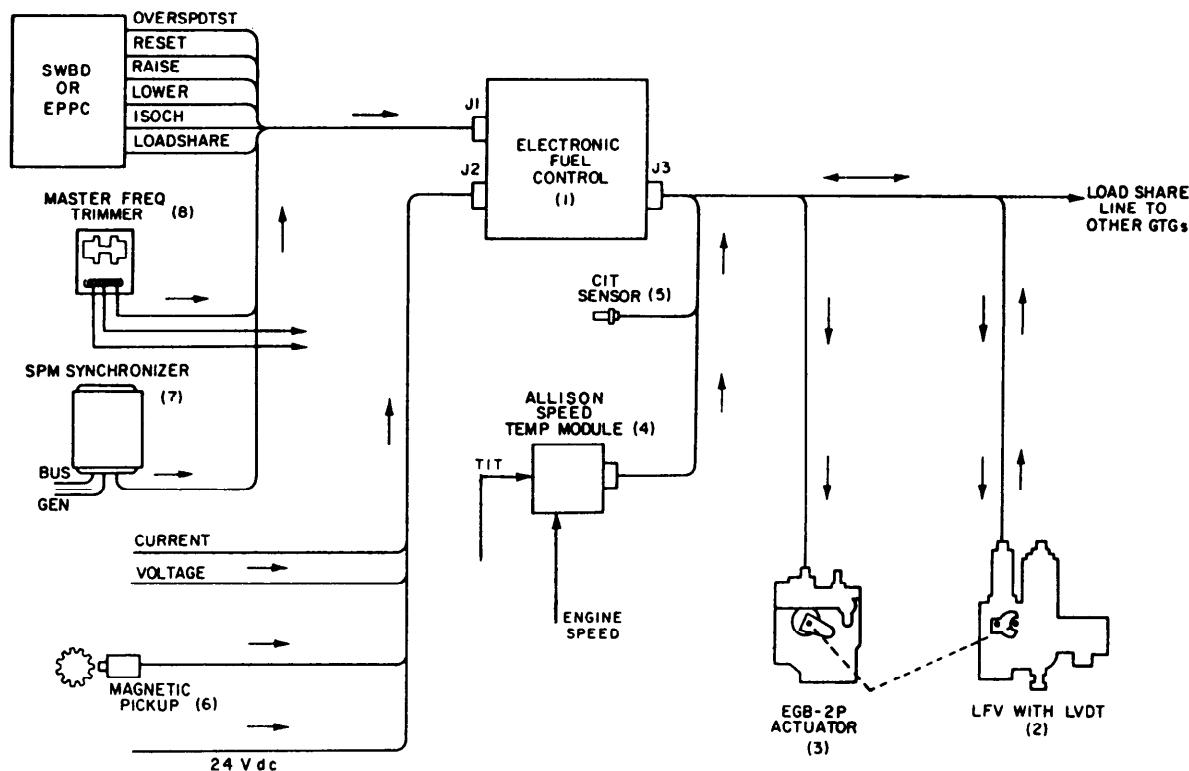
The mechanical centrifugal governor system backs up the ECU of the Woodward governor system. The centrifugal governor speeder spring device takes over control if the ECU fails and the engine speed increases due to the actuator positioning itself for full-speed failure mode. It is set for about 62 Hz (depending on load) or the equivalent speed of about 14,300 rpm. This is 480 rpm above the 60-Hz speed of 13,821 rpm. The centrifugal governor is part of the EG actuator assembly.

## **MODEL 139 GOVERNOR SYSTEM**

The engine speed governor on the model 139 GTGS is the Woodward 9900-302 electrohydraulic control system. It also uses a backup centrifugal governor override. There are eight components within the system. These components are shown on figure 3-26, an interface diagram of the Woodward 9900-302 governor. They are an electronic fuel control (1), an LFV with an LVDT (2), an EGB-2P actuator (3), an Allison speed and temperature module (4), a CIT sensor (5), a magnetic speed pickup (6), a speed phase

matching (SPM) synchronizer (7), and a master frequency trimmer (8). Following is a list of these eight components and a brief description of their functions. The items are keyed to figure 3-26.

1. The electronic fuel control regulates fuel during turbine lightoff, acceleration, and 60-Hz power generation. It monitors speed, TIT, and liquid fuel valve position.
  2. The LFV with the LVDT meters the fuel to the engine.
  3. The EGB-2P actuator positions the LFV feeding the valve position back to the fuel control through the LVDT.
  4. The Allison speed and temperature module monitors the TIT and engine speed. It supplies signals to the electronic fuel control. This is for the start fuel schedule and for maximum temperature control.
  5. The CIT sensor monitors the ambient air temperature. It applies the signal to the speed correction and acceleration temperature reference circuits.
  6. The magnetic pickup senses turbine speed as an ac pulse signal with a



**Figure 3-26.—Woodward 9900-302 governor interface diagram.**

- frequency proportional to the speed of the turbine.
7. The SPM synchronizer compares the phase of the generator with that of the bus. If an error is sensed, a signal is applied to the fuel control unit. Then the generator phase angle will be brought in phase with the bus.
  8. The master frequency trimmer is used when the turbine is in load sharing. It changes power system frequency without changing the load division between engines.

## Governor Control Unit

The GCU supplies field excitation to its associated GTGS. Except for the remotely mounted selector switches, the GCU components are mounted in the GCU cabinet. Each cabinet contains the redundant voltage regulator systems with associated relays, transformers, motor-operated potentiometers, selector switch indicating lights, a reset button, and the governor control assembly.

## Electronic Fuel Control Unit

The electronic fuel control unit is a modular solid-state electronic package. The nine major modules are the load sensor, isolation, speed reference, speed channel, power supply, fuel limiter, temperature channel, final driver, and motherboard modules. These modules are found in the governor box in the GCU. Figure 3-27 is a functional diagram of the governor control system. It shows the three major control functions separated by broken lines. These functions are speed control, temperature control, and fuel metering.

The following paragraphs describe the operation of the electronic fuel control to the board level. The module titles are descriptive of their major function.

**LOAD SENSOR MODULE.**—This module uses inputs from the generator voltage and CTs. Each phase is monitored for current and voltage by potential transformers and CTs to determine the actual load. Each CT develops a voltage across a burden resistor, proportional to generator current. The signal representing the load on the three phases is summed in the load sensor.

The current in all three phases is corrected for power factor and summed in the load sensor module. This provides a signal proportional to the load on the bus. A load gain potentiometer is

located within the load sensor. It determines the percentage of the load that this generator handles in a load sharing situation with other generators.

The droop potentiometer within the load sensor determines the percentage of speed change. This is used when the turbine generator is operating in droop mode. The effect of operating in droop mode is a decrease in speed setting for an increase in load. A portion of the load gain voltage is applied to the speed channel as a droop signal.

When the turbine is in isochronous mode, the load pulse amplifier provides a speed error correction signal in advance of the normal speed error signal. This improves the short-term transient response of the controller. The output of the load pulse amplifier is applied to the speed control summing point in droop mode. It is applied to the load matching circuit in isochronous mode.

In the load sharing mode, a bridge within the load matching circuit is connected in parallel with the bridges in other controls. When the load on the generator varies, an error signal is generated by the load matching circuit. This adjusts the load carried by the generator. An LED indicator shows the selection of isochronous or load sharing modes.

**ISOLATION MODULE.**—The isolation module provides buffering of the governor master frequency trimmer and governor SPM synchronizer signals. Also, the discrete logic signals for the overspeed test, reset to 60 Hz, raise, lower, isochronous, and load sharing control are buffered through isolators on this module.

**SPEED REFERENCE MODULE.**—The speed reference module generates the dc reference signal used by the speed control module. The reference values are selected by inputs from the SWBD or the EPCC. When the command is made to change frequency, a digital counter within the speed reference starts to count. It counts in an increasing or decreasing direction toward the new reference level. The counting process continues as long as the input command to change frequency is present. It continues until the new reference level is reached. The output of the counter is applied to a DAC. The converter changes the digital output of the counter to the output analog speed reference voltage. The speed reference module indicators show when it is at the reset, lower, or upper limits. They also show when they are moving.

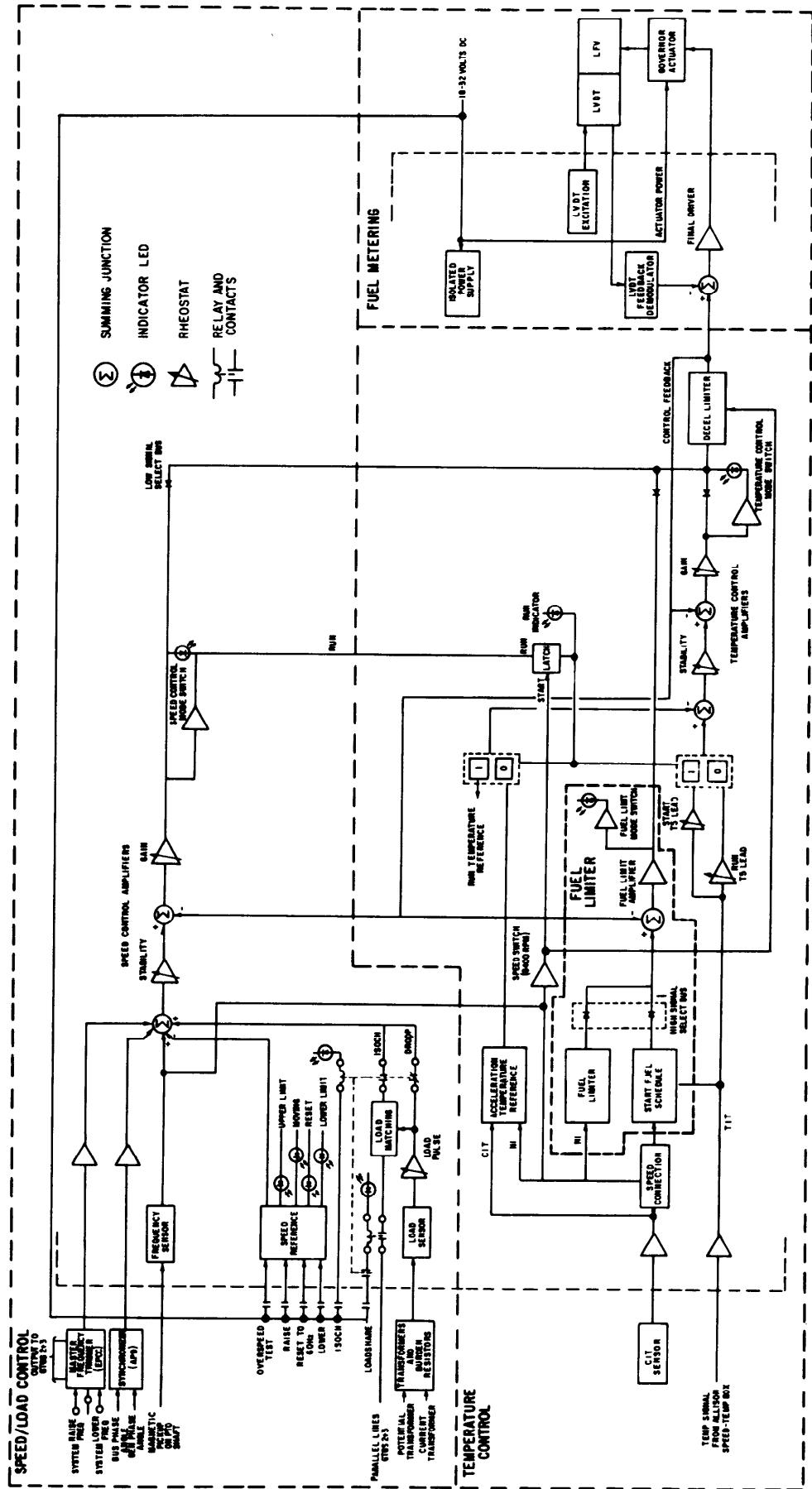


Figure 3-27.—Model 139 governor control system functional diagram.

**SPEED CHANNEL MODULE.**—The speed channel module maintains turbine speed at the value selected by the operator. A magnetic pickup unit (MPU) provides an ac signal that is proportional to turbine speed. The frequency sensor circuits convert the MPU signal to a proportional dc turbine speed signal. The speed control compares the actual turbine speed signal with the reference signal. The speed control amplifiers then generate a voltage signal to maintain or correct turbine speed. The speed control loop has the following inputs:

- Master frequency trimmer
- Synchronizer
- Frequency sensor
- Speed reference signal
- Load sensor

These speed error signals are input to the summing point. The stability amplifier applies the summed signal to the speed control gain amplifier.

The control amplifiers provide proper transient response of the turbine. The stability amplifiers control the time required to recover from a transient. The gain amplifiers control the amplitude of the transient. Correct adjustment is achieved when the time and off speed are both minimized without turbine instability.

The output for the speed control circuit is applied to the low-signal select (LSS) bus. The LSS bus has diode inputs from the speed, temperature, LSS bus maximum limit clamp, and the fuel filter control amplifiers. The bus allows the lowest signal input to dominate the bus. The output of the LSS bus is applied to the input of the high-signal select (HSS) bus. A speed control feedback signal is used so the control amplifier can anticipate control of the LSS bus. This provides for smooth transition between control channels without excessive overshoot.

**POWER SUPPLY MODULE.**—The power supply module provides isolated dc power for the control circuits. The power supply converts +28 volts dc to +12 volts dc and +R and -R precision reference voltages for use by the control circuits. The +12 volt dc and -12 volt dc voltages power the control electronics. The +R and -R voltages are reference voltages where precise voltages are required. The dc voltages are distributed to the

modules by the motherboard. During maintenance on the governor system, a jumper wire must be used between two designated test points. This enables the LEDs on the circuit cards to illuminate.

**FUEL LIMITER MODULE.**—The fuel limiter module contains the circuits required during turbine start and acceleration. The start fuel schedule circuit controls the fuel flow to the turbine during start. It monitors three signals from the turbine—first TIT, second CIT, and third N<sub>1</sub> (speed voltage). The combination of the CIT and N<sub>1</sub> inputs produces corrected speed. Corrected speed is the voltage from the speed frequency sensor corrected by the CIT temperature. Speed correction results in increased fuel as CIT decreases. Start fuel is decreased as a function of TIT.

The output from the start fuel schedule is applied to the HSS bus. The HSS bus is a comparator circuit. It allows the highest signal applied to the bus to pass. The other input to the HSS bus is the fuel limiter circuit. The fuel limiter limits the maximum amount of fuel to the turbine as a function of speed. At rated or isochronous speed, fuel is limited by the mechanical stop on the fuel valve. When turbine speed is in the low-speed range, the fuel limiter signal is less than the start fuel schedule. So the fuel limiter signal is not selected by the HSS bus. The output from the HSS bus is applied to the fuel limiter amplifier. This amplifier then drives the LSS bus when its voltage is less than the speed or temperature control inputs. The fuel limit mode LED illuminates when the fuel limiter module is controlling fuel.

The fuel limiter module has a deceleration limiter circuit. The deceleration limiter controls the minimum fuel flow to the turbine. If fuel is decreased too rapidly, a flameout will occur. During a start, the output of the LSS bus is high-signal selected. It has a fixed voltage when the engine speed is below 8400 rpm. This voltage limiter prevents the fuel valve from reaching the minimum fuel flow stop during start.

The acceleration temperature reference voltage increases as the turbine speed increases during acceleration. A CIT bias sets the reference lower as the ambient temperature decreases. An 8400-rpm speed switch and a start/run latch are used to select the temperature channel operating reference. Below 8400 rpm, the latch is set to the start mode. This selects the acceleration temperature reference and start TIT LED. When the speed switch is above 8400 rpm and speed

control has been achieved, the start/run latch is set to run. The run indicator LED lights up.

#### **TEMPERATURE CHANNEL MODULE.—**

The temperature channel prevents turbine temperature from exceeding safe operating limits. A signal proportional to TIT is compared with the start or run temperature reference. The amplifier generates a voltage signal output to the LSS bus to limit TIT.

The temperature control amplifiers operate similar to the speed control amplifiers. Separate start and run LEDs are provided. They compensate for the longer thermocouple reaction time at low turbine speeds. This lag is due to low airflow at low speeds.

A start fuel schedule supplies enough fuel for TIT to reach the acceleration temperature range. When the turbine reaches the acceleration range, the temperature control requires less fuel than the fuel limiter. The LSS bus then selects the temperature control for the rest of turbine acceleration.

When the turbine reaches isochronous or rated speed (60 Hz), the speed control takes control from TIT control. Then the start/run reference switches to run limit. TIT is a function of load on the turbine. If load is increased until TIT equals the TIT reference, the temperature control will maintain TIT at that level. In droop mode or when paralleled with other units, the generator load will be maintained at a level to produce the set TIT. When no other source is available to carry the excess load, the temperature control will reduce speed.

**FINAL DRIVER MODULE.—**The final driver module generates current to position the actuator as required by the controlling channel. An oscillator generates an excitation voltage for the LVDT located on the LFV. As mentioned before, the LVDT is mechanically linked to the fuel valve metering sleeve. It senses the fuel valve position. This sleeve is moved through the action of the actuator. As it moves, the excitation voltage transmitted to the LVDT output is changed. The output of the LVDT is proportional to the position of the fuel metering sleeve. A de-modulator in the final driver changes the LVDT feedback signal to a dc voltage. This voltage is proportional to the sleeve position on the fuel valve. The final driver amplifier compares the input from the control circuits with the LVDT voltage. Then it correctly positions the fuel valve. The final driver and actuator are reverse acting.

The less current supplied to the actuator, the greater the fuel supplied to the turbine.

#### **MOTHERBOARD MODULE.—**

The motherboard's primary function is to interconnect the eight daughter boards with each other and the J1, J2, and J3 receptacles. The motherboard also has the power drive transistor for the actuator. This transistor is mounted on a heat sink that is connected to the chassis.

### **ALTERNATING CURRENT GENERATOR AND VOLTAGE REGULATOR**

As stated earlier in this chapter, two different ac generators are powered by the Allison 501-K17 engine. The model 104 GTGS is a 2000-kW, 3200-amp unit, while the model 139 GTGS is a 2500-kW, 4000-amp unit. Each generator outputs 450-volt, 60-Hz, 3-phase ac at a 0.8 power factor with an 1800 rpm input. Each unit is a totally enclosed, salient-pole, two-bearing generator. Each unit has an air cooler mounted above it to cool the generator. An independent lube oil system using 2190 TEP lube oil provides lubrication for the generator bearings.

### **GENERATOR ASSEMBLY**

The model 104 and the model 139 generator assemblies both have eight major components. However, only seven of these components are identical on both generators. The identical components are as follows:

- The stator assembly of four-pole, four-circuit delta connection
- The rotor assembly with four salient poles
- The front and rear end bracket assemblies
- The front and rear bearing assemblies
- The permanent magnet alternator (PMA) and lube oil pump assembly
- The air cooler assembly
- The stator terminal/connection box.

The unique components of each generator are a slip ring and brush assembly on the model 104 and a brushless exciter assembly on the model 139. This is because the model 104 is a brush-type generator and the model 139 is a brushless-type generator.

### Generator Lube Oil System

The generator lube oil system (fig. 3-28) is independent of the gas turbine/reduction gear lube oil system. The generator lube oil system uses 2190 TEP mineral oil. It force-feeds the two bearings with a flow of 3 gpm at 12 to 15 psig pressure. Oil is taken from the sump tank in the GTGS base by a pump mounted on the PMA shaft. The oil is passed through a 25-micron filter and the base-mounted cooler before reaching the sleeve bearings. Gravity flow through sight flow indicators return the oil to the sump.

The model 104 generator lube oil system must be manually prelubed only if the GTE has remained idle for 5 days or more. On the model 139 an installed prelube pump is provided for the initial lubrication to the generator upon each start-up.

### Generator Space Heater

Electric heater elements are mounted at the bottom of the generator. They prevent the condensation of moisture when the generator is secured or on standby. Four 120-volt, 250-watt, tubular, finned heaters are mounted crosswise under the stator. A heater control switch with an indicator lamp is mounted on the control section of the SWBD. An interlock on the generator circuit breaker automatically disconnects the space heaters when the breaker is closed.

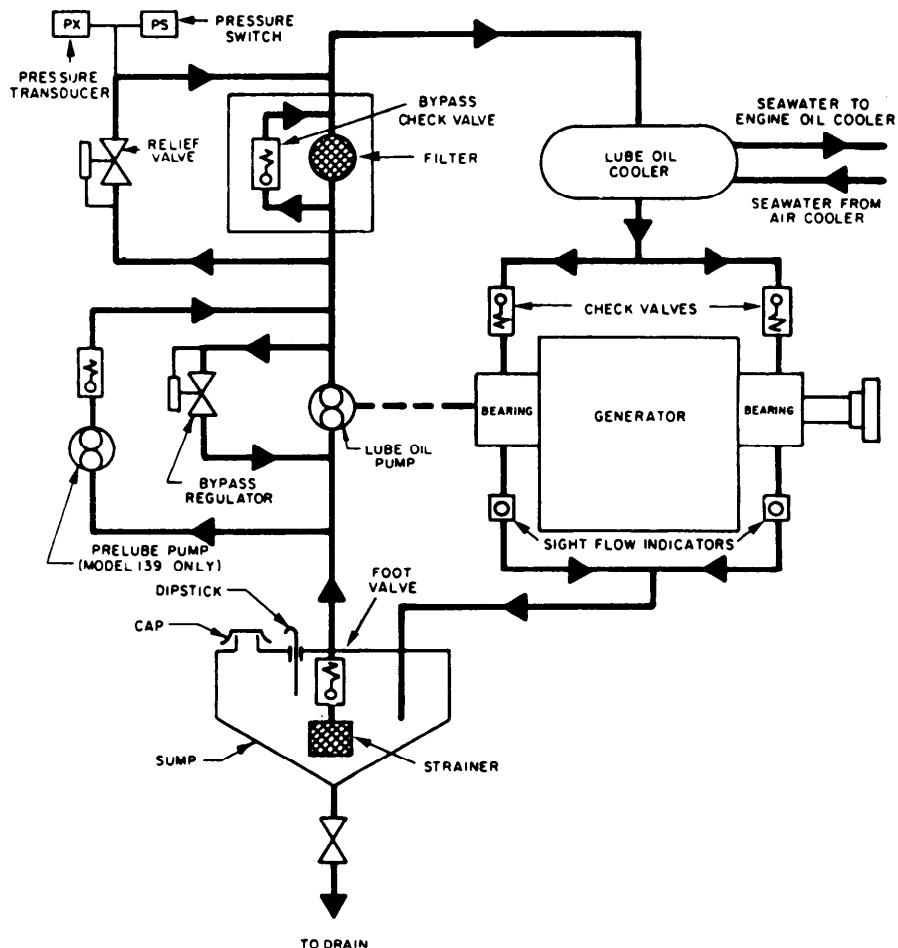


Figure 3-28.—Generator lube oil system.

## Generator Temperature Monitoring

Nine copper RTDs are embedded in the generator stator winding slots. The three-wire lead of each RTD is brought to an internal terminal board. A rotary selector switch and a temperature indicator are mounted on the LOCOP for monitoring six stator winding temperatures. The three remaining RTDs serve as spares.

A tip-sensitive RTD is embedded in the babbitt of each generator bearing. A terminal assembly, connector, and straight plug are provided for each RTD. A rotary selector switch and temperature indicator, mounted on the LOCOP, selects and monitors the two bearing temperatures. Both stator and generator bearing RTD outputs are

signal conditioned at the LOCOP. They are transmitted to the ECSS for monitoring.

## VOLTAGE REGULATION

The model 104 and the model 139 use different voltage regulators. The major components of the voltage regulators are mounted in the generator or in the GCU. The GCU is mounted in the same area as the SWBD.

### Model 104 Voltage Regulation

The following four items are the major components of the model 104 voltage regulator (fig. 3-29):

1. Static exciter/voltage regulator assembly deck mounted near the associated SWBD

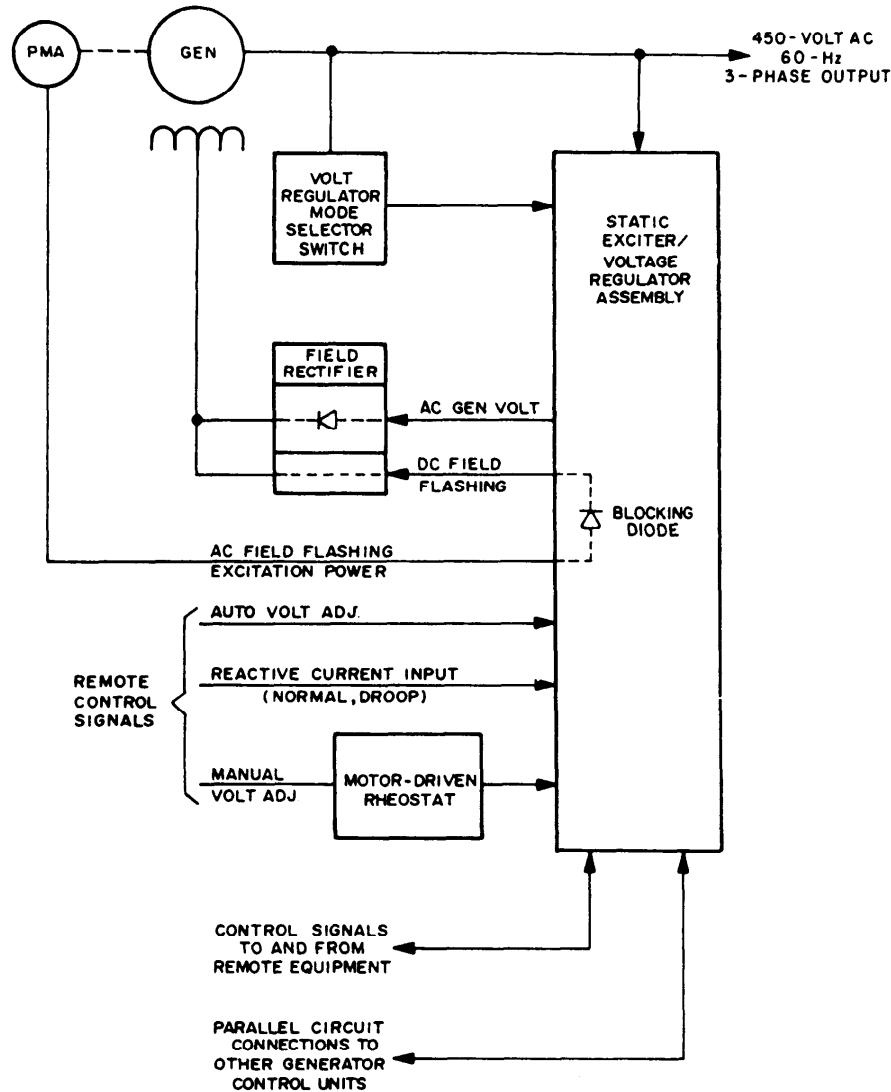


Figure 3-29.—Model 104 voltage regulator functional diagram.

2. Field rectifier assembly mounted in the generator enclosure air path
3. Motor-driven rheostat mounted on the associated SWBD for manual voltage control
4. Mode select rotary switch mounted on the associated SWBD

The GCU provides generator field excitation at 100 amperes at 150 volts dc at full load. Voltage control is in automatic or manual modes.

**GENERATOR FIELD EXCITATION.**—Excitation power for the generator field is supplied by the generator output. It is controlled by a 3-phase magnetic amplifier. Different values of dc flowing in a control winding provide different levels of saturation in the magnetic amplifier. This controls the output of the magnetic amplifier to the generator field.

Another source of field excitation comes from three CTs. This is rectified by a 3-phase, full-wave bridge in the field rectifier assembly. Since the source of field excitation for the magnetic amplifier comes from the generator output, a short circuit on the system will cause the voltage to collapse. This results in a loss of excitation voltage. The excitation source from the CTs can supply enough excitation to the generator field under short circuit conditions to keep the generator output at a minimum 320 percent of rated current. In this way the overcurrent devices can sense the short circuit. They can trip the generator breaker to clear the fault.

On initial start-up of the generator, the magnetic amplifier has little or no excitation voltage. To assure that the generator voltage will build up, another source of excitation must be used. Excitation is supplied by the PMA on the generator shaft extension. It is rectified through a 3-phase, full-wave bridge. The output voltage of this excitation source is less than the normal output of the magnetic amplifier at 450-volt generator output. It is automatically removed by a blocking diode once the magnetic amplifier output takes over. This function is called field flashing.

Under manual operation (fig. 3-30, view A), the source of control current for the magnetic

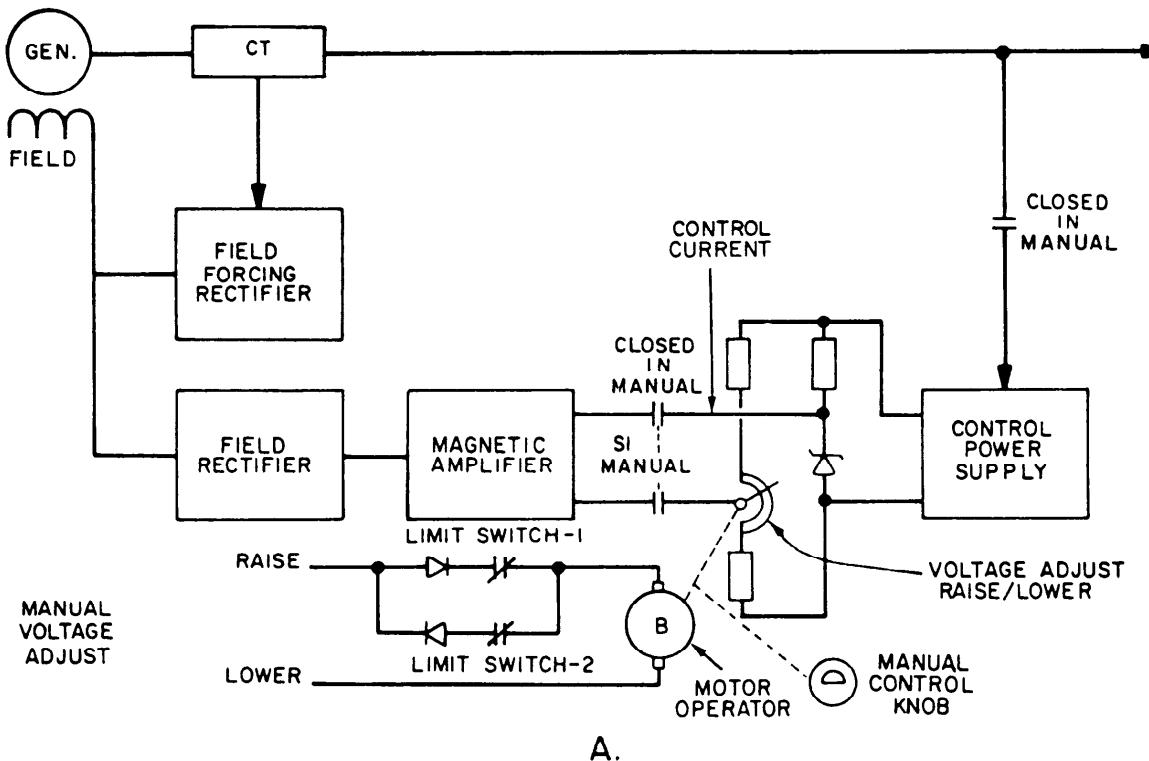
amplifier is an internal power supply. You can adjust the control current from the SWBD by the MANUAL MODE VOLT ADJ knob or the GEN VOLTAGE RAISE-LOWER switch (with the VOLT REG MODE switch in the MAN position). With the EPCC in manual control, the control current may also be varied through the VOLT LOWER-OFF-RAISE switch at the EPCC.

In automatic operation (fig. 3-30, view B), the voltage regulator output supplies control current to the magnetic amplifier fields. An internal motor-driven rheostat sets the required voltage. Control for this motor is from the SWBD for local operation and from the EPCC for remote operation.

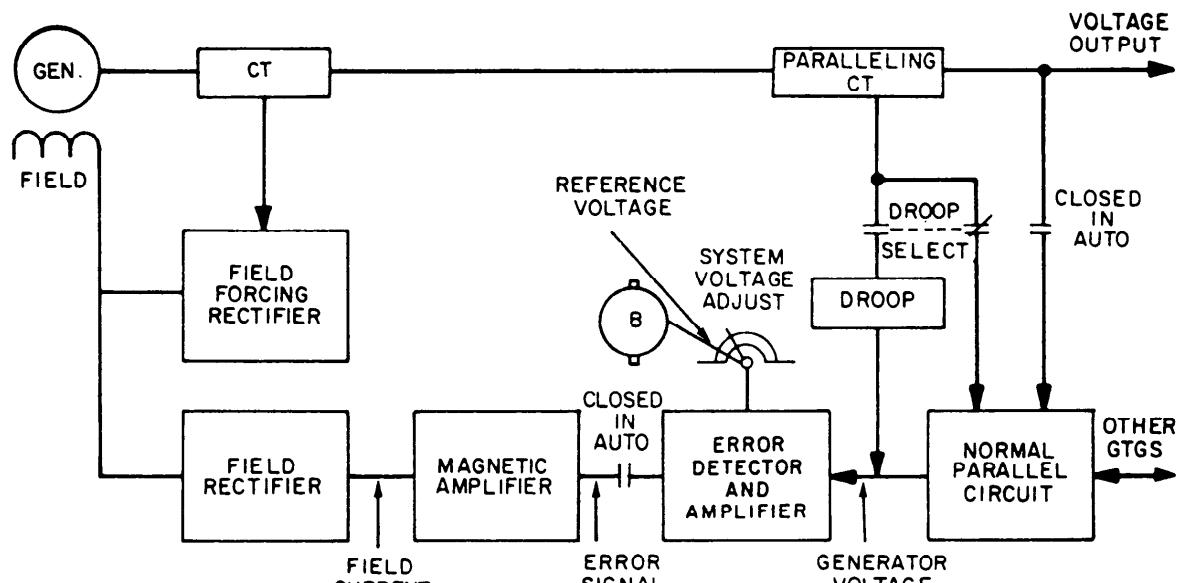
**VOLTAGE REGULATOR.**—The voltage regulator in auto operation compares generator voltage with a reference voltage to provide an error signal (fig. 3-30, view B). This error signal is amplified and applied to the magnetic amplifier control winding. This changes the output of the magnetic amplifier. This, in turn, provides field current to set the output voltage of the generator. The reference voltage is adjustable through the motor-driven rheostat in the static exciter/voltage regulator assembly.

A line current signal is brought in from the three paralleling CTs to the field forcing rectifier. This provides two functions in automatic mode.

1. When an individual generator is on line, this current signal acts to compensate for load changes. When load increases, this signal will call for an increase in excitation. This relieves the voltage regulator of having to make the entire correction with its error signal. This load compensation increases the accuracy of voltage regulation.
2. When two generators are operating in parallel, their voltages are equal. Therefore, any adjustments in the excitation of individual machines can only change the power factor of both machines. This creates circulating reactive currents between machines. In this case, the current signal brought in from the paralleling CT will help regulate the division of reactive line current. This reduces circulating current between machines.



A.



B.

Figure 3-30.—Model 104 voltage regulation. A. Manual mode. B. Automatic mode.

## Model 139 Voltage Regulation

The major components of the model 139 voltage regulator (fig. 3-31) consist of the following:

1. Two voltage regulator assemblies (normal and standby), mounted in the GCU enclosure
2. Motor-operated rheostat for auto voltage regulation, mounted in the GCU enclosure
3. Brushless exciter assembly, mounted on the generator

4. Permanent magnet alternator (PMA), mounted on the generator
5. Auto voltage control RAISE/LOWER switch, mounted in associated SWBD
6. Motor-driven variac for manual voltage adjustment, mounted in the associated SWBD
7. Mode select

The GCU provides brushless exciter field excitation and voltage control in the automatic control modes.

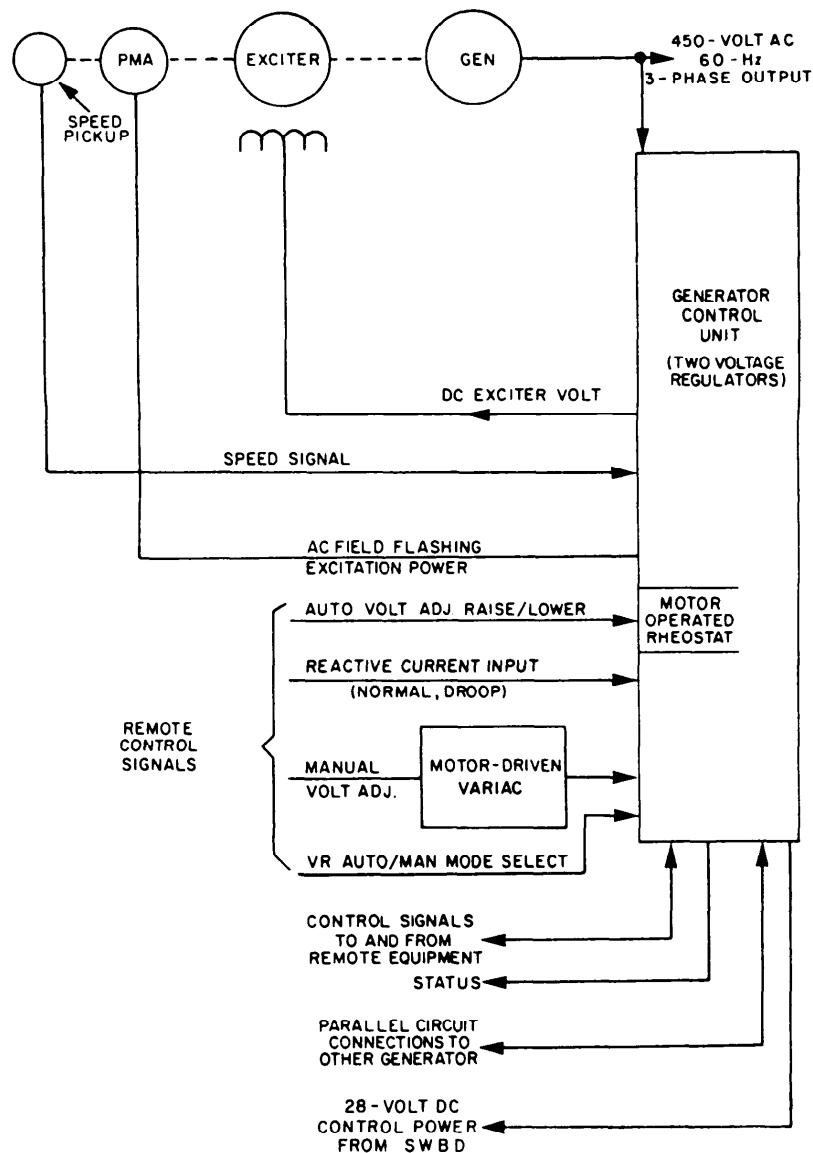


Figure 3-31.—Model 139 voltage regulator functional diagram.

**GENERATOR FIELD EXCITATION.**—Main generator field excitation is supplied by a brushless exciter assembly. The brushless exciter assembly has three main parts: stator, rotor, and rectifier assembly. The rotor and rectifier assembly are attached to the generator shaft. They turn inside the stator that is attached to the generator frame. The operation of the exciter is similar to that of any ac generator. The exception is that the rotor and stator functions have been reversed. When dc is passed through the exciter field winding, lines of magnetic flux are created that pass through the air gap. This creates a 3-phase ac output from the rotor. This 3-phase ac is rectified to dc by the rectifier assembly. It is then conducted through the generator field. An advantage of using this brushless exciter over the brush slip ring type of generator is the greatly reduced maintenance.

**VOLTAGE REGULATOR.**—Two solid-state voltage regulators (normal and standby) control the exciter field in normal automatic operation (fig. 3-32). Indicator lights on the face of the GCU depict which regulator is in use. Overvoltage relays

are provided to automatically switch regulators if a regulator fails. This prevents an overvoltage condition. An indicating light on the face of the GCU will illuminate when a regulator fails. A RESET push button is provided on the face of the GCU. When depressed, it will return control to the (normal) regulator. It also extinguishes the regulator failed light. Manual or automatic control may be selected at the SWBD by the VOLT REG MODE-OFF/AUTO/MANUAL control. The regulators receive their power from the generator output through potential transformers. Thus, on initial start-up of the generator in automatic mode, the voltage regulator will have little or no excitation voltage. To assure that the generator voltage will build up, excitation is obtained from the PMA. A relay internal to the regulator will divert power from the PMA to the generator field until voltage has risen about 340 volts (75 percent of rated). Then, the relay will switch excitation control over to the regulator.

The source of regulator power is the generator output. Therefore, a short circuit on the system will cause the voltage to collapse. This results in

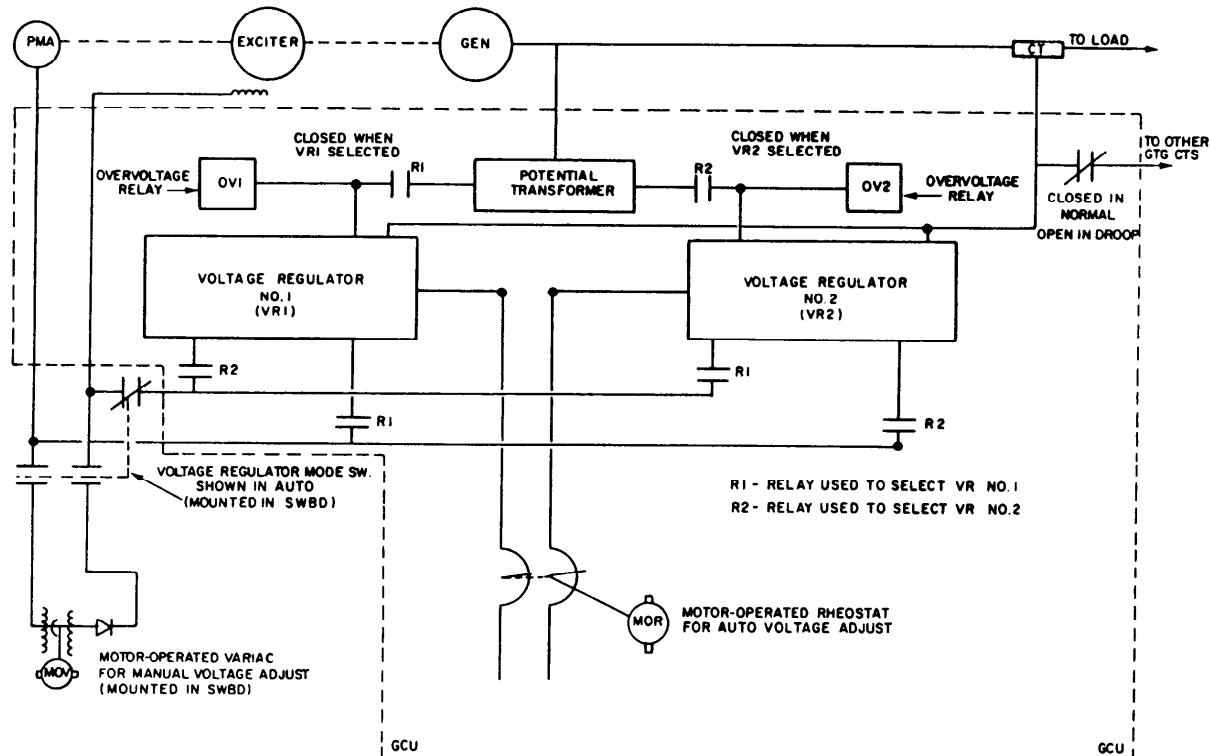


Figure 3-32.—Model 139 voltage regulator.

a loss of excitation voltage. If a short circuit occurs, a relay internal to the regulator will transfer excitation from the regulator to the PMA. This is done if the voltage drops below 225 volts. This will allow the generator to supply enough current to activate overcurrent devices. It will also trip the generator breaker to clear the fault.

In manual operation, the generator excitation is controlled by the motor-operated variac mounted in the SWBD. Power is received from the PMA. It is scaled by the variac, then rectified and conducted to the exciter field. You can make adjustments at the SWBD by turning the manual mode volt adjuster knob (with the VOLT REG MODE switch in the MAN position). When in the manual mode, you may make voltage adjustments from the EPCC. Operation of the voltage LOWER/RAISE control on the EPCC activates the motor-operated variac. In the manual mode, generator voltage will decrease with load unless field excitation is increased. Thus when operating in the manual mode, observe generator operation carefully.

In automatic operation (fig. 3-32), the voltage regulator output supplies control current to the exciter fields. The GCU internal motor-driven rheostat sets the required voltage. Control of this motor is from the SWBD voltage raise/lower control for local operation and the EPCC for remote operation. When in automatic, the MASTER VOLTAGE ADJ located on the EPCC will also operate the motor-operated rheostat in the GCU. It changes the reference for the voltage regulator. This command will be parallel to the GCUs. It will raise or lower the reference to all regulators.

A line current signal is brought in from the paralleling CT. It provides two functions in automatic mode.

1. When two generators are operating in parallel, their voltages are equal. Therefore, any adjustments in the excitation of individual machines can only change the power factor of both machines. This creates circulating reactive currents between machines. In this case, the current signal brought in from the paralleling CT will help regulate the division of reactive line current. This reduces circulating current between machines.
2. When two generators are operating in parallel and in droop mode, the reactive current signal will produce a fixed droop in the voltage output of a generator. If an

individual generator takes on an increased share of reactive current, its voltage will droop more. This, in turn, will tend to transfer some of that reactive current to the other machine. If both machines have equal voltage droop, they will tend to share reactive currents at various loads. The voltage droop is not self-regulating.

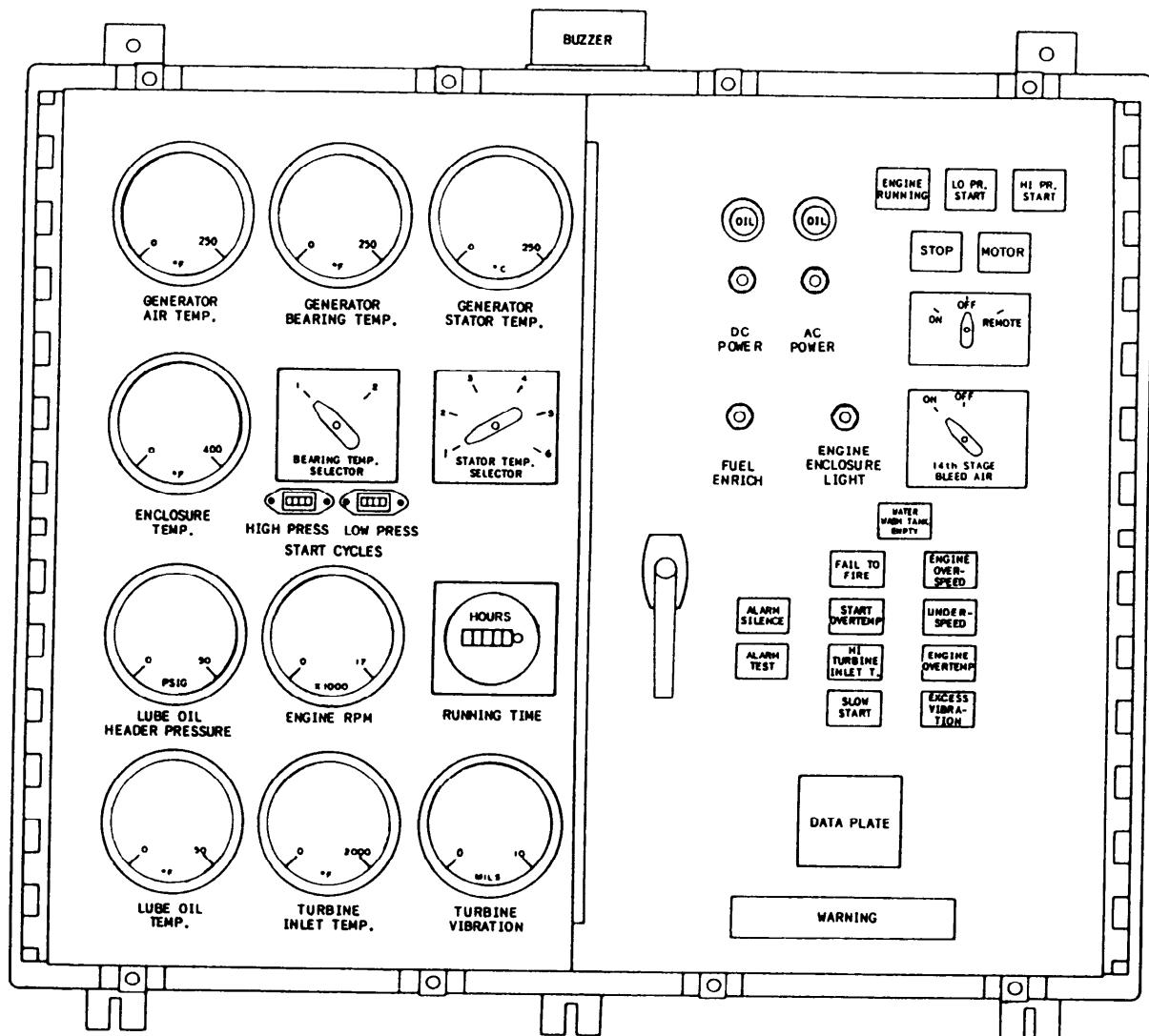
## LOCAL OPERATING CONTROL PANEL

The LOCOP is the major operator interface with the GTGS. It has the controls and indicators necessary to start, stop, motor, and monitor the GTGS operation. The LOCOP is also the interface with the ECSS which provides control of each GTGS at the EPCC. Many of the indicators available at the GTGS LOCOP are not available at the EPCC. This feature requires personnel to monitor the LOCOP during GTGS operation. Usually this monitor is a junior GS. For this reason, you should know and become very familiar with the material in this section.

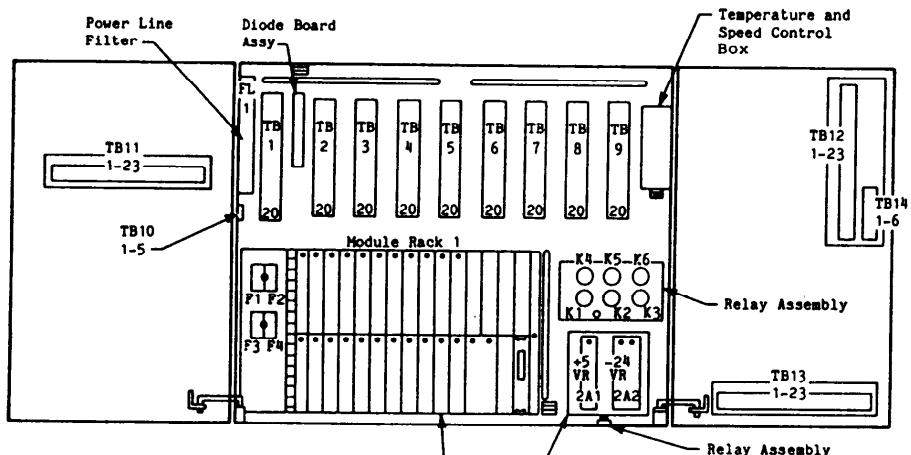
Two LOCOPs are used to control the two different GTGS models. Their construction is very different. They are made by two different manufacturers. Even though they are very different, they provide the engine and the operator almost identical signals and data. Their main difference lies in the method in which their data and signals are provided.

## MODEL 104 LOCOP

The model 104 LOCOP (fig. 3-33, view A) is contained in a cabinet mounted on the generator end of the module. On the outside of the cabinet doors are the controls and indicators for local GTGS operation. Inside the cabinet are the electronic components of the system (view B). Among these components are the logic cards (or PCBs), the 28-volt dc power line filter, power supplies, relays, fuses, and the temperature and speed control unit. Both 115 volts ac and 28 volts dc are required for the operation of the equipment. The 115-volt ac circuits are protected by the F1 and F2 fuses. The control elements of the system are powered by 28 volts dc from the SWBD. The 28-volt dc electronic circuits are supplied through a power line filter, the F3 fuse, and the dc power switch. The ignition exciter is supplied through the F4 fuse and the contacts of a relay operated from the logic circuits.



A.



B.

Figure 3-33.—Model 104 LOCOP. A. External view. B. Internal view.

The SWBD 28-volt dc supply uses a bank of 15 amp-hr lead-acid batteries for backup. This battery bank allows starting of a GTGS when the ship is without 450-volt ac power.

The model 104 LOCOP electronics also include the turbine start/stop sequencing and the turbine temperature and speed control, which is enclosed in its own box.

### Turbine Start/Stop Sequencing

The turbine start/stop sequencing has seven logic card assemblies. Each logic card assembly performs a specific function. The functions of these logic cards are as follows:

- **Relay or solenoid drivers** energize relays or solenoids in response to a signal from a logic unit. They are used because the relay and solenoid coils require more current than can be supplied directly from a logic unit.
- **Contact buffers** minimize the effect of contact bounce (due to the operation of a push button or relay contacts) on a logic input.
- The **RTD signal conditioners** convert generator stator, air, lube oil, and bearing temperature to signals for local and remote monitoring.
- The **RTD temperature/pressure signal conditioner** converts engine enclosure temperature and lube oil header pressure to signals for local and remote monitoring.
- A **set point card** (1850°F to 1870°F) converts the TIT signal from the speed temperature control unit for control of the 14th stage bleed air valve.
- The **vibration signal conditioner** is a special card. It is used to convert the signal from a vibration pickup unit to a signal for local and remote monitoring and alarm when vibration of the turbine occurs.
- The remaining cards are **logic cards** for control, alarm, and alarm control.

### Turbine Temperature and Speed Control Box

The turbine temperature and speed control box (fig. 3-33, view B) is a combination electronic speed switch and temperature amplifier. The box receives a speed signal from a magnetic pickup on the PTO shaft and a temperature signal from the turbine inlet thermocouples. These signals position control relays in four speed channels and five temperature channels within the box. They also provide signals for local and remote monitoring of speed and TIT. In combination with logic circuitry described in the last section, the four speed channels and five temperature channels provide the functions as described in the following paragraphs.

**2200 RPM SPEED CHANNEL.**—Energizes (opens) the fuel shutdown valve and opens the fuel enrichment valve if fuel enrichment has been selected. The fuel enrichment valve will be closed again when the fuel manifold pressure reaches 50 psig. The 2200 rpm speed channel also provides these functions:

- Energizes the ignition system.
- Closes the fuel manifold drain valve.
- Energizes the fuel pump paralleling valve solenoid (closed) to place the fuel pump HP primary and secondary elements in parallel operation.
- Positions the start limit control valve to provide normal acceleration fuel flow. However, the valve circuit remains armed, permitting the valve position to be controlled by the 1500°F temperature channel.
- Arms the fail-to-fire circuit, providing an automatic shutdown through the 600°F temperature channel if 600°F TIT is not reached within 10 seconds.

**8400 RPM SPEED CHANNEL.**—Provides the following functions:

- Positions the paralleling valve to place the fuel pump in series operation.
- De-energizes the ignition system.
- Provides starter cutoff.

**12,780 RPM SPEED CHANNEL**—Provides the following functions:

- Inhibits the start temperature limit valve control circuit to permit TIT to increase above 1525°F.
- Inhibits the start overtemperature shutdown circuit to permit TIT to increase above 1600°F.
- Arms the engine underspeed alarm circuit to enable an alarm to sound if the speed drops below 12,780 rpm after being at 12,780 rpm for more than 2 seconds.

**15,800 RPM SPEED CHANNEL**—Provides engine overspeed protection. If engine speed exceeds 15,800 rpm, an automatic shutdown is initiated.

**600°F TEMPERATURE CHANNEL**—Provides automatic shutdown if 600°F TIT is not reached within 10 seconds after reaching 2200 rpm. It also de-activates the fail-to-fire circuit when 600°F TIT is obtained.

**1500°F TEMPERATURE CHANNEL**—Activates the start temperature limit valve control circuit if 1500°F TIT is reached before the turbine reaches 12,780 rpm. The circuit intermittently energizes the start temperature limit control valve solenoid through a pulse timer. This reduces acceleration fuel flow, and thereby reduces TIT below 1500°F.

**1600°F TEMPERATURE CHANNEL**—Initiates an automatic shutdown if 1600°F TIT is reached below 12,780 rpm.

**1880°F TEMPERATURE CHANNEL**—Causes an alarm to sound if 1880°F TIT is reached.

**1945°F TEMPERATURE CHANNEL**—Starts an automatic shutdown if 1945°F TIT is reached above 12,780 rpm.

## MODEL 139 GTGS LOCOP

The model 139 LOCOP provides start/stop sequencing for the GTGS, monitoring and alarms for critical turbine and generator parameters, signal conditioning for panel meters, and transmission of selected data to the ECSS.

The LOCOP (fig. 3-34, view A) is a cabinet mounted on the generator end of the module. On the outside of the cabinet doors are the controls and indicators for local GTGS operation. Inside the cabinet (view B) are the electronic components of the system. Among these components are printed circuit cards, voltage regulators, a ± 12 volt dc converter module, a relay assembly, and a temperature and speed control unit. The control elements of the system are powered by 28 volts dc from the SWBD. The SWBD 28-volt dc supply has a bank of 15 amp-hr lead-calcium batteries for backup. This battery bank allows starting of a GTGS when the ship is without 450-volt ac power.

The model 139 LOCOP is a computer controlled digital system. It uses a central microprocessor to control and monitor the GTGS. The LOCOP has the necessary power supplies to power all logic and switching level voltages.

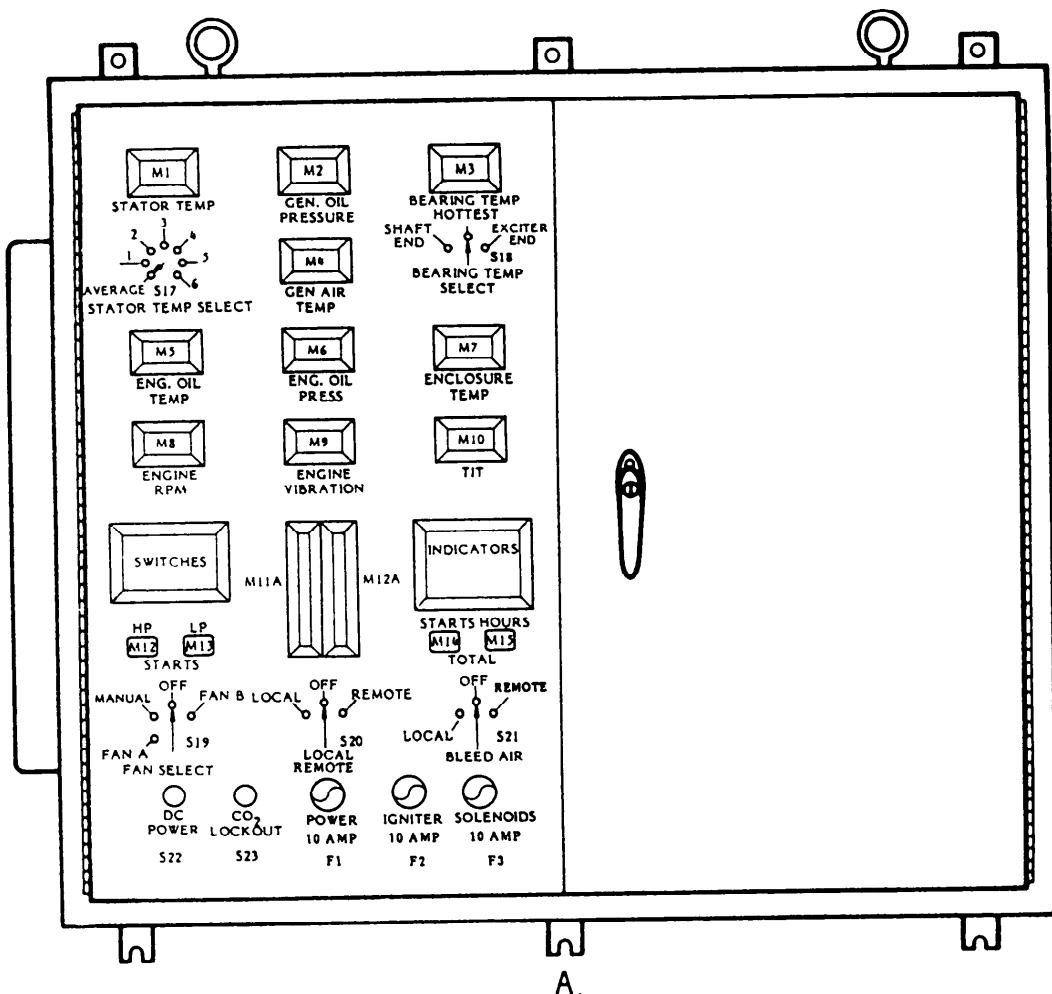
The LOCOP system power supply printed circuit card and associated heat sink are mounted on the left side of the LOCOP cabinet. The power supply has the following components:

1. A dc-dc converter that supplies ± 5 volts dc and ± 15 volts dc
2. A switching power supply that supplies ± 12 volts dc and ± 10 volts dc
3. A switching power supply that supplies ± 5 volts dc

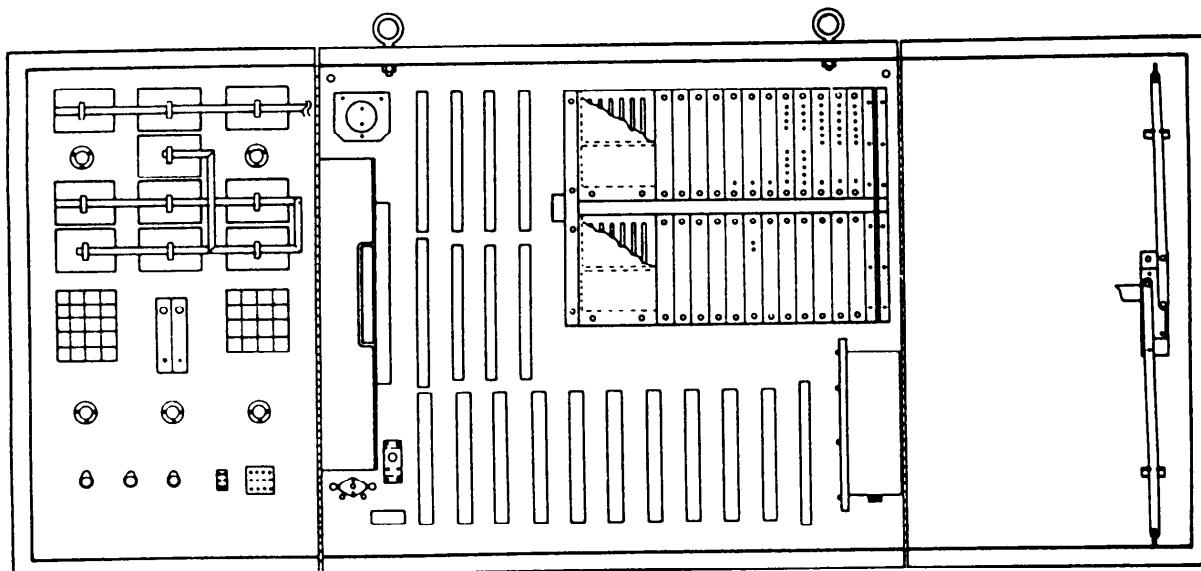
The audible alarm system has a printed circuit card where six different audible signals are electronically generated and any one of the six are programmably selected. The selected signal is then amplified by the alarm amplifier assembly. The amount of amplification is adjustable to fit the environment. The printed circuit card is mounted in the card rack. The alarm amplifier assembly and speaker are mounted externally on the right side of the LOCOP cabinet.

For general description purposes, we have grouped the LOCOP electronics into their associated tasks.

**CPU, MEMORY, AND I/O INTERFACE**—Comprise two microprocessors in the system computer control. The central processing unit (CPU) card has the microprocessor. The memory card has the system control program and data storage memory space. The I/O interface card provides the link between the computer control and the outside world. The LOCOP has two computer control systems for faster, more



A.



B.

Figure 3-34.—Model 139 LOCOP. A. External view. B. Internal view.

efficient control of the GTGS and for backup purposes.

**BUS CONTROLLER**—Generates the system's real time clocks and the synchronization signals. These are required to allow the two computer control systems to operate together.

**I/O MEMORY**—Contains the data storage memory space. It is independent of the computer control memory. This memory may be used by either computer control system where data needs to be shared between them.

**CONTACT BUFFER**—Monitors 16 inputs to interpret a switch closure. Electronics are included to interrupt the microprocessor so the special task requested by the switch can be handled. The card may be programmed to accept normally open or closed contacts. It will interrupt the microprocessor on both transmissions of the switch. Each LOCOP system has two contact buffer cards.

**SWITCH BUFFER**—Monitors 8 inputs to interpret a switch closure. It differs from the contact buffer by interrupting the microprocessors only upon initial closure. The switch release is not buffered. Each LOCOP system has two switch buffer cards.

**LAMP DRIVER**—Contains 8 output driver circuits used to illuminate the visual indicators on the LOCOP front panel. The indicators can burn steadily or flash, depending on the control program. If a lamp fails, circuitry is provided to interrupt the microprocessor to indicate an internal failure. Each LOCOP system has three lamp driver cards.

**RELAY CONTROL**—Contains 8 relays, all independently controlled by the control program. Each relay provides normally open and normally closed contacts. Circuitry also detects a failure of the driver circuits. The circuits will interrupt the microprocessor to indicate an internal failure. Each LOCOP system has two relay control cards.

**SOLENOID DRIVER**—Contains 6 solenoid driver circuits. They are independently controlled by the control program. The circuitry detects a failure of the driver circuits or a shorted solenoid. This circuit will interrupt the microprocessor to indicate an internal failure.

## **DISPLAY CONTROL/DIGITAL METER**—

Receives, from the computer control, the digitized monitor data. It then directs this data to the associated digital display card located on the LOCOP front door. Up to 16 channels may be handled.

## **ANALOG INPUT/MULTIPLEXER, ANALOG-TO-DIGITAL CONVERTER (ADC), AND DIGITAL-TO-ANALOG CONVERTER (DAC)**—

Comprise the monitor data handling system of the LOCOP. The analog input/multiplexer has 8 input circuits with 10-mA output current sources. These inputs are designed to accept a 0- to 10-volt dc signal. The data can be attenuated or amplified by electronics or the control program. Once conditioned, this card multiplexes the data to be digitized by the ADC card. The digitized data is then sent to the I/O memory card for storage. The control program then conditions this data for the digital displays and analog output card. The analog output card can convert up to 8 channels of data to a 0- to 10-volt dc signal. This analog signal can be used depending on the control program. Each LOCOP system has two analog input cards, two analog output cards, and one ADC card.

**VIBRATION MONITOR**—Monitors the engine vibration pickup and scales it for control purposes. The card also splits the signal and sends it to the remote monitor outputs and analog input card. Also, an electronic switch circuit detects high vibration. This switch signals the microprocessor control via a contact buffer input.

**ALARM BOARD**—Generates the alarm tones required for the audible alarm system. Seven tones are possible. The circuitry can also be used to adjust the volume of the audible alarm.

## **I/E CONVERTER**—

Converts current inputs (I) to voltage outputs (E). It converts the 4- to 20-mA pressure transducer current outputs to a 0- to 10-volt dc signal. The circuitry is also used to calibrate the rpm/TIT analog meter on the LOCOP front panel. An electronic switch closure is adjustable for any predetermined rpm set point.

## **ALLISON SPEED/TEMP CONTROL BOX**—

Generates switch closures required by the computer control system to control the GTGS. These include engine speed as well as engine TIT set points. The unit also supplies the signals for the analog rpm/TIT meter located on the LOCOP front door.

The speed and temperature channels on the model 139 are almost identical to the channels used on the model 104 set. A few exceptions are as follows:

- The start temperature limit control valve is not used on the model 139. No signal is sent to it at 2,200 rpm or 12,780 rpm.
- During start above 2200 rpm, the engine must accelerate at a rate of 40 rpm/second over any 3-second period. This is enabled by the 2200-rpm speed channel. If the engine fails to accelerate at that rate, an antistagnation feature will shut down the engine and sound the slow start alarm.
- The 1945°F temperature channel has been reset to 2050°F. This is to allow for higher load transients. The 1880°F temperature channel remains the same.

## SUMMARY

In this chapter we have discussed the construction and operation of the model 104 and

model 139 GTGSs and their differences. We have discussed the construction of the engine, its systems, and its control circuits. We have also discussed the reduction gear, generator, and support systems. After studying this material and completing the associated NRTC, you should be able to start qualifying as an operator of the Allison 501-K17. If your ship does not use these generators for electric power generation, you should know how GTEs are used in constant speed applications.

Chapter 8 of this training manual (TRAMAN) will also give you information to help you understand shipboard electrical equipment. The Gas Turbine Systems Technician rating is rapidly becoming one of the major ratings in the field of shipboard power generation and distribution. To become a competent EPCC operator, you must know not only the GTGS, but also the electric plant of the ship.

Remember, before you attempt to operate any ship's system, but especially one as important as a generator, follow all EOSS procedures. This will help prevent any major casualty from occurring because of operator error.

## CHAPTER 4

# ENGINEERING AUXILIARY AND SUPPORT SYSTEMS

As a GS, you will primarily be assigned to operate and maintain the GTEs. You will also be tasked with the maintenance and repair of some of the auxiliary or support systems. In this chapter we will describe the lube oil (LO) fill and transfer system, the main LO system, the fuel oil (FO) systems, the bleed air system, the compressed air systems, the drainage and ballast systems, the firemain system, the seawater service system, the steam and waste heat systems, and the fire extinguishing systems.

The main propulsion plant could not operate without FO for the engines and LO for the reduction gears or salt water for cooling. All these systems and others are part of the overall main propulsion plant and are in your areas of responsibility. You will be assigned to perform PMS, repair, and maintain the numerous pumps, valves, and piping associated with these systems. You may also be assigned to the oil lab and have to maintain and test the ship's FO and LO. As a member of the oil lab on the CG-, and DD-class ships, your area of responsibility will also include the waste heat boiler (WHB) water chemistry.

In volume 1, chapter 7, NAVEDTRA 10563, of this TRAMAN series, you learned about the various types of pumps and valves and their uses. In this chapter you will learn about the different ships' engineering systems, how they relate to the propulsion plant, and how the pumps and valves are used in the systems. Since the engineering systems vary between ship classes, we will describe the systems in general terms. The examples of the systems we show in this chapter are from various ship classes. Always consult your ship's EOSS for detailed information on these systems. Your diligence in the maintenance and upkeep of these systems is extremely important since the ship could not operate properly if any of these systems should fail.

### LUBE OIL SYSTEM FUNDAMENTALS

To understand the functions and importance of the LO fill, transfer, and purification system, and the main LO system, you first need to understand the fundamentals of lubrication. The lubrication requirements of shipboard machinery are met in various ways, depending on the nature of the machinery. In the following paragraphs we discuss the basic principles of friction and lubrication, the effects of friction and fluid lubrication, the classification of lubricants, and the properties of LO used aboard ship. We also discuss the lubrication systems installed for many shipboard units and the devices used to maintain LO in the required condition of purity.

### FRICTION AND LUBRICATION

The friction that exists between a body at rest and the surface upon which it rests is STATIC friction. The friction that exists between moving bodies (or between one moving body and a stationary surface) is KINETIC friction. Static friction, in addition to inertia, must be overcome to put any body in motion. Static friction is greater than the kinetic friction, which must be overcome to keep the body in motion.

The three types of kinetic friction are sliding friction, rolling friction, and fluid friction. Sliding friction exists when the surface of one solid body moves across the surface of another solid body. Rolling friction exists when a curved body, such as a cylinder or a sphere, rolls upon a flat or curved surface. Fluid friction is the resistance to motion exhibited by a fluid.

Fluid friction exists because of the cohesion between particles of the fluid and the adhesion of fluid particles to the object or medium that is tending to move the fluid. If a paddle is used to stir a fluid, for example, the cohesive forces between the molecules of the fluid hold the

molecules together and thus prevent motion of the fluid. The adhesive forces of the molecules of the fluid cause the fluid to adhere to the paddle and thus create friction between the paddle and the fluid. Cohesion is the molecular attraction between particles that holds a substance or body together; adhesion is the molecular attraction between particles that causes unlike surfaces to stick together. In lubrication, adhesion is the property of a lubricant that causes it to stick (or adhere) to the parts being lubricated; cohesion is the property that holds the lubricant together and enables it to resist breakdown under pressure.

Different materials have cohesion and adhesion in widely varying degrees. In general, solid bodies are highly cohesive but only slightly adhesive. Most fluids are highly adhesive but only slightly cohesive; however, the adhesive and cohesive properties of fluids vary considerably.

Lubrication reduces friction between moving parts by substituting fluid friction for sliding or rolling friction. Without lubrication, moving a 100-pound weight across a rough surface is difficult; however, with lubrication and proper attention to the design of bearing surfaces, a 1-million-pound load can be moved with a motor that is small enough to be held in the hand. By reducing friction, lubrication reduces the amount of energy required to perform mechanical actions and also reduces the amount of energy that dissipates as heat.

Lubrication is important throughout the shipboard engineering plant. Moving surfaces must be steadily supplied with the proper kinds of lubricants. Lubricants must be maintained at specified standards of purity and at designed pressures and temperatures in the lubrication systems. Without adequate lubrication, many units of shipboard machinery would quite literally grind to a screeching halt.

A liquid is used for most lubrication requirements because, in an enclosed space, a liquid is incompressible. Were it not for this incompressibility, separating moving metal surfaces from each other (preventing metal-to-metal contact) would be impossible. As long as the lubricant film remains unbroken, fluid friction replaces sliding friction and rolling friction.

In any process involving friction, some power is consumed and some heat is produced. Overcoming sliding friction consumes the greatest amount of power and produces the greatest amount of heat. Overcoming fluid friction

consumes the least power and produces the least amount of heat.

Several factors determine the effectiveness of oil film lubrication, such as pressure, temperature, viscosity, speed, alignment, condition of the bearing surfaces, running clearances between the bearing surfaces, starting torque, and the nature of the lubricant's purity. Many of these factors are interrelated and interdependent. For example, the viscosity of any given oil is affected by temperature, and the temperature is affected by running speed; hence, the viscosity is partially dependent on the running speed.

A lubricant must be able to stick to the bearing surfaces and support the load at operating speeds. More adhesiveness is required to make a lubricant adhere to bearing surfaces at high speeds than at low speeds. At low speeds, greater cohesiveness is required to keep the lubricant from being squeezed out from between the bearing surfaces.

Large clearances between surfaces require high viscosity and cohesiveness in the lubricant to ensure maintenance of the LO film. The larger the clearance, the greater must be the lubricant's resistance to being pounded out with consequent destruction of the LO film.

High unit load on a bearing requires high viscosity of the lubricant. A lubricant subjected to high loading must be sufficiently cohesive to hold together and maintain the oil film.

## LUBRICATING OILS

Lube oils approved for shipboard use are limited to those grades and types that provide proper lubrication under all anticipated operating conditions. In the following paragraphs, we will discuss the classification and properties of LO. The *Naval Ships' Technical Manual*, Chapter 262, "Lubricating Oils, Greases, Hydraulic Fluids, and Lubrication Systems," is a good source for additional information (not covered in the following paragraphs) on LO.

### Classification of Lube Oils

The Navy identifies LO by symbols. Each identification number has four digits and, in some cases, appended letters. The first digit shows the class of oil according to type and use; the last three digits show the viscosity of the oil. The viscosity digits show the number of seconds required for a 60-milliliter (ml) sample of oil to flow through a standard orifice at a certain temperature.

Symbol 3080, for example, shows that the oil is a 3000 series oil and that a 60-ml sample should flow through a standard orifice in 80 seconds when the oil is at a certain temperature (210°F, in this instance). Another example is symbol 2135 TH. This symbol shows that the oil is a 2000 series oil and that a 60-ml sample should flow through a standard orifice in 135 seconds when the oil is at a certain temperature (130°F, in this case). The letters *H*, *T*, *TH*, or *TEP* added to a basic number indicate a primary specific use within the general category. In this case it indicates the oil contains additives for special purposes.

## Properties of Lube Oils

Lube oils used by the Navy are tested for several properties. These include viscosity, pour point, flash point, fire point, autoignition point, neutralization number, demulsibility, and precipitation number. Standard test methods are used for each test. The properties of LO are briefly explained in the following paragraphs.

- **Viscosity**—The viscosity of an oil is its tendency to resist flow or change of shape. A liquid of high viscosity flows very slowly. In variable climates, for example, automobile owners change oil according to the seasons. Oil changes are necessary because heavy oil becomes too thick in cold weather, and light oil becomes too thin in hot weather. The higher the temperature of an oil, the lower its viscosity becomes; lowering the temperature increases the viscosity. On a cold morning, the high viscosity or stiffness of the LO makes an automobile engine difficult to start. The viscosity must always be high enough to keep a good oil film between the moving parts; otherwise friction will increase, resulting in power loss and rapid wear on the parts.

Oils are graded by their viscosities at certain temperatures. The grade is determined by the number of seconds required for a given quantity (60 ml) of the oil at the given temperature to flow through a standard orifice. The right grade of oil, therefore, means oil of the proper viscosity.

Every oil has a viscosity index based on the slope of the temperature-viscosity curve. The slope of the curve is based on the rate of change in viscosity of a given oil with a change in temperature, but with other conditions remaining unchanged. A low index figure means a steep slope of the curve, or a great variation of viscosity with a change in temperature; a high index figure

means a flatter slope, or lesser variation of viscosity with the same changes in temperatures. If you are using an oil with a high viscosity index, its viscosity or body will change less when the temperature of the engine increases.

- **Pour point**—The pour point of an oil is the lowest temperature at which the oil will barely flow from a container. At a temperature below the pour point, oil congeals or solidifies. Lube oil used in cold weather operations must have a low pour point. (**NOTE:** The pour point is closely related to the viscosity of the oil. In general, an oil of high viscosity will have a higher pour point than an oil of low viscosity.)

- **Flash point**—The flash point of an oil is the temperature at which enough vapor is given off to flash when a flame or spark is present. The minimum flash points allowed for Navy LO are all above 300°F, and the temperatures of the oils are always far below that under normal operating conditions.

- **Fire point**—The fire point of an oil is the temperature at which the oil will continue to burn when ignited.

- **Autoignition point**—The autoignition point of an oil is the temperature at which the flammable vapors given off from the oil will burn without the application of a spark or flame. For most LO, this temperature is in the range of 464° to 815°F.

- **Neutralization number**—The neutralization number of an oil indicates its acid content. It is defined as the number of milligrams of potassium hydroxide (KOH) required to neutralize 1 gram of the oil. All petroleum products deteriorate (oxidize) in the presence of air and heat; the products of this oxidation include organic acids. If organic acids are present in sufficient concentration, they have harmful effects on alloy bearings at high temperatures, on galvanized surfaces, and on the demulsibility of the oil with respect to fresh water and seawater. This last effect, in turbine installations, may result in the formation of sludge and emulsions too stable to be broken by the means available. An increase in acidity is an indication that the LO is deteriorating.

- **Demulsibility**—The demulsibility, or emulsion property, of an oil is its ability to separate cleanly

from any water present—an important factor in forced-feed systems.

- Precipitation number—The precipitation number of an oil indicates the amount of solids classified as asphalt or carbon residue contained in the oil. The number is reached when a known amount of oil is diluted with naphtha and the precipitate is separated by centrifuging. The volume of separated solids equals the precipitation number. This test detects the presence of foreign materials in used oils. An oil with a high precipitation number may cause trouble in an engine. It could leave deposits or plug up valves and pumps.

### LUBE OIL FILL, TRANSFER, AND PURIFICATION SYSTEM

The LO fill, transfer, and purification system is shown in figure 4-1. This system provides the means for storing, transferring, purifying, and

heating MRG and CRP/CPP lube oil. The major components of this system are the LO storage tanks, LO settling tanks, LO purifier, and interconnecting piping and valves.

The LO fill, transfer, and purifying system is used to fill the LO storage tanks and to transfer LO between the storage, settling, and sump tanks. It purifies the LO with the centrifugal oil purifier and preheats the reduction gear LO before MRG operation. You can set the system up for either batch purification of one tank or for continuous purification using the purifier. The LO for the reduction gear is the same type as the hydraulic oil for the CRP system. The purifier is used for both systems.

### STORAGE AND SETTLING TANKS

Replenishment oil for the MRG, CRP system and, in some cases, other machinery is stored in bulk in the LO storage tanks. These tanks are filled from a deck connection located near the replenishment stations. These tanks must be kept

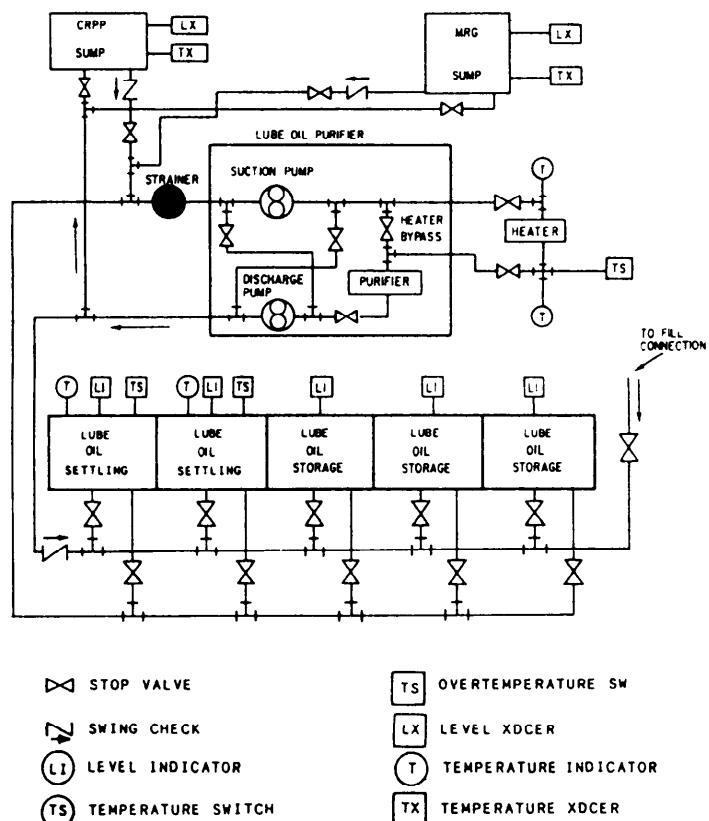


Figure 4-1.—Typical LO system.

very clean because the oil stored in them can go directly into either the MRG or the CRP system.

Lube oil levels within these tanks are monitored by a liquid level indicating system. The two components in this system are the transmitter and the indicating meter.

The transmitter is the level detector unit mounted vertically within the tank by brackets or flanges. A magnet-equipped float moves along the transmitter subassembly to vary a voltage, which causes the meter to show the number of gallons of oil in the tank.

Storage tanks are nothing more than small enclosed compartments with fill and suction piping connected to them. These storage tanks also have overflow piping attached to prevent overfilling and overpressurizing the tanks.

Settling tanks are similar to storage tanks except that they have heating coils installed in them to speed up the settling process. Settling tanks allow the oil to stand while accumulated water and other impurities settle to the bottom. The settling action is caused by the difference in specific gravity of the impurities and oil. The force of gravity causes several layers of contamination to form at the bottom of the tank; the number of layers depends on the different specific gravities of the contaminants. The heaters not only speed up the settling but also increase the efficiency of the process.

In Navy ships, combined storage and settling tank capacity is two times the combined capacity of the involved LO sumps. The recommended LO storage on hand is one for one; that is, for each gallon of sump capacity, a gallon should be in on-hand storage.

## LUBE OIL PURIFIERS

Centrifugal purifiers, frequently called centrifuges, are used extensively in naval service to remove LO impurities. A centrifuge is a bowl or hollow cylindrical vessel that rotates at high speed while a liquid (in this case contaminated oil) passes through it. The centrifugal force created by the high rotative speed acts perpendicular to the axis of rotation and causes solid impurities to be deposited on the bowl's inner surface. Water entrained in the oil is segregated in a layer between the solid impurities and the remaining purified oil.

A centrifuge can separate only materials that are insoluble in one another. For example, gasoline and diesel fuel cannot be separated from LO; likewise, salt cannot be removed from

seawater. This is because they are in solution. Water, however, can be separated from oil because water and oil are immiscible (incapable of being mixed). Also, the specific gravities of the materials to be separated must differ. Particle size, fluid viscosity, and length of the centrifuge period influence the effectiveness of the centrifugal process. In general, the greater the difference in specific gravity between the liquids to be separated and the lower the viscosity of the oil, the greater the rate of separation. Lube oils are heated before being centrifuged to decrease their viscosity.

Centrifugal purifiers used on naval ships have bowls of two types, tubular and disc. Refer to volume 1, chapter 7, of this TRAMAN series, for additional information on these purifiers.

**1. Tubular type.** The tubular type has a small diameter and rotates at a comparatively high speed. The bowl has a three-wing device that keeps the liquid rotating at the speed of the bowl and prevents slippage. The tubular bowl is fed through a nozzle at the bottom.

**2. Disc type.** The disc type is large in diameter and rotates at a comparatively lower speed. This bowl is fitted with a series of discs that separates the liquid into thin layers. Liquid is ordinarily fed directly toward a series of holes punched through the disc stack; the liquid flows upward through these holes, depending on specific gravity.

In both the tubular and disc types, separated oil moves toward the center for discharge into one of the covers; the separated water moves toward the outside and is delivered from the bowl into the other cover. Solids separated from the liquids are retained in the bowls.

Some ships are being outfitted with a self-cleaning centrifugal purifier whose operation is similar to the self-cleaning FO purifier. It is capable of purifying up to 500 gpm LO to not more than 0.3 percent water and not more than 0.02 percent solids.

## Purification of Lube Oil

The purity of LO is essential to the operation of the ship's machinery. Dirt, sludge, water, or other contaminants will act as abrasives to score and scratch metal surfaces. Contaminants in oils used for hydraulic applications, such as in the CRP system, could clog small ports and filtering mechanisms in the controls.

Two primary methods of purification are in use at the shipboard level. One method is the

batch method and the other is the continuous method.

**BATCH METHOD.**—In the batch process, the LO is transferred from the sump to a settling tank. The oil is heated in the settling tank. There its temperature is maintained at  $160\pm5^{\circ}\text{F}$  for 2190 TEP for several hours by steam-heating coils or electric heaters. Water and other impurities are stripped from the settling tank through a drain valve. The oil is then centrifuged and returned to the sump from which it was taken. Alternatively, oil may be transferred from the sump to a settling tank. You can replenish the sump tank with clean oil immediately by transferring oil from the storage tank via the purifier. After the oil in the settling tank has been heated, allowed to settle, and then stripped, it is centrifuged and transferred back to the storage tank.

**CONTINUOUS METHOD.**—In the continuous purification process, the centrifugal purifier takes suction from a sump tank and, after purifying the oil, discharges it back to the same sump. As the oil passes through a heater, its temperature is raised to the correct level. All oil must be returned to the sump from which it was taken. All ships with forced lube systems equipped with centrifugal purifiers will operate the purifiers while underway until no visible water remains in the oil and no water is discharged from the purifier. Generally, the MRG lube oil system must be purified 12 hours daily. On gas turbine ships the CRP oil must be purified for 8 hours, with the remaining 4 hours of the day reserved for cleaning the purifier.

When the main propulsion equipment is secured, the LO should be purified until no water is discharged from the purifier. Also, all oil in the lube system should be pumped to the settling tanks and renovated each year.

### **Sampling of Lube Oil**

When monitoring LO, you must sample the oil properly because an improper sample produces unreliable test results. You should be sure your samples are representative of the oil you are testing. Thoroughly clean and inspect the sampling containers. Before using the containers, flush them with the oil to be sampled. Cap all sample containers promptly after sampling to prevent contamination.

Sampling of lube oil should be done the following the directions of NSTM Chapter 262 and shipboard PMS procedures. When conducting shipboard tests, you should follow the sampling procedures listed in Naval Ships' Technical Manual, chapter 262, beginning at paragraph 262-8.1.22. After testing is completed, deposit lightly contaminated oil into the LO settling tank for purification and reuse. Place grossly contaminated samples in the contaminated

LO holding tank. When applicable, return satisfactory samples to the sump to prevent inadvertent depletion of the sump. Never dispose of oil samples in the bilges or other pollution-producing areas.

Each ship is required to have a LO management program. The LO management program has two parts.

1. An onboard sampling and testing program
2. The Navy Oil Analysis Program (NOAP), which is an off ship oil test program

In the onboard LO program, all designated operating machinery is sampled on a periodic basis. The samples are then compared to samples of the original oil installed in the machinery. A LO sample rack is installed in a designated area that contains the sample bottles. The original oil installed in each piece of machinery is sampled. This sample is dated and used as the basis of comparison for all other samples. Samples are taken on the following schedule:

1. Daily—operating machinery at sea or in port
2. Prior to starting all machinery
3. After casualty to machinery
4. When ordered by the engineering duty officer (EDO)/EOOW

The sample rack contains one sample bottle for each piece of machinery. A log of all samples taken and the condition of each sample is maintained and initialed by designated personnel.

The NOAP provides spectrometric analysis of a ship's LO at a designated laboratory. This program can be used to detect accelerated wear in machinery, without the machinery being disassembled, long before any other trouble is indicated. Lube oil samples of selected equipment are submitted to the laboratory on a periodic basis for examination. The ship is advised of the test results by the testing activity. The ship maintains accurate records of operating hours after major overhauls, oil changes, and any repairs effected as a result of recommendation by the laboratory.

## MAIN LUBE OIL SYSTEM

All GTE-powered ship classes have the same basic LO service system. In this section we will describe the basic system and components and point out (where applicable) the differences in the design of some ships' LO systems. If no difference is noted in the description, the reader can assume the component to be basically the same on all classes of GTE-powered ships.

## SYSTEM LUBE OIL FLOW

The pumps take suction from the MRG sump through check valves. The check valves maintain system prime (that is, they ensure the suction line to the pump and the pump casing remain full) and prevent reverse flow of oil through a secured pump. The pumps supply oil under pressure to a common line where the unloader valve returns oil in excess of demand to the MRG sump. Oil from the common line flows to the LO cooler, where its temperature is reduced to about 120°F. From the cooler, oil flow is divided into two paths, one to supply the MRG and the other to supply the two LOSCA coolers. Oil to the MRG flows through the duplex filter into the MRG lube oil header. From the MRG header, oil is distributed to lubricate and cool the reduction gear components, the clutch/brake assemblies, and the thrust bearings. The oil then returns to the sump. Oil to each LOSCA passes through a pneumatically controlled valve. This valve controls oil flow to the synthetic LO cooler to regulate temperature at the synthetic oil discharge. Service system LO from the LOSCAs join in a common line to return to the MRG sump.

## SYSTEM COMPONENTS

The reduction gear LO service system is a closed loop system with the sump tank vented to the atmosphere. Circulation of the LO (as described in system flow earlier) is accomplished by pumps. In this section we will describe the components the LO passes through during this circulation. They include (1) the LO sump, (2) the LO pumps, (3) the unloading valve, (4) the temperature regulating valve, (5) the LO cooler, (6) the LO filter, and (7) the main LO header.

### Lube Oil Sump

The MRG lube oil sump is located in the inner bottom beneath the MRG. The sump

contains the supply of oil for the main LO service system. It collects and retains oil as it returns from the MRG, main thrust bearing, and propulsion turbine synthetic LO system coolers. The LO return from the MRG to the main sump has a convoluted flexible connection bolted between the MRG oil pan and the top of the sump. The normal operating capacity is 1500 to 1550 gallons, and the low operating level is 1400 gallons. When the sump is filled to the operating level, the pump suction bellmouths will be submerged under all operating conditions. The pump suctions are located away from the turbulent area so the oil is permitted to deaerate before entering the suctions. The sump is designed to allow free drainage of pockets formed by stiffeners inside the sump and to allow access for inspection and cleaning. Lube oil return drains are located as far as possible from suction bellmouths. Structural members in the tank act to smooth the turbulence in the oil return area. The sump is equipped with a sludge pit located at the lowest point. It is also equipped with a liquid level transmitter, an RTE, pump and purifier suction connections, and oil return connections.

### Lube Oil Pumps

Three positive-displacement LO pumps are used to supply oil to the MRG and the LOSCAs for the propulsion GTEs with an adequate amount of filtered, heated, and purified oil during normal ship operations.

#### **CG, AND DD LUBE OIL PUMPS.—**

Three positive-displacement LO pumps are installed in each engine room. There are two electric-motor driven LO pumps and a third LO pump that is attached to and driven by the MRG. Each of the electric-motor driven units has a vertical screw, positive-displacement pump that is flexibly coupled to a two-speed electric motor mounted on a common steel bracket. Resilient mounting is used between the bracket and the ship's structure. The pump is rated at 700 gpm at high speed and 250 gpm at low speed at a discharge pressure of 60 psig. The pumps take suction from the MRG sump through a common suction line and discharge to the LO service piping.

The attached LO pump is of a similar design to the motor-driven pumps. The principal difference is in the larger size and greater rated capacity. The attached pump is rated at 1140 gpm

at 60 psig discharge pressure and 1220 rpm (about 168 shaft rpm (srpm)). The attached pump is supported by a bracket immediately above the LO sump top. It is driven by the MRG lower inboard second-reduction pinion shaft through a right angle drive. The angle drive is equipped with a manually operated disconnect device that may be used to disconnect the attached pump when the main shaft is stopped. The attached pump takes suction from the sump through an individual suction line and discharges into the LO service piping system. The pump speed is proportional to shaft speed; therefore, the attached pump does not deliver enough oil by itself to lubricate the MRG and to cool the GTE synthetic oil until higher shaft speeds are reached. The attached LO pump is engaged or disengaged by a lever attached to the pump coupling.

The motor-driven pumps supply oil to the system when the propulsion shaft is stopped and augment the attached pump at low shaft speeds. The motor-driven pumps are controlled by the ECSS pump logic as a function of pressure at the inlet to the MRG lube oil header. The output of the attached pump is not controlled and is proportional to shaft speed. Primary system pressure regulation is accomplished by the unloader valve. When the ship's speed increases and the total pump output exceeds the regulating capacity of the unloader, MRG inlet pressure increases. The ECSS pump control logic then sequences the motor-driven pumps to change to a slower speed or secure to maintain oil pressure in the normal operating range. When the pump control logic has sequenced both motor-driven pumps to secure, the attached pump supplies the total LO system requirements. A similar control sequence operates to maintain oil pressure when shaft speed decreases. As shaft speed decreases and LO pressure drops, the ECSS pump logic will start the appropriate pump(s) and control their speed to maintain normal LO pressure.

The pumps may be controlled locally at their respective controllers. With the LOCAL-REMOTE selector switch in LOCAL, the STOP-SLOW-FAST selector switch is operative. With the LOCAL-REMOTE selector switch in the REMOTE position, control is transferred to the ECSS.

**FFG LUBE OIL PUMPS.—**This class of ship also has three LO pumps. Two of the LO pumps are two-speed, motor-driven, vertically mounted, screw-type pumps. The third LO pump is an air-motor driven, vertically mounted, screw-type

pump. The system controls allow either electric pump to be designated NORMAL with the other designated as STANDBY. The normal pump runs at low speed only for preheating the LO and runs at high speed during normal operating conditions. With the pump controller mode switch in the AUTO position, operation of the pumps is controlled by a set of pressure switches. If the oil pressure to the reduction gear hydraulically most remote bearing begins to drop below 13 psig, a pressure switch closes and causes the standby pump to start operating at low speed. If the oil pressure continues to drop below 11 psig, another pressure switch closes and the standby pump switches to high speed. A further drop in pressure to 9 psig closes a third pressure switch. It also causes the air-motor driven coast down pump to start operating by opening the solenoid valve to the coast down pump air motor.

When the oil temperature is below 90°F, preheating of the oil is required. A connection to the lube oil fill, transfer, and purification system allows use of one of the LO service pumps to circulate oil through the LO purifier heater. Priming lines are provided at each pump so that the operation of either service pump will maintain a continuous oil prime to the other two pumps. A relief valve set at 80 psig is located at each service pump discharge to protect the system from overpressurization.

If the propeller shaft is rotating during an electric power failure on the ship, the electric pumps stop. This loss of pressure causes the LO coast down pump to start and continue to run until the propulsion plant can be secured. The duration of operation of this pump is limited by the quantity of air stored in the HP air flasks provided in the engine room. The discharge of the coast down pump goes into the reduction gear oil inlet header via the LO service filter. The discharge bypasses the rest of the LO service system. If the electric pumps restore normal system pressure to 15 psig, a pressure switch opens and the air solenoid valve that controls air flow to the pump motor closes and stops the coast down pump. The coast down pump also stops if the propulsion shaft stops rotation.

### Unloading Valve

This air pilot-operated valve senses the oil pressure at the reduction gear hydraulically most remote bearing and regulates the oil supply flow to maintain 15 psig at that bearing. If the sensed pressure exceeds 15 psig, the valve will open and

return excess system flow to the LO sump tank. The valve is fully open at a sensed pressure of 20 psig. Control air from the ship's LP vital air main is used for the operation of this valve.

### Temperature Regulating Valve

This air pilot-operated valve is located at the inlet to the LO cooler and regulates the amount of oil flow through the cooler. The temperature sensing element is mounted in the oil supply piping to the reduction gear. Based on the signal from the temperature sensor, the valve regulates the amount of flow through the cooler and bypasses the rest. The valve is set to maintain a  $110 \pm 5^{\circ}\text{F}$  oil temperature to the reduction gear. Control air from the ship's LP vital air main is used for operation of this valve.

### Lube Oil Cooler

The LO coolers are designed to maintain the LO temperature at  $110 \pm 5^{\circ}\text{F}$ . The coolers on the different class ships have physical differences, but they function the same. We will describe these differences in the following paragraphs.

#### CG, AND DD LUBE OIL COOLER.—

A LO cooler is installed in each LO service system downstream from the LO pumps. The cooler has a shell assembly, a tube bundle, and inlet and outlet water boxes. The cooler is a single-pass shell and tube type of heat exchanger. Seawater is used as the cooling medium. It enters the inlet water box through the inlet connection, makes one pass through the tubes, and is discharged through the outlet water box. Seawater flow is regulated by a pneumatically operated valve controlled by a temperature sensor installed in the LO piping downstream from the cooler. The LO inlet is at the opposite end from the water inlet, resulting in counterflow heat transfer.

#### FFG LUBE OIL COOLER.—

This cooler is made of two shell and tube type of heat exchangers piped in series. Seawater from the main seawater cooling system circulates through the tubes in a single pass through each shell of the cooler in series. The LO flows through each shell in series. The oil enters the cooler through the upper shell and leaves the cooler through the lower shell. Vent connections are provided on both the upper shell and water box, and drain connections are provided on the lower shell and water box.

## Lube Oil Filter

The LO filter has two separate filter housings connected by interlocked inlet and outlet valves arranged so only one housing is in operation at a time. Each filter housing contains 14 filter elements rated at 65 microns. You can clean and reuse the filter elements. Each filter housing has vent and drain connections. The filter is installed in the piping downstream from the LO cooler to remove particulate matter from the LO. The filter has a single cast steel body mounted on a fabricated steel base. The filter body contains two filter chambers and a diverting valve assembly. The diverting valve connects the filter chambers to the inlet and outlet ports. The filter chambers are covered by bolted steel plates.

A manually operated changeover assembly positions the diverting valve to place the right or left filter element in service. The selector lever is positioned over the chamber selected. A hydraulic interlock prevents the shifting of oil flow to an open (nonpressurized) filter chamber. An interlock cylinder is connected to each of the filter chambers. When a differential pressure exists between the chambers, the cylinders engage a notch in the diverting valve cam plate and positively lock the selector lever. The changeover assembly has a balancing valve that is used to equalize pressure between the chambers to allow shifting. The assembly also fills the filter chamber

after cleaning. Each filter chamber has a vent and a drain.

The liftout filter elements are pleated wire cloth, supported by inner and outer perforated metal tubes. Magnets, supported inside each filter element, remove ferrous particles from the oil.

## Header

Oil is supplied to the MRG and accessories by the ship's main LO service system through a single oil inlet LO header. The header has spray bar assemblies equipped with spray nozzles to lubricate all gear and pinion teeth. The spray nozzles are arranged to direct oil across the full width of the teeth at the gear mesh. This properly lubricates tooth bearing surfaces and dissipates heat generated during operation.

Safety orifice plates are used for journal and thrust bearings. The openings are sized to allow sufficient lubrication under normal conditions but to restrict excessive flow, such as that caused by extreme bearing wear or bearing failure. These orifice plates are installed in the flange joints connecting the oil supply line to each bearing. Orifice plugs are installed in the bearing seats for the high-speed pinions and input shafts.

## SYSTEM MONITORING

During operation, another one of your duties as watch stander is to monitor the LO system.

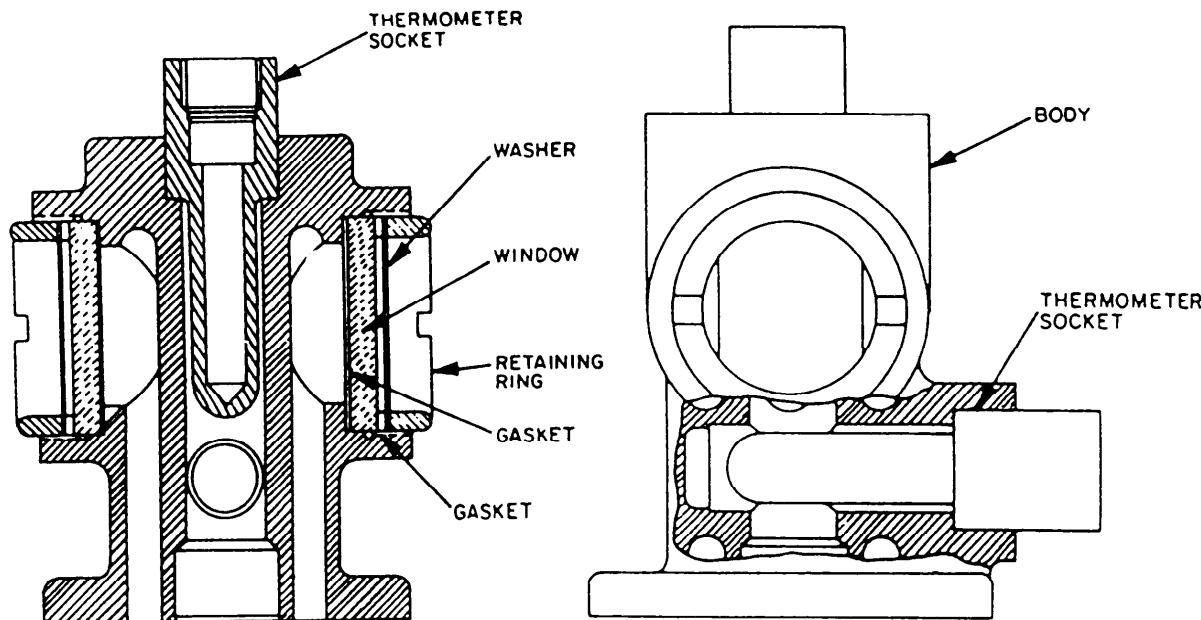


Figure 4-2.—Liquid sight indicator.

Various components/devices installed in the system will assist you in this duty. We will describe a few of these aids in the following paragraphs.

A liquid sight indicator (fig. 4-2) is provided at each main bearing. Each indicator has a fitting with a bull's eye through which you can see a stream of oil flowing from the bearing, a fitting for a dial-type thermometer, and a well for installation of remote reading RTEs.

Lube oil pressure at the inlet to the header is sensed by both a pressure transducer and a pressure switch. The transducer sends signals to ECSS for METER/DDI display, pump logic operation, data logging, and HEADER PRESS HI/LO alarming at the PAMCE and the PLOE. The pressure switch provides the permissives for the turning gear and GTE starting.

Most remote bearing LO pressure is sensed by a transducer located at the lower outboard first-reduction gear bearing.

A temperature switch, located in the clutch/brake oil inlet, is set to open contacts at 130°F to prevent clutch/brake operation. A temperature sensitive bellows actuates a switch to open or close electrical contacts at the set point.

A temperature transducer, located at the inlet to the header, will provide you with both meter displays and a HEADER TEMP HI/LO alarm at the PAMCE and the PLOE.

## FUEL SYSTEMS

The gas turbine ships carry two types of FO aboard-fuel, naval distillate, NATO symbol F-76 (formerly designated as diesel fuel, marine (DFM)), and JP-5, NATO symbol F-44. Fuel, naval distillate is identified as MIL-F-16884.

Fuel, naval distillate is the type of FO normally used for the GTEs, with JP-5 being an alternate FO that can be used when necessary. While JP-5 may be used for the ship's propulsion plant, its main purpose is for use in the helicopter assigned to the ship for antisubmarine warfare (ASW) operations. Both of these FOs must be delivered to the equipment in a clean and water-free state. This is the purpose of the ship's FO system.

The shipboard FO system is basically a method of receiving, storing, purifying, and removing FO from the ship. The bulk FO is stored throughout the ship in storage tanks. The FO is then taken from the storage tanks through the transfer system to the service tanks. The transfer system removes water and contaminants from the FO and prepares it for use in the GTE. The service tanks stow the FO either in use or FO ready to be used in the engines. The FO is taken from the service tanks, through the ship's FO service system where it is further conditioned before use.

The fuel, naval distillate, and JP-5 fuel oil systems are separate systems. Both have the FO fill and transfer system and the FO service system. We will discuss these systems separately in the following sections.

## NAVAL DISTILLATE SYSTEM

Fuel, naval distillate is the FO used for the main propulsion plant and generators on the CG-, DD-, and FFG-class ships. Naval distillate is the main type of FO carried aboard ships and used in the FO fill and transfer and the FO service system.

### Fuel Oil Fill and Transfer System

The FO fill and transfer system for F-76 has a fill and transfer header, storage tanks, and a transfer system. We will discuss these individually in the following paragraphs.

**THE FUEL OIL FILL AND TRANSFER HEADER.**—The fill and transfer header is a system of piping and valves connecting the main deck filling stations to the storage tanks. This system allows FO to be taken from the storage tanks to the service tanks. It also provides the capability to defuel the ship.

Fueling and defueling operations begin at the main deck fueling stations. Gas turbine ships have fueling stations on the port and starboard sides forward and aft.

Ships are fueled both at sea and in port. The main difference between fueling at sea and in port is the method used to connect the supplying station to the ship. At sea the probe fueling system

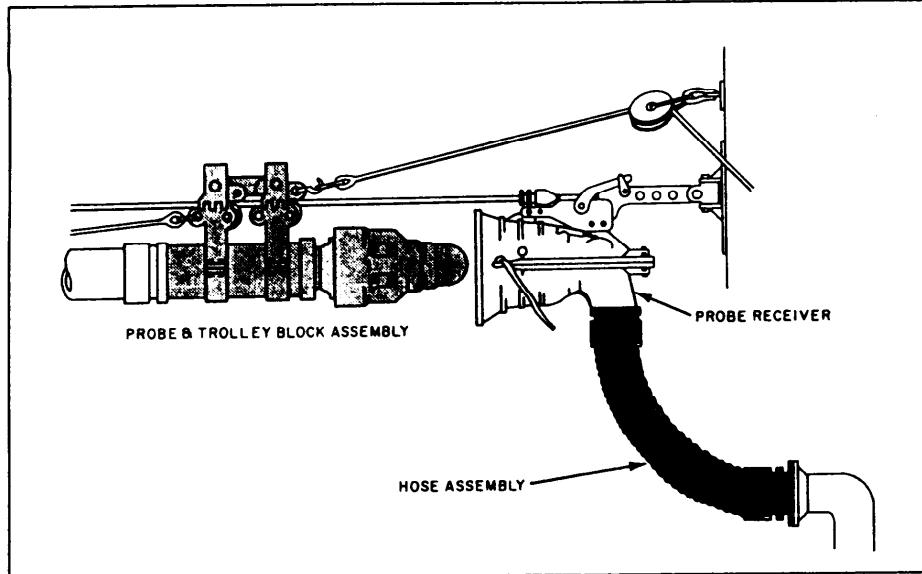


Figure 4-3.—Probe fueling system.

(fig. 4-3) is used. The probe method is the most common method used and is standard among ships of the U.S. Navy. Various adapters are available for fueling from ships not equipped with the probe unit. Part of this system is the probe receiver and the hose assembly. They are connected to deck filling connections on the outboard side of the receiving ship. During import refueling, the supplying activity's hose is bolted to a flanged fitting on board the receiving ship's fueling station.

With the commanding officer's approval, the chief engineer along with the oil king sets up and controls the fueling operation. The oil king aligns the system as specified in the EOSS and controls the fueling operation. Standard refueling stations are manned and the entire operation is monitored from a central point on the ship. Various tests of the FO are required before, during, and at the securing of fueling. The oil king is responsible for these tests and also the reports that must be submitted.

The FO flows from the receiving station to the main header pipe and from there to the storage tanks through various valves. The valves are set up in a manifold system on the FFG-class ships and are located in auxiliary machinery room No. 1 (AMR1). On the CG-, and DD-class ships, FO flows from the deck riser through a motor-operated valve that can be used as a throttling valve to maintain FO flow. From there

the FO enters the main header and from there to the FO banks through branch lines. Each FO bank has its own motor-operated valve. These valves are operated from the fuel console and are either fully opened or fully closed.

The storage tank valves on the CG-, and DD-class ships are electrically operated from the fuel control console located in CCS. Except for the manual operation of the valves at the fueling station, the entire fueling operation can be conducted and monitored at the fuel control console. These valves can be opened and closed manually if needed. A diagram of the FO fill and transfer header piping on the DD-class ship is shown in figure 4-4.

**STORAGE TANKS.**—The FO storage tanks are nothing more than large enclosed compartments with piping connected to them.

The CG-, and DD-class ships are provided with seawater-compensating systems. In this system, the storage tanks are always kept completely filled with either FO or seawater ballast or a combination of both. The receiving tank is connected to a bank of storage tanks by sluice piping between tanks. As a receiving tank becomes full, FO overflows into the adjoining tank in the bank. This continues until all tanks in the bank are full. During the fueling operation, seawater in the tank bank is displaced by the FO

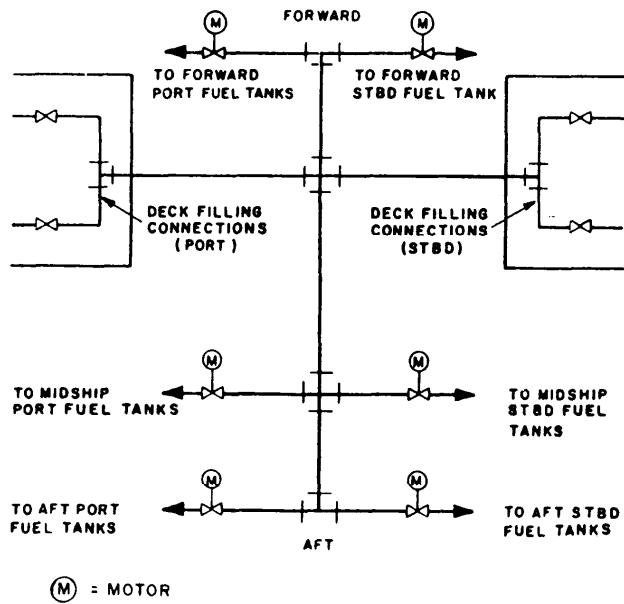


Figure 4-4.—Piping diagram of a DD-class ship fill and transfer header.

and is discharged overboard through an overflow line from the overflow expansion tank.

When FO is taken from the storage tanks for ship's use on gas turbine ships, seawater from the fire main provides a positive head on the system to the suction side of the transfer pump. Seawater replaces the FO in the tanks and maintains the proper ship's trim.

### CAUTION

Because of the danger of overpressurizing the ship's receiving system during refueling, maintain extremely close liaison between the receiving ship and the supply ship relative to flow rates and line pressure. Means for throttling flow to each tank bank is provided to prevent tank overpressurization by use of the throttling valve. Keep a close watch on liquid levels and receiving tank pressures of banks being filled on ships with compensating systems.

The clean ballast system provides complete separation between the ship's FO storage tanks and the seawater ballast system. Tanks designated for FO storage are used for this purpose only. Fuel fill, transfer, and stripping systems are isolated

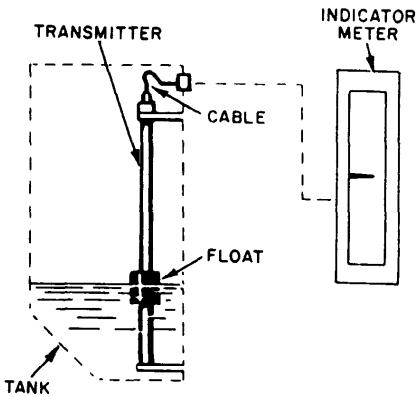


Figure 4-5.—Typical gas turbine FO tank level indicator system.

from the drainage, ballast, and bilge systems and are used solely for FO storage and management. Tanks used for ballast are so designated and can be filled with seawater for ship stability and trim. Some ship classes, such as the FFG, have a modified clean ballast system. Designated FO tanks can be ballasted with seawater through this system whenever the total FO load is reduced below a set percentage and additional ballast is required.

The rated full capacity of a FO tank is 95 percent of the total capacity. The rated full capacity is computed after allowance has been made for all obstructions in the compartment. The remaining 5 percent of the total tank capacity is reserved to allow for FO expansion. Accordingly, when FO is received, tanks should not be filled beyond their rated capacity. This filling requirement does not apply to ships having seawater compensating systems since these tanks are always 100 percent full. Expansion tanks are provided on the CG-, and DD-class ships to provide for FO expansion caused by temperature changes.

An electric level indicator with a magnetic float (fig. 4-5) is used for FO tanks on gas turbine ships. It is replacing the pneumatic-type systems on ships with water-compensating systems because of its improved reliability and accuracy. The Navy Oil Pollution Abatement Program requires installation of a magnetic-float level indicator with a high-level alarm in all FO tanks that overflow directly overboard.

This type of indicator has a magnetic float, transmitter (or sensor), and primary and secondary receivers (meters). The transmitter stem

is composed of a rod or series of rods mounted vertically within the tank. The magnetic float is cylindrically shaped and has a hole in the center. As it moves up and down on the surface of the fluid, the magnetic float operates tap switches in the rod. The electrical resistance of the transmitter changes according to which rod switches are closed. This provides an indication of tank level. The float movement is transmitted to a receiver that is calibrated in gallons.

Magnetic-float, liquid-level indicators in tanks that overflow directly overboard have integral, high-level alarms to warn of an impending overboard oil discharge. These alarms are set to sound when the tank has reached 95 percent of total capacity. This alarm warns that the tank will overfill and that oil will be discharged overboard unless the operator takes preventive action(s). On most gas turbine ships, the FO system is monitored from a central point on the ship. A system control panel has gauges and alarms that

indicate FO levels in the tanks, indications of valve alignment, alarms for high and low tank levels, and, in the seawater-compensated system, an alarm for receiving tank overpressurization.

**TRANSFER SYSTEM.**—The FO transfer system transfers FO from the storage tanks to the service tanks. In the transfer process, the FO is cleaned for use in the GTEs. The system has transfer pumps, heaters, and centrifugal purifiers.

Figure 4-6 is a basic diagram of the FO transfer system for the DD-class ship. It should give you a good idea of how the system works. The oil king's first step is to decide from which storage bank FO is to be taken and to which service tank it is to go. The FO is moved from the storage tank by the transfer pump through the FO transfer heater. The heater warms the FO to the proper temperature for cleaning by the purifier. The FO purifier removes water and contaminants as FO is transferred to the service

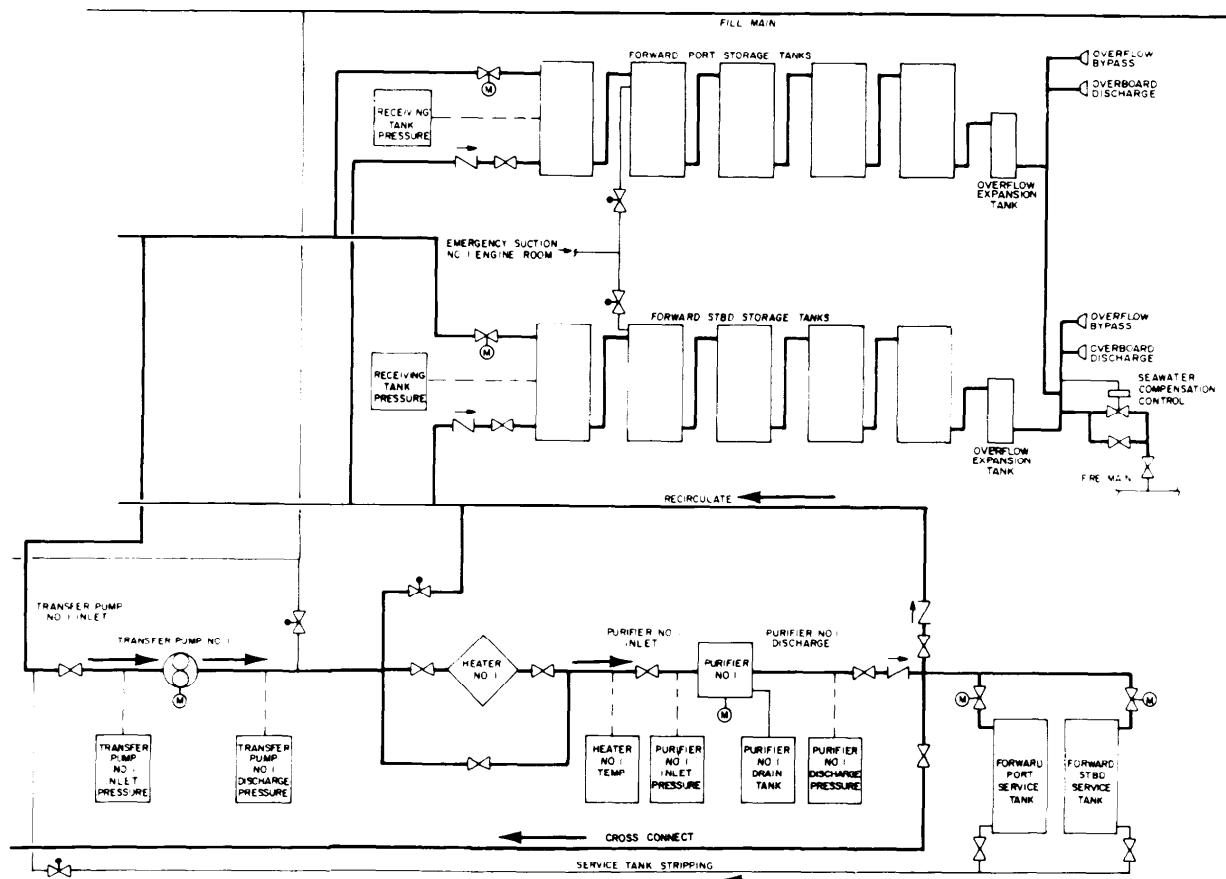


Figure 4-6.—DD-class ship fuel oil system.

tanks. The FO in the service tanks can also be recirculated through the purifier and back to the service tanks by realigning the valves. The FO must be circulated for a minimum of 3 hours before a service tank is placed in operation. This provides a means of continuously reducing the amount of solid contaminants in the FO.

The CG-, and DD-class ships are being furnished with self-cleaning centrifugal purifiers (SCCPs). The purifier is a vertical, direct-drive, centrifugal, self-cleaning (solids ejecting) machine that has the capacity to purify 110 gpm of contaminated diesel fuel, marine. The FO contaminated with water and solids is fed into the purifier. It separates the pure FO from the contaminants and returns the purified FO to the ship's FO system. The water is continuously passed from the purifier through the ship's piping to a waste oil tank. Separated solids in the form of sludge are retained within the bowl during the cycle. Cleaning the bowl during purifier operation is referred to as "shooting" the bowl. The ejected sludge is also passed to the waste oil system. The purifier can remove water from a contaminated mixture comprised of as much as half water, half FO. Also, under emergency conditions, the purifier can process 100% water for a period of 5 minutes without any water discharge from the fuel discharge port.

## Fuel Oil Service System

The FO service tanks are similar to storage tanks except they are not saltwater ballasted. The FO service tanks have the same type of liquid-level indicating system as other tanks aboard ship. The major concern for the service tanks is cleanliness. The FO service tanks must be maintained in a clean state of readiness. To maintain cleanliness, you must allow only clean FO to enter the service tanks. The components of this system that we will discuss are the FO strainers, the FO heater, and the filter/coalescer.

**FUEL OIL STRAINERS.**—A wire-mesh basket strainer is normally installed between the service tank and the booster pump suction to filter out large solid particles. Figure 4-7 is an example of a duplex FO strainer. Refer to volume 1, chapter 6, of NAVEDTRA 10563 for more detailed information on this type of strainer.

The FO enters the top section of the strainer body and is directed into one of the wire-mesh baskets. Large, solid particles are trapped inside the strainer basket, and clean FO travels on

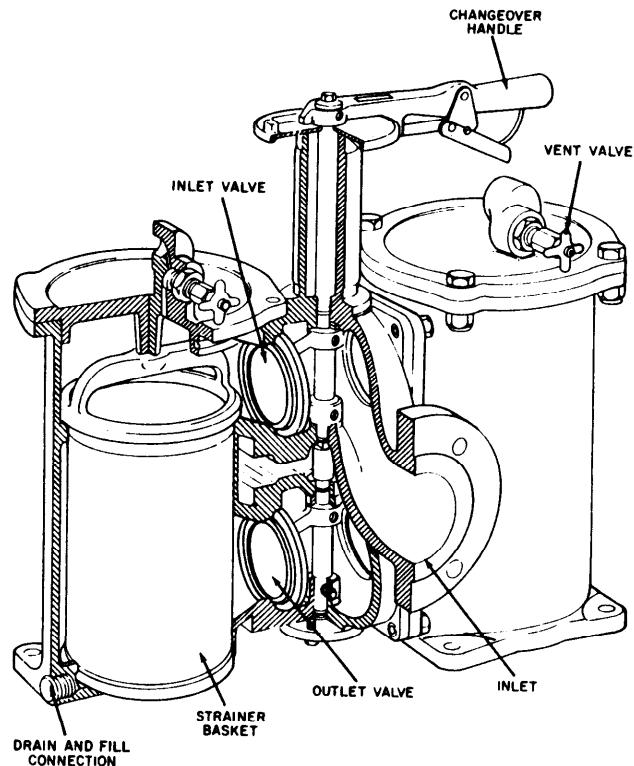


Figure 4-7.—Duplex FO strainer.

through the outlet. Duplex strainers contain two separate strainer housings and baskets and a changeover mechanism that is a shaft with inlet and outlet valves attached to it. As the handle is moved, one set of valves opens and the other set closes, isolating one strainer assembly. The strainers have differential pressure gauges and alarm indicators to alert the operator when the strainer is dirty.

**FUEL OIL BOOSTER PUMPS.**—Each FO service system has two booster pumps to provide the system pressure. The FO booster pump is a vertical, screw-type, positive-displacement pump that is driven by a two-speed electric motor. This type of pump is found on the CG-, and DD-class ships. A sliding vane pump is used on the FFG-class ships. Directly following the pump discharge is a relief valve. Since the pump is positive displacement, a relief valve is required to protect the system and the pump. The relief valve bypasses FO back to the pump inlet.

**FUEL OIL HEATER.**—Fuel oil heaters are installed in the service system after the FO booster

pumps. The heaters are heat exchangers of the conventional shell and U-tube type. Either steam or hot waste water is used with a temperature-regulating valve to maintain the FO at normal operating temperatures. An alarm in the system indicates high FO temperature to the plant operator.

**FILTER/COALESCER.**—The filter/coalescer (also called the coalescer) is the last conditioning station before the FO is used in the GTEs. The coalescer filters sand, dust, dirt, and scale from the FO. The coalescer also coalesces water particles and removes essentially all free water from the FO supplied to the propulsion gas turbines.

The coalescer (fig. 4-8) is a self-contained, static, two-stage unit that combines the process of filtration and water separation in one housing. The basic principle of operation is that contaminated FO enters the unit through the inlet port and flows into and through the coalescing elements. The flow through the coalescer elements is from the inside to the outside. The coalescer elements remove solid contaminants from the FO. As FO passes through the elements, entrained water coalesces into large droplets that fall to the bottom of the coalescer (sump) where they accumulate.

After passing through the coalescer elements, the FO passes through the hydrophobic screen and the separator elements, which remove the final traces of coalesced water that have not fallen by

their own weight into the sump. The flow through the separator elements is from the outside to the inside. The FO, free of contaminants, then flows out of the coalescer through the discharge valve into the FO system.

When the water/sediment level in the sump reaches a preset level, the automatic drain valve dumps into the water/sediment waste oil system. A sampling valve is provided at the discharge point for testing discharged FO.

As you can see, both the compensated and noncompensated FO systems are basically the same in their operation. However, the quality of the FO must meet stringent requirements. These requirements help to protect the GTEs from serious damage, such as corrosion of the hot section, fouling of engine controls, and plugging of fuel nozzles. This level of FO quality is achieved through the continuous purification, sampling, and testing of FO throughout the system. This is the responsibility of the oil king on board the ship.

#### JP-5 SYSTEM

The JP-5 system provides FO to the helicopter fueling station and to the small boat refueling station. It also transfers JP-5 to the ship's FO service system under emergency conditions to operate the main engines and generators. On the CG-, and DD-class ships, JP-5 can be introduced into the system through the system piping just before it enters the FO booster pumps. On the FFG-class ships, JP-5 is normally provided to emergency head tanks, which provide enough FO for the normal cool down period (5 minutes) of a main engine.

The JP-5 system is basically similar to the ship's FO and transfer system in that it has refueling stations, storage tanks, transfer pumps, service tanks, and filter separators that provide clean FO to the equipment. Onboard FO capacity for JP-5 is much less than for fuel, naval distillate.

JP-5 is taken on board from topside fueling stations and transferred to the storage tanks. The storage tanks are noncompensated tanks and have the same type of tank level indicators as the fuel, naval distillate tanks. The FO is transferred from the storage tanks to the service tanks through the JP-5 transfer pump and filter separator. The filter separator removes water and contaminants from the FO before it reaches the service tanks. The transfer piping system also branches off before it reaches the service tanks. This provides JP-5 for emergency use in the ship's FO system and also to the small boat refueling station.

The FO from the service tanks is used for helicopter (helo) refueling and has its own JP-5

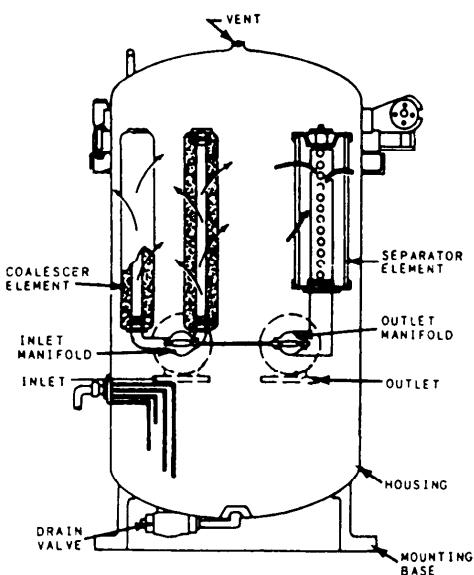


Figure 4-8.—Filter/coalescer assembly.

service pump and filter separator. The service system provides the capability to refuel and recirculate FO for the helo station. Helo defueling capability is also provided. This capability is necessary because FO removed from the helo is returned to the storage tanks or diverted to a separate contaminated FO tank. A stripping pump is provided on both types of ships for removal of water and sludge accumulations on the bottoms of the tanks.

As with the fuel, naval distillate, stringent requirements for FO purity are necessary. The responsibility for testing the FO again belongs to the oil king.

### BLEED AIR SYSTEM

Bleed air, as we discussed in chapter 2 of this TRAMAN, is compressed air taken from ports on different stages of the engines. On all classes of ships, the LM2500 GTE provides customer bleed air for shipboard use from the 16th stage of the compressor. On the CG-, DD-, and

class ships, bleed air is also provided from the 14th stage of the GTG compressor. Bleed air is used aboard ship for starting, anti-icing, masker air, and prairie air.

### BLEED AIR START SYSTEM

Bleed air used for starting is extracted from the compressor section of the GTE and passes through a regulating valve. The bleed air is regulated at 75 psi and has a maximum temperature of 925°F. It then enters the bleed air header and is used for the various purposes mentioned previously.

The CG-, and DD-class ships use starter air differently from the FFG-class ships; therefore, the systems differ in their method of cooling the bleed air and directing it to the starter.

On the CG-, and DD-class ships, bleed air is the primary method of starting the GTEs and SSGTGs. The bleed air of the four GTEs and three GTGs enters a common header and can be used to start any other engine or generator. Refer to figure 4-9, a piping diagram of the

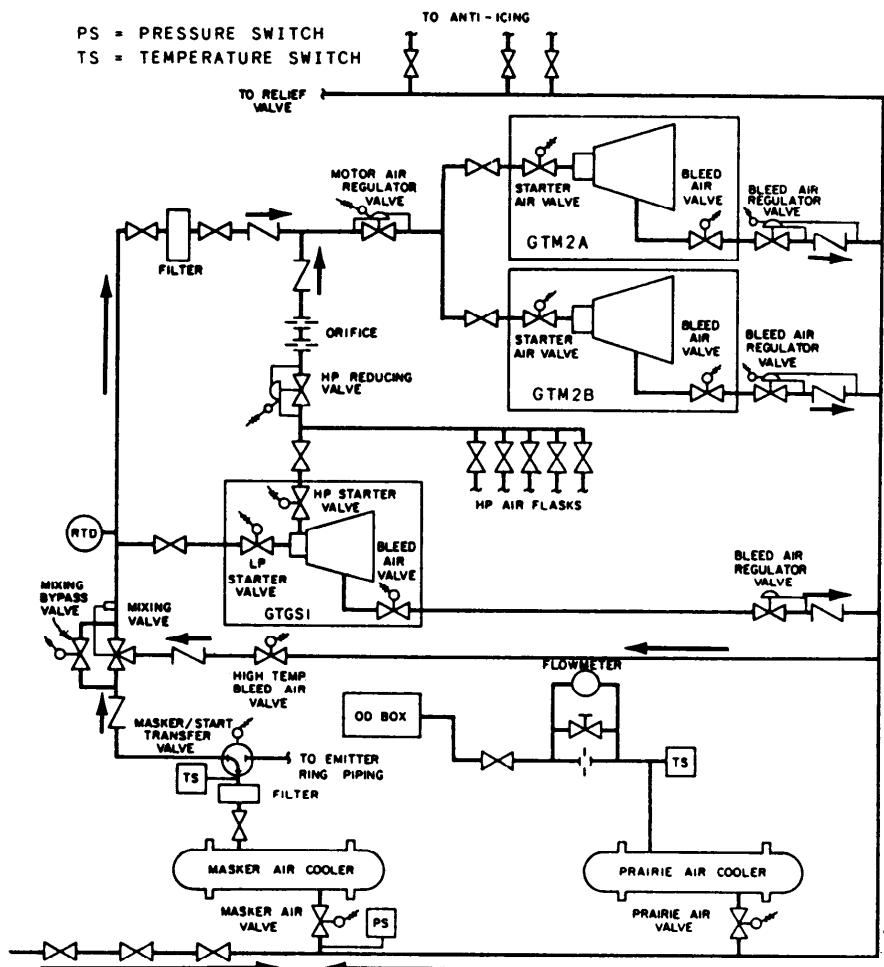


Figure 4-9.—Piping diagram of a DD bleed air system in the forward engine room.

bleed air system on a DD-class ship, as we describe the system.

Bleed air is taken from any operating GTE and generator through a bleed air regulator valve, which reduces the pressure to 75 psig. It then enters the header. The various valves that control the flow can be operated from the PACC in CCS or the PLCC in the engine room. The AUTO MODE can be used to automatically set the valves in sequence during GTE start, or they can be sequenced individually by the operator. The operator can also operate the valve manually by overriding the electrical signal at the valve.

Bleed air for starting goes through two separate pipes. Hot bleed air flows to the mixing valve through the high-temperature bleed air valve. Bleed air also flows through the masker air valve through the masker air cooler where it is cooled to about 190°F. The cool bleed air then flows through a filter to remove any solid contaminants and then to the masker/start transfer valve. In the start position the masker/start transfer valve allows the cool bleed air to flow to the mixing valve. In the mixing valve, the hot bleed air and cool bleed air are mixed to maintain a temperature of about 400° to 450°F. Air then flows through a start air filter and then to the motor air-regulator valve. The motor air-regulator valve regulates start air at 45 psig for starts and 22 psig for motoring. Another valve in the start system is the mixing bypass valve. This valve allows only the cool bleed air to pass to the starter during motoring.

Start air on the FFG-class ships flows from the GTE into a common header through a reducing valve where it is reduced to 75 psig. It then passes through the bleed air cooler, which maintains the air at a temperature of about 400°F; from there it passes to the start air system and to the motor air-regulator valve. This valve operates the same as on the CG-, and DD-class ships.

## ANTI-ICING AIR SYSTEM

The anti-icing systems on the CG-, and DD-class ships differ greatly from the FFG-class ships. We will describe these systems separately.

### CG, and DD Anti-Icing System

The gas turbine anti-icing systems take hot bleed air from the bleed air header and distribute it to each GTM and GTGS intake to prevent the formation of ice under an icing condition. An

icing condition exists when the inlet air temperature to a GTE is 41°F or less and the humidity of the inlet air is 70 percent or greater.

Bleed air from the header enters the anti-icing system piping for each GTM and GTGS and is directed to the anti-icing, air-flow regulator valves. The forward and after bleed air header risers provide the hot bleed air for each GTM and GTGS in the No. 1 and No. 2 engine rooms. The bleed air header in the No. 3 generator room provides the hot bleed air for the No. 3 GTGS. The anti-icing, air-flow regulator valves control the flow of hot bleed air into the intake of each GTE. This maintains the temperature of the inlet air to each GTE at 38°F, or greater, during engine operation. Each valve is a double-pneumatic, piston-actuated, butterfly-vane, regulating valve. This valve is electronically controlled by an associated anti-icing temperature controller. These controllers are enabled or disabled by the seven anti-icing ON/OFF push-button switch indicators on the PLCC and PACCs. (NOTE: This system is described as it currently exists. SHIPALTS have been issued that remove the electronic controls of the valves and make them manually operated.)

The controller used to operate the anti-icing valve for each GTE intake combines and compares three signals with the fixed temperature signals. The three input signals are CIT,  $N_{G\ G}$ , and bulk air temperature. The fixed temperature signals are 38°F or bulk air temperature. The comparison of these signals determines the torque motor control positioning signal. This signal drives the anti-icing valve torque motor, which positions a poppet valve in the valve's pneumatic regulating control assembly. The poppet valve, in turn, regulates the amount of pressure the 100 psig ship's service (SS) air can exert on the valve's pneumatic actuating pistons; the position of the pistons determines the valve setting. When SS air pressure on the pistons is not working, a spring in the valve's actuator assembly maintains the valve's butterfly vane in the closed position.

When the GTM anti-icing temperature controller is enabled, it maintains the temperature of the inlet air in the intake at 38°F. The controller maintains this temperature by comparing bulk air temperature to the controller's 38°F fixed temperature reference. However, when changes in engine speed are made, the speed sensor ( $N_{G\ G}$ ) signals the controller to complement immediately the increase or decrease in intake air flow with a corresponding increase or decrease in hot bleed

air flow. The ambient air temperature sensor signal determines the magnitude of valve position change that will accompany any given engine speed change. Following an engine speed change, the controller will again regulate the temperature of the inlet air in the intake to 38°F. It does this by comparing the bulk air temperature to the controller's 38°F fixed temperature reference.

The controller used to operate the anti-icing valve for each GTGS intake combines and compares one input signal (duct air temperature) with the fixed temperature signals (38°F) to produce a torque motor control position signal. The anti-icing valve used on a GTGS is the same as that used on a GTM.

When the GTGS anti-icing temperature controller is enabled, it maintains the temperature of the inlet air in the intake at 38°F. Again the controller compares duct air temperature to the 38°F fixed temperature.

After the bleed air passes the anti-icing, air-flow regulator valves, it becomes anti-icing air and is piped to the GTGS intakes. Anti-icing air entry into a GTGS intake is made through an 8-inch pipe. The hot anti-icing air flows into the intake duct and mixes with the intake air. No manifolds or nozzles are used.

Injection of hot anti-icing air into the GTE intakes is accomplished through the U-shaped manifolds mounted at the O2 level above the silencers inside each duct. The manifolds are constructed from 8-inch diameter pipe with 1 1/4-inch holes drilled along the sides of each leg. Because of the larger cross-sectional area and capacity of the propulsion intakes, manifolds must be used to mix the air thoroughly.

#### FFG Anti-Icing System

In the FFG anti-icing air system (fig. 4-10), bleed air is taken from the common header and

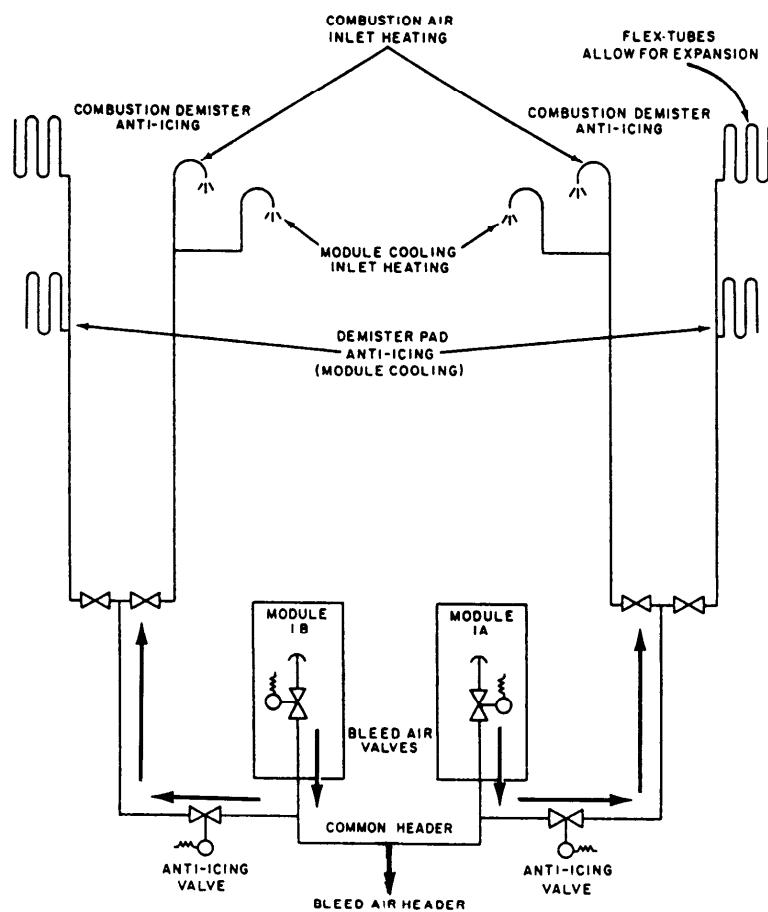


Figure 4-10.—FFG anti-icing system.

flows through the reducing valve where it is reduced to 38 psi. It then branches out into two piping systems going to the demister pads. When anti-icing is activated, bleed air is discharged on the inlet side of the demister pads through flexible piping to prevent icing on the demister pads for both module cooling air and combustion air. Bleed air is also provided to the intakes for module cooling and combustion air to heat the inlet air after it has passed through the demister pads.

## MASKER AIR SYSTEM

Because of the existing differences between the ship classes, we will describe their masker air systems separately.

### CG, and DD Masker Air System

The CG, and DD, masker air system takes hot bleed air from the bleed air system, cools

it to 190°F, and distributes it to the masker emitter rings outside the ship's hull. This reduces or modifies the machinery noise being transmitted through the hull to the water. Refer to figure 4-11, a diagram of the CG, and DD masker air system, to help you understand the following paragraphs.

Bleed air at 500° to 800°F and at 75 psig from the bleed air header enters the masker air system within each engine room and is directed to the masker air cooler valve. After the hot bleed air has passed through the masker cooler valve, it is piped to the masker air cooler where it is cooled to 190°F. The masker air cooler is a shell and tube type of cooler. It uses seawater as the cooling medium. The cooled masker air is piped through to the masker air filter to remove any solid contamination and then to the masker/start transfer valve. The masker/start transfer valve controls the flow of the 190°F masker air to either the masker air system or to the gas turbine start/motor air system. Push buttons at the

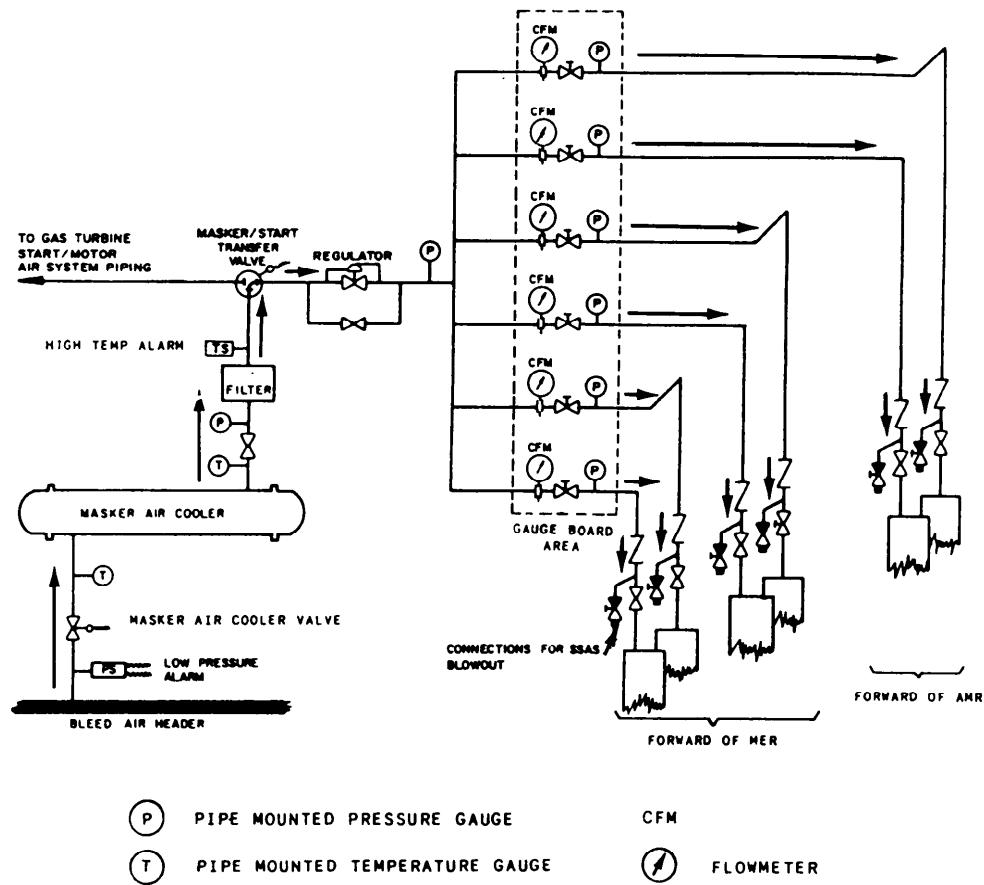


Figure 4-11.—CG, and DD masker air system.

control consoles or, in an emergency, manual override can be used to select the position of the valve.

After the masker air passes through the masker/start transfer valve, it is piped to the masker air pressure-regulator valves. The regulating valve maintains a 30 psig regulated pressure in the masker emitter ring flow manifolds. Masker air then passes into the emitter flow distribution manifold. As the masker air leaves the manifold and enters each branch line, it passes through a flowmeter orifice to a manual flow control valve. The flowmeter orifice creates the differential pressure required to operate its associated flowmeter. The manual flow control valve establishes the prescribed masker air flow to its respective emitter ring. From the manual flow control valve, masker air continues on through a check valve and a shutoff valve. It then flows into the hollow emitter ring on the ship's outer hull. The emitter ring has a series of 1/16-inch diameter holes in its outer wall through which the air escapes.

### FFG Masker Air System

In the FFG masker air system, the discharge header from the bleed air heat exchanger divides into two branch headers, one for the prairie/masker air and one for the starting air. Between the bleed air heat exchanger and the two branch headers are a temperature switch and an RTD. The temperature switch shuts the bleed air reducing valve when the bleed air discharge temperature reaches 425°F. The RTD supplies a temperature signal to the auxiliary control console (ACC) for display and alarm (400°F) indication.

The prairie/masker header divides into two branches, one for prairie air and one for masker air. The prairie/masker branch header has a prairie isolation valve. The masker air system contains a pressure-reducing valve to reduce the pressure from 75 psig to 28 psig. The masker air system divides into two branches, one for the forward emitter belts and one for the aft emitter belts. The forward and aft masker flow control valves are operated by push buttons from the ACC. Venturi-type flowmeters are provided in each masker system branch to measure airflow.

The emitter belts are located forward and aft in port and starboard halves, each half belt having a separate air connection. The masker air system discharges bleed air through each of the four emitter connections at a rate of 425 standard

cubic feet per minute (scfm) at an approximate discharge pressure of 12 psig. The emitters are perforated with 3/64-inch holes through which masker air discharges from the keel to the design waterline. An orifice plate is fitted into the emitter belt halves on the port side to balance the air flow. A check valve is provided to prevent the backflow of seawater into the system.

### PRAIRIE AIR SYSTEM

The prairie air system modifies the thrashing noise produced by the ship's propellers to disguise the sonar signature of the propellers. The system does this by taking hot bleed air from the bleed air header, cooling it, and distributing it to the leading edges of the propeller blades.

The prairie air system is basically the same on all classes of gas turbine ships. Bleed air is directed from the header to a prairie air cooler by the prairie air valve. On the CG-, and DD-class ships, the prairie air valve is operated from the control console. On the FFG-class ships, the prairie air valve is a thermostatically operated valve, which automatically closes when the discharge air from the cooler exceeds 150°F. The bleed air is cooled to 100°F on the CG-, and DD-class ships and to 125°F on the FFG. These are the maximum prairie air temperatures. An alarm indication is given when these temperatures are exceeded.

A manually operated flow valve is used to establish the prescribed prairie air flow to the propeller. From the prairie air flow control valve, prairie air is piped to the oil distribution (OD) box on the front of the MRG. At the OD box, the prairie air enters the propeller shaft through a rotoseal and travels through the shaft to the propeller blade. It then enters the water through a series of holes on the leading edge of each blade.

## COMPRESSED AIR SYSTEMS

Compressed air systems consist of the SSAS or LP air system and the HP air system. The systems vary between ship classes and are described in the following sections.

### CG, AND DD LOW-PRESSURE AIR SYSTEM

The SSAS is the general-purpose air system. It provides LP air throughout the ship for operation of most pneumatically operated

equipment and pneumatic controls. It supplies purified LP air to the electronics and to the HP air system dryers. Some uses of LP air in the engineering plant include the following areas:

- FO fill and transfer compensating system
- WHB control air
- Seawater temperature control valves
- FO coalescer
- Clutches and/or brakes

The system has LP air compressors, air dryers, purifiers, main receivers, and a piping system. The piping system has valves, reducing stations, and connections necessary to distribute compressed air to various services. A reducing station is provided in the HP air system to supplement the SSAS when compressed air consumption exceeds ship's compressor output. Automatic shutoff valves, called priority valves, are installed downstream from all mission essential (vital) equipment and upstream from all nonessential (nonvital) services. If air pressure falls below a prescribed setting, these valves close and eliminate use of non-essential services during the reduced pressure period.

Ships have so many variations as to the type and number of compressors, the system pressure settings, and priority valve settings that we will not attempt to cover this material. Refer to the ship's equipment technical manuals and EOSS for a more in-depth description of each individual system.

#### **CG, AND DD, HIGH-PRESSURE AIR SYSTEM**

The HP air system provides HP air to the weapons systems, aviation equipment, gas turbine starting, and backup air for the SSAS. The system has two compressors that supply 3000 psig of air to the storage flask. The air then goes into the system through a dehydrator. The dehydrator provides moisture-free, oil-free, and contaminant-free air to the system.

The HP air system is primarily maintained by A Division. As a GS, you will find it is used in the engine room as the primary/emergency air start for the ship's main engines and generators. The HP air flasks are located in each engine room and the No. 3 generator room. Air for the main

engine start is reduced to 250 psig by the HP reducing valve and then to 85 psig through a series of orifices. The ships do not have HP air start capability for its main engines. The CG-class ships have air pressures of 220 psig through the reducing valves and 45 psig through the orifices. All ships have HP air start capability for the ships' generators. The 3000 psig of air is reduced to starting pressure by the start air valve. The 3000 psig of air is also used to back up the LP air supply through a reducing station in the No. 1 engine room. The pressure varies between ships. For the proper setting, consult your ship's EOSS.

#### **FFG LOW-PRESSURE AIR SYSTEM**

The SS air is provided by two LP, screw-type compressors that have a capacity of 100 scfm at a discharge of 125 psig. The compressors provide air to a vital air main, a nonvital air main, and a loop branching off the vital air main that supplies air to electronics equipment. Dry air is delivered to the electronics equipment by the processing of air from the vital main through dehydrators. The vital air main piping is cross connected between the two compressors and provides control air to the vital services in the machinery spaces. The nonvital services are fed from the nonvital air main through priority valves. The priority valves are located between the vital and nonvital air mains. These priority valves are designed to shut off air to the nonvital air main if the demands on the whole system (vital and nonvital) are greater than the compressors can provide and if the pressure falls to 85 psig.

A cross connection through a manifold reducing station automatically provides HP air to the vital air main. The HP air at 3000 psi is reduced to the SSAS pressure and thereby backs up the vital air main. The reducing station is set at 80 psig so it will deliver air when the vital main has dropped to 80 psig.

#### **FFG HIGH-PRESSURE AIR SYSTEM**

The FFG HP air system has two HP air compressors capable of providing 3000 psig to the system. Each compressor is provided with an air dehydrator to remove solid contaminants and particulate and vaporous water and oil from the air. An air flask is installed at each compressor downstream of the dehydrators. The air compressors are designed for continuous automatic operation. A pressure switch located

in the discharge piping from each compressor automatically controls the starting and stopping of the compressor based on pressure in the HP air main. Relief valves are provided throughout the system to provide protection from over-pressurization. Some uses of HP air in the engineering plant include the following areas:

- Ship's service diesel generator (SSDG) starting
- Emergency LO coast down pump
- Propulsion shaft brake
- Back up for LP air system
- LM2500 GTE start

## DRAINAGE AND BALLAST SYSTEMS

This section describes the three primary systems that make up a ship's drainage system, the major equipment that makes up each system, and the function of each system in support of the propulsion plant. The systems are the main drainage system, the secondary drainage system, and the ballast system. The purpose of these systems is to provide a means for dewatering the main engine room(s) (MER) and the AMRs, as well as several other spaces both forward and aft of the machinery spaces. Always refer to your ship's EOSS for detailed information on these systems.

### MAIN DRAINAGE SYSTEM

The main drainage system has two types of subsystems, the main drainage eductor subsystem (a fixed-eductor subsystem) and the main drainage bilge pump subsystem (a positive-displacement pump subsystem). The fixed-eductor subsystem is arranged with the other main drainage subsystem so they can be cross connected. Both subsystems are primarily associated with drainage within the main machinery spaces and with branch lines that serve various auxiliary space bilges throughout the ship. The main drainage system also takes suction from and discharges to the clean ballast tanks, the FO overflow and ballast tanks, and the FO or ballast tanks through interlocked manifolds for ballasting and deballasting.

The main drainage system will normally have the following major components:

1. Eductors of 1250 gpm capacity (in each engine room and auxiliary space).
2. Suction stop-check valves (one for each drain well and each waste water tank).
3. Deck-operated gate valves used to isolate sections of the system. These valves are equipped with manual local and remote operators.
4. Discharge stop-check valves to prevent inadvertent flooding of other spaces during eductor operation.
5. Interlocked valve manifolds to provide connection between the main drainage, ballast, and firemain system.
6. Various valves, gauges, and indicating and control devices to support the eductor system.

The main drainage bilge pump subsystem serves the same drainage main as the eductor subsystem. However, it uses an electric motor-driven pump to remove drainage. This system also has cross-connect fittings to provide a backup pump for the bilge pump installed in the oily waste water system. It allows the pump in that system to backup the pump in the main drainage system.

### SECONDARY DRAINAGE SYSTEM

The secondary drainage system is an independent fixed-eductor system primarily associated with dewatering the following types of spaces:

- The chain locker
- The eductor rooms
- The magazine service rooms
- The guided missile launcher system (GMLS) magazines
- The steering gear room (usually served by a separate drain pump, but considered part of the secondary drain system)

### BALLAST SYSTEM

The ballast system is used to ballast and deballast clean ballast, FO overflow and ballast, and FO or ballast tanks. Seawater connections

from the firemain system through interlocking manifolds provide the source of ballast water.

## FIREMAIN SYSTEM

The firemain system (also called fire and flushing system) is a dual-purpose system. It combines the services normally provided by the auxiliary seawater cooling system besides the normal services provided by the fire and flushing system. This system provides the following types of service:

1. Fire fighting
2. Ballast and flooding control
3. Sanitary and waste disposal
4. Countermeasures
5. Electronics cooling
6. Auxiliary machinery cooling
7. Weapons cooling
8. Sprinkling system
9. Flushing

A simplified schematic of a firemain is shown in figure 4-12. This schematic shows this system as having five pumps feeding two firemains, one on the port and the other on the starboard side. The port is also referred to as the upper main and the starboard as the lower main. These mains can be cross-connected or isolated by opening or closing the valves designated Z.

## SEAWATER SERVICE SYSTEM

The seawater service system is the ship's principal cooling water system. This system distributes seawater throughout the engineering plant at prescribed pressures and flow rates for cooling LO, compressed air, and auxiliary machinery. Although the different ship classes provide the same basic services, they are set up differently. Therefore, we will describe them individually.

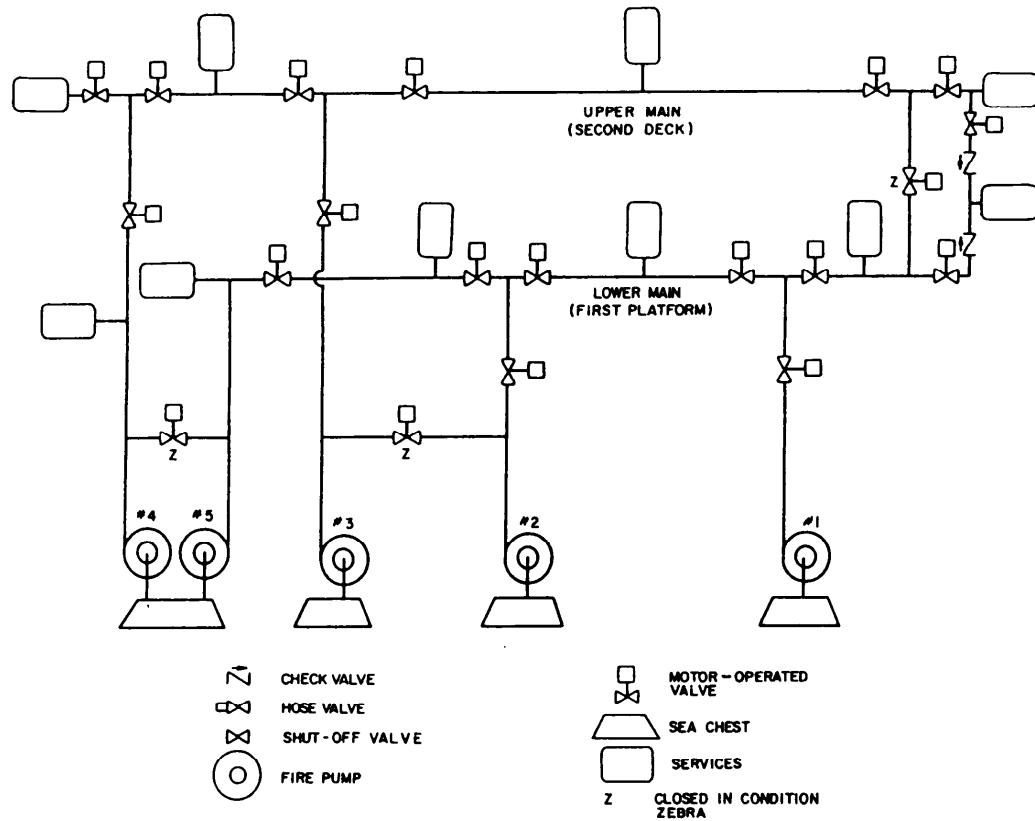


Figure 4-12.—Firemain diagram.

## **CG, AND DD SEAWATER SYSTEMS**

During normal operations, seawater is supplied to the seawater service system through one of the three seawater service pumps. When the system demand increases, a second pump can be started or seawater can be supplied through one of three fire main reducing stations. The seawater main also provides backup cooling to the SS generators. If the generator cooling system fails, the seawater main automatically cuts in.

The systems on the CG-, and DD-class ships are basically the same. The basic system has three seawater service pumps that supply cooling water to a variety of equipment. These pumps are centrifugal pumps that can be controlled locally at their respective motor controllers or remotely from the PACC. These pumps take suction through a sea chest and then through a hydraulically operated valve. This valve is controlled from the damage control deck. It is used in case of damage to the system piping to prevent flooding from the sea. This valve can also be manually overridden at the valve location. From there flow is through a manual suction valve, a manual discharge valve, and a check valve that is used to prevent backflow to the pump. Relief valves protect the seawater system and associated equipment from overpressurization. Pressure settings on the relief valves and reducing stations and system pressure itself vary between ships. Consult your ship's EOSS for the proper settings and alarm conditions.

Reducing stations are provided on the DD-class ships to reduce pressure for use on the various equipment. However, design modifications to the system pressure on the CG-class ships have eliminated most of the reducing stations. The ones remaining are for the firemain-to-seawater system and the CRP cooler.

Temperature regulation of the reduction gear LO cooler, control of the waste heat boiler condensers, and the condensate drain coolers is done by pneumatically operated temperature regulators. These regulators control the flow of seawater through the coolers to maintain the temperature of the liquid being cooled within prescribed limits. The CG-class ships have a CRP cooler that is temperature regulated.

Nine manual/hydraulic operated butterfly valves are associated with the seawater service system. Three of these valves control the flow of seawater to the three seawater pumps, as mentioned previously. Six valves are installed at various

locations along the seawater service main to control the flow of seawater through the main.

To prevent marine growth and system contamination, the system has simplex, duplex, basket, and Y-type strainers located throughout the system.

## **FFG SEAWATER SYSTEMS**

The FFG-class ships have three separate systems within the seawater cooling system. These systems are

1. the main propulsion reduction gear cooling system,
2. the SSDG cooling system, and
3. the auxiliary cooling system.

### **Main Propulsion Reduction Gear Cooling System**

Two propulsion seawater circulating pumps suction directly from the sea and discharge to the reduction gear LO cooler. Each pump can supply 100 percent of system capacity and serves as a standby for the other pump. Each pump has its own sea suction line that suctions from the sea through its own independent sea chest and suction valve. Each pump discharges to a common header through its own strainer and discharge valve. The common header is connected to the reduction gear LO cooler. Cooling water discharged from the LO cooler is piped overboard through a common pipe and the LO cooler overboard discharge valve. Each seawater circulating pump can be started and stopped either locally or remotely.

### **SSDG Cooling System**

Each SSDG has its own dedicated seawater cooling system and an emergency cooling water supply from the firemain. Each SSDG cooling system has a seawater circulating pump, a duplex strainer, and motor-operated suction and overboard discharge valves. Each pump takes suction from its own sea chest by way of its own suction line and valve. The pump's discharge passes through a duplex strainer and then branches into multiple paths to provide cooling water to the various coolers of the SSDG. The outlet of the coolers then joins into a single discharge line before going overboard through the motor-operated discharge valve. The seawater circulating

pump for each SSDG is interlocked to start automatically whenever the SSDG starts.

Emergency cooling water from the firemain system is piped directly to each diesel generator cooling system at a point downstream of the duplex strainer. The firemain interface has a motor-operated emergency cooling valve and a pressure-regulating valve. The motor-operated valve is electrically connected to the generator output and opens on start-up and closes upon securing the diesel. The pressure-regulating valve controls firemain flow and pressure by opening whenever the normal cooling water system pressure drops below 35 psig. The two SSDGs in AMR2 are provided with one common emergency firemain cooling water supply. The SSDGs in AMR1 and AMR3 have their own emergency firemain cooling water supplies.

### Auxiliary Cooling System

The firemain also provides direct seawater cooling to various nonpropulsion auxiliary equipment. Such equipment includes the LP and HP air compressors, air-conditioning plants, refrigeration plants, and some electronic cooling water systems. The firemain in the engine room provides cooling water to the propulsion gas turbine, the bleed air cooler, the prairie air cooler, and the gas turbine starting/motoring air cooler. The firemain in AMR3 provides filtered seawater for cooling, lubricating, and flushing the stern tube shaft seal and the stern tube bearing.

### STEAM AND WASTE HEAT SYSTEMS

On the CG-, and DD-class ships, steam is generated by three WHBs using the hot exhaust gas from the GTGSs as the heat source. This steam is used for numerous support system functions, which will be described in the next paragraph. On the FFG-class ship, these same functions are performed by the waste heat circulating system. The primary purpose of the waste heat circulating system is to conserve the ship's expenditure of energy. This is accomplished by using waste heat from the SSDGs.

### CG, AND DD STEAM DISTRIBUTION SYSTEM

Steam from the WHBs is piped to the port and starboard steam mains and auxiliary machinery

rooms at 100 psig. It is distributed for the following equipment and usage:

- FO system service heaters, service tank heating coils (when used), and transfer heaters
- LO system purifier heaters and settling tank heaters
- Seawater suction sea chest steam out
- Hot water heating system
- Mk 26 GMLS anti-icing system
- Distilling plant steam air ejectors and feed-water heating through a 100/50 psig reducing station
- Galley equipment, steam kettles, dishwashers, the dough proofer, and the garbage disposal area through a 100/50 psig reducing station
- Filter cleaning room
- Laundry dryer and presses
- Antisubmarine rocket (ASROC) heating and cooling system (where applicable)
- Heating, ventilation, and air conditioning (HVAC) system preheaters and reheaters (where applicable)

### FFG WASTE HEAT DISTRIBUTION SYSTEM

Each SSDG is supported by two jacket water heat exchangers. One heat exchanger cools the jacket water using seawater as a cooling medium and the other cools the jacket water with the waste heat circulating system. The waste heat circulating system is a pressurized closed loop hot-water system. It provides heating to the following services:

- Distilling plants Nos. 1 and 2
- Potable water heater
- Hot potable water accumulator
- LO purifier heater
- FO service heaters Nos. 1A and 1B
- FO transfer heaters Nos. 1 and 2

## FIRE-EXTINGUISHING SYSTEMS

The fire-extinguishing systems discussed in this section are limited to fixed equipment. The portable fire-fighting equipment is mentioned for information purposes only. The fire-fighting systems are numerous and vary among the different ship classes. The fire-fighting systems discussed here include the Halon 1301 system, the aqueous film forming foam (AFFF) system, and the fixed CO<sub>2</sub> system. Other systems or fire-fighting equipment used onboard ship include the aqueous potassium carbonate system, portable CO<sub>2</sub> fire extinguishers, and portable potassium bicarbonate (PKP) extinguishers. You will have to qualify on the systems pertinent to your ship during your general damage control qualifications.

### HALON 1301 FIRE-EXTINGUISHING SYSTEM

Halon fire extinguishing is accomplished by flooding a space with Halon 1301 gas to interrupt the chain reaction during combustion. Halon 1301 is a colorless, odorless, electrically nonconductive vapor that puts out fires by using a different principle than most other fire-extinguishing systems. While CO<sub>2</sub>, water, or foam attack fire by smothering, cooling, or separating the fuel from its oxygen source, Halon combines with the fuel vapors/oxygen molecules in such a way as to stop the combustion process from occurring. The amount of Halon 1301 gas stored on the various class ships is solely dependent on the number and volume of the spaces being protected.

Although Halon 1301 is a very low toxicity vapor allowing limited exposure without detrimental effects, it decomposes upon contact with flames and on hot surfaces above 900°F. While this action is necessary for the product to function effectively as a fire-extinguishing agent, it also results in the formation of several new chemical compounds, which have different properties. These post combustion products are lethal in large concentrations, but they are easily detectable at sublethal levels by eye, skin, and mucous membrane irritation. At higher sublethal levels, a sour taste becomes evident.

### AQUEOUS FILM FORMING FOAM SYSTEM

The AFFF system provides fire protection for areas of the ship where major fuel and/or oil fires

are likely to start. The AFFF system mixes concentrated AFFF with seawater from the firemain. A mixture of 6 percent foam and 94 percent seawater is used to blanket (smother) a fire. After the water is initially drained off, a film remains denying oxygen to the fuel source. Being sealed off from reignition allows time for cooling off. Each AFFF station aboard ship supports several hose reel/sprinkling heads in its area. Each AFFF station usually has a concentrate storage tank and a foam proportioner. The mixture discharged from the proportioners is piped either to sprinkling heads or hose connections.

### FIXED FLOODING CO<sub>2</sub> SYSTEM

Independent fixed flooding CO<sub>2</sub> systems are installed in the GTE modules and certain other auxiliary spaces on various classes of ships. When CO<sub>2</sub> release is activated, a time delay permits personnel to escape from the space before CO<sub>2</sub> is actually released. A pressure switch in each system activates audible and visual alarms locally and remotely (usually at the DCC). Ventilation fans serving the affected area are also shut down.

### SUMMARY

We have described the functions and operations of the following auxiliary and support systems for the gas turbine powered ships in this chapter: the LO fill and transfer system, the main LO system, the FO systems, the bleed air system, the compressed air systems, the drainage and ballast systems, the firemain system, the seawater service system, the steam and waste heat systems, and the fire extinguishing systems. You will need to become familiar with all of these systems to properly operate the engineering plant. While the main engines are the heart of the engineering plant, without the support systems the ship would not operate.

As you can see in reading through this chapter, the systems vary greatly between ship classes and even between ships of the same class. You should study your own ship's engineering plant and read the ship's EOSS and technical manuals to be able to operate, repair, and maintain your individual ship's equipment.



# CHAPTER 5

## PACC AND PLCC FOR DD- AND CG-CLASS SHIPS

Up to this point we have discussed the operation and the construction of the gas turbine engineering plant. One of the revolutionary aspects of the gas turbine plant is its ability to be operated locally or from a remote central point. Local operation is accomplished at the PLCC, while the central point is the PACC in the CCS. Systems that are not controlled in the CCS may at least be monitored from there. This allows for reduced watch standing outside the CCS as opposed to older ships that required watch standers throughout the plant. Also, the EOOW and propulsion, electrical, and damage control watch standers have a quicker look at all vital parameters associated with plant operation.

The CCS is manned 24 hours a day either in port or at sea. At sea it is normally manned by an EOOW (either an officer or senior enlisted), a PACC operator (usually a senior GS petty officer), an EPCC operator (usually a petty officer GSE or EM), and a DCC operator (normally a Damage Controlman (DC) or a HT). A fuel king will monitor the fuel system control console (FSCC) when necessary. Normally, the in-port watch in the CCS is stood by a single watch stander, who is usually a qualified engineering petty officer. At some point you will stand watch in the CCS. Therefore, you should become familiar with all operations that may occur in the CCS.

After reading this chapter and completing the associated NRTC, you should have a good understanding of the functions of the PACC and PLCC for the DD- and CG-class ships. This material is meant for training purposes only. It is not meant to replace the EOSS or technical manuals.

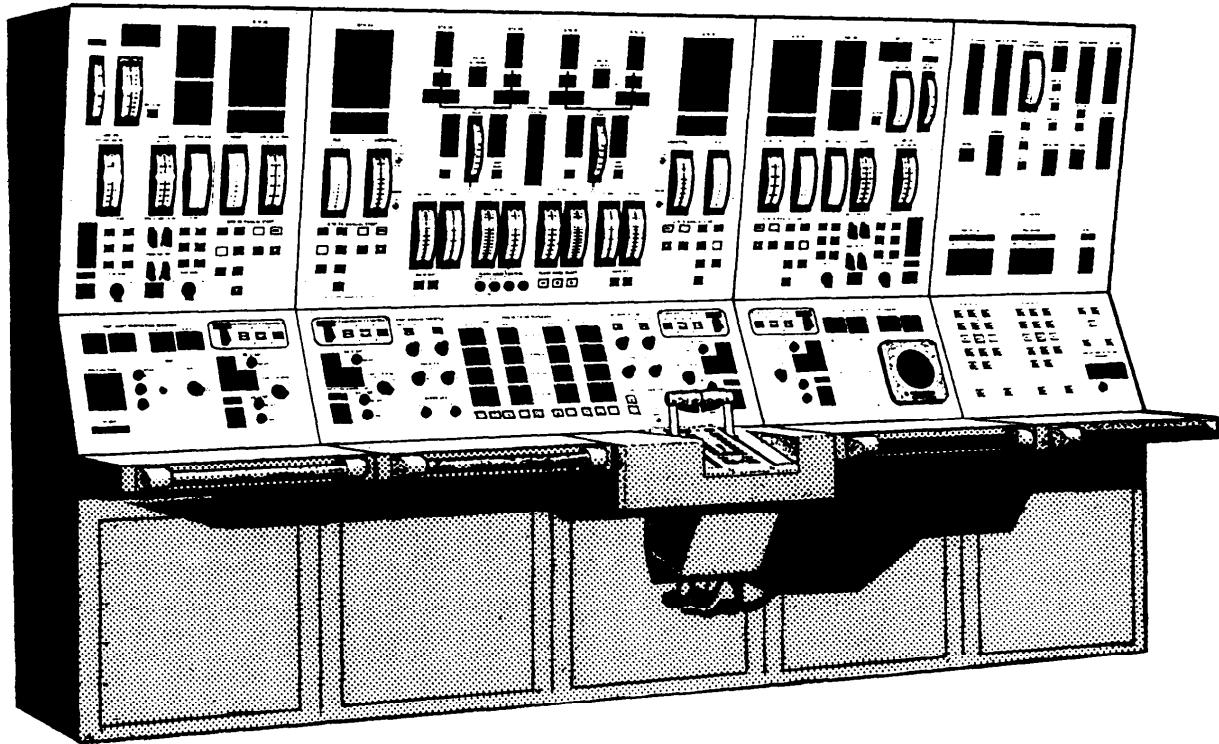
You should have no problem qualifying as a watch stander if you seek the help of an experienced watch stander, use the knowledge

gained in this chapter, follow the EOSS, and complete the PQS requirements.

The abbreviations and acronyms for an item may differ between the ship classes. For example, on the DD-class ships, GB is the abbreviation used for generator circuit breaker. On the FFG-class ships, generator CB is the abbreviation used for generator circuit breaker. In this book we will use the abbreviation/acronym appropriate for the class ship discussed.

### PROPELLSION AND AUXILIARY CONTROL CONSOLE

The PACC is a five-bay console (fig. 5-1) with eight front panels and an integrated throttle control (ITC) panel. The primary purpose of the PACC is to house the controls and status/alarm indicators of the four gas turbine modules (GTM) and all the auxiliary equipment for operating the main GTMs for both engine rooms. The operator, when seated facing the PACC panels, is facing the bow of the ship. All the controls and indicators on the two left bays correspond to the equipment in engine room No. 1, which drives the port shaft of the ship. All the controls and indicators on bays No. 3 and No. 4 are related to the equipment in engine room No. 2, which drives the starboard shaft of the ship. The controls and indicators on bay No. 5 are directly related to the ship's auxiliary subsystems and the GTM/GTG bleed air systems. We will try, where possible, to describe the PACC panels from left to right, top to bottom. The figures used in this chapter will show the PACC and PLCC for the DD-class ship. If the section or subsection of the console on a CG-class ship is different, we will use inserts only of that particular section of the CG-class PACC and PLCC. In some instances, where the components are directly related, we may describe a component out of sequence.



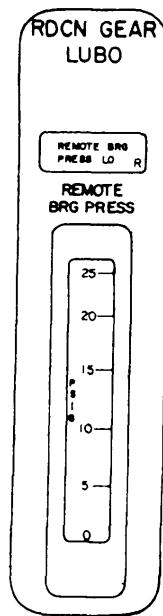
**Figure 5-1.—PACC.**

## ENGINE ROOM NO. 1 PANEL

Figure 5-2 shows the engine No. 1 panel divided into five sections for engine room No. 1. These sections are labeled RDCN GEAR LUBO, CRP, FUEL OIL, GTM 2B (including alarm, manual start push-button indicators, and torque and LO pressure meters for both GTMs), and LUBE OIL.

### RDCN GEAR LUBO Section

The first section on the panel, the RDCN GEAR LUBO section, is used to monitor the MRG LO system. It has an alarm indicator and a pressure meter. The parameters for this panel are sensed at the lower outboard first reduction gear bearing. The alarm indicator set point is 5 psig. The meter reads 0 to 25 psig. Because there is a certain amount of head pressure in the LO supplied to this bearing and its sensor, the meter tends to read 1 to 3 psig higher than actual LO header pressure.



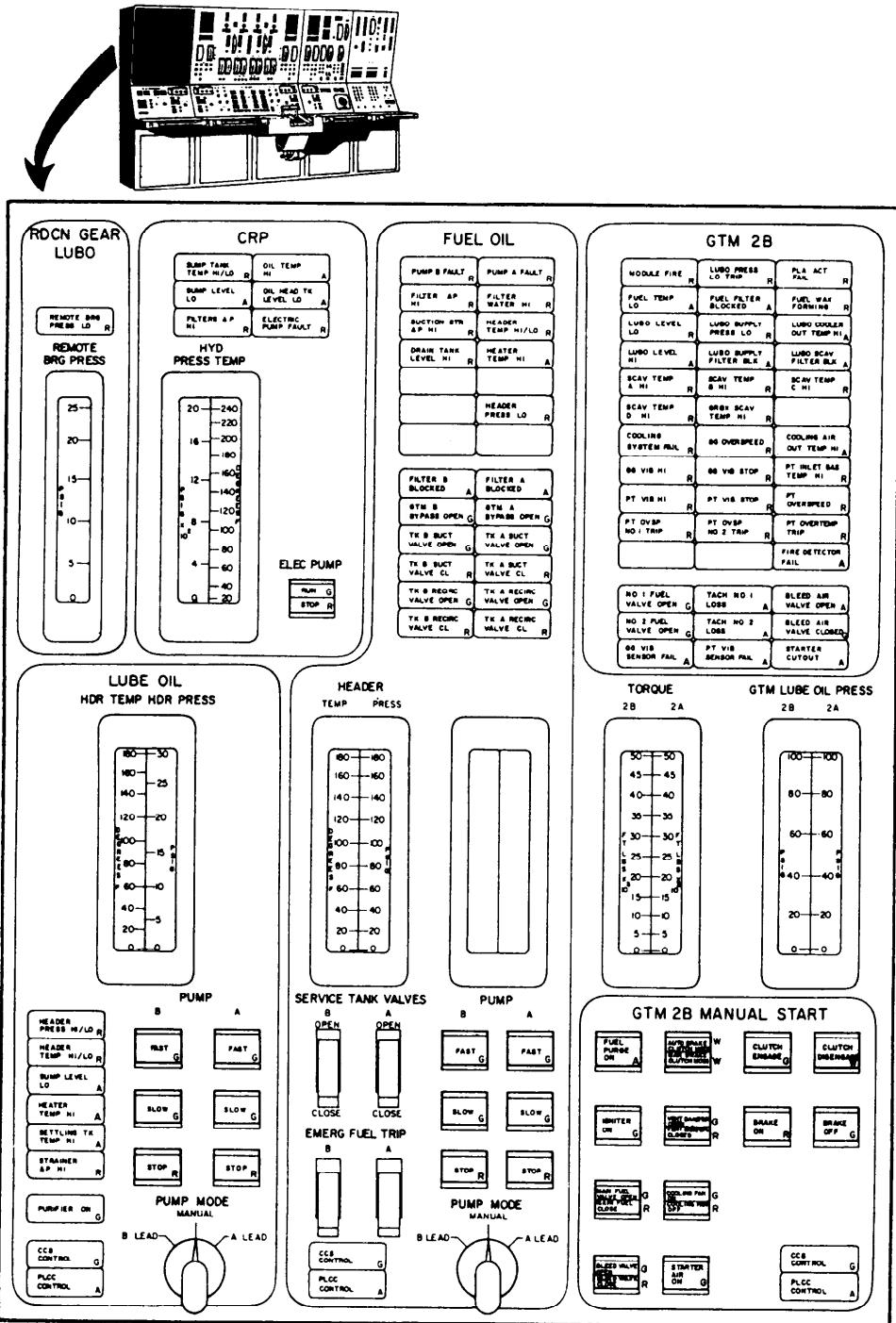


Figure 5-2.—PACC—engine No. 1 panel.

### CRP Section

The next section on the panel, the CRP section, is used to monitor the CRP system. It has six alarm indicators (seven on the CG), a meter, and a push-button control indicator (two on the CG). The first alarm indicator is labeled SUMP TANK TEMP HI/LO. It is a red indicator that illuminates when the CRP sump tank LO temperature is below or exceeds its alarm set

and a push-button control indicator (two on the CG). The first alarm indicator is labeled SUMP TANK TEMP HI/LO. It is a red indicator that illuminates when the CRP sump tank LO temperature is below or exceeds its alarm set

point. To the right is an alarm indicator labeled OIL TEMP HI. It is an amber indicator that illuminates when the temperature of the LO from the pump to the system exceeds its alarm set point. The next alarm indicator is labeled SUMP LEVEL LO. It is also an amber indicator that illuminates when the CRP sump tank LO level is below 500 gallons. To the right is an alarm indicator labeled OIL HEAD TK LEVEL LO. It is an amber indicator that illuminates when the CRP head tank LO level is below 10 gallons. On the third row is the alarm indicator labeled FILTERS ΔP HI. It is a red indicator that illuminates when the LO pressure across either of the three filters on the hydraulic oil power module (HOPM) of the CRP system exceeds its alarm set point. The last alarm indicator on the DD console is labeled ELECTRIC PUMP FAULT. It is a red indicator that illuminates when the electric pump is running and pump discharge pressure drops below 100 psig for more than 5 seconds.

On the CG console, the last alarm indicator is labeled HYDRAULIC PRESS LO. It illuminates red when the pump discharge pressure drops below 100 psig for 5 seconds.

The only meter associated with the CRP is labeled HYD PRESS TEMP. It is a dual-indicating meter used to monitor the pressure and temperature of the HP oil at the output of the HOPM to the OD box.

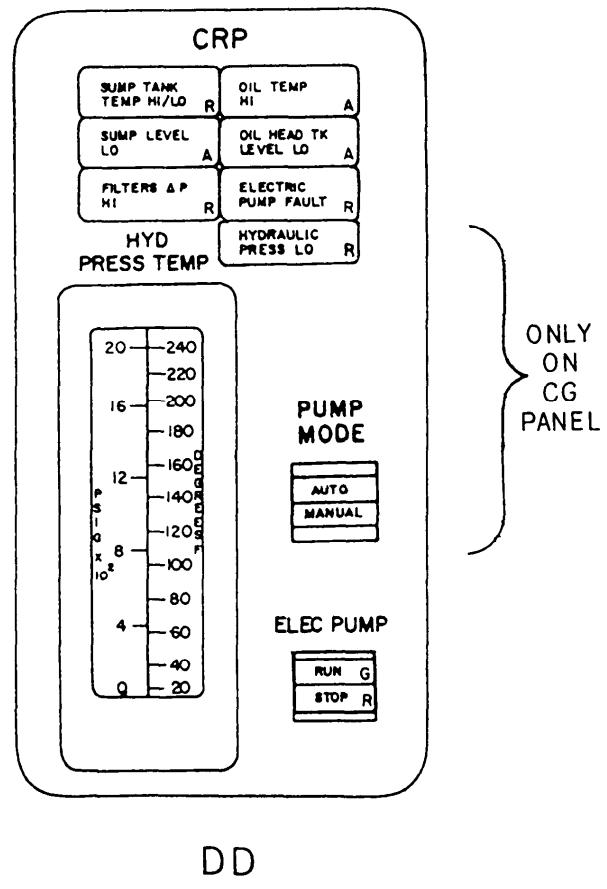
The push-button control indicator on the CG console under the label PUMP MODE has a split-legend indicator, labeled AUTO/MANUAL. If the AUTO mode is selected by the PACC operator, the electric CRP pump will come on the line if any one of the following conditions are true:

1. The attached pump output pressure is < 100 psig for 1 second.
2. Shaft speed is < 90 rpm for 10 seconds.
3. If the pitch mismatch > 10 percent for 1 second.

#### NOTE

On the CG-class ship, if the electric pump control mode is in auto, once the hydraulic oil pressure recovers (as a result of pump speed increase or other operator actions) the electric pump must be manually secured by the PACC operator.

The push-button control indicator on the DD console under the label ELEC PUMP has a split-legend indicator labeled RUN/STOP. It is used to control the CRP electric LO pump and illuminates (either green or red) to indicate the status and operator command to the pump.



DD

#### FUEL OIL Section

This section is used to monitor the FO service system. It has 11 alarm indicators, 10 status indicators, a meter, 4 valve control switches, a three-position rotary switch for pump mode control, 6 push-button control indicators, and 2 station-in-control status indicators.

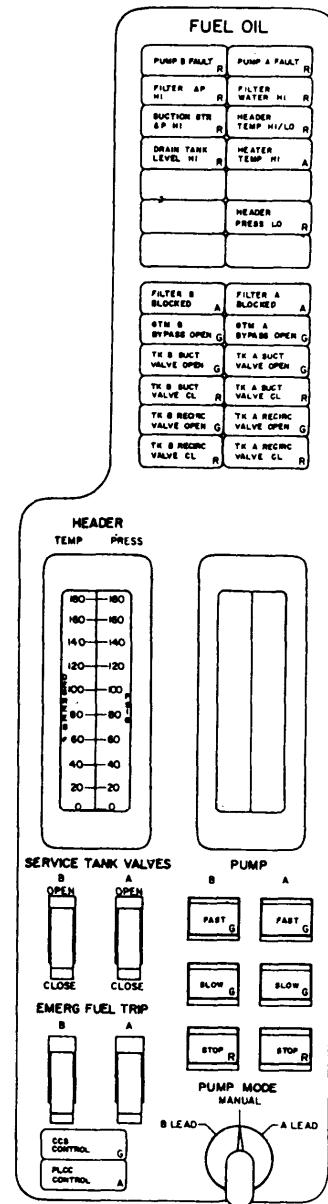
The first two alarm indicators are a pair of functionally identical indicators. They are labeled PUMP B FAULT and PUMP A FAULT. These indicators are red and illuminate when either FO service pump is running and the pump discharge pressure drops below 35 psig for 5 seconds. The next alarm indicator is labeled FILTER ΔP HI.

it is a red indicator that illuminates when the differential pressure across the fuel coalescer exceeds 30 psid. The alarm indicator labeled FILTER WATER HI is a red indicator. When it is illuminated, the water level in the fuel coalescer is high. The alarm indicator labeled SUCTION STR ΔP HI is a red indicator. When it is illuminated, the differential pressure across the FO suction strainer exceeds 4 psid. The alarm indicator labeled HEADER TEMP HI/LO is a red indicator. When it is illuminated, the header FO temperature either exceeds 130°F or is below 80°F. The alarm indicator labeled DRAIN TANK LEVEL HI is a red indicator that indicates the FO leak detection tank fuel level exceeds 2.5 gallons. The alarm indicator labeled HEATER TEMP HI illuminates red to indicate that the FO heater discharge temperature is > 140°F. The last alarm indicator labeled HEADER PRESS LO illuminates red when the FO header pressure is < 40 psig.

The next group of alarm and status indicators are pairs of functionally identical indicators. The first pair of alarm indicators labeled FILTER B BLOCKED and FILTER A BLOCKED are amber indicators. When they illuminate, the differential pressure across their respective coalescer exceeds 25 psid. Below this pair are two status indicators labeled GTM B BYPASS OPEN and GTM A BYPASS OPEN. These two status indicators were part of the original system design, but due to later system modifications, neither indicator is functional. The next pair of status indicators TK B SUCT VALVE OPEN and TK A SUCT VALVE OPEN are green indicators. They illuminate when their respective FO service tank suction valves open. Next are two status indicators labeled TK B SUCT VALVE CLOSED and TK A SUCT VALVE CLOSED. They illuminate red when their respective FO service tank suction valves close. Next are two status indicators labeled TK B RECIRC VALVE OPEN and TK A RECIRC VALVE OPEN. They illuminate green when their respective FO service tank recirculating valves open. The last pair of status indicators are labeled TK B RECIRC VALVE CLOSED and TK A RECIRC VALVE CLOSED. They illuminate red when their respective FO service tank recirculating valves close.

Under the label HEADER is a dual-indicating meter. This meter monitors the TEMP and PRESS of the FO system. The FO system

temperature is sensed at the FO heater outlet and the FO system pressure is sensed at the coalescer outlet. A second meter, located to the right of the HEADER dual-indicating meter was originally designed for this console. It has been deleted by design changes and the space on the console blanked off.



Under the label SERVICE TANK VALVES are two covered toggle control switches. They are a pair of functionally identical switches labeled B OPEN/CLOSED and A OPEN/CLOSED.

Each toggle switch controls its respective tank's suction and recirculation valves. The PACC operator uses these toggle switches to command the respective FO tank suction and recirculation valves either open or closed. Under the label EMERG FUEL TRIP are a pair of functionally identical, covered toggle control switches labeled B and A. The PACC operator uses these toggle switches to close the emergency FO trip valves. These valves must be manually reopened at the valve.

Under the label PUMP are the six push-button control indicators. There are two columns of three push buttons for each pump (B or A). The PACC operator uses these push buttons to control the pump speed of either or both FO pumps. The push buttons labeled FAST and SLOW are green status indicators that illuminate the status or command to the respective pump, depending on the operating mode the PACC operator selects. The push buttons labeled STOP are red indicators that illuminate the status or command to the respective pump.

Under the EMERG FUEL TRIP toggle switches are two status indicators. The first indicator is green and labeled CCS CONTROL. It illuminates when CCS has control of the FO system. The other indicator is amber and labeled PLCC CONTROL. It illuminates when control of the FO system is at the PLCC.

Under the label PUMP MODE is the three-position rotary switch. The positions are labeled B LEAD, MANUAL, and A LEAD. The PACC operator uses this rotary switch to select either the manual mode of pump operation or the automatic mode. The automatic mode is selected by placing the rotary switch in either the B LEAD or A LEAD position. The position designated by the PACC operator determines which pump is the lead pump and which pump is the standby pump.

## GTM 2B Section

The GTM 2B section is used to monitor various parameters of the GTM 2B. It has 30 alarm indicators (32 on the CG console), 9 status indicators (7 on the CG console), 2 dual-indicating meters, and the GTM 2B MANUAL START controls with 12 push-button control indicators (9 on the CG console) and 2 status indicators. The indicators are arranged in three columns. We will

describe them from left to right and top to bottom.

The first alarm indicator labeled MODULE FIRE illuminates red when a fire occurs in the GTM module. It can be activated either by the UV sensors in the module or an RTE in the overhead of the module. The alarm indicator labeled LUBO PRESS LO TRIP illuminates red when a GTM shutdown at 6 psig LO pressure occurs. The alarm indicator labeled PLA ACT FAIL illuminates red when the voltage level to the PLA is out of limits or an overtorque condition exists on the GTM. The first alarm indicator on the second row across is labeled FUEL TEMP LO. It illuminates amber when the FO temperature to the GTM is below 80°F. The alarm indicator labeled FUEL FILTER BLOCKED illuminates amber when the differential pressure of the filter on the GTM exceeds 27 psid. The alarm indicator labeled FUEL WAX FORMING illuminates red when the FO temperature at the MFC is 60°F or below.

The first alarm indicator on the third row down is labeled LUBO LEVEL LO. It illuminates red when the LO level in the LOSCA is 8 gallons or less. The alarm indicator labeled LUBO SUPPLY PRESS LO illuminates red when the LO pressure to the GTM is 15 psig or less. The alarm indicator labeled LUBO COOLER OUT TEMP HI illuminates amber when the LO temperature at the outlet of the LOSCA exceeds 250°F. The alarm indicator labeled LUBO LEVEL HI on the fourth row illuminates amber when the LO level in the LOSCA is 40 gallons or more. The alarm indicator labeled LUBO SUPPLY FILTER BLK illuminates amber when the differential pressure of the LO supply filter in the GTM module exceeds 20 psid. The alarm indicator labeled LUBO SCAV FILTER BLK illuminates amber when the differential pressure of the LO scavenge filter on the LOSCA exceeds 20 psid.

Beginning on the fifth row, the next five alarm indicators labeled SCAV TEMP A HI, SCAV TEMP B HI, SCAV TEMP C HI, SCAV TEMP D HI, and GRBX SCAV TEMP HI are all functionally identical indicators. They illuminate red when the respective LO scavenge temperature is > 300°F. The next alarm indicator (on the CG console) is labeled BLOW IN DOOR OPEN. It illuminates red when the blow-in doors in the uptakes are open.

On the seventh row, the first alarm indicator is labeled COOLING SYSTEM FAIL. It illuminates red when the cooling system fan pressure is out of limits or the vent damper is not

open. The alarm indicator labeled GG OVERSPEED illuminates red if the GG speed is  $> 9700$  rpm. The alarm indicator labeled COOLING AIR OUT TEMP HI illuminates amber when the module cooling air is  $> 350^{\circ}\text{F}$ .

On the eighth row, the first alarm indicator is labeled GG VIB HI. It illuminates red when the GG vibration is at 6 mils or higher. The alarm indicator labeled GG VIB STOP illuminates red when an auto shutdown of the GTM at a GG vibration of 7 mils occurs. The alarm indicator labeled PT INLET GAS TEMP HI illuminates red if  $T_{5.4}$  is  $> 1500^{\circ}\text{F}$ .

On the ninth row, the first alarm indicator is labeled PT VIB HI. It illuminates red when power turbine vibration is at 7 mils or higher. The alarm indicator labeled PT VIB STOP illuminates red when an auto shutdown of the GTM occurs at a power turbine vibration of 10 mils. The alarm indicator labeled PT OVERSPEED illuminates red if power turbine speed exceeds 3700 rpm.

On the tenth row, the next pair of alarm indicators, labeled PT OVSP NO 1 TRIP and PT OVSP NO 2 TRIP, are functionally identical indicators. They illuminate red when an auto shutdown of the GTM occurs. This is caused by the respective PT speed sensor detecting a PT speed of  $3960 \pm 40$  rpm. The alarm indicator labeled PT OVERTEMP TRIP illuminates red if an auto shutdown of the GTM occurs due to  $T_{5.4}$  exceeding  $1625^{\circ}\text{F}$ .

On the CG console, the first alarm indicator on the eleventh row is labeled MDL ACCESS DOOR OPEN. It illuminates amber when a door on the GTM module is open. The alarm indicator labeled FIRE DETECTOR FAIL illuminates amber if the fire detection circuitry fails or if a UV sensor in the GTM fire detection system fails.

The first status indicators on the twelfth and thirteenth rows are labeled NO 1 FUEL VALVE OPEN and NO 2 FUEL VALVE OPEN. They are a pair of functionally identical indicators. They illuminate green to indicate the respective fuel supply valve is open. The second status/alarm indicators on the twelfth and thirteenth rows are labeled TACH NO. 1 LOSS and TACH NO. 2 LOSS. They are a pair of functionally identical indicators. They illuminate amber if the respective speed sensor detects a PT speed of  $< 100$  rpm (or

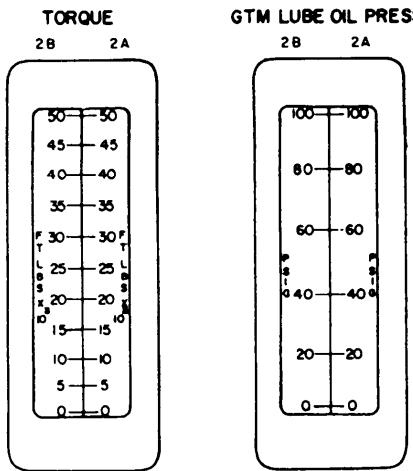
a speed sensor failure). The last status indicator on the twelfth row is labeled BLEED AIR VALVE OPEN. It illuminates amber when the bleed air valve is open. The last status indicator on the thirteenth row is labeled BLEED AIR VALVE CLOSED. It illuminates green when the bleed air valve is closed.

The first two alarm indicators on the fourteenth row are labeled GG VIB SENSOR FAIL and PT VIB SENSOR FAIL. They are a pair of functionally identical indicators. These two alarm indicators are NOT on the CG console. They illuminate amber if one of the GG or one of the PT vibration sensors fail. The last status/alarm indicator labeled STARTER CUTOUT illuminates amber if the starter fails during a start or when the GG speed reaches 4500 rpm and the start air valve closes.

GTM 2B			
MODULE FIRE R	LUBO PRESS LO TRIP R	PLA ACT FAIL R	
FUEL TEMP LO A	FUEL FILTER BLOCKED A	FUEL WAX FORMING R	
LUBO LEVEL LO R	LUBO SUPPLY PRESS LO R	LUBO COOLER OUT TEMP HI A	
LUBO LEVEL HI A	LUBO SUPPLY FILTER BLK A	LUBO SCAV FILTER BLK A	
SCAV TEMP A HI R	SCAV TEMP B HI R	SCAV TEMP C HI R	
SCAV TEMP D HI R	GRBX SCAV TEMP HI R		
COOLING SYSTEM FAIL R	GG OVERSPEED R	COOLING AIR OUT TEMP HI A	
GG VIB HI R	GG VIB STOP R	PT INLET GAS TEMP HI R	
PT VIB HI R	PT VIB STOP R	PT OVERSPEED R	
PT OVSP NO. 1 TRIP R	PT OVSP NO. 2 TRIP R	PT OVERTEMP TRIP R	
		FIRE DETECTOR FAIL A	
NO. 1 FUEL VALVE OPEN G	TACH NO. 1 LOSS A	BLEED AIR VALVE OPEN A	
NO. 2 FUEL VALVE OPEN G	TACH NO. 2 LOSS A	BLEED AIR VALVE CLOSED	
GG VIB SENSOR FAIL A	PT VIB SENSOR FAIL A	STARTER CUTOUT A	

Under the label TORQUE is a dual-indicating meter labeled 2B and 2A. This meter indicates the torque output of the respective PTs and reads in ft/lb. The signals to these meters come from the respective GTMs and are conditioned by the FSEE before being sent to the console for display. Under the label GTM LUBE OIL PRESS is a dual-indicating meter labeled 2B and 2A. This meter indicates the GTM LO supply pressure of the respective GTM. The signals for these meters come from the discharge side of the respective LO

supply pump and are sent to the console for display.



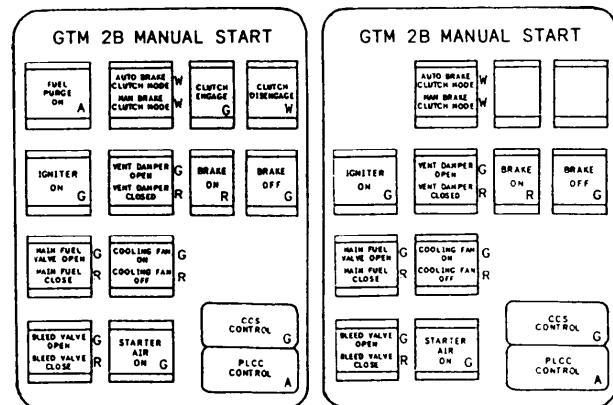
In the subsection labeled GTM 2B MANUAL START are 12 push-button control indicators (9 on the CG console) and 2 status indicators. The first push-button control indicator (not on the CG console) is labeled FUEL PURGE ON and illuminates amber when activated by the PACC operator. The PACC operator uses this push button to dump cold fuel from the GTM to the waste oil drain tank. This push button is normally used when the module FO temperature is below 80°F.

The next push-button control indicator is a split-legends type labeled AUTO BRAKE CLUTCH MODE/MAN BRAKE CLUTCH MODE (AUTO BRAKE MODE/MAN BRAKE MODE on the CG console). The AUTO BRAKE CLUTCH MODE (AUTO BRAKE MODE on the CG console) must be illuminated when an auto sequence start is initiated at the PACC. It works with the AUTO INITIATE start/stop mode. Automatic clutch and brake commands are transmitted to the PLCC MRG control circuitry. The MAN BRAKE CLUTCH MODE (MAN BRAKE MODE on the CG) portion of this indicator illuminates white when the PACC operator wants to perform a manual start of the GTM. The PACC operator will command the different statuses of the clutch and brake using the four momentary-contact push buttons to the right of this indicator. They are labeled CLUTCH ENGAGE (not on the CG console) (illuminates green to show command), CLUTCH DISENGAGE (not on the CG console) (illuminates white to show command), BRAKE ON

(illuminates red to show command), and BRAKE OFF (illuminates green to show command).

The push-button control indicator on the second row labeled IGNITER ON illuminates green when the PACC operator commands the igniters on during a manual start. It also illuminates when the igniters are energized during an auto initiate start. The next split-legends, push-button control indicator is labeled VENT DAMPER OPEN/VENT DAMPER CLOSED. It illuminates to show the command to the vent damper. On the third row is a split-legends, push-button control indicator labeled MAIN FUEL VALVE OPEN/MAIN FUEL VALVE CLOSED. It illuminates to show the command to the fuel supply valve during a manual start, auto start, manual stop, or auto stop. The split-legends, push-button control indicator labeled COOLING FAN ON/COOLING FAN OFF illuminates to show the PACC operator's command to the cooling fan during a manual start. It also illuminates when the electronics generates the command during an auto start. On the fourth row is a split-legends, push-button control indicator labeled BLEED VALVE OPEN/BLEED VALVE CLOSE. It illuminates to show the PACC operator's command to the bleed air valve during a manual start. It also illuminates when the electronics generates the command during an auto start. The push-button control indicator labeled STARTER AIR ON illuminates to show the PACC operator's command to the start air regulating valve during a manual start or when the starter air is on during an auto initiate start.

The two status indicators at the lower right are labeled CCS CONTROL and PLCC CONTROL. The CCS CONTROL indicator illuminates green when the PACC has control of the GTM. The PLCC CONTROL indicator illuminates amber when the PLCC has control of the GTM.



## LUBE OIL Section

This section is used to monitor the MRG LO system. It has one dual-indicating meter, a column of six alarm indicators (seven on the CG console), three status indicators, six pump push-button control indicators, and a three-position rotary switch for pump mode control.

The dual-indicating meter is labeled HDR TEMP/HDR PRESS. It is used to monitor the temperature and pressure of the LO at the MRG header. The temperature side reads in degrees Fahrenheit and the pressure side reads psig.

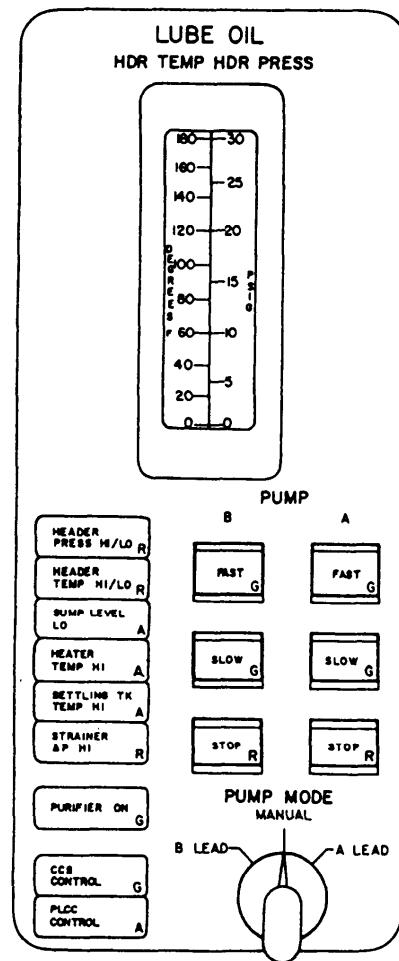
The alarm indicator labeled HEADER PRESS HI/LO is the first of the six alarm indicators. It illuminates red if the MRG LO pressure exceeds 27 psig or drops below 15 psig. Next is HEADER TEMP HI/LO, which illuminates red if the MRG LO temperature  $> 130^{\circ}\text{F}$  or is  $< 90^{\circ}\text{F}$ . The third one is SUMP LEVEL LO, which illuminates amber if the LO level in the MRG sump drops below 1400 gallons. The alarm indicator labeled HEATER TEMP HI illuminates amber if the LO discharge temperature of the LO service system heater exceeds  $170^{\circ}\text{F}$ . The fifth alarm indicator is labeled SETTLING TK TEMP HI. It illuminates amber if the temperature of the LO in the settling tank exceeds  $170^{\circ}\text{F}$ . The last one is STRAINER DP HI. It illuminates red if the differential pressure across the LO strainer exceeds 10 psid.

Under the label PUMP are the six push-button control indicators. There are two columns of three push buttons for each pump (B or A). The PACC operator uses these push buttons to control the pump speed of either or both LO pumps. The push buttons labeled FAST and SLOW are green status switch/indicators that illuminate to show the status or command to the respective pump, depending on the operating mode the PACC operator selects. The push buttons labeled STOP are red status indicators that illuminate to show the status or command to the respective pump. On the CG console, the additional alarm indicator labeled LO PURIFIER MALFUNCTION illuminates red when a malfunction of the MRG LO purifier occurs.

The status indicator labeled PURIFIER ON illuminates green when the MRG LO purifier is running. Under the PURIFIER ON indicator are two status indicators. The first status indicator is green and labeled CCS CONTROL. It illuminates when CCS has control of the LO

system. The other status indicator is amber and labeled PLCC CONTROL. It illuminates when control of the LO system is at the PLCC.

Under the label PUMP MODE is the three-position rotary switch. The positions are labeled B LEAD, MANUAL, and A LEAD. The PACC operator uses this rotary switch to select either the manual mode of pump operation or the automatic mode. In the MANUAL mode the PACC operator can start (slow or fast) or stop the electric LO pumps. The automatic mode is selected by placing the rotary switch in either the B LEAD or A LEAD position. The position designated by the PACC operator determines which pump is the lead pump and which pump is the standby pump.



## MIMIC PANEL

Figures 5-3 and 5-4 show a detailed view of the DD- and CG-class ships' PACC MIMIC

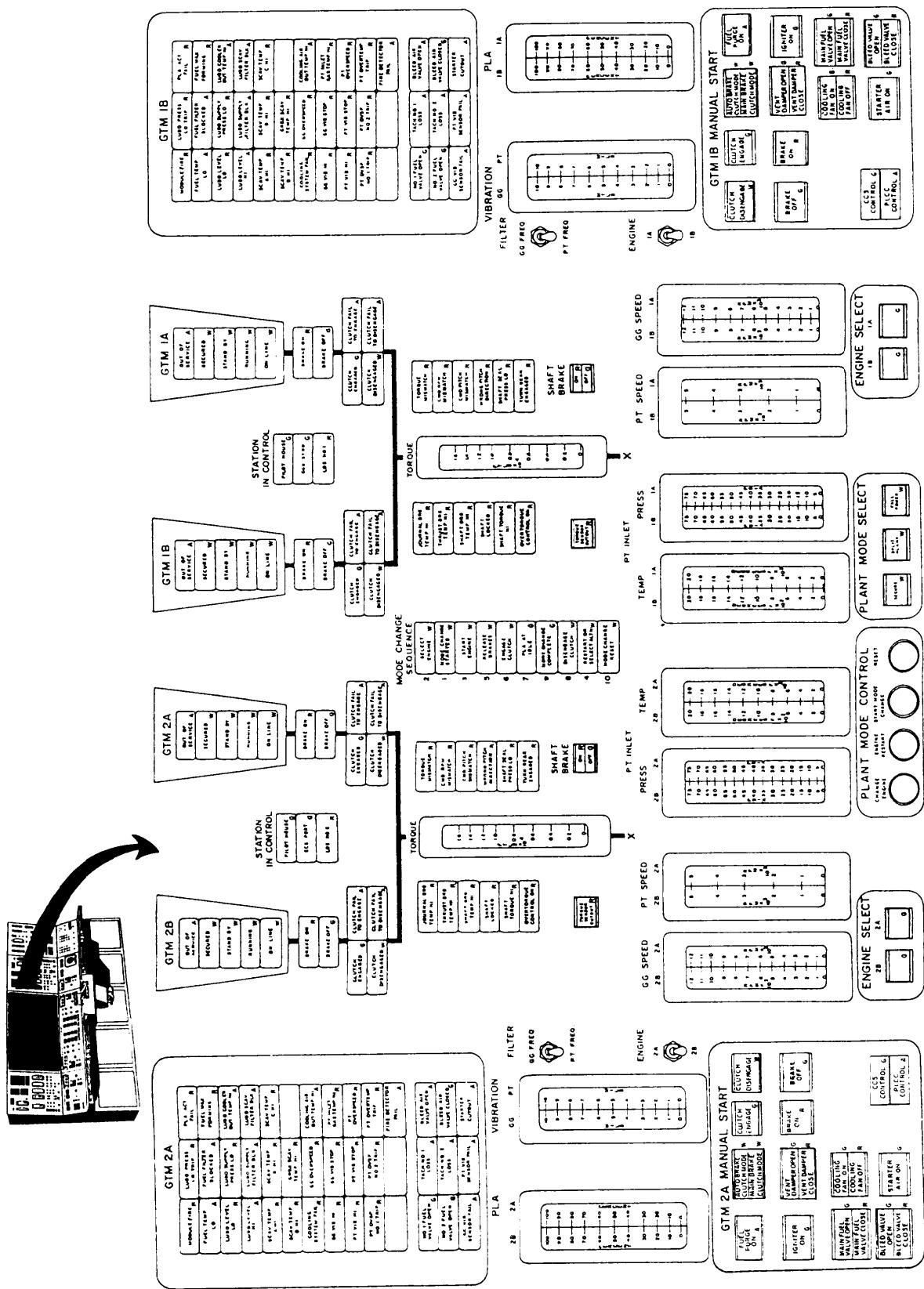


Figure 5-3.—DD PACC MIMIC panel.

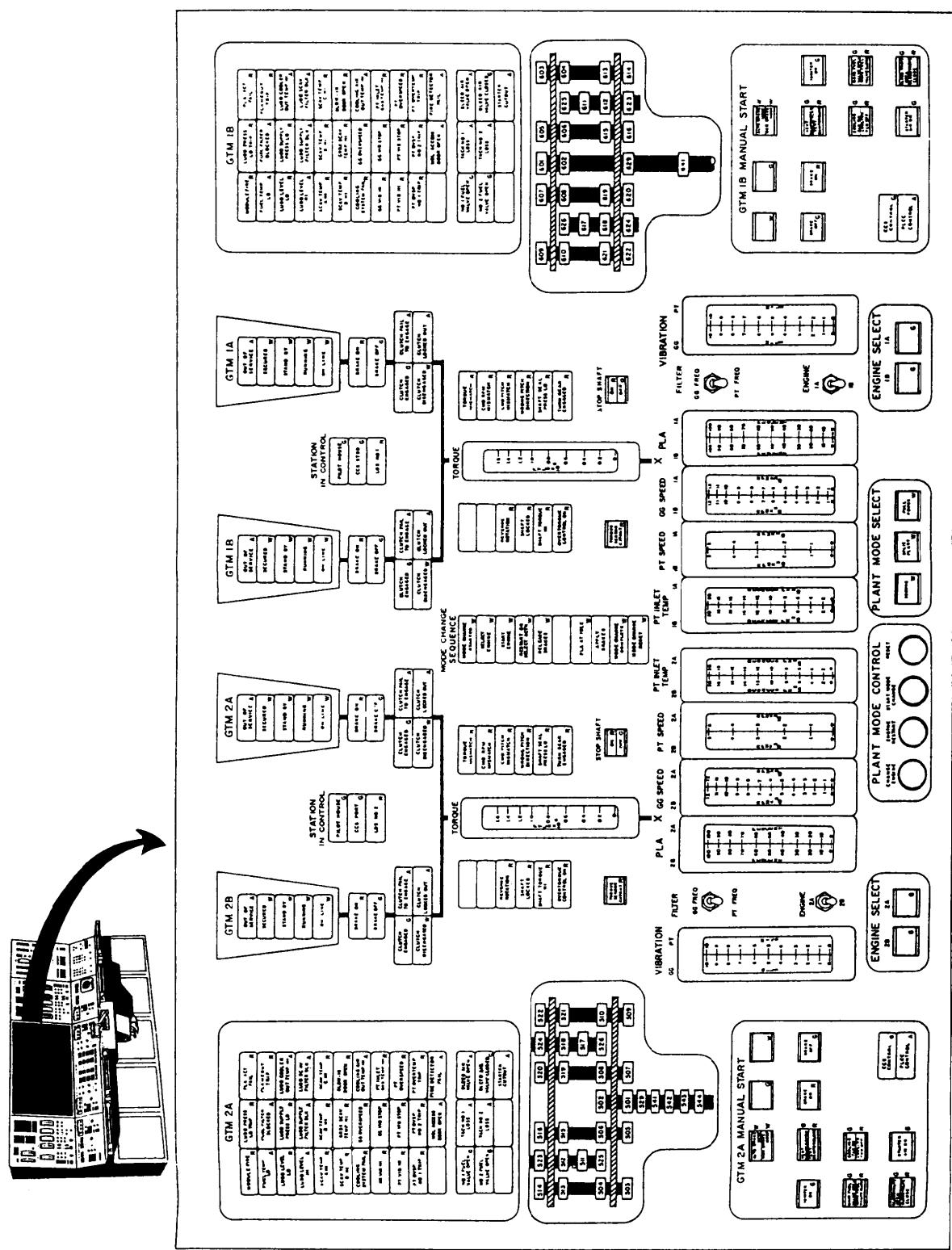


Figure 5-4.—CG PACC MIMIC panel.

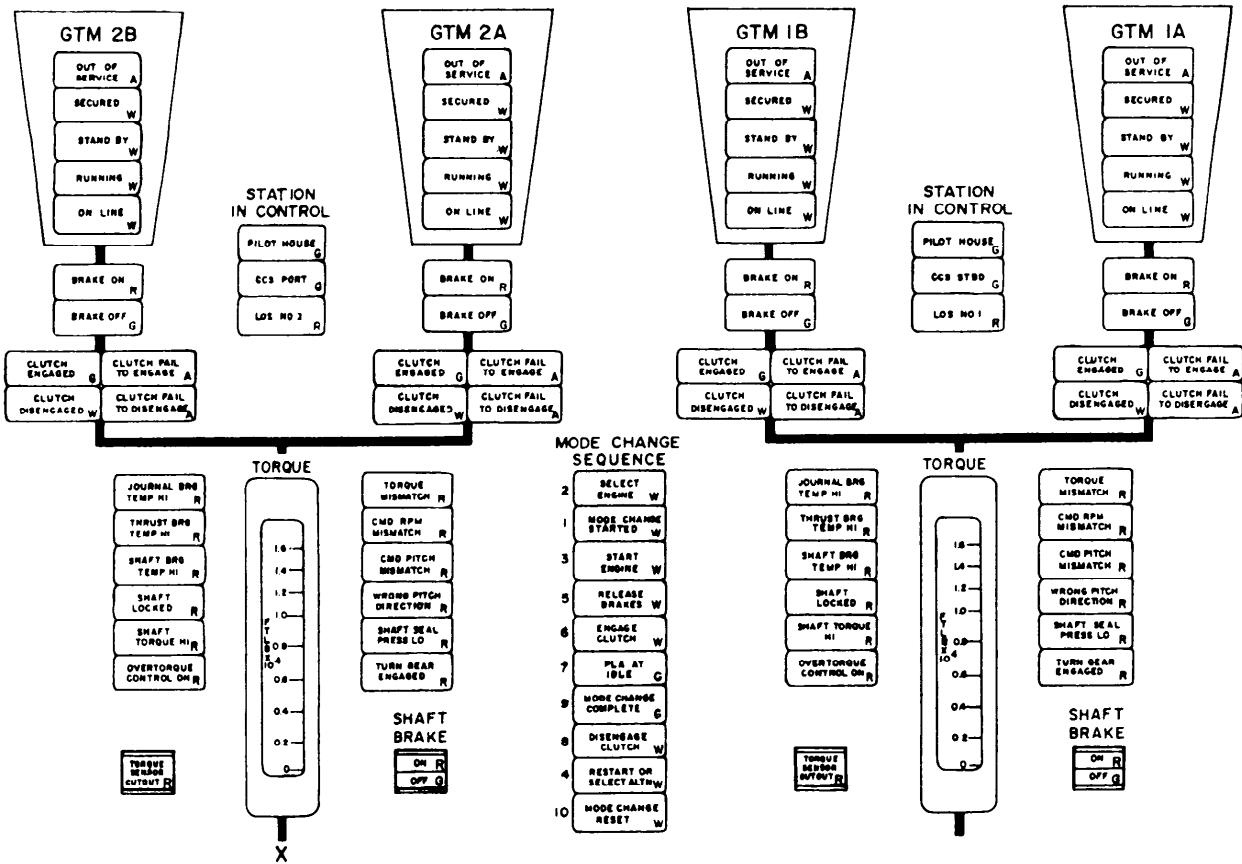


Figure 5-5.—Main center section of the DD MIMIC panel.

panels. The MIMIC panel provides a schematic representation of the four GTMs, clutches, reduction gears, and shafts. For this reason it is called the MIMIC panel. The left side of the MIMIC panel contains the status/alarm indicators and manual start push-button control indicators for the GTM 2A, an MRG bearing mimic on the CG console, PLA and vibration meters, and vibration select switches for GTM 2A and 2B. The right side of the MIMIC panel is identical to the left but labeled for GTM 1A and 1B. The main center part of the MIMIC panel displays the status of each GTM, which station has control of the individual engine rooms, which engines are connected to the main shaft, the alarms and status indicators for the individual engines, and the automatic mode selectors (ENGINE SELECT, PLANT MODE CONTROL, and PLANT MODE SELECT).

### GT M 2A Section

The GTM 2A section is a mirror image of the GTM 2B section. The alarm indicators and status

indicators were described under the GTM 2B section of the engine No. 2 panel and will not be described again.

### Main Center Section

Figure 5-5 shows the main center section of the DD and CG MIMIC panel. This section has 84 status/alarm indicators (80 on the CG console), 2 meters, and 4 push-button control indicators.

We will only describe one engine of the left engine group mimic section, as the indicators are identical for both engines and engine groups. The only difference in the engine groups is the left one is labeled GTM 2B/GTM 2A, while the right one is labeled GTM 1B/GTM 1A.

Starting with the first status indicator under the GTM 2B label is an indicator labeled OUT OF SERVICE. It illuminates amber when the key switch at the PLCC is in the out of service position. When illuminated, it prevents start of the GTM. The status indicator labeled SECURED illuminates white if the auxiliary systems are not

running or are not ready. These auxiliary systems are the FO, LO, MRG, and bleed air systems. The status indicator labeled STAND BY illuminates white when the auxiliary systems are ready. The systems and conditions required for this indicator to illuminate are as follows:

- FO header pressure > 40 psig
- LO header pressure > 9 psig
- MRG turning gear disengaged
- Bleed air header pressure > 40 psig

The status indicator labeled RUNNING illuminates white when

- the GTM has  $N_G > 4300$  rpm,
- $T_{5.4} > 400^{\circ}\text{F}$ , and
- the clutch is disengaged.

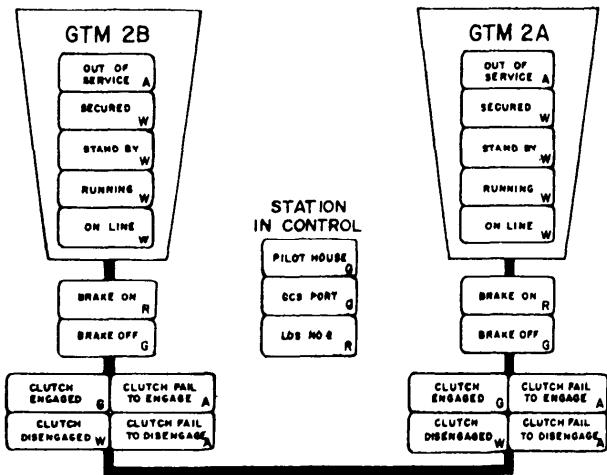
The status indicator labeled ON LINE illuminates white when the engine is running and the clutch is engaged. The status indicator labeled BRAKE ON illuminates red when the PT brake is on, and the status indicator labeled BRAKE OFF illuminates green when the PT brake is off.

The next four status indicators are for the clutches. The first two on the left are labeled CLUTCH ENGAGED and CLUTCH DISENGAGED. They illuminate (either green or white) to indicate the clutch status. The two clutch alarm indicators on the right are labeled CLUTCH FAIL TO ENGAGE and CLUTCH FAIL TO DISENGAGE on the DD console. On the CG console they are labeled CLUTCH FAIL TO ENGAGE and CLUTCH LOCKED OUT. On either the DD or the CG console, these indicators illuminate amber to indicate the clutch status.

Between the two engine mimics, under the label STATION IN CONTROL, are three status indicators. These status indicators and the conditions required for them to illuminate are as follows:

- PILOT HOUSE—It illuminates green when the pilot house is in control.

- CCS PORT—It illuminates green when the CCS is in control of the port MER.
- LOS NO 2—It illuminates red when the local operating station has control.



The following alarm indicators, located to the left and right of the edgewise meter labeled TORQUE, are on the DD PACC console. We will describe these 12 alarm indicators first, then describe the 3 alarm indicators that are different on the CG PACC.

The first alarm indicator on the left side is labeled JOURNAL BEARING TEMP HI. It monitors all of the MRG journal bearings and illuminates red if one (or more) of the bearings temperature(s) exceeds its high temperature set point. The alarm indicator labeled THRUST BRG TEMP HI illuminates red if one (or more) of the three thrust bearings monitored exceeds its high temperature set point. The three bearings monitored are a thrust bearing in each of the two GTM clutch/brake assemblies and the MRG thrust bearing. The alarm indicator labeled SHAFT BRG TEMP HI monitors the line shaft bearing temperature. It illuminates red when one or more of the line shaft bearings exceeds its high temperature set point. The status indicator labeled SHAFT LOCKED illuminates red when the shaft lock mechanism on the MRG turning gear is engaged. The alarm indicator labeled SHAFT TORQUE HI illuminates red to indicate high shaft torque. This indicator is set to alarm at different set points for either one-engine operation or two-engine operation. The status indicator labeled OVERTORQUE CONTROL ON illuminates amber when the engine is in torque limiting. It flashes intermittently as the

engine goes in and out of torque limiting, or remains illuminated as long as the engine is in torque limiting.

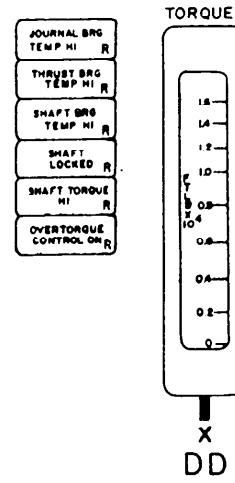
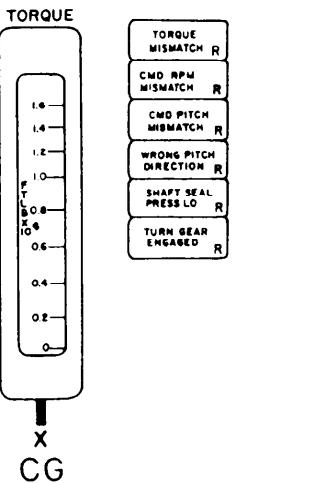
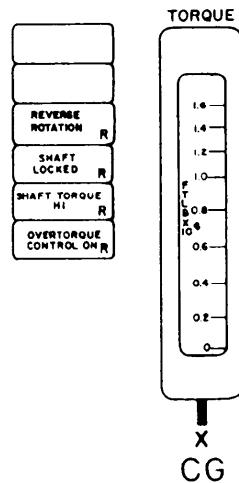
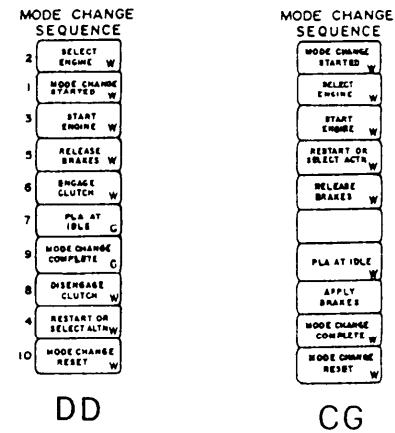
On the right side of the TORQUE meter are five alarm indicators. The first one, labeled TORQUE MISMATCH, illuminates red when a discrepancy exists between actual shaft torque and computed shaft torque. The next one, labeled CMD RPM MISMATCH, illuminates red if a discrepancy exists between actual shaft rpm and commanded shaft rpm. The third indicator, labeled CMD PITCH MISMATCH, illuminates red if a discrepancy exists between actual pitch and commanded pitch. The alarm indicator labeled WRONG PITCH DIRECTION illuminates red if the actual pitch moves in the opposite direction from the commanded pitch setting. The last one, labeled SHAFT SEAL PRESS LO, illuminates red when the cooling/sealing water pressure to the propeller shaft seal drops below 12 psig. The status indicator labeled TURN GEAR ENGAGED illuminates red when the MRG turning gear is engaged.

Three alarm indicators, located to the left of the edgewise meter labeled TORQUE on the CG MIMIC panel, are different. We will describe these indicators that are located at the same position as those described on the DD MIMIC panel.

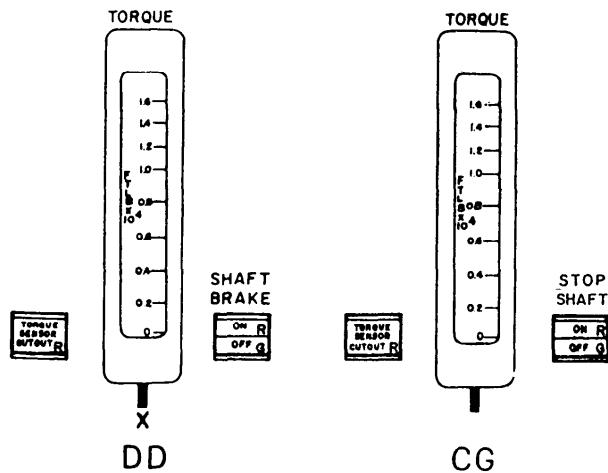
The first two alarm indicators on the left side are blank. The alarm indicator labeled REVERSE ROTATION monitors the shaft rotation and illuminates red if the shaft is rotating in the reverse direction from designed rotation. The rest of the alarm indicators on this section are identical to the DD console alarm indicators.

Between the engine group sections under the label MODE CHANGE SEQUENCE are the 10 status indicators (9 on the CG console) that

illuminate white at various stages in the start of a GTM. Their sequence of illumination varies depending on which plant mode logic start of a GTM is selected. We will not describe the various mode changes in this TRAMAN. For detailed information on the plant mode change sequence, consult the applicable NAVSEA technical manual for either the DD- or CG-class ships. The indicators on the DD console are labeled as follows from top to bottom: SELECT ENGINE, MODE CHANGE STARTED, START ENGINE, RELEASE BRAKES, ENGAGE CLUTCH, PLA AT IDLE, MODE CHANGE COMPLETE, DIS-ENGAGE CLUTCH, RESTART OR SELECT ALTN, and MODE CHANGE RESET. The indicators on the CG console are labeled as follows from top to bottom: MODE CHANGE STARTED, SELECT ENGINE, START ENGINE, RESTART OR SELECT ACTN, RELEASE BRAKES, PLA AT IDLE, APPLY BRAKES, MODE CHANGE COMPLETE, and MODE CHANGE RESET.



Located at the bottom and to the left and right of the TORQUE meter are two push-button control indicators. The left push-button indicator is identical on the DD and CG consoles. It is labeled TORQUE SENSOR CUTOUT. When depressed by the PACC operator, it illuminates red to indicate the shaft torque limiting is inhibited. Commanding officer's permission is required for the PACC operator to activate this push button. The other push button on the DD console, under the heading SHAFT BRAKE, is labeled ON and OFF. It illuminates either red or green to indicate the command to the shaft brake. On the CG console, this push-button indicator is under the heading STOP SHAFT. It DOES NOT engage the shaft brake. It is labeled ON and OFF and illuminates either red or green to indicate the PACC operator's command to the on line engine(s) PT brake. When the PT brakes are ON (engaged), they will allow the shaft to coast to a stop.

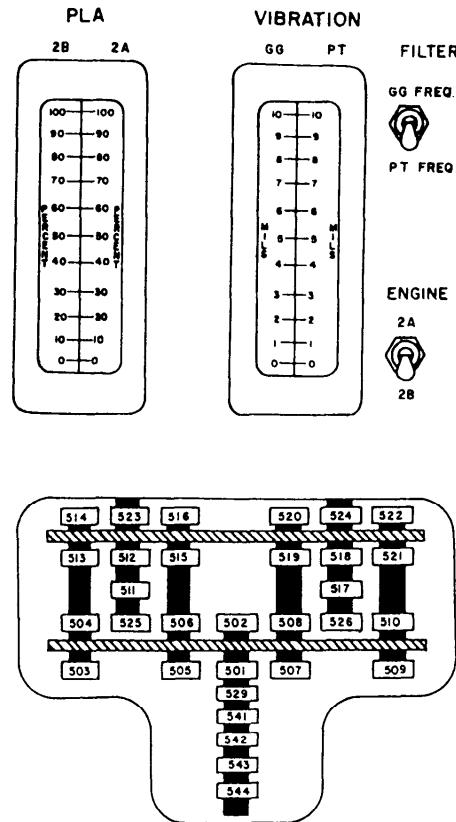


### PLA and VIBRATION Meters and MRG Mimic Section

Two dual-indicating meters are located below the GTM 2A (GTM 2B) section at the left and right side of the DD MIMIC panel. These meters are identical and labeled for the related engine. On the CG console this position is filled with a mimic of the MRG and has red LEDs to indicate a bearing high temperature. The DDI address for each bearing is also on this mimic.

The first dual-indicating meter under the heading PLA is labeled 2B and 2A. It displays the applicable engine's PLA position in percent of power.

The other dual-indicating meter under the heading VIBRATION is labeled GG and PT. Associated, and located to the right of this meter, are two toggle switches. The top toggle switch under the heading FILTER is a two-position switch labeled GG FREQ and PT FREQ. This switch is used to select which vibration sensor the signal displayed on the meter is monitoring, either the GG vibration transducer or the PT vibration transducer. The other toggle switch, under the heading ENGINE, is a two-position switch labeled 2A and 2B. It is used to select which engine's vibration is to be displayed on the meter.



### GTM 1B Section

The GTM 1B section, located in the upper right corner of the MIMIC panel, is a mirror image of the GTM 2B section. It has alarm indicators and status indicators identical to the GTM 2B. These were described under the GTM 2B section of the engine No. 2 panel and will not be described again.

### GTM 2A Manual Start Section

The GTM 2A MANUAL START section, located in the lower left corner of the MIMIC

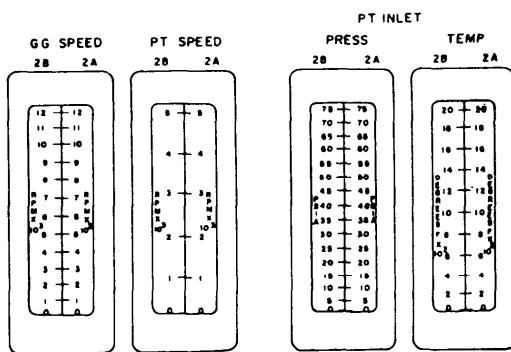
panel, is a mirror image of the GTM 2B MANUAL START section. It has alarm indicators and status indicators identical to the GTM 2B section. These were described under the GTM 2B MANUAL START section of the engine No. 2 panel and will not be described again.

### Lower Center Section

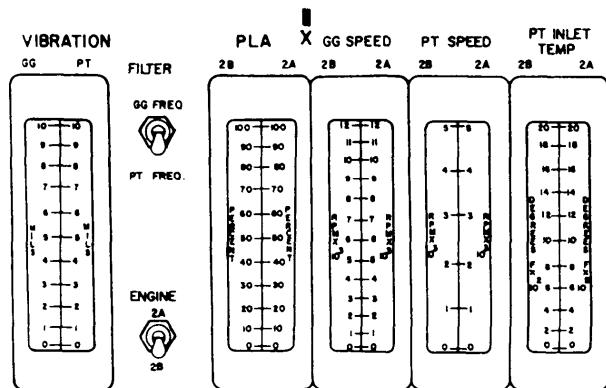
The lower center section of the DD MIMIC panel has 8 dual-indicating meters (4 for each engine group) (10 on the CG PACC, with 5 for each engine group), 2 ENGINE SELECT sections that have 2 push-button control indicators, a PLANT MODE CONTROL section with 4 push-button control indicators, and a PLANT MODE SELECT section that has 3 push-button control indicators. The CG MIMIC panel also has 4 two-position toggle switches. We will only describe the meters for the engine 2B and 2A group. The meters for the engine 1B and 1A group are identical.

The first two dual-indicating meters on the DD console, under the headings GG SPEED and PT SPEED, are both labeled 2B and 2A. The signals displayed on these meters originate at the GG and PT speed pickups of the respective engines. The GG speed pickup is located on the accessory gearbox. The PT speed pickups (two) are located in the turbine rear frames. The speed meters read in rpm. The next two dual-indicating meters, under the heading PT INLET, are labeled PRESS 2B/2A and TEMP 2B/2A. These meters display the pressure (in psia) and temperature ( $^{\circ}\text{F} \times 10^2$ ) of the respective engines. The signals displayed on these meters come from sensors in the respective engine's turbine midframe. The pressure sensors are probes that pressurize a transducer, and the temperature sensors are thermocouples.

The last four dual-indicating meters' are mirror images of the four just described. Remember, the only difference in the meters is their label for the engine 1B and 1A group.



On the CG MIMIC panel, the first two dual-indicating meters are labeled VIBRATION GG/PT and PLA 2B/2A. Associated with these two meters are two toggle switches labeled FILTER GG FREQ/PT FREQ and ENGINE 2A/2B. These meters and toggle switches are identical to the PLA and vibration meters described previously for the DD console. The next three dual-indicating meters are labeled GG SPEED 2B/2A, PT SPEED 2B/2A, and PT INLET TEMP 2B/2A. These meters are identical to those described on the DD console. A difference in the CG console is that it does NOT have a PT INLET pressure meter.



The last five dual-indicating meters on the CG MIMIC panel are mirror images of the five just described. Remember, the only difference in the meters is their label for the engine 1B and 1A group.

The ENGINE SELECT sections at the lower center of the MIMIC panel are located on the lower left and right sides of the panel. Each section has two push-button control indicators labeled 2B and 2A and 1B and 1A, respectively. These push-button indicators illuminate green to indicate the engine(s) selected by the PACC operator for a start/stop sequence.

The section labeled PLANT MODE CONTROL has four push buttons. They are labeled CHANGE ENGINE, ENGINE RESTART, START MODE CHANGE, and RESET. The change engine command allows for GTMs in the same engine room to be rotated on and off line automatically when in the split-plant mode. The change engine mode begins when the START MODE CHANGE and CHANGE ENGINE push buttons are depressed simultaneously. This initiates a sequence that will start the selected engine, bring it up to speed, bring the other engine to idle, and secure it (if requested). The system

may be manually reset by the PACC operator depressing the RESET push button. If the engine selected to start does not come on line, the PACC operator may elect to press the ENGINE RESTART push button to initiate another attempt at starting the selected engine. If the PACC operator does nothing, the system will automatically reset after 20 seconds.

The PLANT MODE SELECT section has three push-button control indicators. They are labeled SECURE, SPLIT PLANT, and FULL POWER. These push buttons are used by the PACC operator to automatically place the main propulsion plant in the desired plant configuration. The PACC operator selects which mode of plant operation he desires the plant to operate. The selected mode illuminates white to indicate the command to the system electronics.

### GTM 1B Manual Start Section

The GTM 1B MANUAL START section, located in the lower right corner of the MIMIC panel, is a mirror image of the GTM 2B MANUAL START section. It has alarm indicators and status indicators identical to the GTM 2B section. These were described under the GTM 2B MANUAL START section of the engine No. 2 panel and will not be described again.

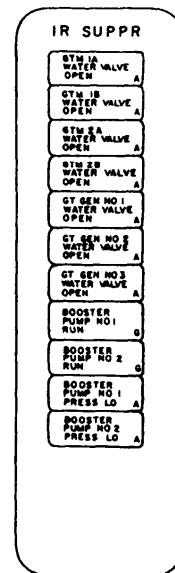
### ENGINE NO. 2 PANEL

Figure 5-6 shows the engine No. 2 panel divided into five sections for engine No. 1A. These sections are labeled RDCN GEAR LUBO, CRP, FUEL OIL, GTM 1 A (including alarm, manual start push-button indicators, and torque and LO pressure meters for both GTMs), and LUBE OIL. This panel is a mirror image of the engine room No. 1 panel shown in figure 5-2. The components are labeled for the 1B and 1A engines. The meters, switches, and alarm/indicators are identical and will not be described again.

### PACC AUXILIARY/BLEED AIR PANEL

The PACC auxiliary/bleed air panels for the DD- and CG-class ships' consoles are shown in figures 5-7 and 5-8. The DD-class ship's console is divided into 14 sections (16 on the CG console). Again, we will describe the DD console and use

inserts to point out the differences between the DD and CG consoles.



### WASTE HT BLR Section

This section has 10 alarm indicators (9 on the CG console) and a spare indicator. These alarm indicators are used to monitor the waste heat boilers. Starting at the top of the column, the first three alarm indicators on both the DD and CG consoles are functionally identical, although they are labeled slightly different. These alarm indicators illuminate red if a summary fault condition has been detected on either Nos. 1, 2, or 3 WHB. After these three, the next two alarm indicators on both consoles are also functionally

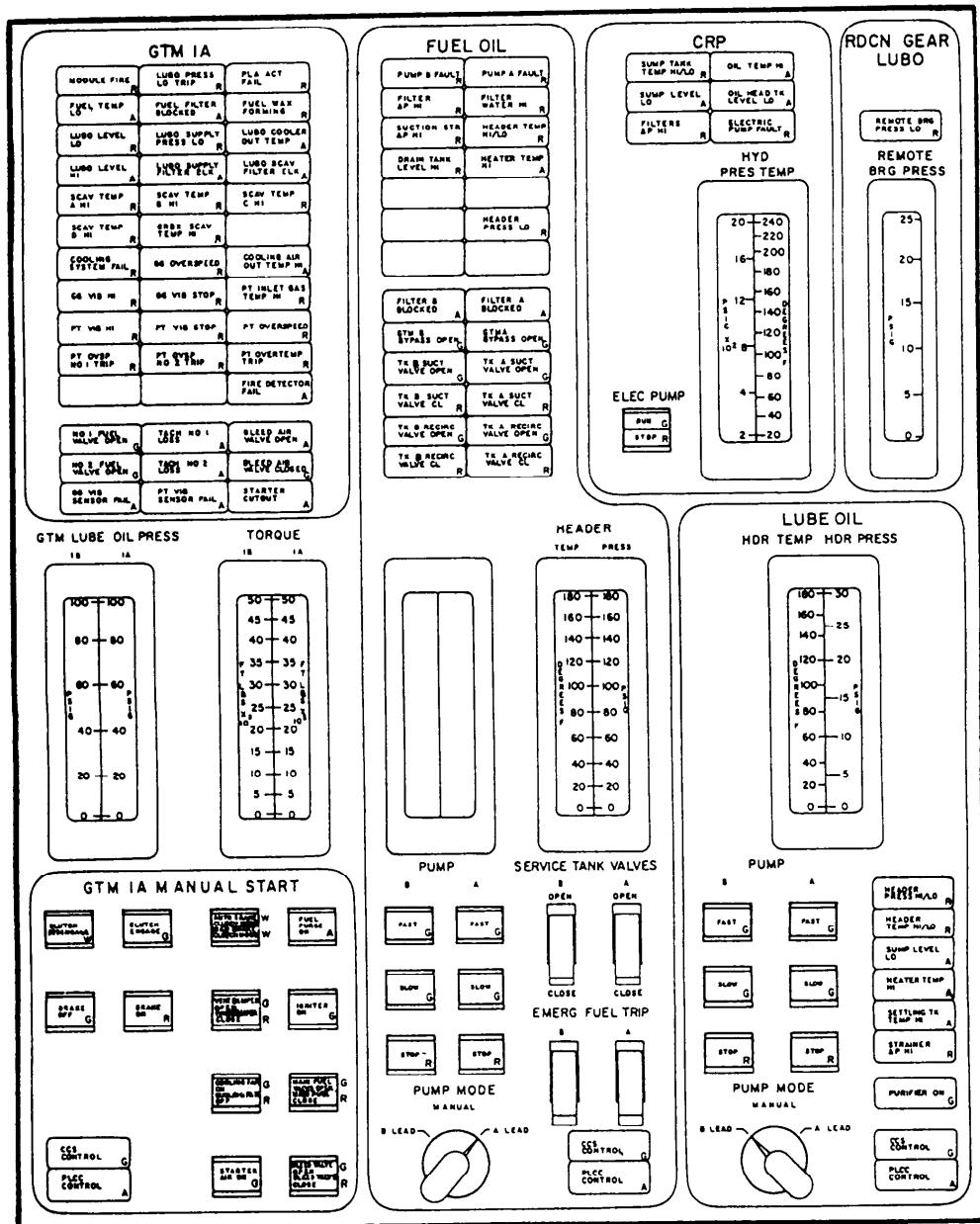
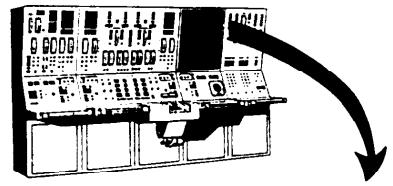
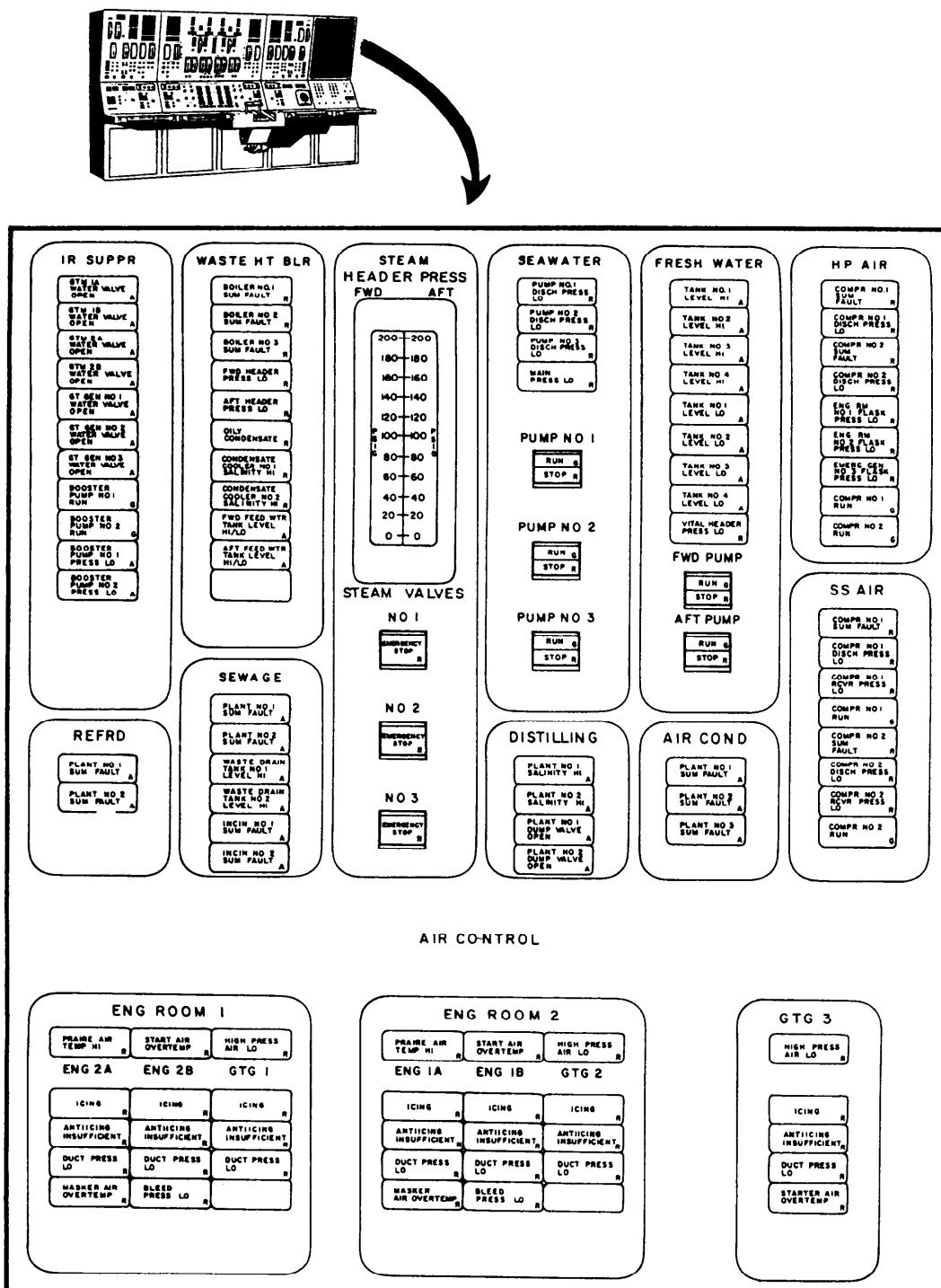


Figure 5-6.—PACC-engine No. 2 panel.



**Figure 5-7.—DD PACC—auxiliary/bleed air panel.**

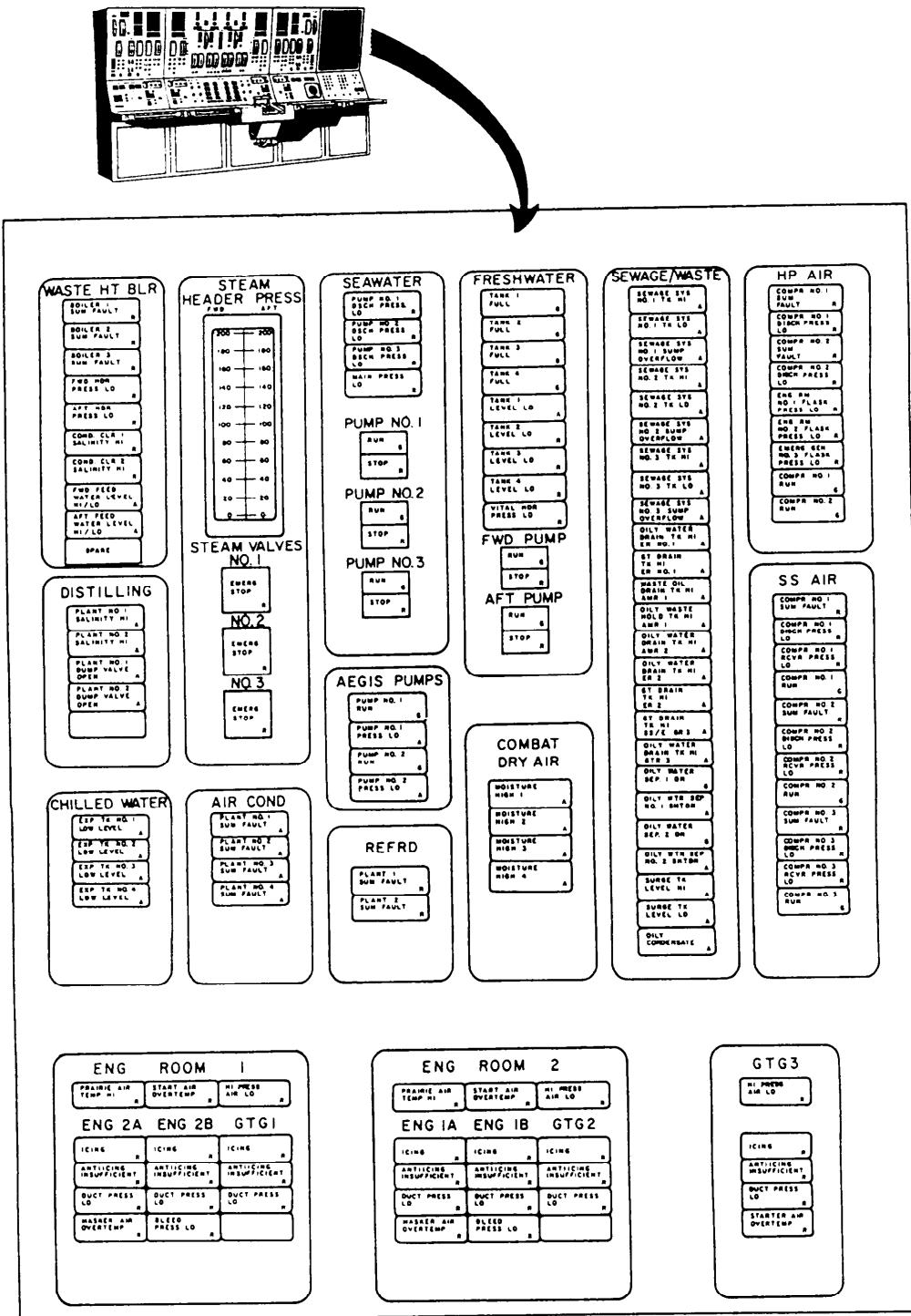
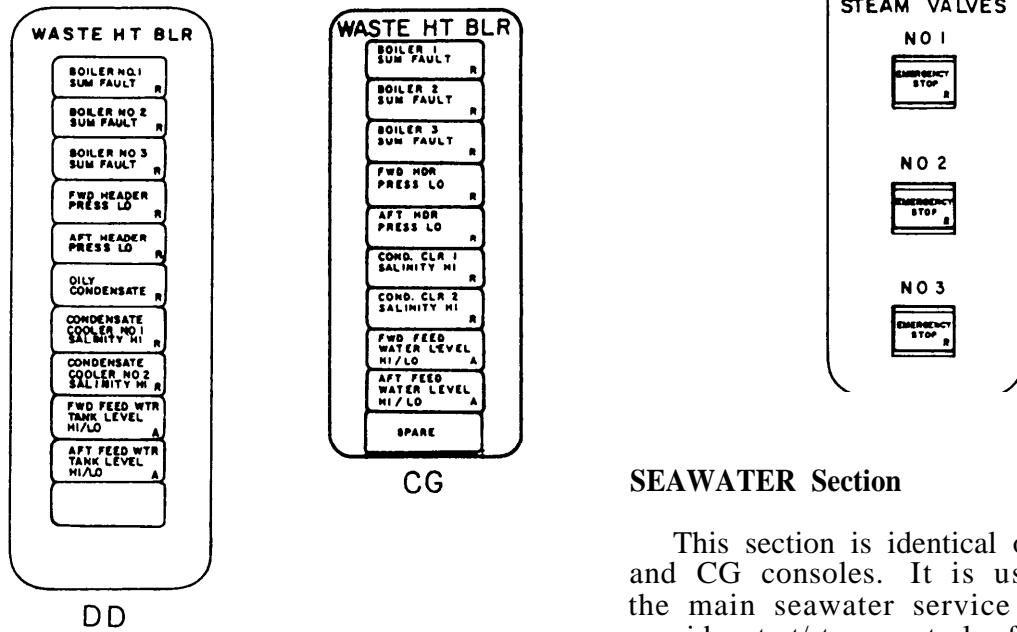


Figure 5-8.—CG PACC—auxiliary/bleed air panel.

identical, although they are labeled slightly different. They monitor the forward and aft boiler header pressure and illuminate red to indicate low header pressure in their respective header. The sixth alarm indicator on the DD console is labeled OILY CONDENSATE. It illuminates red if the presence of oil is detected in the condensate system. The next two alarm indicators on both consoles are a pair of functionally identical indicators. They monitor the salinity level of the condensate coolers and illuminate red if a high salinity condition exists on either condensate cooler No. 1 or No. 2. The last two alarm indicators are functionally identical on both consoles, but they are labeled slightly different. They monitor the forward and aft feed water tank HI/LO levels and illuminate amber if the feed water tank level is either high or low in the respective

push-button control indicators are used to emergency stop either the Nos. 1, 2, or 3 WHBs by closing their respective steam stop valves. They illuminate red when depressed.



## SEAWATER Section

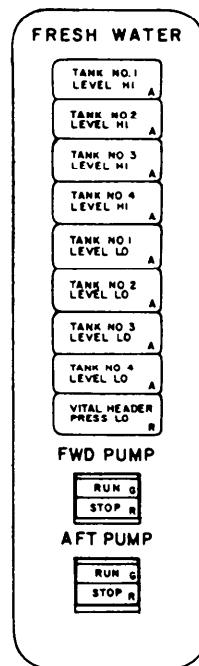
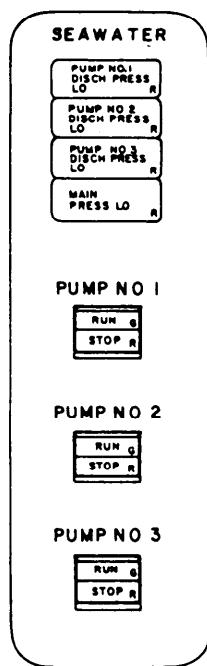
This section is identical on both the DD and CG consoles. It is used to monitor the main seawater service system and to provide start/stop control of the three seawater pumps. It has four alarm indicators and three split-legend, push-button control indicators. The alarm indicators are a set of functionally identical indicators, each being labeled slightly different. Starting at the top, the first three indicators illuminate red if either Nos. 1, 2, or 3 seawater pump discharge pressure is low. The fourth alarm indicator illuminates red if main seawater system pressure is low. The three push-button indicators illuminate either green or red to indicate the status and

## STEAM HEADER PRESS Section

This section has a dual-indicating meter and three push-button control indicators. It is identical on both the DD and CG consoles. It is used to monitor and secure (in an emergency) the ship's steam system. The dual-indicating meter is used to monitor the forward and aft steam header pressure, which is displayed in psig. The three

the operator's command (RUN/STOP) to sea-water pump Nos. 1, 2, or 3.

to indicate the status/operator command (RUN/STOP) to the respective pump.



## FRESH WATER Section

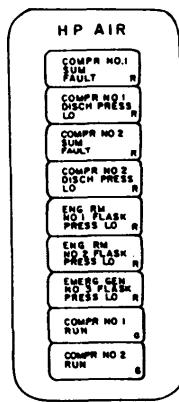
This section is used to monitor the ship's freshwater system and to provide start/stop control of the freshwater pumps. This section is functionally identical on both the DD and CG consoles, but it is labeled slightly different. It has four status indicators, five alarm indicators, and two split-legends, push-button control indicators.

Starting at the top of the column, the first four status indicators monitor the high (full) level of the four freshwater tanks. They illuminate green when a full condition exists in their respective tank. The next four alarm indicators monitor the low level of the four freshwater tanks. They illuminate amber if a low-level condition exists in their respective tank. The last alarm indicator monitors the vital header pressure and illuminates amber when the freshwater system pressure is low. Below the alarm indicators are the two split-legends, push-button control indicators. They are used to control the forward and aft pump respectively. They illuminate either red or green

## HP AIR Section

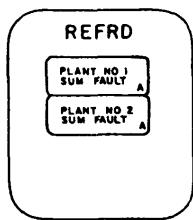
The HP AIR section is used to monitor the ship's HP air system. It has seven alarm indicators and two status indicators. The alarm/status indicators in this section are functionally identical on both the DD and CG consoles, but they are labeled slightly different. Starting at the top of the column, the first two alarm indicators monitor the No. 1 compressor for a summary fault or low discharge pressure. They illuminate red if a summary fault condition or low discharge pressure condition occurs on the No. 1 compressor. The next two alarm indicators monitor the No. 2 compressor for a summary fault or low discharge pressure. They illuminate red if a summary fault condition or low discharge pressure condition occurs on the No. 2 compressor. The next three alarm indicators monitor the two engine room flasks and the emergency generator No. 3 flasks for a low-pressure condition. They illuminate red if this condition occurs at either flask. The last two indicators are status indicators that monitor the No. 1 and No. 2 compressors.

They illuminate green when the respective compressor is running.



### REFRD Section

This section monitors the ship's refrigeration plant and is identical on both the DD and CG consoles. It has two alarm indicators that illuminate amber if a summary fault condition is detected on either the No. 1 or No. 2 refrigeration plant.

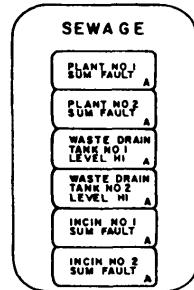


### SEWAGE and SEWAGE/WASTE Sections

These sections monitor the sewage and waste systems and serve the same purpose on both PACCs. They are functionally identical, but they are NOT physically identical. On the DD console, this section is labeled SEWAGE and has six alarm indicators. On the CG console, it is labeled SEWAGE/WASTE and has 25 alarm indicators. We will describe the DD console alarm indicators and then the CG console alarm indicators.

The SEWAGE section monitors two sewage plants, two waste drain tanks, and two incinerators. The six alarm indicators are actually three pairs of functionally identical indicators. Starting at the top of the column, the first two alarm indicators illuminate amber if a summary

fault is detected on either sewage plant No. 1 or plant No. 2. The next pair of alarm indicators monitor the waste drain tank levels. They illuminate amber if a high-level condition occurs on either waste drain tank No. 1 or No. 2. The next two indicators monitor the ship's incinerators. They illuminate amber if a summary fault is detected on either incinerator No. 1 or No. 2.



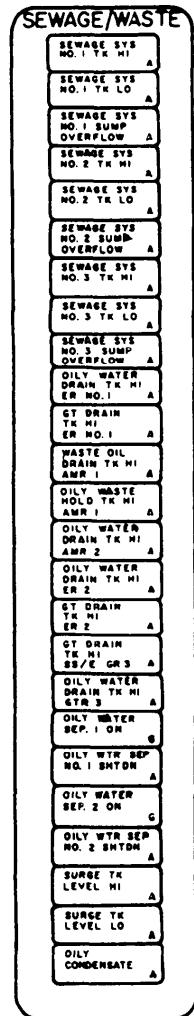
The CG console SEWAGE/WASTE section monitors three sewage system tanks, the oily water drain tank and the GT drain tank in engine room No. 1, the waste oil and oily waste drain tanks in AMR1, the oily water drain tanks in AMR2 and engine room No. 2, the GT drain tank in engine room No. 2, the GT drain tank and the oily water drain tank for SS/E gtr (generator) No. 3, the three oily water separators, the surge tank levels, and the oily condensate of the oily water separators.

Starting at the top of the column, the first nine alarm indicators monitor the sewage systems, Nos. 1, 2, and 3. They illuminate amber if either a high, low, or overflow tank level condition exists on the sewage holding tanks or sumps for systems Nos. 1, 2, or 3, respectively.

The tenth and eleventh alarm indicators monitor the engine room No. 1 oily water drain tank and gravity drain tank, respectively. They illuminate amber if a high level occurs in either tank. The thirteenth and fourteenth alarm indicators monitor the level of the waste oil drain tank and the oily waste holding tank in AMR1. They illuminate amber if a high level occurs in the respective tank. The fifteenth alarm indicator monitors the level of the oily water drain tank in AMR2. It illuminates amber if a high level occurs in this tank. The sixteenth and seventeenth alarm indicators monitor the engine room No. 2

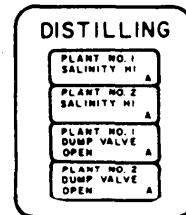
oily water drain tank and gravity drain tank. They illuminate amber if a high level occurs in their respective tank. The eighteenth indicator monitors the level of the oily water drain tank in the GTG3 enclosure. It illuminates amber if a high level occurs in the tank.

The next four indicators are status indicators that monitor oily water separators No. 1 and No. 2. They illuminate either green to indicate the respective separator is running or amber to indicate the respective separator is shut down. The next two alarm indicators monitor the surge tank high or low level, respectively. They illuminate amber if either alarm condition exists in the respective tank. The last indicator is an alarm indicator which monitors the condensate of the oily water separators. It illuminates amber to indicate an oily effluent is being discharged from the separators.



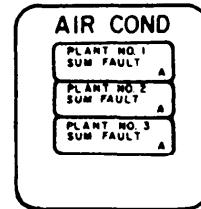
## DISTILLING Section

This section monitors the distilling plants and has four alarm indicators. The first two alarm indicators monitor the salinity of distilling plant No. 1 and plant No. 2. They illuminate amber when a high salinity condition exists at the respective distilling plant. The next two alarm indicators monitor the distilling plant No. 1 and No. 2 dump valves. They illuminate amber when the respective dump valve has opened due to high salinity or during system startup.



## AIR COND Section

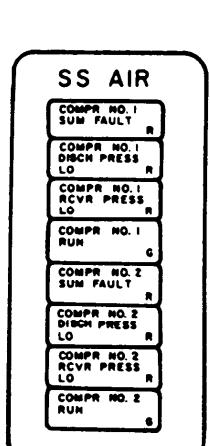
This section monitors the ship's air conditioning plants and has three alarm indicators (four on the CG console). These three (four) alarm indicators monitor summary alarms on A/C plants Nos. 1, 2, and 3 (and A/C plant No. 4 of the CG-class ships). The alarm indicators illuminate amber if a summary alarm is detected on the respective A/C plant.



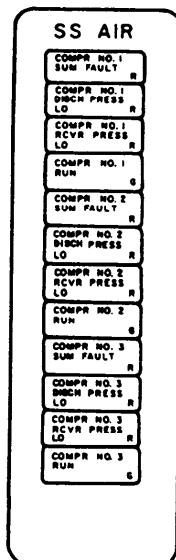
## SS AIR Section

This section monitors the SSAS and has six alarm indicators (nine on the CG console) and two status indicators (three on the CG console). These alarm indicators and status indicators monitor the two LP air compressors and receivers (three on the CG console). The alarm indicators for each plant monitor for a summary fault (red), compressor discharge pressure low (red), and receiver pressure low (red). If a monitored condition occurs, the appropriate indicator will illuminate. The status indicators illuminate green

when the respective LP compressor (either 1, 2, 3, or 4) is running.



DD



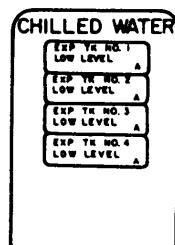
CG

#### NOTE

The next three sections, CHILLED WATER, AEGIS PUMPS, and the COMBAT DRY AIR section, are applicable only to the CG console.

#### CHILLED WATER Section

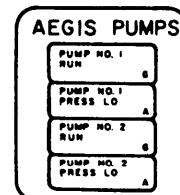
This section has four alarm indicators used to monitor the ship's A/C chilled water system. The alarm indicators actually monitor the level of chilled water in the four system's expansion tanks. The alarm indicators illuminate amber to indicate an expansion tank low-level condition exists on the applicable expansion tank(s).



CG

#### AEGIS PUMPS Section

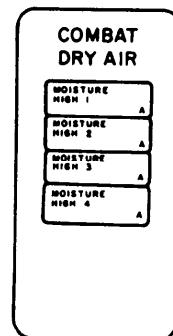
This section monitors the aegis weapons system cooling water pumps on the CG console. It has two status indicators and two alarm indicators. The status indicators illuminate green when the applicable aegis cooling water pump (No. 1 or No. 2) is running. The alarm indicators illuminate amber if the respective aegis cooling water pump discharge pressure is low.



CG

#### COMBAT DRY AIR Section

This section monitors the moisture content of the combat system's dry air system on the CG console. It has four alarm indicators that illuminate amber if a high moisture content has been detected at the applicable monitoring station.



CG

#### AIR CONTROL Section

Under the heading AIR CONTROL at the bottom of the auxiliary/bleed air panel are three sections labeled ENG ROOM 1, ENG ROOM 2, and GTG 3. These sections are used to monitor the air systems of the GTMs in the applicable engine rooms. The alarm indicators in the sections

labeled ENG ROOM 1 and ENG ROOM 2 are identical as to the systems monitored, but they differ in the engines monitored. We will describe the alarm indicators only in the ENG ROOM 1 and GTG 3 sections. The alarm indicators that are the same on the GTG 3 section and ENG ROOM 1 section will not be described separately.

**ENG ROOM 1 SECTION.**—Under this heading are three alarm indicators that monitor the engine room air systems. The alarm indicators are labeled PRAIRIE AIR TEMP HI, START AIR OVERTEMP, and HIGH PRESS AIR LO. These indicators illuminate red when the parameter of the applicable system monitored exceeds or drops below its designed set point.

The GTM air systems for ENG 2A, ENG 2B, and GTG 1 are each monitored by three identical alarm indicators. These alarm indicators are labeled ICING, ANTIICING INSUFFICIENT, and DUCT PRESS LO. Either alarm indicator illuminates red if the monitored parameter for that engine exceeds or drops below its designed operating parameter. The next two alarm indicators, labeled MASKER AIR OVERTEMP and BLEED PRESS LO, are located under the headings ENG 2A and ENG 2B, respectively. As these systems are common to both engines, only one of each alarm indicator is required in each engine room. These alarm indicators illuminate red if the monitored parameter is not in the designed operating range.

**GTG 3 SECTION.**—This section has five alarm indicators and is used to monitor the

GTG 3 air systems. The alarm indicators are identical to those on the ENG ROOM 1 and ENG ROOM 2 sections. There is a slight difference in the labeling of the last alarm indicator. It is labeled STARTER AIR OVERTEMP vice START AIR OVERTEMP. Both alarm indicators have the same function.

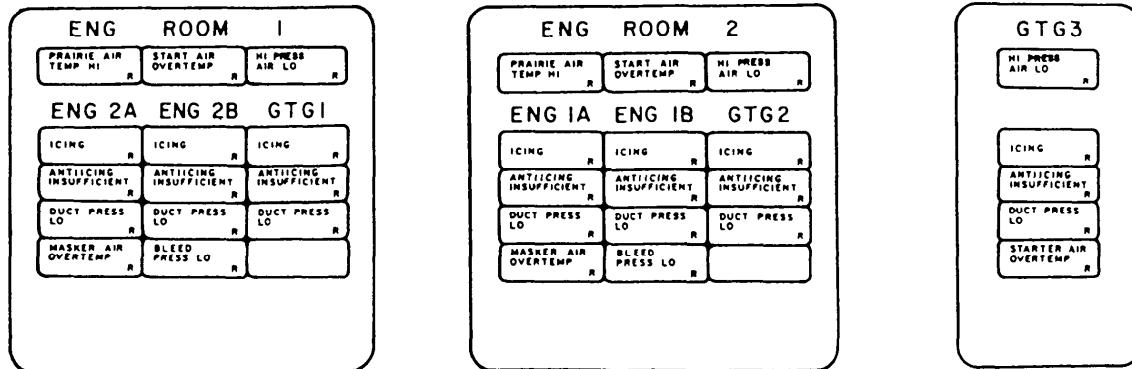
## PORT SHAFT DEMANDS PANEL

This panel is functionally identical on both consoles, but has slight physical differences. The panel shown in figure 5-9 is for the DD console. It has the start/stop and emergency controls for GTM 2B, DDIs to monitor shaft speed, an alarm test section, a power supply monitoring section, and a console malfunction monitoring section. It is located on the left-hand side of the PACC in bay No. 1. This panel is divided into six sections labeled PORT SHAFT PROPULSION DEMANDS, 2B EMERGENCY CONTROLS, MALFUNCTION, TEST, 2B START/2B STOP, and POWER.

## PORT SHAFT PROPULSION DEMANDS Section

This section has two thumbwheels and two DDI displays. The PACC operator uses the thumbwheels to select a plant parameter address which will be displayed in the adjacent DDI. These selected parameters are displayed in the appropriate units of measurement. The PORT SHAFT PROPULSION DEMANDS section on the CG console is functionally the same, but it

## AIR CONTROL



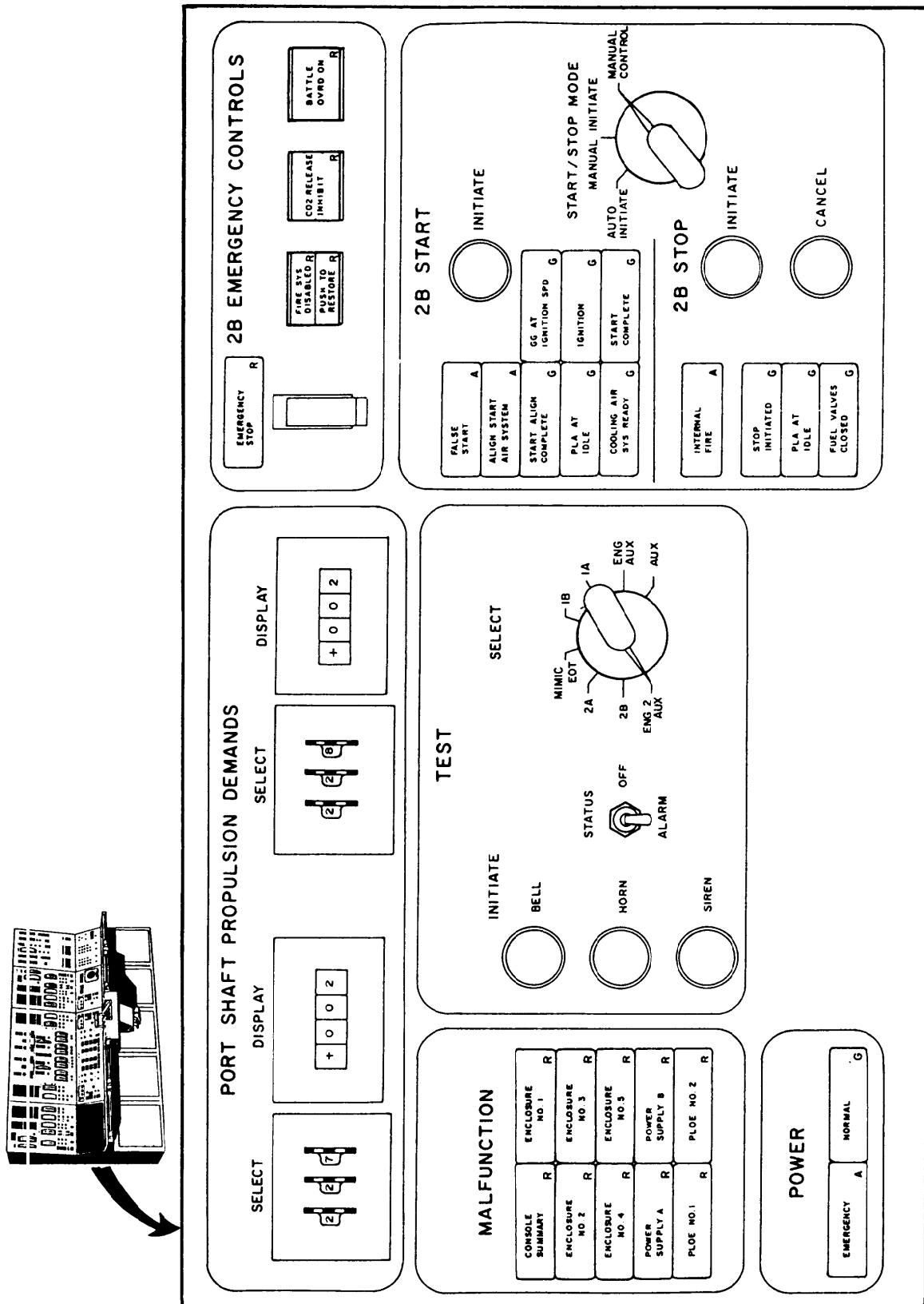
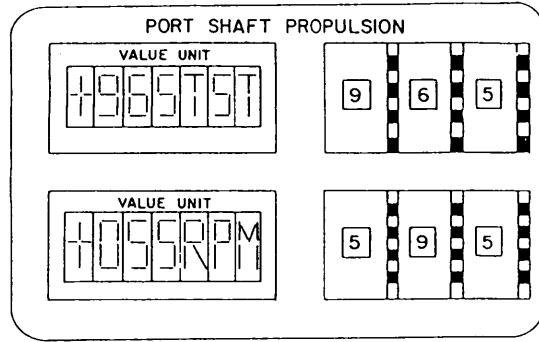


Figure 5-9.—Port shaft demands panel.

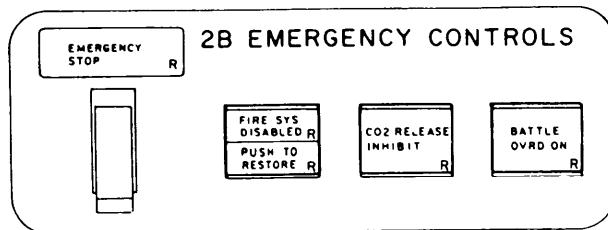
has slight physical differences from the DD console as shown in the following graphic.



## 2B EMERGENCY CONTROLS Section

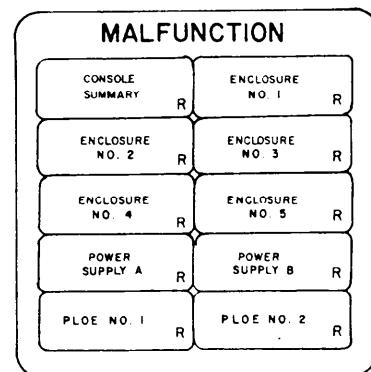
This section is identical on the DD and CG console. It has an alarm indicator, a guarded toggle switch, and three push-button control indicators. The alarm indicator illuminates red when the PACC operator performs an emergency stop using the guarded toggle switch directly below the EMERGENCY STOP status indicator or when an emergency stop command is generated by the electronics. The first control indicator is a split-legend, push-button indicator labeled FIRE SYS DISABLED/PUSH TO RESTORE. The top portion of this indicator illuminates red when the GTM fire detection system is temporarily disabled. When illuminated, a module fire stop is prevented from being generated. If the symptoms causing the casualty are restored prior to the normal stop timing out, you may restore the fire system by depressing this switch when the bottom label illuminates red.

The second push-button control indicator labeled CO<sub>2</sub> RELEASE INHIBIT is used by the PACC operator to disable the CO<sub>2</sub> system while personnel are in the module. It illuminates red when it is depressed at the PACC, PLCC, or when the CO<sub>2</sub> inhibit switch at the module is activated. The third push-button control indicator, labeled BATTLE OVRD ON, illuminates red when the PACC operator depresses it to activate the battle override electronics.



## MALFUNCTION Section

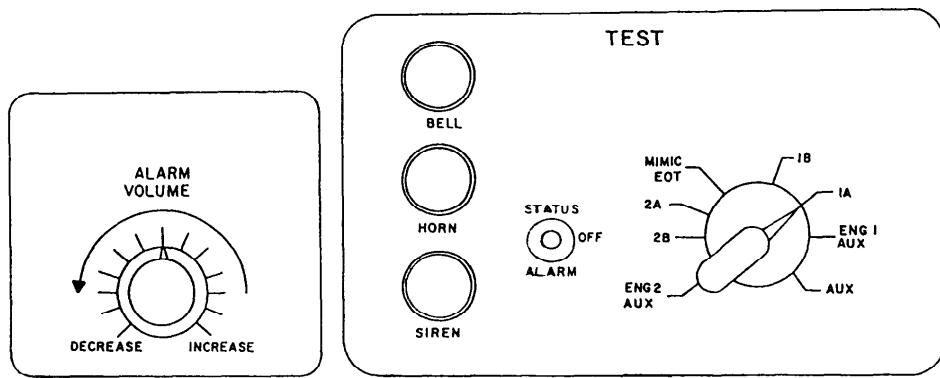
This section has 10 alarm indicators used to monitor summary alarms of the console. The first alarm indicator, labeled CONSOLE SUMMARY, illuminates red if an alarm condition has been detected in the PACC. The next five alarm indicators across and down are functionally identical. They are labeled ENCLOSURE NO. 1, 2, 3, 4, and 5, respectively. These alarm indicators illuminate red if a console malfunction is detected in one of the five bays of the PACC. The next two alarm indicators are a pair of functionally identical indicators labeled POWER SUPPLY A and POWER SUPPLY B. They illuminate red if an alarm condition exists in their respective PACC power supply. The last two alarm indicators are labeled PLOE NO. 1 and PLOE NO. 2. They illuminate red if a summary alarm has been detected in the respective PLOE electronics.



## TEST Section

The TEST section is used for testing all the PACC alarm and status indicators and the siren, horn, and bell. It has three momentary-contact push buttons, a three-position toggle switch, and an eight-position, rotary selector switch. The CG console also has a rotary switch to the left of the TEST section which is used to vary the volume of the bell, horn, and siren.

Under the heading INITIATE are the three momentary-contact push buttons labeled BELL, HORN, and SIREN. The PACC operator may test either audible alarm by depressing the appropriate push button. On the CG console, the operator may select a comfortable volume by depressing the appropriate push button and rotating the ALARM VOLUME switch to the acceptable level.



The three-position toggle switch is labeled STATUS, OFF, and ALARM. If it is in the OFF position, testing of the alarm and status indicators is inhibited. In the ALARM position, the alarm indicators on the panel selected by the rotary selector switch will be tested. In the STATUS position, the status indicators on the panel selected by the rotary selector switch will be tested. The eight-position rotary selector switch is labeled ENG 2 AUX, 2B, 2A, MIMIC EOT, 1B, 1A, ENG 1 AUX, and AUX.

#### GTM 2B START/GTM 2B STOP Section

This section is used by the PACC operator to start/stop the GTM. It has 9 status indicators (10 on the CG console) and 3 alarm indicators, a start initiate push button, a three-position rotary start/stop mode selector switch, a stop cancel push button, and a stop initiate push button.

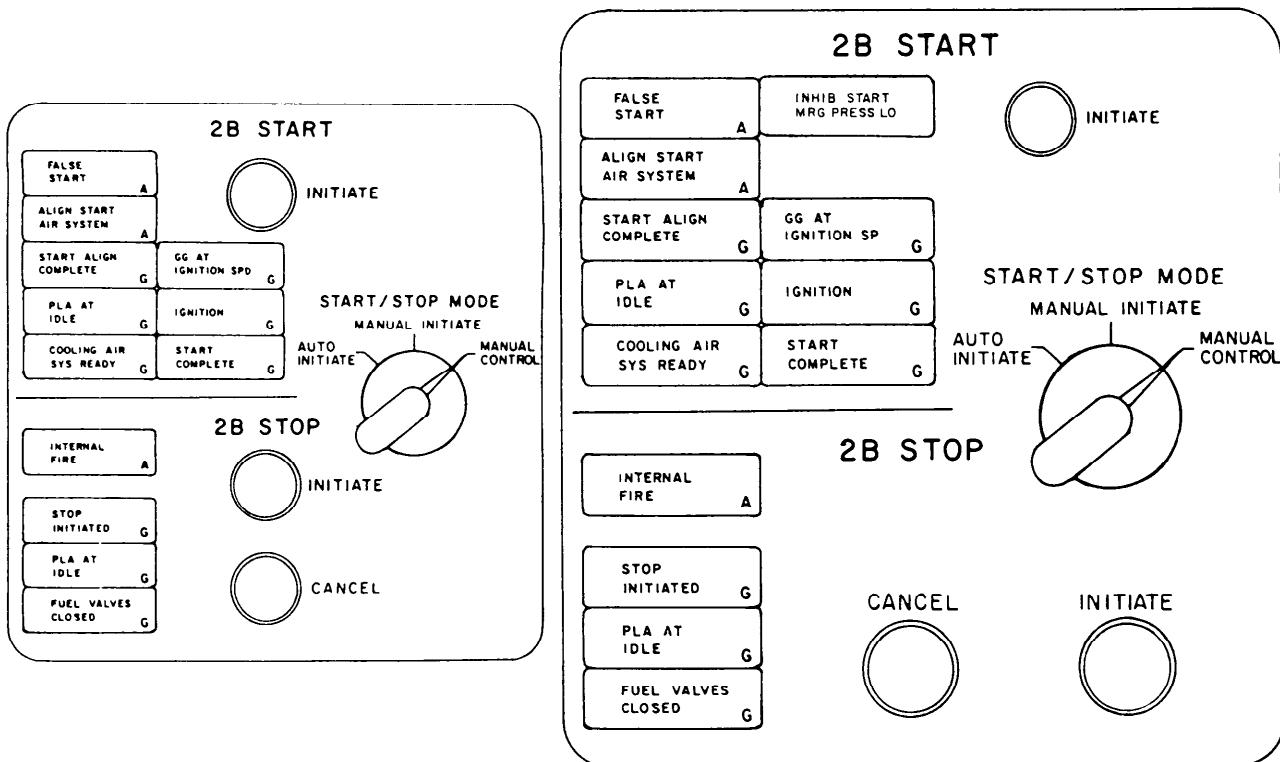
Under the heading 2B START is the first alarm indicator, labeled FALSE START. It illuminates amber if one of two conditions has occurred: (1)  $< 1200 N_{GG}$  20 seconds after the start air valve opens; (2)  $T_{5,4} < 400^{\circ}\text{F}$  40 seconds after the main fuel valves open at  $1200 N_{GG}$ . The next indicator is labeled ALIGN START AIR SYSTEM and is a dual status/alarm indicator. As a status indicator, it illuminates amber in a steady state to show the air start system is being aligned for start. As an alarm indicator, it comes on flashing to show the air start system will not properly align (either valve failed to properly position or anti-icing air is on). Below this indicator is the status indicator labeled START ALIGN COMPLETE. It illuminates green after the logic circuits check alignment of the following: GTM in service, start air system aligned, HP start priority check, fuel temperature, and bleed air valve closed. A status indicator

labeled PLA AT IDLE is next. It illuminates green when the PLA is at the 0 percent setting. Below it is a status indicator labeled COOLING AIR SYS READY. It illuminates green when the vent damper is open and the cooling fan is operating properly. A push button, labeled INITIATE, is at the top of the next column on the DD console. It is used to manually initiate a start.

On the CG console, a status indicator is at the position of the INITIATE push button on the DD console. This status indicator is labeled INHIB START MRG PRESS LO. It illuminates to alert the PACC operator to check the MRG LO pressure before initiating a start and will not allow a start of the GTM while illuminated. Below this indicator is a status indicator labeled GG AT IGNITION SPD. It illuminates green when the GG speed is  $> 1200 \text{ rpm}$ . The next status indicator is labeled IGNITION and illuminates green when  $T_{5,4} > 400^{\circ}\text{F}$ . The last status indicator under the 2B START heading is labeled START COMPLETE. It illuminates green when GG speed is  $> 4300 \text{ rpm}$ .

To the right of these indicators, under the heading START/STOP MODE, is the three-position rotary switch. The three positions are labeled AUTO INITIATE, MANUAL INITIATE, and MANUAL CONTROL. This switch is used by the PACC operator to select the starting and stopping modes.

Under the heading 2B STOP is an alarm indicator, three status indicators, and the last two push buttons. The alarm indicator is labeled INTERNAL FIRE and illuminates amber if an internal (post-shutdown) fire occurs. This alarm indicator illuminates if  $T_{5,4} > 700^{\circ}\text{F}$  3 minutes after the shutdown is complete. The status indicator labeled STOP INITIATED illuminates green when a stop has been initiated. The status indicator labeled PLA AT IDLE illuminates green when the PLA has come to the idle (0 percent) position. When this indicator illuminates, a



5-minute cool-down timer is activated in the control electronics. At the completion of the cool-down time, the status indicator labeled FUEL VALVES CLOSED illuminates green and the fuel valves close, which secures the GTM. The first push button is labeled CANCEL. It is used by the PACC operator to cancel a normal stop of a GTM. The other push button is labeled INITIATE and is used by the PACC operator to start a normal stop of a GTM.

### ENGINE ORDER TELEGRAPH (EOT) PANEL

This panel is shown in figure 5-10. Its main function is concerned with EOT signals (rpm and pitch signals) for both engine rooms. The EOT panel is divided into nine sections. The extreme left and right portions have the GTM 2A and GTM 1B EMERGENCY CONTROLS sections and GTM 2A and GTM 1B START/STOP sections. These sections are mirror images of the GTM 2B EMERGENCY CONTROLS and GTM 1A START/STOP sections covered on the engine No. 2 demands panel. We will not describe these controls and indicators again.

The other five sections of this panel are labeled PORT MANUAL THROTTLE, ENGINE ORDER TELEGRAPH, STBD MANUAL THROTTLE,

ALARM ACK, and THROTTLE TRANSFER. The manual throttle sections are identical.

### PORT MANUAL THROTTLE Section

This section is a mirror image of the STBD MANUAL THROTTLE section. It has two push-button control indicators and four rotary switches. The push-button control indicator under the heading THROTTLE CONT. is a split-leg switch/indicator. It is labeled AUTO/MAN and illuminates green to indicate the PACC operator's selection of either AUTO (which is integrated throttle control) or manual control of the throttles and pitch. When this switch is in the MAN position, the PACC operator uses the three rotary selector switches labeled MANUAL PITCH and MANUAL PLA (2B/2A) to set the pitch (- or +) and the PLA of the respective engine(s) to the required percent of power.

The second push button is a status indicator/switch labeled SEASTATE ADJUST ON which illuminates amber when depressed. The PACC operator depresses this switch electing to change the reaction time of the PLA electronics due to sea state conditions or following EOP. After depressing this switch, the operator uses the ten-position rotary selector switch labeled SEA STATE to manually set the PLA electronics reaction time.

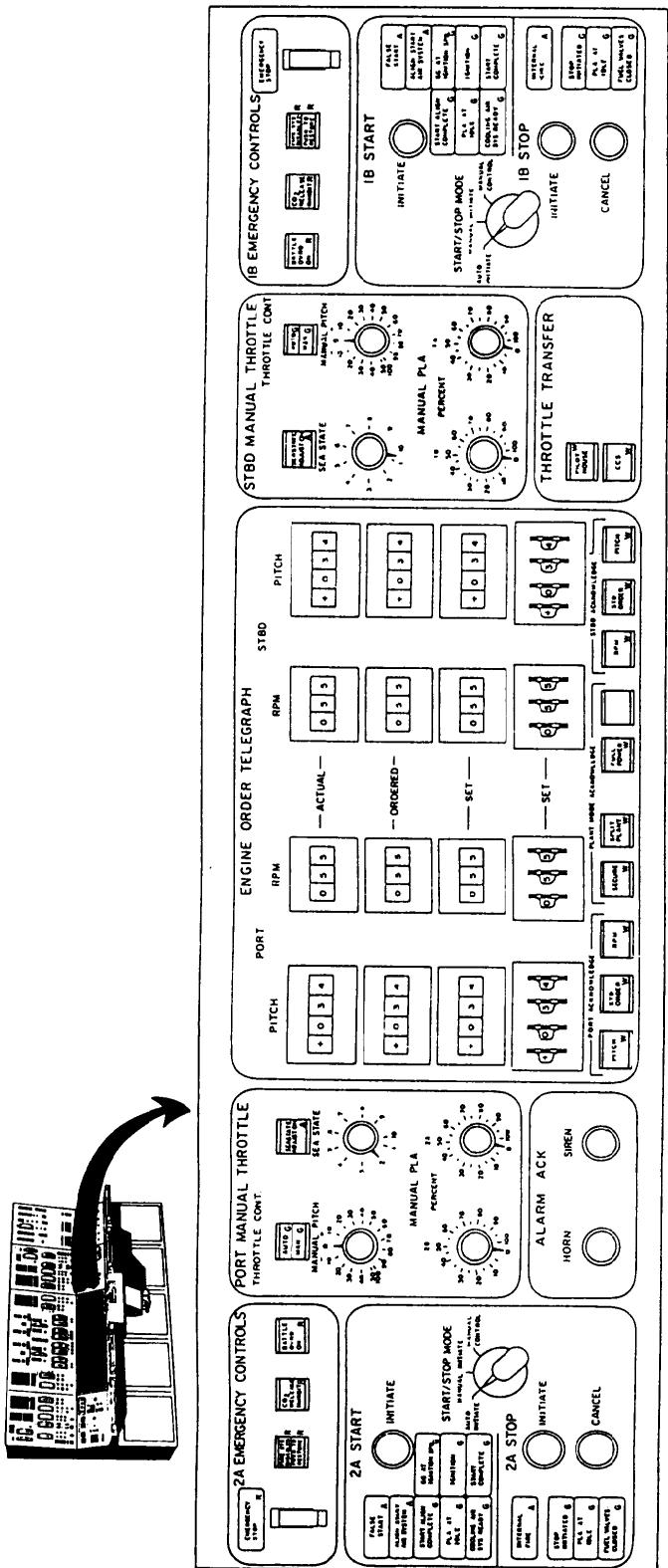


Figure 5-10.—EOT panel.

## **ENGINE ORDER TELEGRAPH Section**

This section is a set of digital displays used primarily as a backup throttle communications systems. This system is used when the PACC is in control of the throttles. The digital displays are identical for the port and starboard shaft. There are three digital displays and a set of thumbwheels to indicate PITCH and RPM for each shaft. The digital displays are labeled ACTUAL, ORDERED, and SET. Each shaft has three push-button indicators under the headings PORT ACKNOWLEDGE and STARBOARD ACKNOWLEDGE. These push buttons are labeled PITCH, STD ORDER, and RPM. Between these two headings is a set of three push buttons under the heading PLANT MODE ACKNOWLEDGE. The push buttons are labeled SECURE, SPLIT PLANT, and FULL POWER. The PACC operator uses these push buttons to acknowledge the respective change of plant mode order from the officer of the deck (OOD).

The digital display of the pitch and rpm, labeled ACTUAL, is the actual pitch setting and rpm of the shaft at that moment in time. The digital display of the pitch and rpm, labeled ORDERED, is the commanded pitch setting and shaft rpm from the OOD. The digital display of the pitch and rpm, labeled SET, is the pitch and rpm selected by the thumbwheels by the PACC operator.

The actual RPM and PITCH are digitally displayed at the SCC, PACC, and PLCC. When the OOD orders the SCC operator to change RPM and/or PITCH, the following events occur:

- The SCC operator sets the new values of RPM and PITCH on the thumbwheels and then depresses the RPM and PITCH ALERT push buttons.
- These signals are sent to the PACC and PLCC where they appear on the digital displays labeled RPM and PITCH ORDERED. At the same time, an audible alarm is sounded and the RPM and/or PITCH ACKNOWLEDGE push-button lights begin to flash.

When the PACC is in control of the throttle, the operator responds in the following manner:

- The operator sets the new RPM and/or PITCH on the thumbwheels and depresses

the flashing RPM and/or PITCH ACKNOWLEDGE push button.

1 The light stops flashing and the audible alarm is turned off.

1 The operator then manually changes the proper PLA and/or PITCH potentiometer or moves the ITC lever.

## **ALARM ACK Section**

The ALARM ACK section has two push buttons (three on the CG console) labeled HORN and SIREN (and BELL). The PACC operator uses these push buttons to acknowledge and silence an audible alarm (either horn, siren, or bell).

## **THROTTLE TRANSFER Section**

This section has two push buttons for control/display of the station in control of the throttle. They are labeled PILOT HOUSE and CCS. Throttle/pitch control is possible at one of three locations (PLCC, PACC, or SCC).

For the SCC to have integrated throttle control, both the PLCC and PACC must have their remote stations selected. That is, the PLCC must have at least one GTM and EOT control transferred to the PACC. The PACC must have the throttle control transferred to the SCC. At the PLCC, only manual throttle and pitch control for their respective GTMs is available. Manual control of an individual GTM may be transferred to the PACC from the PLCC. At the PACC, each GTM may be controlled manually by rotary potentiometer controls which operate the same as the lever controls found at the PLCC. Either or both GTMs may then be placed in auto control. For the PACC operator to transfer throttle control from the PACC to the SCC, both GTMs must be in auto throttle control. The PACC operator may take throttle control from the SCC at any time. The PLCC operator may take throttle/pitch control from the SCC or PACC at any time.

## **STARBOARD SHAFT DEMANDS PANEL**

This panel is shown in figure 5-11. It is divided into four sections. These sections are

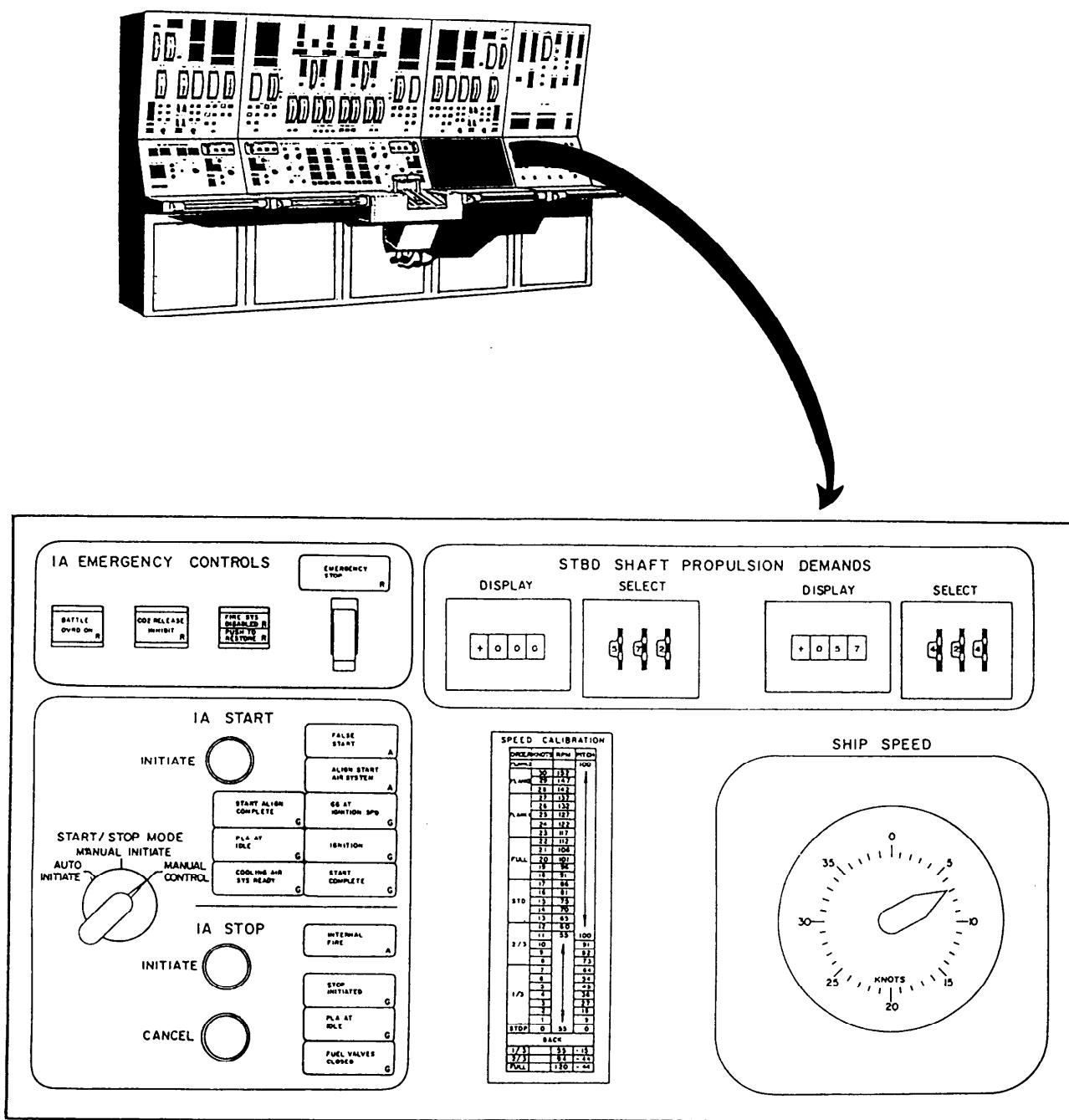


Figure 5-11.—Starboard shaft demands panel.

labeled 1A EMERGENCY CONTROLS, 1A START/1A STOP, STBD SHAFT PROPULSION DEMANDS, and SHIP SPEED. The first three sections are identical to, and have been described previously in, the port shaft demands panel section.

The fourth section, labeled SHIP SPEED, has a meter that displays the actual ship's speed through the water. The speed is displayed in knots. Associated with and to the left of the speed meter is a matrix chart, labeled SPEED CALIBRATION, which equates standard

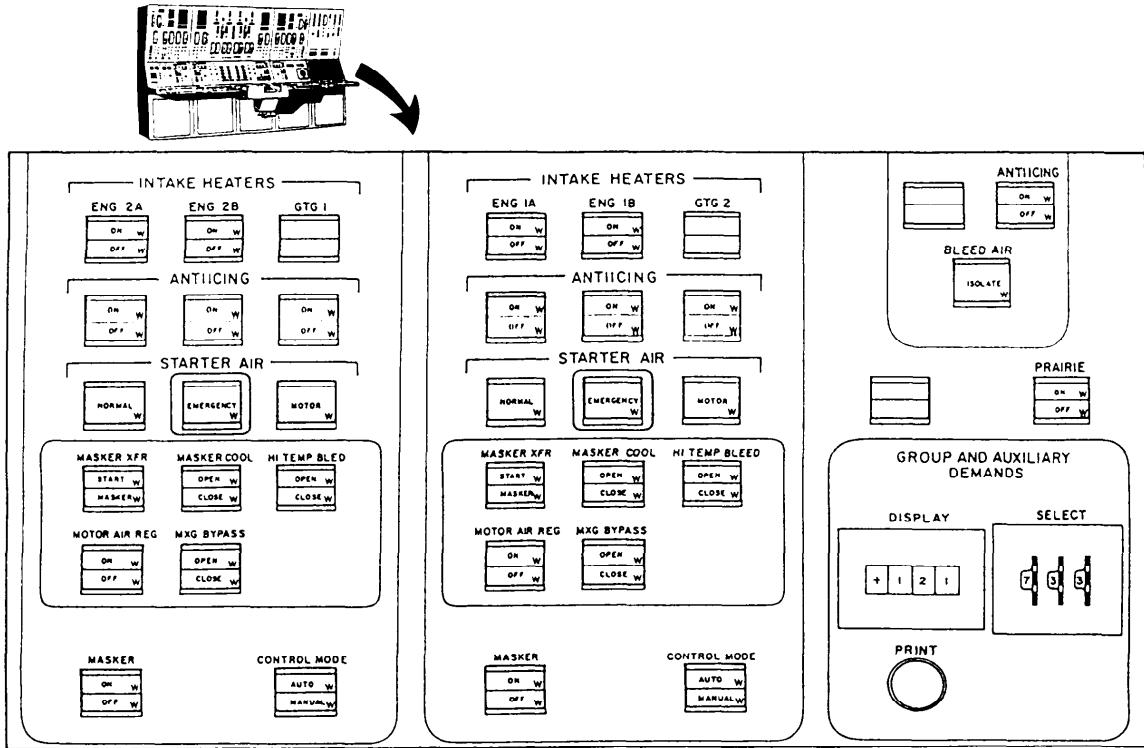


Figure 5-12.—Bleed air control panel.

orders to knots (speed), shaft rpm, and pitch settings.

### BLEED AIR CONTROL PANEL

This panel is shown in figure 5-12. It is divided into three sections (two of which are identical except for labeling). This panel has the control push-button indicators and valve status indicators for the automatic/manual controls related to the bleed air system for each engine room. It also has five push-button control indicators for the masker air, a push-button control indicator for the prairie air, and valve status indicators for the GTG3. In addition, this panel has a thumbwheel controlled demand digital display of various conditions that exist within the control system along with a print push button for printing thumbwheel selected information.

### Port and Starboard Engine Room Sections

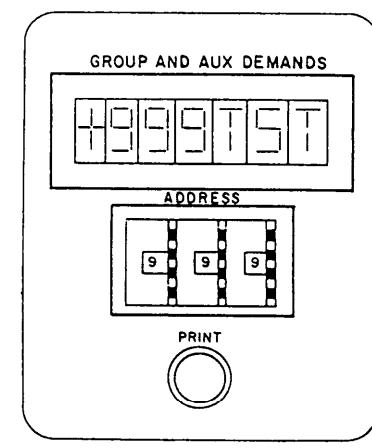
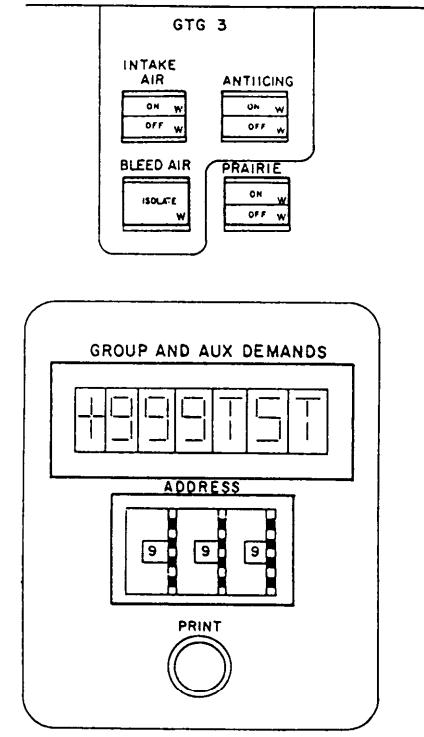
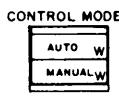
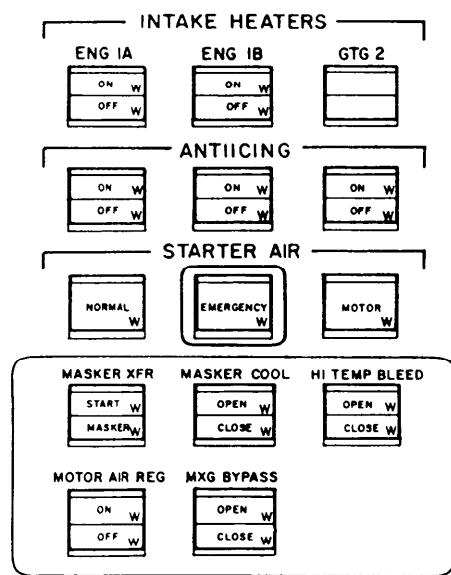
The first section on the left of this panel is for the port engine room. It has 16 split-legends, push-button control indicators. Nine of these indicators (three for each engine) control the INTAKE HEATERS, ANTIICING, and STARTER AIR

for ENG 2A, ENG 2B, and GTG 1. Five of these control indicators control the masker system valves and the motor air regulator valve. The last two of the control indicators are for the automatic/manual operation of the masker air system valves and to select their control mode.

Under the heading INTAKE HEATERS are the manual control indicators (ON/OFF) for the intake heaters of the respective engines. Under the heading ANTIICING are the manual control indicators (ON/OFF) for the antiicing valves of the respective engines. Under the heading STARTER AIR are the control indicators used to select the starting air mode (NORMAL, EMERGENCY, or MOTOR) for the selected engine. The five control indicators for the masker system are for manual control of the masker system valves when the control indicator under the heading CONTROL MODE is in the MANUAL position. When this control indicator is in the AUTO position, the PACC operator can perform an automatic sequence (either ON/OFF) of all the masker valves by depressing the control indicator under the heading MASKER.

The second section is for the starboard engine room and has the identical control indicators mentioned in the first section. The exception

being this section is labeled for ENG 1A, ENG 1B, and GTG 2.



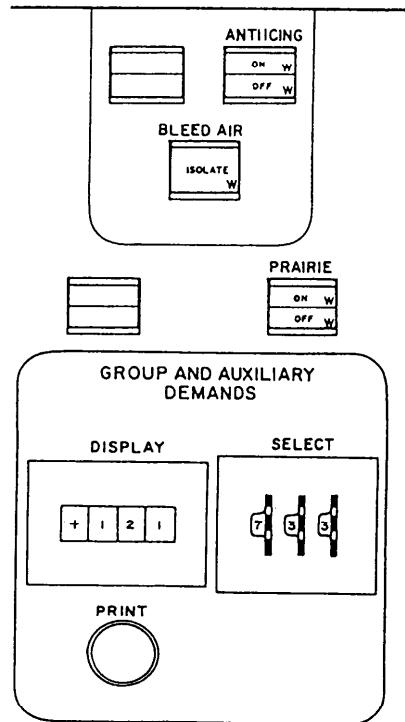
CG

## Group and Auxiliary Demands Section

This is the third section of the panel. It has five split-legends, push-button control indicators (four on the CG console). Only three are used on the DD console. These push buttons are used to control the anti-icing air, the bleed air, and the prairie air on the DD console. The CG console has these same push buttons with a fourth push button used to control the GTG3 intake air heaters. This section also has a digital display with a thumbwheel for parameter address selection and a PRINT push button.

## INTEGRATED THROTTLE CONTROL PANEL

This panel is shown in figure 5-13. It is used by the PACC operator to control the propeller pitch and engine's PLA. Integrated throttle control (or automatic throttle control) is available at the PACC and the SCC. There are two levers, one for each shaft, for simultaneous control of the GTMs and controllable reversible propeller. These levers can be mechanically latched together to control both shafts simultaneously or unlatched for individual shaft control.



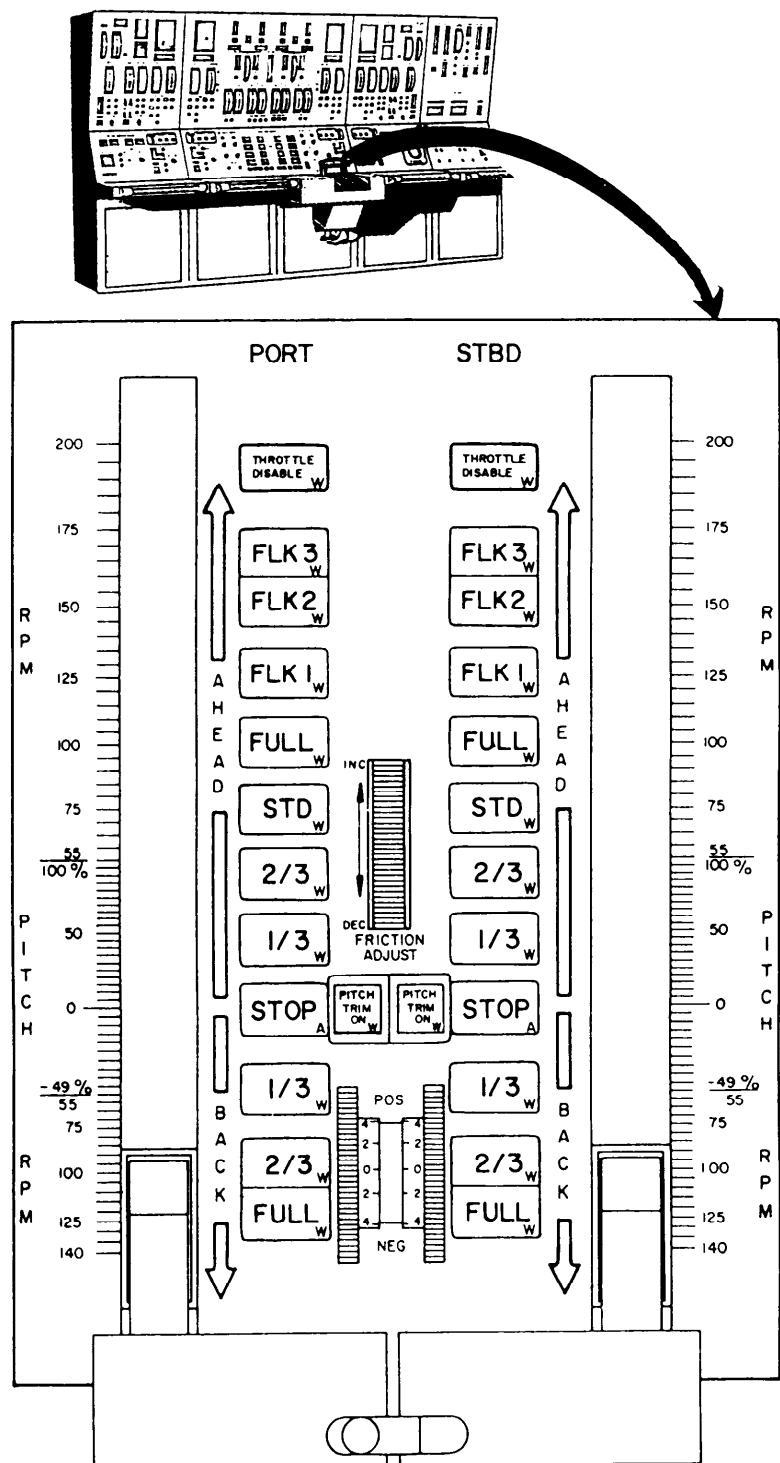


Figure 5-13.—ITC panel.

## NOTE

The major difference between the PACC ITC and the SCC ITC is that the PACC ITC has provisions for pitch trim, while the SCC ITC does not. Therefore, the two ITCs are not interchangeable.

This system is called ITC because the information for both pitch and rpm for an engine room is given by one analog reference voltage. Two references, one for each shaft, are generated by each of the levers at the console (PACC or SCC) that has control.

Table 5-1.—RPM-Pitch Relationship

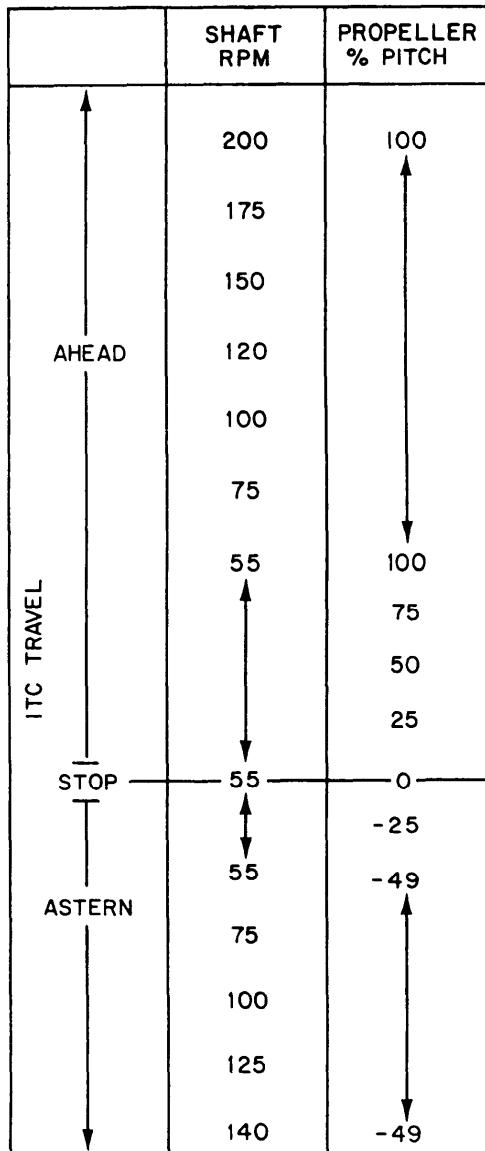


Table 5-1 shows the rpm and pitch relationship over the range of the throttle lever. In the ahead direction, shaft rpm is held at 55 until propeller pitch reaches 100 percent. After this point, shaft rpm is increased and pitch remains at 100 percent. In the astern direction, shaft rpm is held at 55 until propeller pitch reaches -49 percent. After this point, shaft rpm is increased and pitch remains at -49 percent.

## PROPULSION LOCAL CONTROL CONSOLE

The propulsion local control equipment (PLOE) is the engine room control equipment on the DD- and CG-class ships. Two identical PLOEs are on each ship, one in each engine room. PLOE No. 1 is located in MER 2, while PLOE No. 2 is in MER 1. Each PLOE has two units of which the major unit is the PLCC. The second unit is the propulsion local control electronics enclosure (PLCEE). This unit houses the power supplies for the PLCC. Other than on/off control, no operator functions are available at the PLCEE.

The PLCC is divided into six panels and a PLA and pitch control section. These panels are the GTM B PANEL, the GTM A/B PANEL, the GTM A PANEL, the SELF TEST PANEL, the EOT PANEL, and the ALARM TEST PANEL. Figure 5-14 shows the console's six panels and the PLA and pitch control levers.

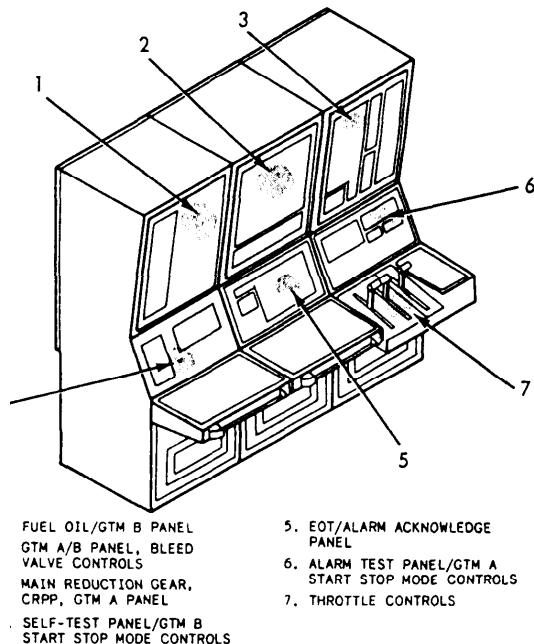


Figure 5-14.—PLCC—major sections.

## GTM B PANEL

The GTM B panel (fig. 5-15) has the controls and status indicators for GTM B and the controls and alarm/status indicators for the FO service system. This panel is divided into three sections,

FUEL OIL, GTM B, and EMERGENCY CONTROLS.

### FUEL OIL Section

This section (with one exception) is a mirror image of the FO section on the PACC engine No. 2

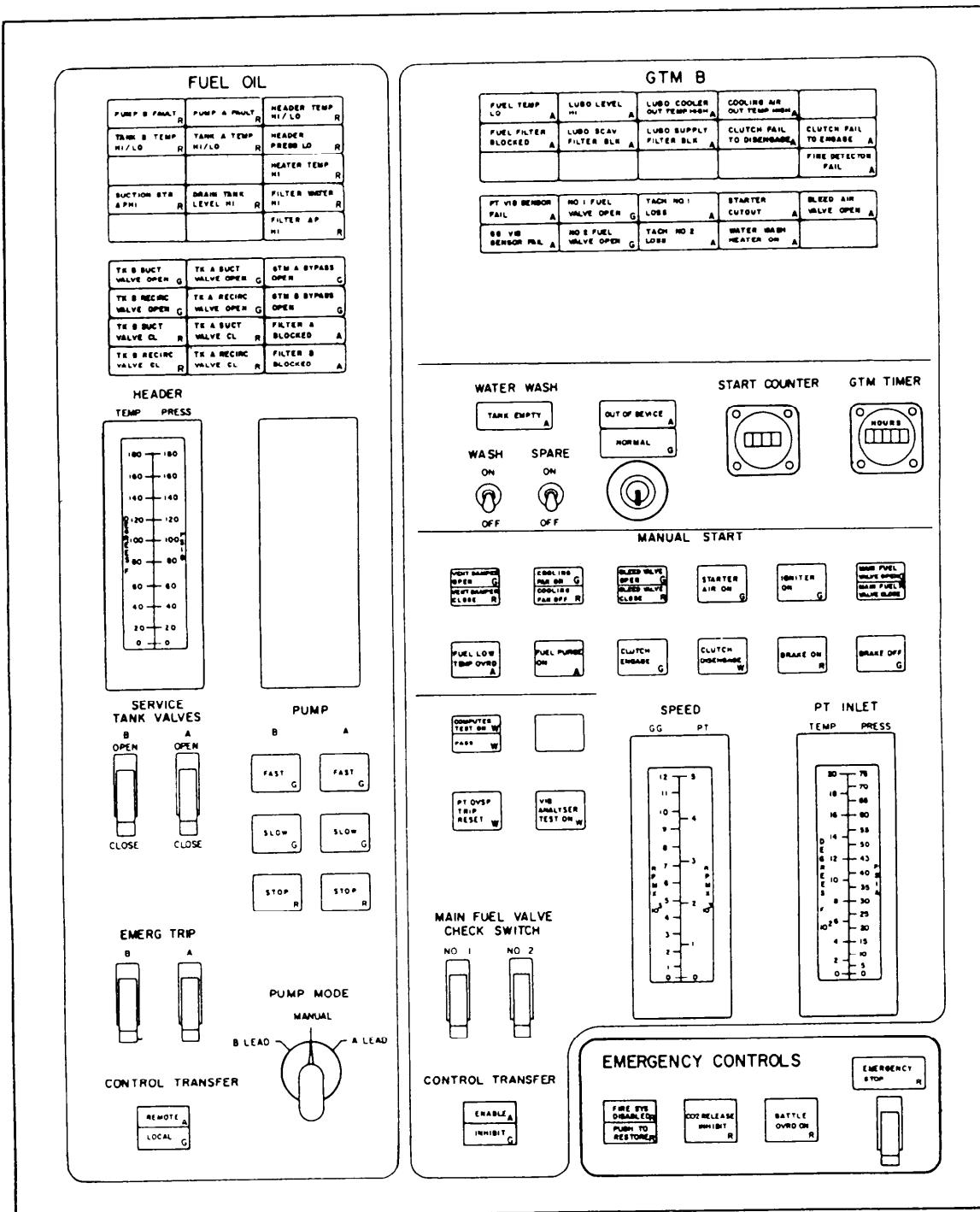


Figure 5-15.—GTM B panel.

panel that was described previously. The one exception is that on the PLCC FO section, the lower left, push-button control indicator under the heading CONTROL TRANSFER is labeled REMOTE/LOCAL vice CCS CONTROL/PLCC CONTROL. The PLCC operator uses this push button to transfer control of the FO system to the PACC in CCS.

### GTM B Section

The GTM B section has 23 alarm/status indicators (25 on the CG console), 4 toggle switches, a two-position key switch, 2 timers, 16 push-button control indicators (13 on the CG console), and 2 dual-indicating meters (1 on the CG console). These components are all used for the control/monitoring of GTM B in the applicable engine room.

Under the heading GTM B, the first five horizontal rows of alarm/indicators have already been described in the PACC engine No. 2 panel description. Under the heading WATER WASH is an alarm/indicator labeled TANK EMPTY. It illuminates amber when the water wash tank is empty of water wash or rinse solution. The two-position toggle switch under the heading WASH is labeled ON/OFF. It is used to open/close the water wash solenoid valves. To the right of this switch on the DD console is a two-position toggle switch labeled SPARE that is not used. However, on the CG PLCC this switch is used to control the water wash heaters. It is under the heading HEATERS and is labeled ON/OFF.

To the right of the HEATERS toggle switch are two status indicators, labeled OUT OF SERVICE and NORMAL. These status indicators show the actual position of the key switch located below them. The status indicator OUT OF SERVICE illuminates amber when the key switch is in the OFF position. This position electronically locks out the start air valve so that the GTM cannot be started or motored. The indicator NORMAL illuminates green when the key switch is in the ON position and the GTM is ready to operate, provided other external parameters are met.

To the right of the key switch under the heading START COUNTER is a digital counter. This counter registers a start each time  $T_{5.4}$  is  $> 400^{\circ}\text{F}$  and  $N_{GG}$  is  $> 4300$  rpm for 0.25 seconds. To the right of this counter, under the heading GTM TIMER, is the other digital counter. It records the actual running time (in hours) for the GTM once the START COUNTER requirements have been met.

Under the heading MANUAL START are 12 push-button control indicators (9 on the CG console) used for the manual start of the GTM. All but one of these control indicators were described under the description of the PACC GTM B panel. The one exception is on the DD PLCC. It is a push-button control indicator labeled FUEL LOW TEMP OVRD. If the FO temperature is below  $80^{\circ}\text{F}$ , the PLCC operator can depress this push button. It provides a logic override step that allows the GTM to be started in the MANUAL or AUTO initiate mode.

Below and to the left of the MANUAL START push-button control indicators are three additional push-button control indicators (two on the CG console). The first push-button control indicator is a split-legends type labeled COMPUTER TEST ON/PASS. When depressed, it starts a test of the torque computer and illuminates PASS if the test was satisfactory. Below this control switch is a momentary contact push-button control indicator labeled PT OVSP TRIP RESET. This switch is depressed to reset the main fuel valves after an overspeed trip.

### NOTE

Do NOT depress this switch until the engine comes to a complete stop. If depressed, the fuel valves may reopen, causing a post shutdown fire.

To the right of this switch (DD console only) is a third push-button control indicator labeled VIB ANALYSER TEST ON. When depressed, it tests the vibration analyser circuits in the PLCC.

The two dual-indicating meters (one on the CG console) are identical to the ones described previously on the PACC MIMIC panel.

The last two toggle switches are of the two-position guarded type. They are used by the PLCC operator to test the individual integrity of the MAIN FUEL VALVES (NO 1 or NO 2). Below these toggle switches under the heading CONTROL TRANSFER is a split-legends, control push-button labeled ENABLE/INHIBIT. This push button enables the transfer of control of the GTM controls to the PACC.

### EMERGENCY CONTROLS Section

The emergency controls section is a mirror image of the 2B emergency controls section on the PACC engine room No. 1 demands panel described previously.

## GTM A/B PANEL

The GTM A/B panel (fig. 5-16) has the alarm indicators for the GTMs A and B, and the controls and indicators for the various air systems. This panel is divided into three sections. The first section has 22 alarm indicators (23 on the CG console) for each engine, and 11 alarm indicators for the air and MRG system. It also allows the PLCC operator to monitor the air systems of the engines in ENG RM 1, ENG RM 2, and GTG3. This monitoring ability consists of three alarm indicators per engine and an alarm indicator for the HP air system of both engine rooms and

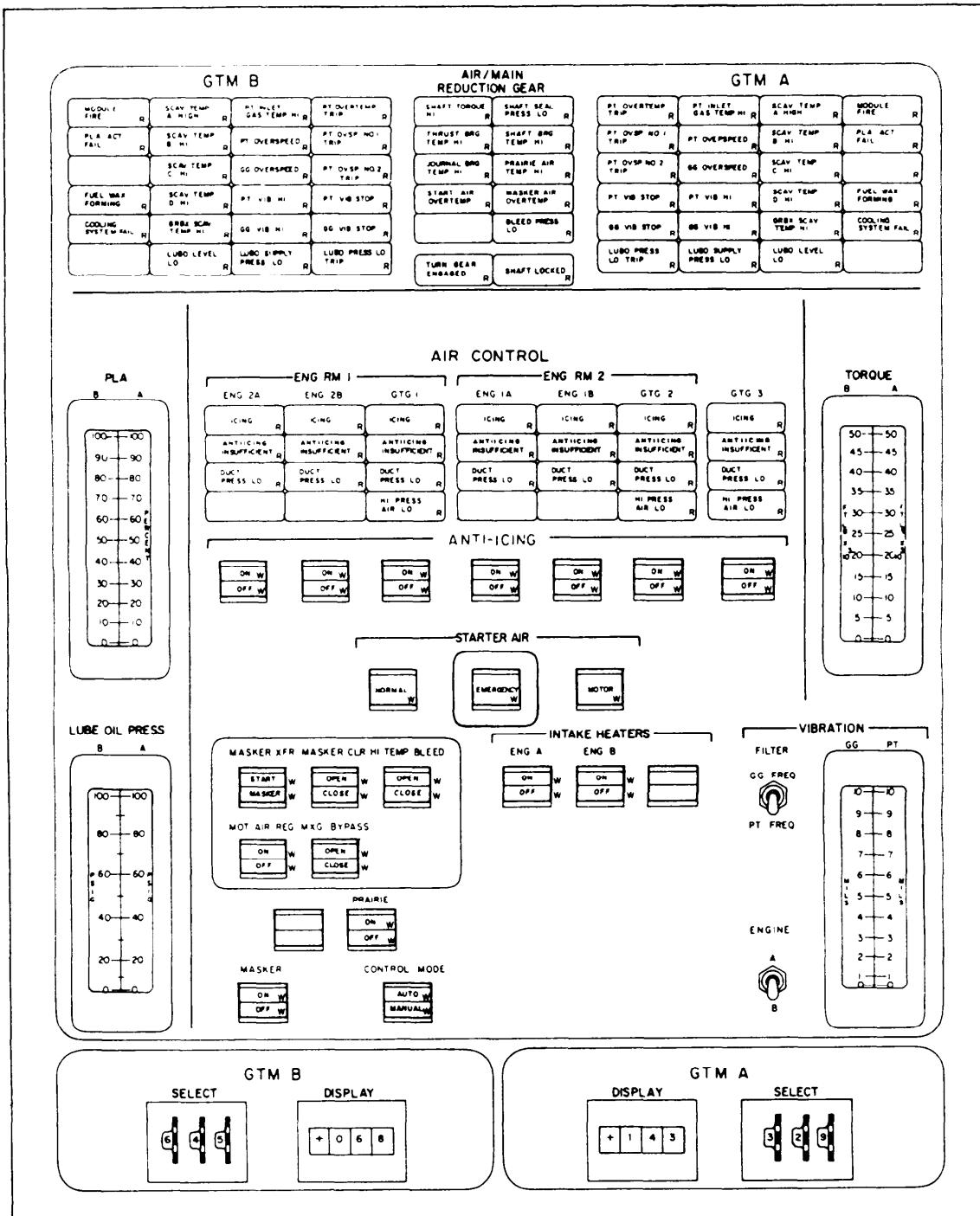


Figure 5-16.—GTM A/B panel.

GTM3. This section of the GTM A/B panel also has 4 dual-indicating meters, 20 push-button control indicators (21 on the CG console), and 2 toggle switches. All of these alarm indicators, push-button control indicators, dual-indicating meters, and toggle switches have been previously described on the PACC.

The last two sections of this panel are the DDIs. They are a mirror image of each other. The DDI system is an operator information system. The system is used to verify parameters, check the system's operation, and troubleshoot system malfunctions. Any parameter monitored can be displayed at any DDI location. The DDI system uses a three-digit address to probe the memory of the computer and find the value of the

parameter. The DDI displays this value in the display windows. To use the DDI system, you

- determine the address for the required parameter,
- dial the address in the SELECT thumb-wheels, and
- observe the value of the parameter in the display window.

In the DDI system, the values are continually updated at the rate of four times a second.

### GTM A PANEL

The GTM A panel (fig. 5-17) has the controls and status indicators for the GTM A and the

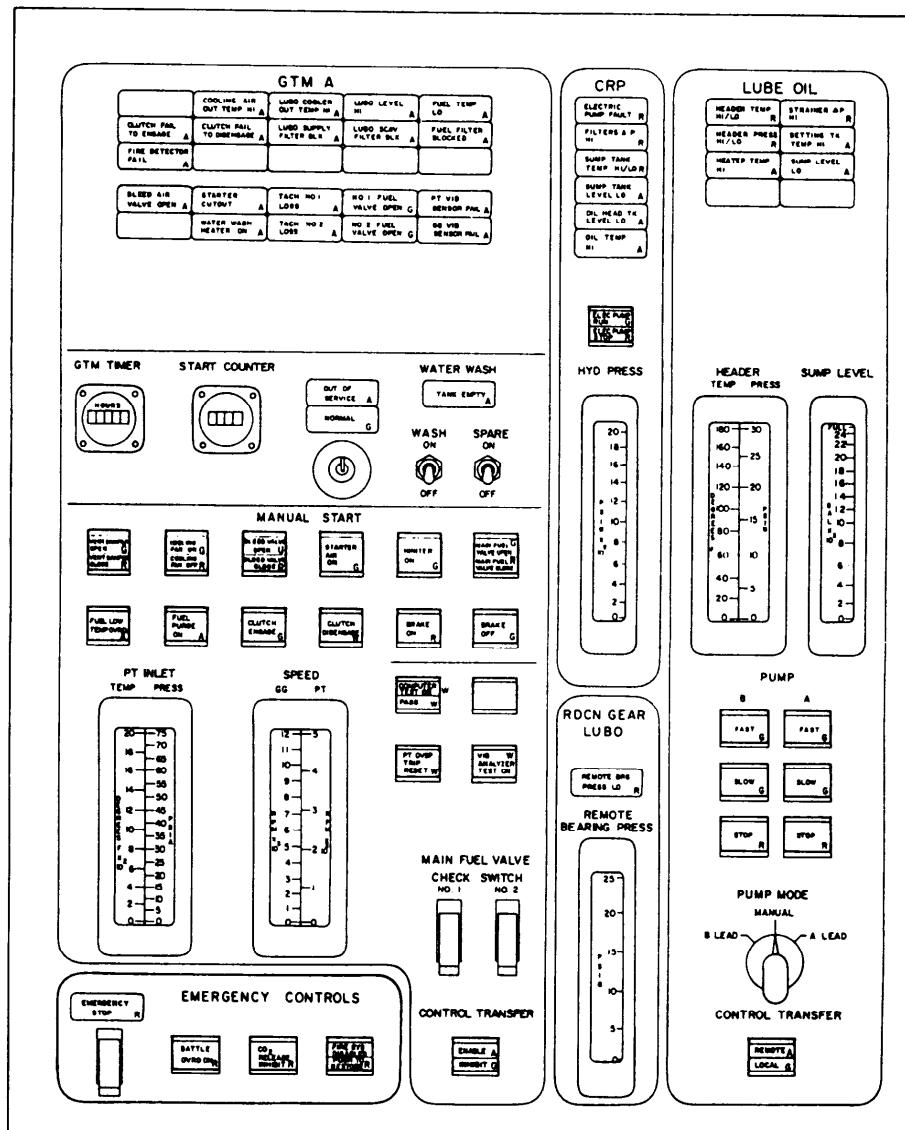


Figure 5-17.—GTM A panel.

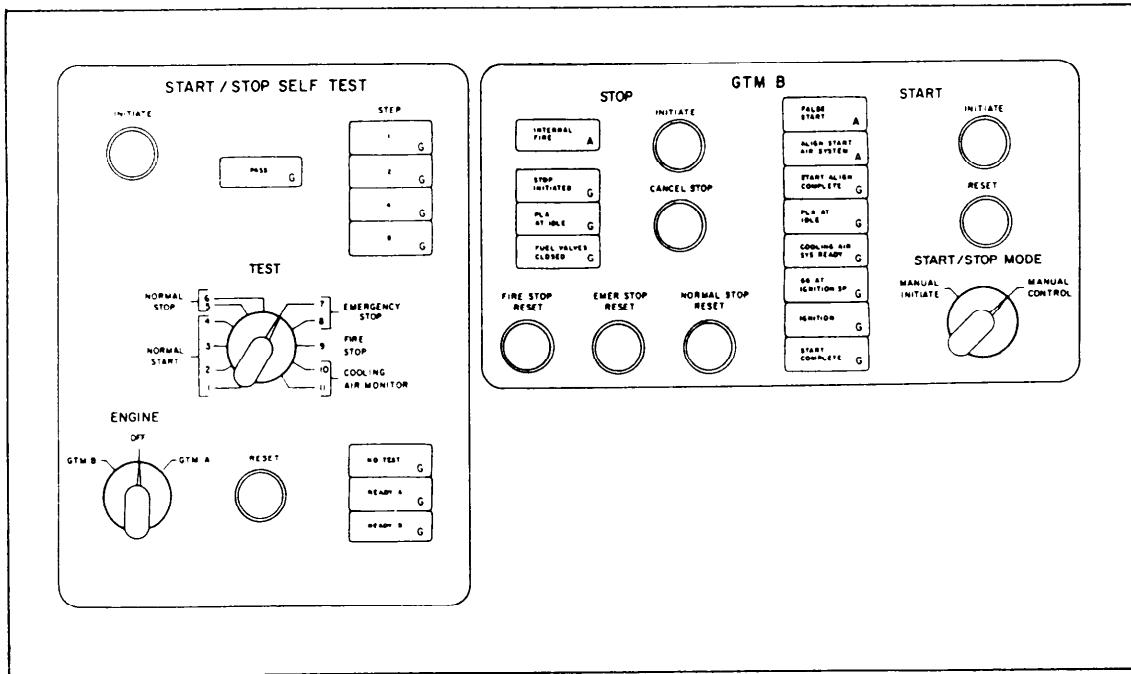


Figure 5-18.—Self test panel.

controls and alarm/status indicators for the CRP and MRG LO system. This panel is divided into five sections, GTM A, CRP, LUBE OIL, EMERGENCY CONTROLS, and RDCN GEAR LUBO.

### GTM A Section

The GTM A section of the GTM A panel is a mirror image of and performs the same function as the GTM B section of the PLCC GTM B panel.

### CRP Section

This section of the GTM A panel on the PLCC is NOT a mirror image of the CRP section on the PACC engine room No. 2 panel, but it does have the identical alarm indicators and push-button control indicators. These indicators will not be described again. The difference between the two sections is that this section of the GTM A panel has a single edgewise meter to monitor HYD PRESS vice the dual-indicating meter found on the PACC which monitors both the pressure and temperature.

### LUBE OIL Section

This section has the identical alarm indicators, dual-indicating meter, push-button control indicators, and three-position rotary switch described on the LUBE OIL section of the PACC engine No. 2 panel. There are three control indicators on this panel that are slightly different. The PLCC LUBE OIL section does not have the PURIFIER ON indicator. Also, under the heading CONTROL TRANSFER is a split-legends, push-button control indicator labeled REMOTE/LOCAL. This push button is used to transfer LO system control to and from the PACC. It illuminates the CCS CONTROL/PLCC CONTROL status indicator at the PACC. The PLCC LUBE OIL section also has an additional edgewise meter under the heading SUMP LEVEL. This meter displays the MRG sump level in gals  $\times 10^2$ .

### SELF TEST PANEL

The self test panel (fig. 5-18) is used to test the GTM start, the GTM stop, and the cooling air control electronics. It also has the start/stop controls for GTM B. This panel is divided into two sections labeled START/STOP SELF TEST and GTM B.

## START/STOP SELF TEST Section

This section is used to conduct a static test of the start sequencer, normal and emergency stop circuits, and the cooling air monitor circuit cards of either GTM A or GTM B. It has two push buttons, two rotary selector switches, and eight status indicators. These buttons, switches, and indicators are used in conjunction with procedural steps outlined in the EOP and table 2-16 of NAVSEA S9234-BT-MMO-010, *Propulsion Local Operating Equipment (PLOE)*, Volume 1.

### GTM B Section

This section is used to start and stop the GTM. It is divided into two subsections labeled STOP and START.

**STOP SUBSECTION.**—This portion of the panel has one alarm indicator, five push buttons, and three status indicators. The alarm indicator is labeled INTERNAL FIRE. It is an alarm that indicates an internal (post-shutdown) fire. If 3 minutes after shutdown  $T_{5.4}$  is  $> 700^{\circ}\text{F}$ , the alarm will activate.

The push buttons are active only when the START/STOP MODE switch is in the MANUAL INITIATE position. The push buttons are as follows:

- **INITIATE**—When depressed, it starts a normal stop of the GTM.
- **CANCEL STOP**—It is used to cancel a normal stop of the GTM.
- **FIRE STOP RESET, EMER STOP RESET, NORMAL STOP RESET**—These are logic circuitry reset push buttons for each of the indicated sequences (active even in manual control mode).

The status indicators are as follows:

- **STOP INITIATED**—It illuminates to indicate a stop has been initiated.
- **PLA AT IDLE**—It illuminates to indicate when the PLA reaches idle. At idle, a 5-minute cool-down timer begins.
- **FUEL VALVES CLOSED**—It illuminates when the cool-down period is over. After cool down, the fuel valves close, which secures the GTM.

**START SUBSECTION.**—The start half of the panel has two alarm indicators, six status indicators, two push buttons, and a rotary select switch. The two alarm indicators are as follows:

- **FALSE START**—This alarm indicates one of two alarm conditions: (1)  $< 1200 \text{ N}_{\text{GG}}$ , 20 seconds after the start air valve opens; (2)  $T_{5.4} < 400^{\circ}\text{F}$ , 40 seconds after the main fuel valves open ( $1200 \text{ N}_{\text{GG}}$ ).
- **ALIGN START AIR SYSTEM**—This is actually a dual-function (status and an alarm) indicator. As a status indicator, it comes on steady to show the air start system is being aligned for a start. As an alarm indicator, it comes on flashing to show the air start system will not properly align (either the valves failed to properly position or anti-icing air is on).

The status indicators are as follows:

- **START ALIGN COMPLETE**—It illuminates after the logic circuits check alignment of the following: (1) GTM in service, (2) start air system aligned, (3) HP start priority check, (4) fuel temperature, and (5) bleed air valve closed.
- **PLA AT IDLE**—It illuminates to indicate PLA is at 0 percent.
- **COOLING AIR SYS READY**—It illuminates to indicate the vent damper is open and the cooling fan is operating properly.
- **CG AT IGNITION SP**—It illuminates to indicate that GG speed is  $> 1200 \text{ rpm}$ .
- **IGNITION**—It illuminates to indicate  $T_{5.4} > 400^{\circ}\text{F}$ .
- **START COMPLETE**—It illuminates to indicate GG speed is  $> 4300 \text{ rpm}$ . (Once the start logic has been reset, electronically, the above status indicators extinguish.)

The two push buttons are active only in the MANUAL INITIATE mode. These two push buttons are as follows:

- **INITIATE**—It is used to initiate a MANUAL INITIATE start.
- **RESET**—It is used to reset the logic circuitry for the MANUAL INITIATE start sequence.

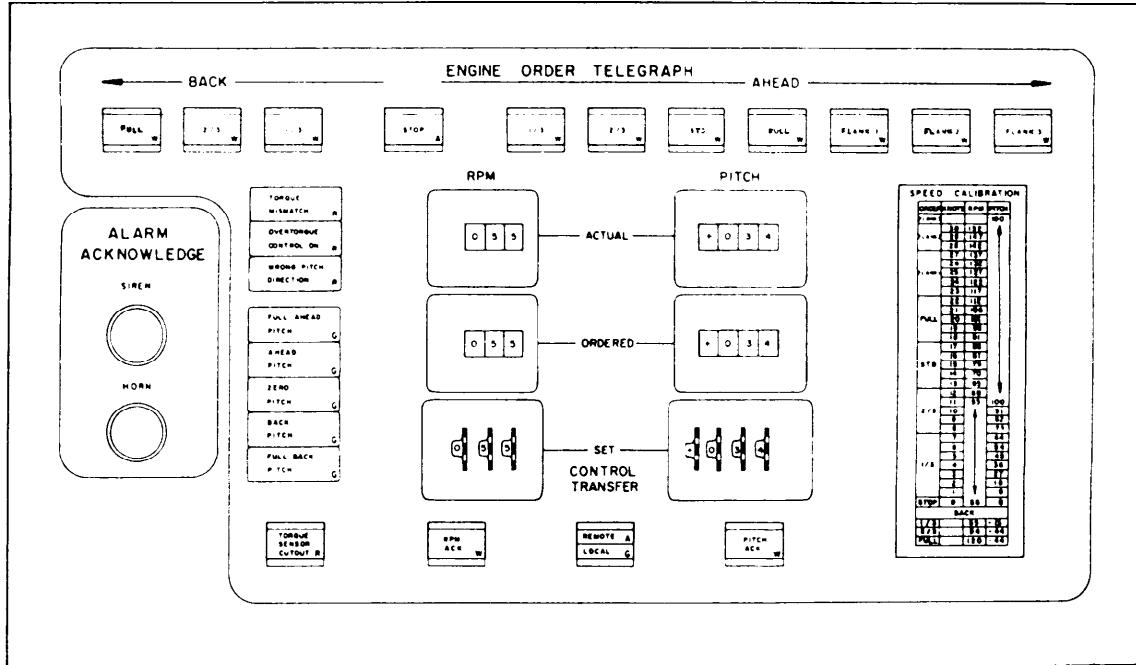


Figure 5-19.—EOT panel.

Under the heading START/STOP MODE is the two-position, rotary select switch labeled MANUAL INITIATE and MANUAL CONTROL. This switch allows you to select the starting and stopping mode.

#### EOT PANEL

The EOT panel (fig. 5-19) is divided into two sections labeled ALARM ACKNOWLEDGE and ENGINE ORDER TELEGRAPH.

#### ALARM ACKNOWLEDGE Section

This section has two push buttons (three on the CG console). They are the main interface between you and the control console. Each time an alarm is activated, an audible alarm sounds. Amber (potential danger) alarms sound a horn and red (danger) alarms sound a siren. When any alarm activates, the recommended procedures to follow are listed as follows:

- Identify the alarm condition. The alarm indicator will come on flashing, and the audible alarm sounds.
- Acknowledge the alarm. Depress the proper alarm acknowledge push button. This action silences the audible and causes the alarm indicator to glow steadily.

- Investigate the alarmed condition following EOCC.

#### ENGINE ORDER TELEGRAPH Section

When the SCC does not have throttle control, the OOD must inform the station in control of speed requirements. This is done through the EOT. The EOT is a communications system. It transmits propulsion command information between the station in command (SCC) and the station in control of the throttles (PLCC or the PACC).

The EOT section has two major subsections, the standard order push-button/status indicators and the digitized EOT.

The standard order push-button indicator section has 13 push buttons. Under the heading BACK, three of the push buttons are labeled FULL, 2/3, and 1/3. The next push button is labeled STOP. Under the heading AHEAD are seven push buttons labeled 1/3, 2/3, STD, FULL, FLANK 1, FLANK 2, and FLANK 3. The last two push buttons are at the bottom of the panel under the digitized EOT. These push buttons are labeled RPM ACK and PITCH ACK. These 13 push buttons provide for communication of standard orders to the PLCC. Standard orders are initiated at the SCC by moving the ITC lever to

the commanded standard order position and depressing the standard order ALERT push-button indicator. This transmits the order to the PACC and PLCC for that shaft (port or starboard). The commanded standard order acknowledge push-button (RPM ACK/PITCH ACK) indicator flashes at both the PLCC and PACC, but the EOT bell annunciator only sounds at the station which has control of that engine room (PACC or PLCC). During a standard EOT order change, the new order is displayed by the flashing indicator and the old order is displayed by the steady illuminated indicator at all three consoles (SCC, PACC, PLCC). If the PLCC has control, the operator can acknowledge the order by depressing the flashing standard order push button. This silences the bell, and the flashing indicator illuminates steady.

The digitized EOT section contains three alarm indicators, five status indicators, the ALARM ACKNOWLEDGE push buttons, a TORQUE SENSOR CUTOUT push button, and a CONTROL TRANSFER push-button/status indicator.

The alarm indicators are as follows:

- **TORQUE MISMATCH**—It illuminates red to indicate a mismatch of torque between the PT and the propulsion shaft. These values are electronically measured by the FSEE and the shaft torque sensor. More than a 25 per cent difference of the two torque values for > 60 seconds will activate this alarm.
- **OVERTORQUE CONTROL ON**—It illuminates yellow to indicate that overtorque control has been activated either in the FSEE (PT torque limiting) or by the console electronics (shaft torque limiting). This indicator illuminates when limiting is occurring. If after 20 seconds the over-torque condition still exists, the alarm will sound.
- **WRONG PITCH DIRECTION**—It illuminates red to indicate a difference between the commanded pitch, the position of the pitch control lever, and the actual pitch of the propeller. If the wrong direction condition exists for longer than 20 seconds, an audible alarm is sounded. If a wrong direction condition exists and

shaft rpm is > 60, the console electronics will bring the PLA to idle.

The status indicators are as follows:

- **FULL AHEAD PITCH**—It illuminates green to indicate + 100 percent propeller pitch.
- **AHEAD PITCH**—It illuminates green to indicate +16 to +100 percent propeller pitch.
- **ZERO PITCH**—It illuminates green to indicate - 16 to +16 percent propeller pitch.
- **BACK PITCH**—It illuminates green to indicate - 16 to - 49 percent propeller pitch.
- **FULL BACK PITCH**—It illuminates green to indicate - 49 percent propeller pitch.

The TORQUE SENSOR CUTOUT is a push-button control indicator that electronically overrides shaft torque limiting. Shaft torque is sensed by a torsion meter installed on the propeller shaft. If propeller shaft torque becomes too great, an electronic signal is generated to limit PLA of the GTM. This action limits the power of the GTM until shaft torque is within normal power limits. When the torque sensor cutout is activated, propeller shaft torque is NOT electronically limited.

At the bottom center of the panel, under the heading CONTROL TRANSFER, is a push-button control indicator labeled LOCAL/REMOTE. It is the control transfer push-button for the following functions:

- GTM controls, start/stop functions
- Clutch/brake controls
- CRP pump control
- EOT control

The control transfer button is used with the GTM ENABLE/INHIBIT push buttons discussed in GTM controls and indicators.

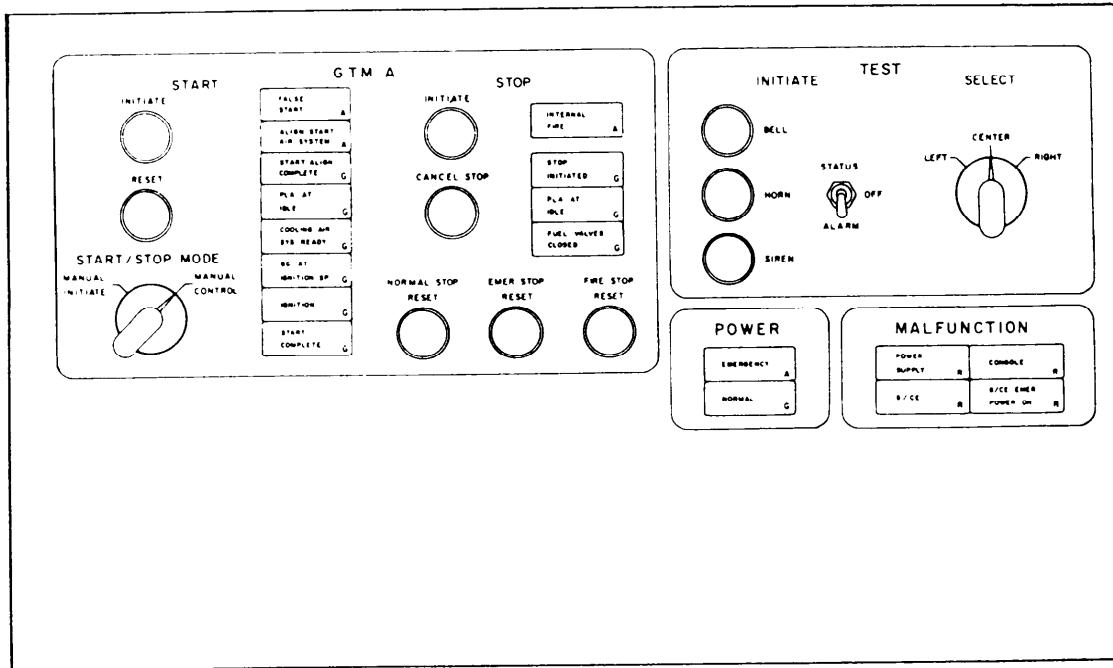


Figure 5-20.—Alarm test panel.

## ALARM TEST PANEL

The alarm test panel (fig. 5-20) is divided into four sections labeled GTM A, TEST, POWER, and MALFUNCTION.

### GTM A Section

The GTM A section is a mirror image of the GTM B section on the PLCC SELF TEST panel.

### TEST Section

This section is used to test the alarm and status indicators on the various panels of the console. Under the heading INITIATE are three push buttons labeled BELL, HORN, SIREN, and a three-position toggle switch labeled STATUS, OFF, and ALARM. Under the heading SELECT is a three-position rotary switch labeled LEFT, CENTER, and RIGHT.

The alarm and status tests are performed by selecting the panel of the console (left, center, or right panel) to be tested with the SELECT switch. By placing the toggle switch to the ALARM position, all the alarm indicators on the selected panel illuminate flashing. After the ALARM test, the toggle switch is placed in the OFF position. At this point, the alarms illuminate steady until

the operator depresses the ALARM ACK push button to turn them off. Moving the toggle switch to the STATUS position illuminates all the status indicators for the selected panel. After the STATUS test, the toggle switch is placed back in the OFF position and all the status indicators extinguish. During a panel STATUS test, any digital display will indicate 888\*\*\*. This provides a test of all segments of each digit of the digital display.

The push buttons under the heading INITIATE are used to test the audible alarms. There are three categories of audible alarms. They are, in order of increasing priority, the BELL, the HORN, and the SIREN.

### POWER Section

This section is used to monitor the console power supplies. It has an alarm indicator labeled EMERGENCY and a status indicator labeled NORMAL. When the EMERGENCY indicator is illuminated, the console is being supplied by the UPS system (150 volts dc). Under normal conditions the NORMAL status indicator is illuminated, indicating the console is being supplied by 120 volts ac from ship's power.

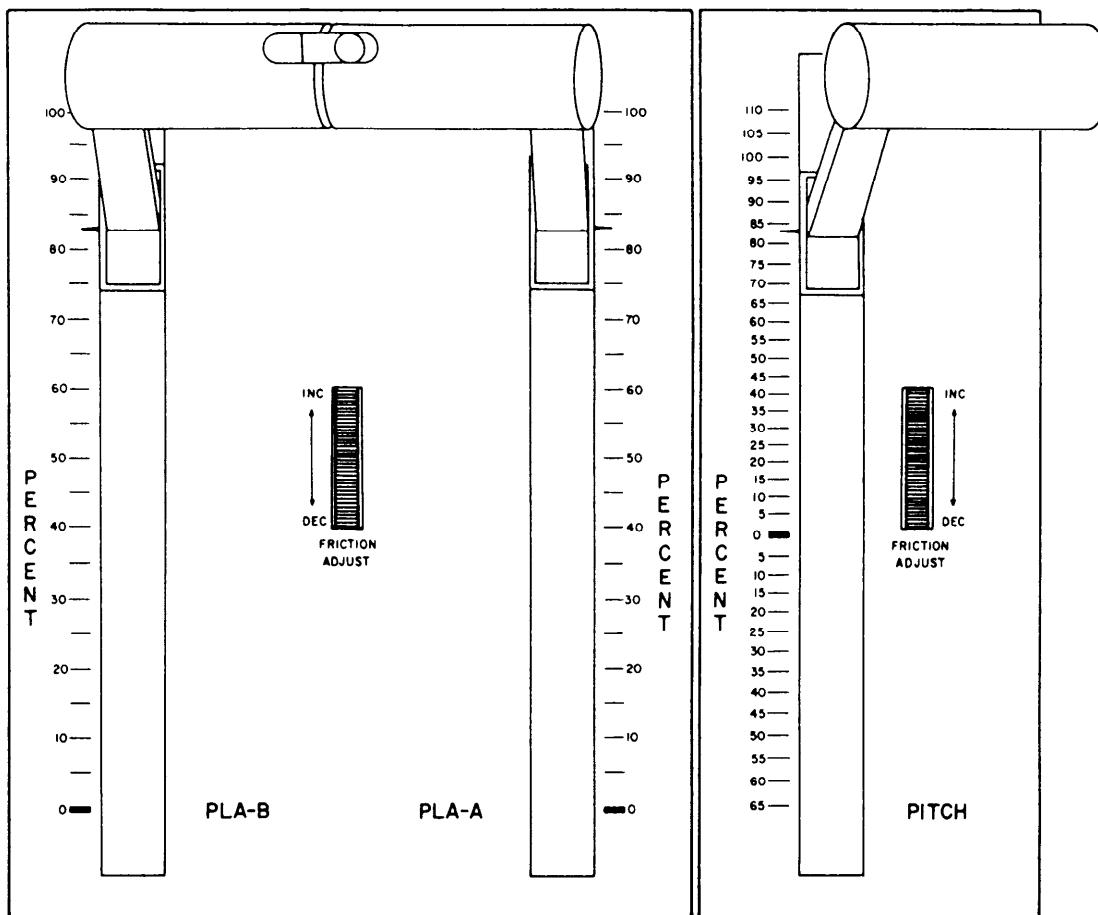


Figure 5-21.—PLA (throttle) and PITCH control levers.

## MALFUNCTION Section

This section has four alarm indicators which are normally not illuminated. The alarm indicators are as follows:

- **POWER SUPPLY**—It illuminates red to indicate a summary fault condition at the PLCEE power supply.
- **CONSOLE**—It illuminates red to indicate a summary fault condition at the PLCC.
- **S/CE**—It illuminates red to indicate a summary fault condition at the PAMISE signal conditioning enclosure.
- **S/CE EMER POWER ON**—It illuminates red to indicate the signal conditioning enclosure is using UPS emergency power.

## PLA AND PITCH CONTROL LEVERS

Figure 5-21 shows the PLA (throttle) and PITCH control levers which are electronically connected to the PLA of the GTM and to the CRP electronic enclosure, respectively. The throttle levers are graduated in percentage of PLA from 0 to 100 percent for each PLA. The pitch lever is graduated in percentage of pitch travel from 0 to 110 percent (ahead) and from 0 to - 65 percent (astern).

## SUMMARY

In this chapter, we have presented information to familiarize you with the controls and indicators located on the consoles of the DD- and CG-class ships. The main consoles of other classes of gas turbine-powered ships will be described in later chapters of this TRAMAN. Do not attempt

LM2500 GTE operation until you understand how the control stations operate.

The material presented so far has given you a basic understanding of the general lay out of the CCS and the engine room consoles. As a GS, you will be assigned watches at these console

watch stations. By the knowledge learned in this chapter, by using PQS and EOSS, and your experience standing under instruction (U/I) watches, you should be able to qualify in your ship's various watch stations. Remember, before you attempt any operation at these consoles, you must be familiar with and use the EOSS.

## CHAPTER 6

# PCC AND LOP FOR FFG-CLASS SHIPS

Operation of main propulsion GTEs is done from several different locations. The major classes of Navy ships that use the LM2500 GTE have three control points. The first control station is in the engine room. It is called the local operating panel (LOP) on the FFG-class ships. On the CG- and DD-class ships, it is called the propulsion local control console (PLCC). It is called the shaft control unit (SCU) on the new 51 class ships. The engine-room control consoles are the primary control consoles. This is not to say that the engine-room console is in control all the time. When we say primary control console, we mean it may take control from any other remote station at any time. For example, on a ship operating with the throttle control at the pilot house, if the engine-room operator places the throttle control to local, automatically the engine room assumes control of the throttle operation.

The next level of control is in the CCS. The CCS is normally the control station for starting, stopping, and monitoring the LM2500 GTE. On the FFG-class ships the console in this station is called the PCC. In this chapter we will discuss only the PCC located in the CCS and the LOP located in the MER on an FFG. The other control consoles located in CCS are discussed in depth in later chapters. On the twin-shaft GTE-powered ships, the main engine control is called the propulsion and auxiliary control console (PACC).

The third level of control is on the bridge. This station, known as the ship control console (SCC) (or bridge control unit (BCU) on the 51 class), may have direct throttle control of the engineering plant. This allows the officer of the deck (OOD) to have direct throttle and pitch control, eliminating the need to pass an engine order verbally to CCS. Quicker maneuvering of the ship is possible with control at the SCC.

Gas Turbine Systems Technicians on the FFG-class ships, like those on the other class GTE-powered ships, stand most of their watches in the CCS. The watch standers in CCS are responsible

for operating and monitoring the ship's engineering plant. To stand these watches, you must be familiar with the operation of the equipment in CCS. This equipment includes the PCC, the DCC, the EPCC, the ACC, and the bell and data loggers. Some of this equipment, along with ship class differences, have been discussed in previous chapters. Chapters 8 and 9 of this TRAMAN contain additional information on the EPCCs and the ACCs.

The equipment design allows for a minimum number of watch standers for the entire engineering plant. Alarms and status indicators keep the CCS operators aware of plant conditions. Digital displays and meters show the parameters, while switches and push buttons allow control of the equipment.

Just knowing the location of the lights, push buttons, and switches is not enough. You must also know the operation of the entire plant. Without a working knowledge of the plant, pushing the wrong push button could endanger the equipment, the ship's maneuverability, or your shipmates.

After reading this chapter, you should be familiar with the operation of the PCC in the CCS and the LOP in the MER and be able to discuss how they relate to the engineering plant. Like other material in this TRAMAN, this chapter will only familiarize you with the equipment. To qualify on any engineering watch station, you should always use the EOSS and the Personnel Qualification Standard (PQS).

After reading this chapter and completing the associated NRTC, you should gain enough knowledge to start qualifying on the propulsion consoles in CCS and the MER. While you may never work on an FFG-class ship, this chapter should provide you enough equipment information to help you advance in rate. As you become senior in the GS rating, this introduction to the FFG control equipment will be helpful in your watch-station qualifications.

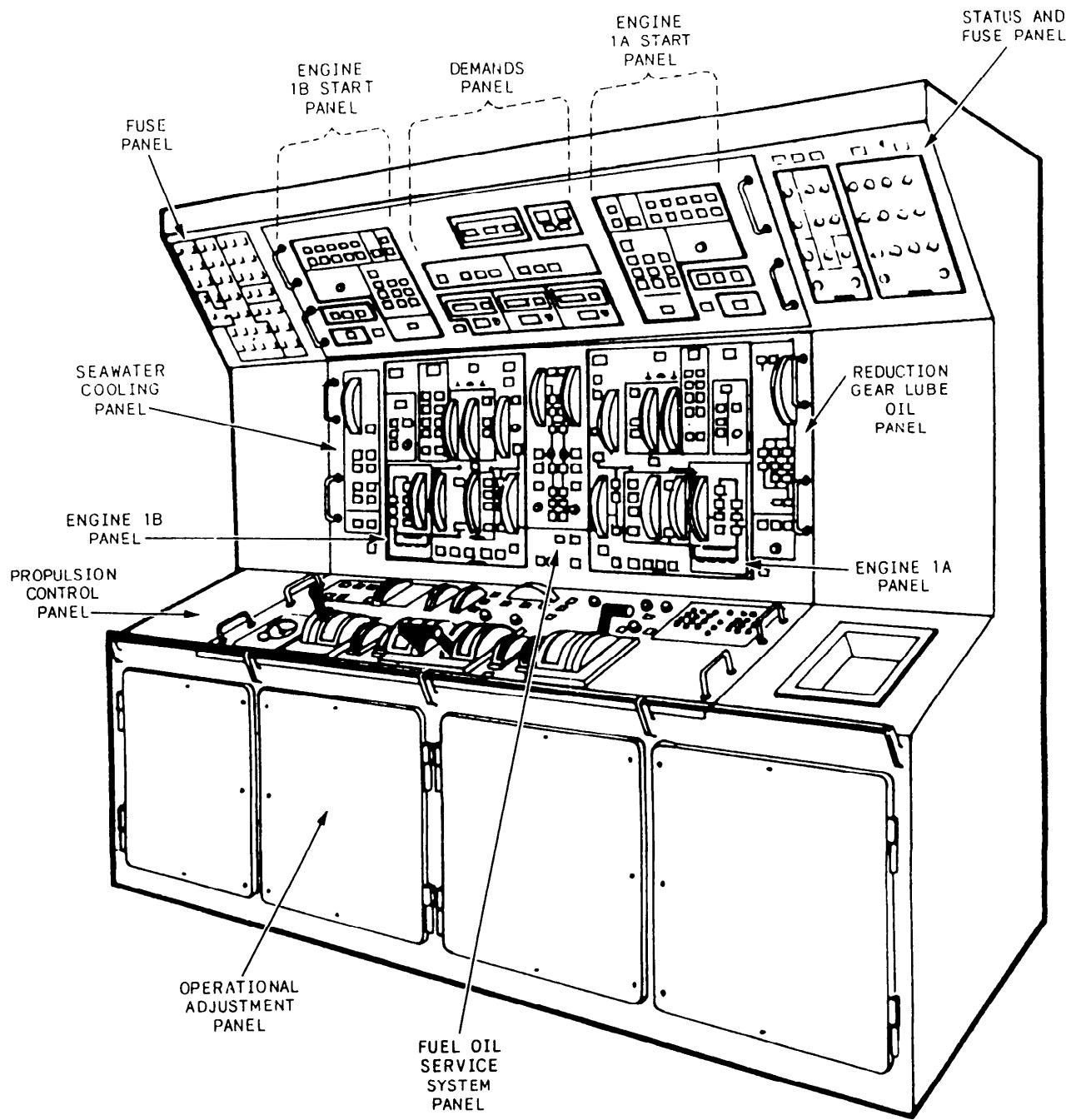


Figure 6-1.—PCC panel breakdown.

## PROPULSION CONTROL CONSOLE

The PCC is the console normally used to operate the ship's main GTEs and propulsion equipment. It is the largest component of the PCS. The PCC provides all the controls and indicators necessary to start, control, and secure the ship's propulsion system and its related

auxiliaries. During this description of the PCC we will attempt, where possible, to describe the panels from left to right and top to bottom.

## PCC CONTROLS AND INDICATORS

The PCC is subdivided into panels (fig. 6-1). On the top outboard sections of the console are

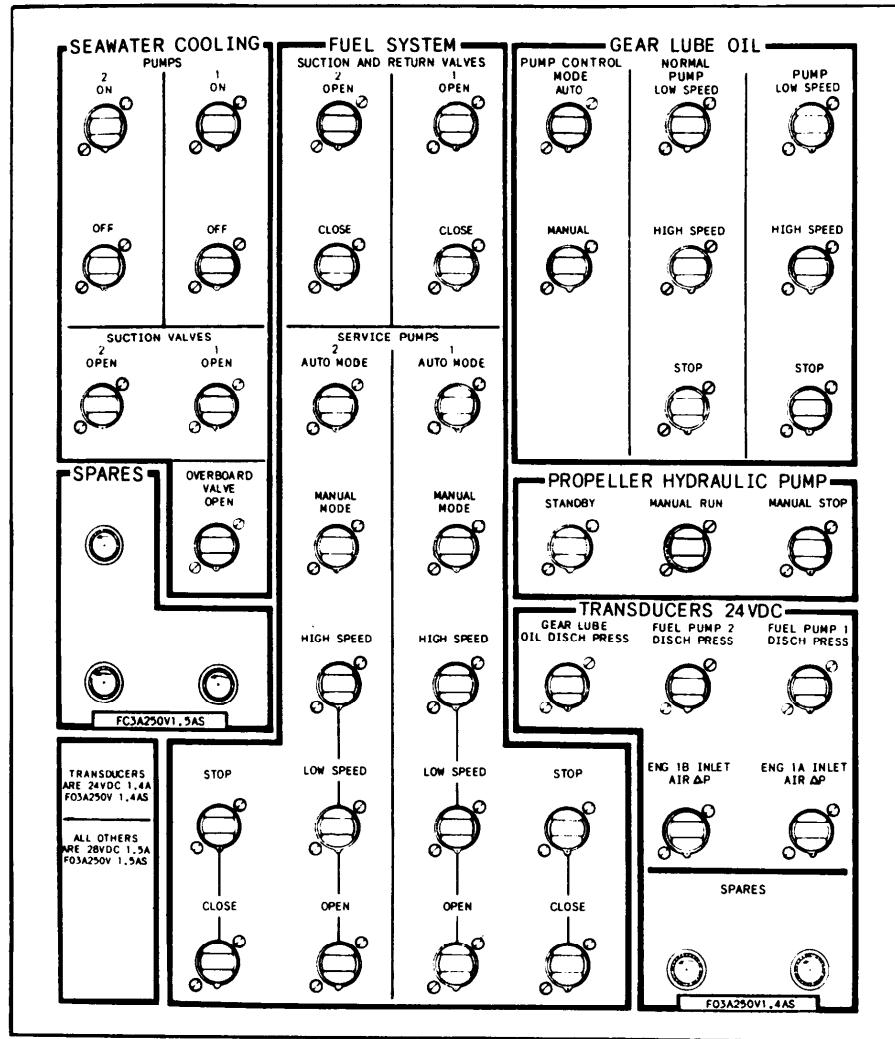


Figure 6-2.—PCC fuse panel.

a fuse panel (left side) and a status and fuse panel (right side). In the center of the top section of the PCC is the demands panel. On either side of the demands panel are the engine start panels (1A on the right side, 1B on the left side). On the middle section of the PCC from left to right are the seawater cooling panel, the engine 1B panel, the FO service system panel, the engine 1A panel, and the reduction gear LO panel. The lower section of the PCC is the propulsion control panel. This panel has the throttle controls, the propeller pitch hydraulic oil panel, and an MRG bearing mimic display.

Follow the related figures as we discuss the various PCC control and indicating panels. The parenthetical letters referenced in the text are

shown on the figures. Refer to these letters to find the section of a panel when it is discussed.

### Fuse and Status Panels

The fuse panel (fig. 6-2) is located to the left of engine start panel 1B. This panel has seven sections of fuses, two of which contain spare fuses for the panel. The other sections are labeled SEAWATER COOLING, FUEL SYSTEM, GEAR LUBE OIL, PROPELLER HYDRAULIC PUMP, and TRANSDUCERS—24 VDC. When a generated command is not received, troubleshooters should begin by checking the associated fuses. The only time voltage is applied across the fuse is when a command is transmitted.

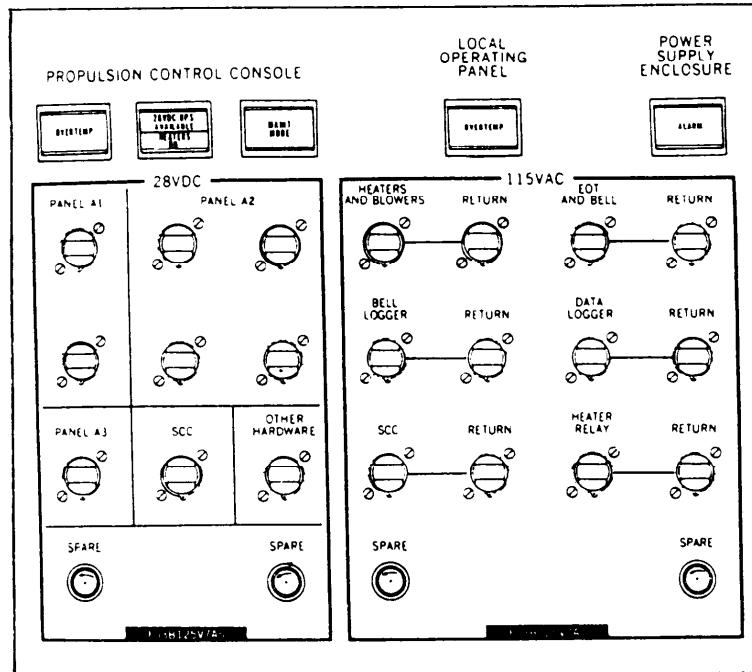


Figure 6-3.—PCC status and fuse panel.

To the right side of engine start panel 1A is the status and fuse panel (fig. 6-3). It has indicators for the PCC, the LOP, and the power supply enclosure and two sections of fuses.

On the upper left side of the status and fuse panel are three status indicators for the PCC. The first indicator is labeled OVERTEMP and is used to monitor the internal temperature of the console cabinet. This is set at 160°F. The second indicator is a split-legends indicator. The upper half is labeled 28VDC UPS AVAILABLE. This indicator illuminates when 28 volts dc from the power supply enclosure assembly (PSEA) is available. The lower half of the indicator is labeled HEATERS ON and illuminates when the console heaters are energized. It will not be illuminated during a lamp test. The last indicator for the PCC on this section of the panel is the MAINT MODE indicator. It illuminates when the operate/test switch of the processor on the maintenance panel is in the test position. The only time this should illuminate is when a maintenance person is working on the system. If it is illuminated, the DDIs and programmed control may or may not be operating.

The next indicator on this section is for the LOP. It is labeled OVERTEMP. This indicator

illuminates when the internal temperature of the LOP is greater than 160°F. The last indicator on this panel is for the power supply enclosure and is labeled ALARM. It illuminates when a monitored voltage in the PSEA has fallen below its set point or the internal temperature of the PCC or LOP console is high.

Underneath these indicators are two sections of fuses. The section to the left is 28VDC fuses for the power fed to the panels. The fuses in the right section are for the 115VAC fed to other components indicated on the panel.

### Engine Start Panels

The two engine start panels are mirror images of each other. They have identical push buttons and indicators. These indicators and controls are used to monitor or control the start of one of the GTEs. Figure 6-4 shows panel 1B.

**PRESTART STATUS SECTION.**—The prestart status section (A) has 10 split-legends indicators that display the status of 18 components in the plant before start. These 18 indicators are called the GTE prestart permissives. We will start our description at the top outside indicator and go across the top row, and then continue with the

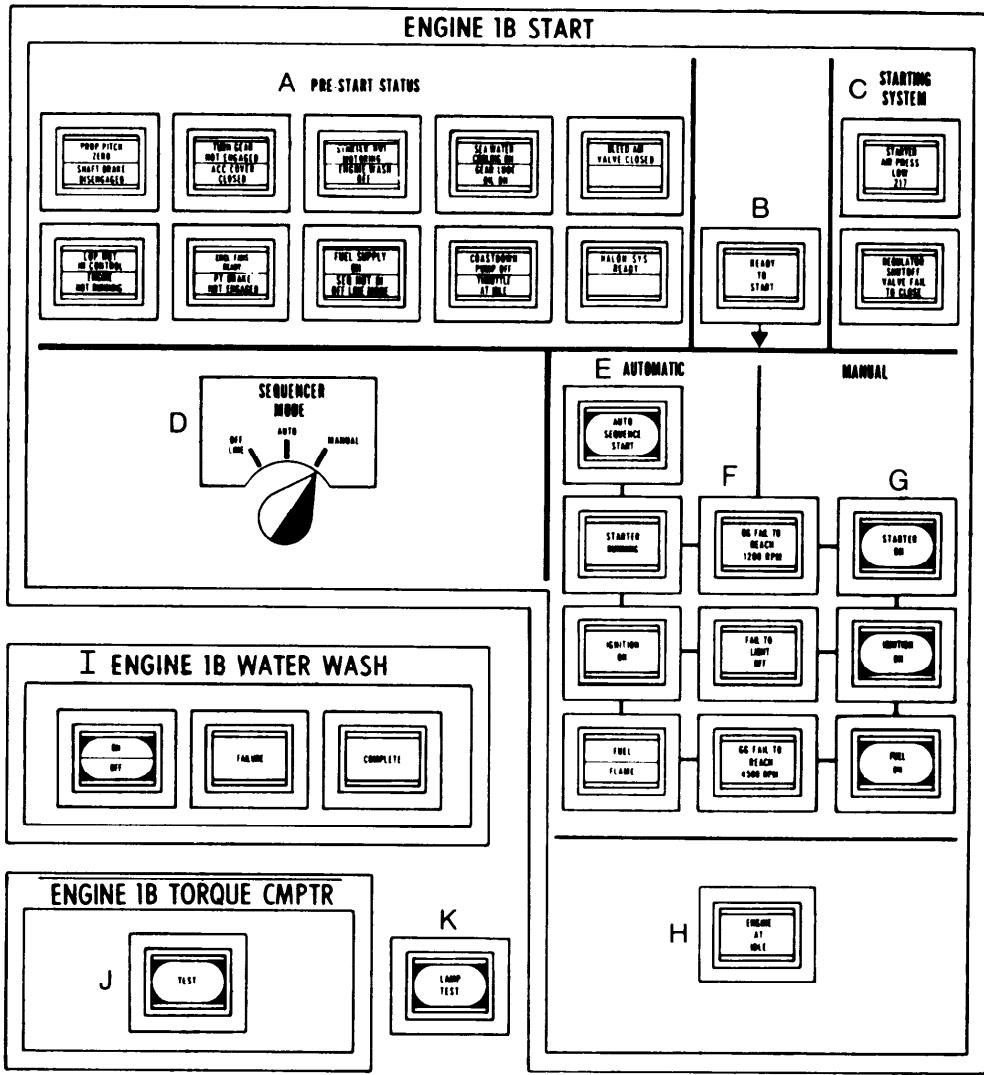


Figure 6-4.—Engine start panel 1B.

indicators on the second row. The indicators and what they represent are as follows:

Top Row:

1. PROP PITCH ZERO—The propeller pitch is at zero (automatically bypassed for start of the second GTE).
2. SHAFT BRAKE DISENGAGED—The shaft brake is disengaged (automatically bypassed for start of the second GTE).
3. TURN GEAR NOT ENGAGED—The turning gear motor is not engaged to the gearbox and is not locked.
4. ACC COVER CLOSED—The clutch access doors on the MRG are closed.

5. STARTER NOT MOTORING—The GTE starter is not motoring (turning).
6. ENGINE WASH OFF—The GTE is not being water washed.
7. SEAWATER COOLING ON—The seawater cooling pressure is greater than 7 psig, and the discharge valve is open.
8. GEAR LUBE OIL ON—The LO supply pressure at the hydraulically most remote bearing of the MRG is greater than 9 psig.
9. BLEED AIR VALVE CLOSED—The bleed air valve on that GTE is closed.

Second Row:

10. LOP NOT IN CONTROL—The control of the GTE is not at the LOP.

11. ENGINE NOT RUNNING—The  $N_{GG}$  is less than 1200 rpm,  $T_{5.4}$  is less than 400°F, and fuel manifold pressure is less than 50 psig.
12. ENCL FANS READY—The enclosure fan is ready to run depending upon automatic fan circuitry.
13. PT BRAKE NOT ENGAGED—The PT brake for that GTE is not engaged.
14. FUEL SUPPLY ON—One of the two fuel tanks has more than 20 percent, the fuel supply cutoff valve is open, and the fuel supply pressure is greater than 8 psig.
15. SEQ NOT IN OFF-LINE MODE—The sequencer mode switch is not in the off-line position.
16. COASTDOWN PUMP OFF—The MRG coastdown pump is not running.
17. THROTTLE AT IDLE—The GTE PLA is in the idle position.
18. HALON SYS READY—The Halon inhibit switch is not on and the Halon system is ready.

**READY TO START.**—The READY TO START indicator (B) only illuminates when the 18 prestart permissives are met. The GTE is not designed to be started in either the automatic or manual mode until this indicator illuminates.

**STARTING SYSTEM SECTION.**—The STARTING SYSTEM section (C) has two indicators used to display abnormal conditions in the starting air system. The STARTER AIR PRESS LOW indicator illuminates when the starting air pressure drops below 35 psig as sensed by one of two pressure transducers. The REGULATOR SHUTOFF VALVE FAIL TO CLOSE indicator illuminates when the start air valve on the GT has not closed and the GG speed has reached 4900 rpm.

**SEQUENCER MODE SELECTOR SWITCH.**—The SEQUENCER MODE selector switch (D) is a three-position rotary switch used to determine the operating mode of the start/stop sequencer. The three modes are OFF LINE, AUTO, and MANUAL. The off-line position will prevent the GTE from being started at the PCC. This mode is normally used only during maintenance, water washing, and motoring. The auto position allows the AUTO SEQUENCE START push button to be used to start the GTE using the start/stop sequencer. In the manual position, the operator

has to start the GTE using the manual push buttons and do the start sequencing.

**START SEQUENCING.**—The start sequencing section (E, F, and G) has 10 push buttons and indicators used to control or monitor the GTE start. An additional indicator (H) in this section indicates when the GTE is at idle. The automatic start section (E) has a push button and three indicators used to start the GTE in the automatic mode. The AUTO SEQUENCE START push button is depressed to initiate the auto start sequence in the start/stop sequencer. This action will only start the sequence if the sequencer mode select switch (D) is in AUTO, and the READY TO START indicator (B) is illuminated. The first indicator to illuminate during an auto start sequence is the STARTER RUNNING indicator. This shows the starter regulator/shutoff valve is open. The next indication is for IGNITION ON. This indicator shows that the igniters are energized through the start/stop sequencer. The third indicator is a split-legends type that reads FUEL/FLAME. The FUEL indicator illuminates when the fuel manifold pressure is greater than 50 psi. The FLAME indicator illuminates when  $P_{t5.4}$  is greater than 400°F.

The three center indicators (F) are used to show out-of-tolerance conditions during a GTE start. These three conditions will also cause an automatic shutdown. These indicators are labeled NGG FAIL TO REACH 1200 RPM, FAIL TO LIGHT OFF, and NGG FAIL TO REACH 4500 RPM. These indicators illuminate when the related condition occurs.

The three manual start push buttons (G) are used to manually sequence the start/stop sequencer during a manual start. The push buttons are labeled STARTER ON, IGNITION ON, and FUEL ON. These push buttons are used when the sequencer mode selector switch (D) is in the MANUAL or OFF LINE mode. When the STARTER ON push button is depressed, it opens the starter shutoff/regulator valve. Depressing it again will close the valve, although it will automatically close at 4500 rpm ( $N_{GG}$ ). The IGNITION ON push button is a momentary push-button switch. When this push button is depressed, it energizes the igniters. It de-energizes them when it is released. The FUEL ON push button is also a momentary-type switch. Depressing it causes the fuel valves to open. During a start, these valves are latched open by the sequencer.

The ENGINE AT IDLE lamp (H) illuminates when  $N_{GG}$  is between 4900 and 5000 rpm.

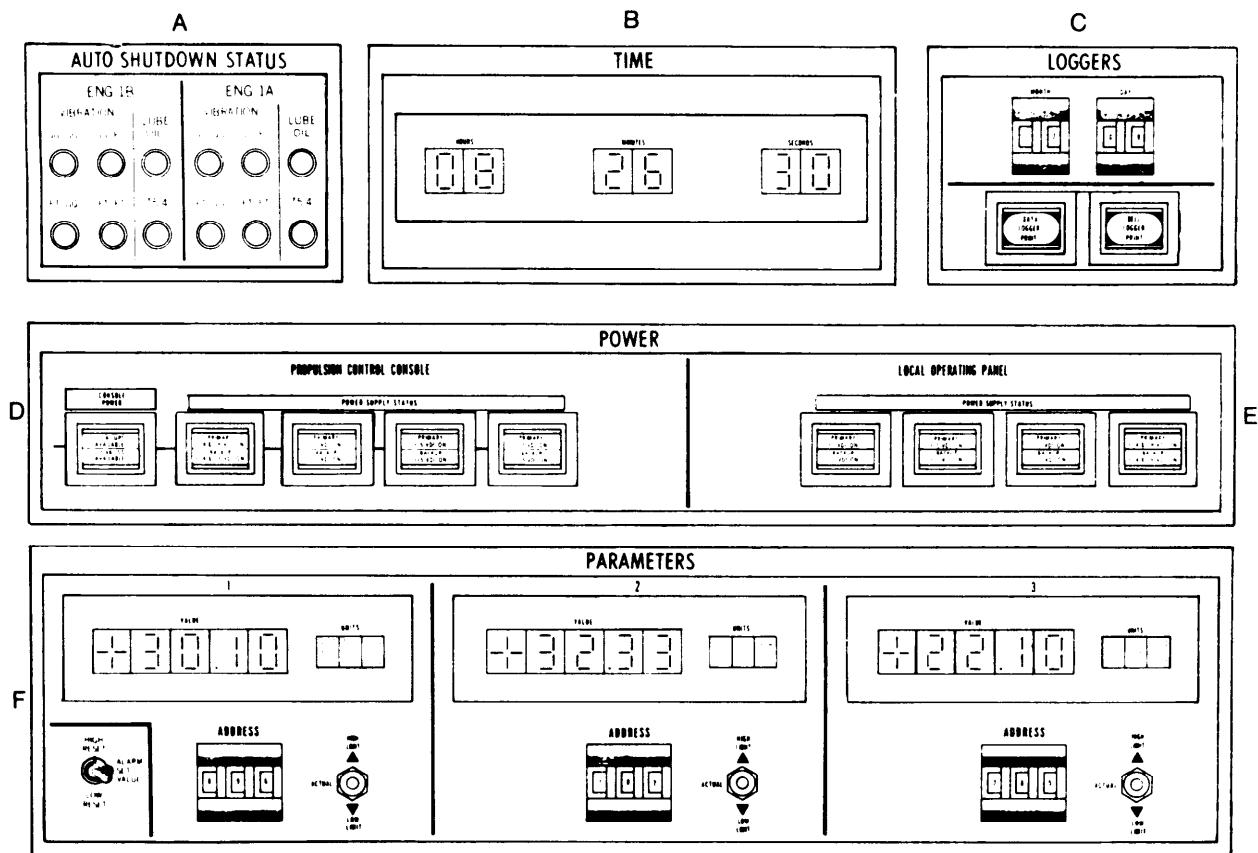


Figure 6-5.—Demands panel.

**ENGINE 1B WATER WASH SECTION.**—The engine water wash section (I) has one split-legends, latching-type, push-button switch and two indicators. The ON/OFF switch/indicator is enabled when (1) the water wash control is in REMOTE at the engine room controller, (2) the sequencer mode switch on the PCC is in the OFF LINE position, and (3) the engine control mode switch is in the PROGRAMMED position. When these conditions have been met, depressing the ON/OFF switch signals the processor to start the engine wash sequence. The indicator labeled FAILURE illuminates if any of the following conditions occur: (1) initially if the wash and the rinse tanks are not full, (2) if the wash cycle has started and the wash tank is not empty within 4 minutes, and (3) if the rinse tank is not empty within 10 minutes. The indicator labeled COMPLETE illuminates when the automatic engine wash cycle is finished.

**ENGINE 1B TORQUE CMPTR SECTION.**—The torque computer TEST push button/indicator (J) is used to perform a confidence check of the GTE torque computer. When this push button is

depressed, it “plugs in” a set of fixed values that replace the normal GTE parameters to calculate the GTE’s torque and horsepower. These calculated values are then compared to fixed reference values in the FSEE. If the result is correct, the TEST push button/indicator illuminates by a test passed signal from the FSEE. If it does not illuminate, the torque computer is not working correctly. This test should only be done when the GTE is secured or at idle. This is because the normal GTE parameters are being replaced with a fixed set of parameters and no overtorque protection exists during this time.

**LAMP TEST.**—The LAMP TEST push button (K) is used to check the condition of the lamps. When it is depressed, all the indicators and light emitting diodes (LEDs) on the top panel, except the HEATERS ON indicator, should illuminate.

#### Demands Panel

The demands panel (fig. 6-5) has five sections with information and controls for auto shutdown

status, time, logger commands, power supply status, and selected parameter values.

#### AUTO SHUTDOWN STATUS SECTION.—

The auto shutdown status indicators (A) are LEDs which illuminate red when an auto shutdown occurs, either on GTE 1A or 1B. An auto shutdown may occur because of vibration, low LO pressure, or high  $T_{5.4}$ . These indicators are extinguished by depressing and holding the AUTOMATIC SHUTDOWN push button on the GTE 1B/1A panel.

**TIME SECTION.**—The time section (B) has an LED digital display of the time in hours, minutes, and seconds generated by the PCC real-time clock.

**LOGGERS SECTION.**—The loggers section (C) has two sets of thumbwheels and two push-button switches. The thumbwheels are used to set the month and day into the processor for use on the automatic logger. These must be updated daily. The push buttons are momentary-contact types labeled DATA LOGGER PRINT and BELL LOGGER PRINT. When either push button is depressed, it will cause the data or bell logger to print.

**POWER SECTION.**—The power section is divided into two subsections, the PCC (D) and the LOP (E). These two subsections provide power supply status for the logic power supplies in the PCC and LOP. They also provide console 115-volt ac status for the PCC. These indicators are split-type and both halves are normally illuminated. If either half of an indicator is dark, perform a lamp test. If the lamp test is satisfactory, check the indicated power supplies for malfunctions.

**PARAMETERS SECTION.**—The parameters section (F) has three digital display subsections that the operator can use to monitor multiple, selected parameters. Each subsection contains a display, a thumbwheel, and a toggle switch. The thumbwheel is used to select an address, found on a DDI listing, that calls up the selected parameter. The parameter is displayed with the decimal in the proper position and with the units used to measure the parameter. The toggle switch is used to display either the high-alarm limit, the actual value, or the low-alarm limit. Another toggle switch, located on the lower left side of the parameters section, is used with either of the other

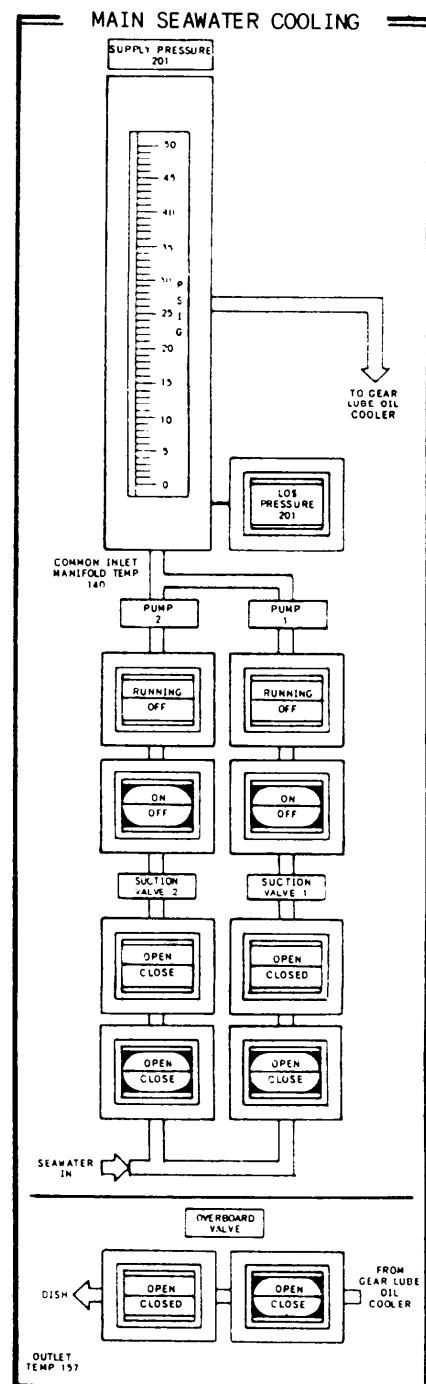


Figure 6-6.—Main seawater cooling panel.

three toggle switches. It allows the operator to verify the high/low reset value of the parameter displayed.

#### MAIN SEAWATER COOLING Panel

The MAIN SEAWATER COOLING panel (fig. 6-6) is located on the left side of the middle

panel of the PCC. It is used to control and monitor the operation of the engine-room main seawater system. This system is used to cool the reduction gear 10. This panel has a meter to monitor seawater pressure, a low pressure alarm indicator to the bottom right of the meter, five momentary-contact push-button indicators and five split-legend indicators.

The supply pressure meter and the LOW PRESSURE alarm are used to monitor main seawater cooling pressure. Normal pressure is 30 to 35 psig. The alarm will sound at 7 psig after a 10-second delay.

This panel allows opening and closing control of the two pump suction valves and one overboard discharge valve, and start/stop control of the two seawater pumps. The three valves controlled from

the PCC are the pump 1A suction valve, the pump 1B suction valve, and the overboard discharge valve. (NOTE: The panel is labeled for pump and suction valves 1 and 2. Pump 1 controls 1A pump and suction valve 1 controls 1A suction valve. Pump 2 controls 1B pump and suction valve 2 controls 1B suction valve.) Each valve has an OPEN/CLOSE push button to operate the valve and an OPEN/CLOSED indicator to show the actual valve status. Also, each pump has an ON/OFF push button to start and stop the pump as well as a RUNNING/OFF indicator to show the status of the pump.

### Engine Panel

The PCC engine panel (fig. 6-7) has many of the same controls and indicators found on the

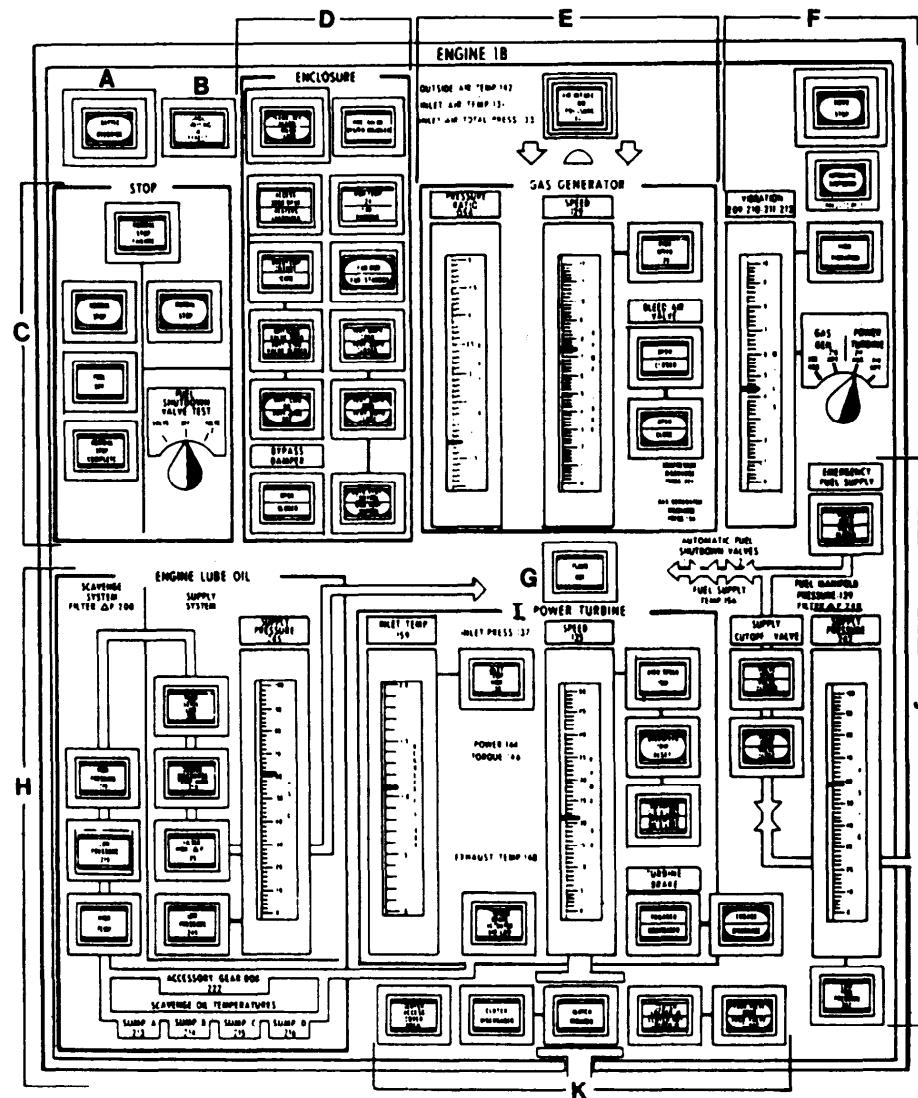


Figure 6-7.—Engine 1B panel.

LOP. It contains the controls, indicators, and meters needed to operate the GTE. The GTE 1A and GTE 1B panels are mirror images of each other. We will describe the independent push buttons, indicators, and sections of the GTE 1B panel in our discussion; keep in mind that the 1A panel has identical features.

**BATTLE OVERRIDE.**—BATTLE OVERRIDE (A) is a guarded, illuminated, push button. You can use it at the PCC only if the PCC is the station in control. This switch will illuminate when activated and overrides the following shutdowns:

1. Low GTE LO pressure
2. High GTE vibration
3. High  $T_{5.4}$
4. PLA failure for
  - a. PCS command signal out of limits,
  - b. PT shaft torque out of limits, and
  - c. PT speed out of limits.

BATTLE OVERRIDE will not override a flame-out or a PT overspeed trip.

**TORQUE LIMITING IN EFFECT.**—The TORQUE LIMITING IN EFFECT indicator (B) illuminates any time the torque limiting circuit is restricting the movement of the PLA. This is done until the torque on the GTE is within safe limits. Then the torque limiting circuit will allow the PLA to advance to the command position, provided the PLA doesn't send the GTE into an over-torque condition. If it does, then the torque limiting circuit will take over as before. This will continue until the command is obtained, or the command is reduced to a lower setting.

**STOP SECTION.**—The STOP SECTION (C) is located above the LO section on the engine panel. The controls on the stop section are used to perform normal and manual stops. This section has three indicators, two push buttons, and a switch used for GTE stopping.

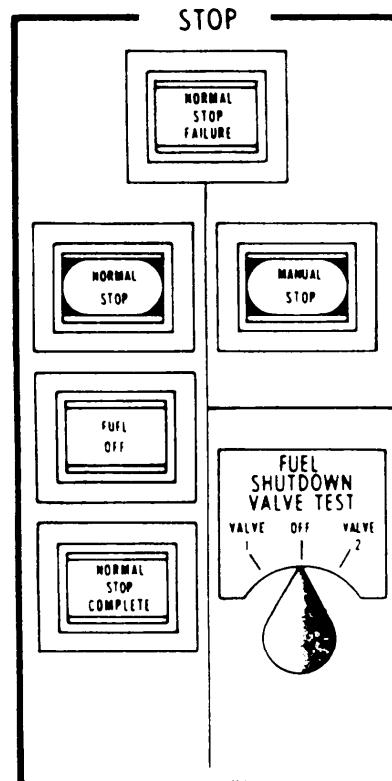
The first indicator is labeled NORMAL STOP FAILURE. This indicator illuminates if 90 seconds after the completion of the 5-minute cooldown timer,  $T_{5.4}$  is above 400°F or fuel manifold pressure is above 50 psig. The first control is a push button labeled NORMAL STOP. It is used to initiate a stop using the start/stop sequencer in the FSEE. This sequence, upon initiation, allows the GTE to run at idle for 5 minutes. After 5 minutes, it de-energizes the fuel shutdown valves, causing the GTE to shut down.

This sequence may only be initiated if the GTE is at idle. By advancing the throttle above idle, you can interrupt the normal shutdown any time before the fuel valve closure.

The indicator labeled FUEL OFF is illuminated any time fuel manifold pressure is below 50 psig. The indicator labeled NORMAL STOP COMPLETE, when illuminated, indicates  $T_{5.4}$  is below 400°F and fuel manifold pressure is less than 50 psig within 90 seconds after the completion of the 5-minute cooldown timer.

The other push button in this section is labeled MANUAL STOP. When it is depressed, the fuel shutdown valves are de-energized, causing the GTE to stop. This stop should only be done after the GTE has been allowed to cool down for 5 minutes to prevent GTE damage.

The three-position switch located below the MANUAL STOP push button is labeled FUEL SHUTDOWN VALVE TEST. This switch is spring-loaded to the OFF position. Moving the switch to either the valve 1 or valve 2 position will shut the corresponding fuel shutdown valve and should stop the GTE if the valve is operating properly. This switch is used during PMS to test the integrity of each of the fuel shutdown valves.



**ENCLOSURE SECTION.**—In the following paragraphs we will describe the switch/indicators of the ENCLOSURE section (D).

The first switch/indicator is located at the top left side of the enclosure section. It is a split-legends indicator. The upper half is FLAME DET ALARM and illuminates when the UV sensor has sensed a flame in the enclosure. The lower half, HALON FLOOD, is a momentary-contact switch. Depressing this switch releases the primary bank of Halon if the manual inhibit switch is in the ACTIVE position at the enclosure. (**NOTE:** No automatic release of Halon is available into the enclosure.)

The next indicator in this column is the ACCESS DOOR OPEN/HEATERS ENERGIZED indicator. The upper half of this indicator is fed from switches at the two GTM doors and indicates that a module door is open. The lower half of this indicator indicates the module heater is energized. The enclosure heater keeps the enclosure air temperature above 60°F. This temperature is required to prevent fuel waxing (fuel hardening) in the GTE fuel system. Control of the heater is provided on the LOP. Indication of the heater status is provided on both the PCC and the LOP.

The OVERTEMP CUTOUT indicator will illuminate when the heater is de-energized because the enclosure temperature was 145°F and the heater was on. The ICING detector indicator measures the temperature and humidity of the incoming combustion air. When icing conditions occur (temperature below 41°F and humidity above 70 percent), this indicator will illuminate and an alarm will sound at the PCC.

The ANTI-ICING VALVE OPEN/ANTI-ICING VALVE CLOSED indicator shows the actual position of the anti-icing valve. Below this indicator is the ANTI-ICING ON/ANTI-ICING OFF momentary-contact switch/indicator. It is used to open and close the anti-icing valve and to indicate the operator's command to the valve.

The last indicator in this column has a legend above it labeled BYPASS DAMPER. Switches at the bypass damper provide signals to the PCC to illuminate the OPEN/CLOSED status indicator of the bypass damper.

The FIRE HALON SYSTEM DISABLED indicator, located at the top of the next column,

is next to the FLAME DET ALARM indicator. It illuminates when a loss of continuity in the fire or the Halon system occurs. This is caused by loss of continuity between the flame detector and signal conditioner or loss of 115-volt ac power to the detection system. Power is supplied by the 115-volt ac CB in the FSEE.

The next indicator down is a split-legends indicator. The upper half, labeled HIGH TEMP, is the indicator fed from the two temperature switches (set at 400°F) in the enclosure. The lower half, labeled FAN RUNNING, illuminates when the enclosure fan is running.

The next indicator down is a momentary-contact switch/indicator labeled FAN RUN/FAN STANDBY. It selects the mode of operation for the ventilation fan. In the FAN RUN position, the fan will be running. In the FAN STANDBY position, the fan automatically starts when the GTE is running below 3000 hp or the GTE is not running and the enclosure temperature is above 125°F. The fan automatically shuts down under the following conditions:

- Halon is discharged into the enclosure.
- The GTE is running above 3000 hp.
- The GTE is not running and the enclosure temperature is below 125°F.
- The vent damper closes.

To start a GTE, the fan controller must be in the remote position and the control switch on the PCC should be in the FAN STANDBY position.

The last three indicators down are for the vent damper. The VENT DMPR OPEN/VENT DMPR CLOSED indicator shows the position of the vent damper. The VENT DMPR OPEN/VENT DMPR CLOSE switch/indicator is for manual control. It is only functional when the AUTO VENT CONTROL/MAN VENT CONTROL switch/indicator is in the MAN VENT CONTROL position. The AUTO VENT CONTROL/MAN VENT CONTROL switch/indicator is used to select the mode of operation for the ventilation damper, either automatic or manual. In automatic mode, the ventilation damper will open under the following conditions:

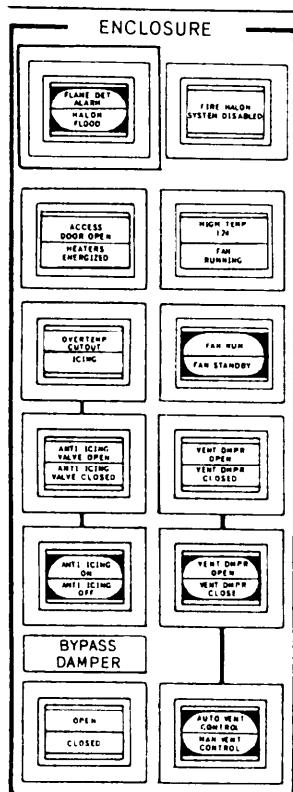
- The ventilation fan is running.
- The GTE is running.

- The GTE is not running and the outside air temperature is above 70°F.

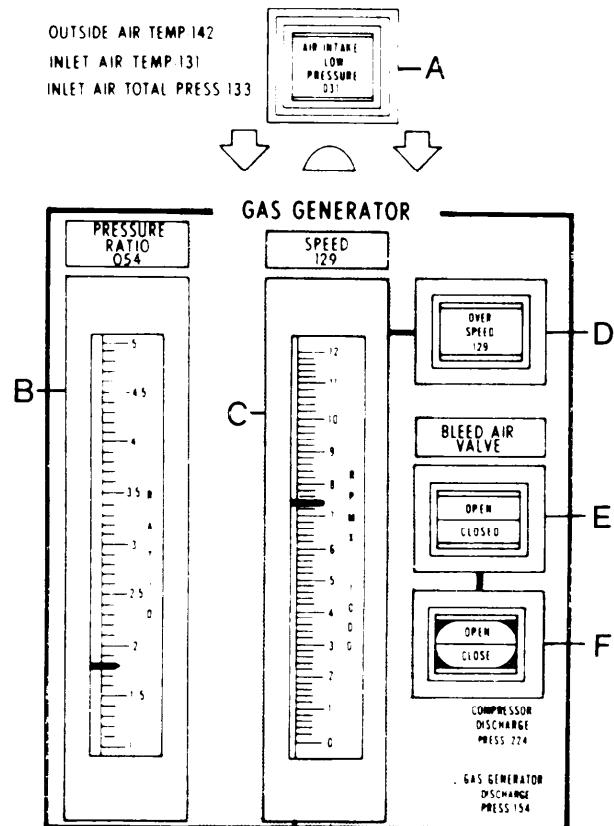
The damper will close automatically under the following conditions:

- Halon is discharged into the enclosure.
- The GTE is not running and the outside air temperature is below 70°F.

In the manual mode, damper control circuits automatically close the damper if Halon is discharged into the enclosure.



indicator are the controls and indicators for the BLEED AIR VALVE. The OPEN/CLOSED indicator illuminates to indicate the actual position of the valve. The OPEN/CLOSE push-button control is used to open and close the valve and will illuminate to indicate the operator's command.



**EMERGENCY STOP AND VIBRATION SECTION.**—This section (F) has two switch/indicators and a vibration subsection with a meter, a switch, and an indicator.

The EMER STOP switch/indicator can be initiated by the operator at any time and in any control mode. Depressing the EMER STOP switch/indicator on the PCC will cause the indicator to illuminate and the circuitry in the LOP and the FSEE to immediately de-energize the PT overspeed trip switch. This causes both automatic fuel shutdown valves to close, which causes the GTE to shut down.

The AUTOMATIC SHUTDOWN switch/indicator illuminates to indicate an automatic shutdown has occurred. This switch resets the automatic shutdown electronics. The PCS initiates automatic shutdown for the following parameters

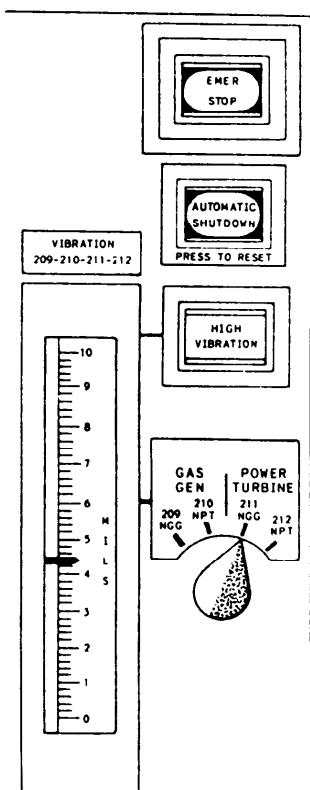
**GAS GENERATOR SECTION.**—This section (E) has two meters and four indicators for the GG of the GTE. The AIR INTAKE LOW PRESSURE alarm is used to indicate when the differential pressure exceeds 7.5 in. $H_2O$ . This is measured between the ambient air and the combustion air intake, downstream from the moisture separator. The PRESSURE RATIO meter continually monitors the condition of the GG. The input of this meter comes from computations between the  $P_{t2}$  and  $P_{t15.4}$ .

The GG SPEED meter displays the speed of the GG. Associated with this meter is the OVERSPEED alarm, which has a set point of  $9700 \pm 100$  rpm. Below the OVERSPEED

after a GTE is running and provides indication of each shutdown on the PCC.

- $T_{5.4}$  above 1530°F.
- GTE oil pressure below 6 psig.
- High GT vibration (GG above 7 mils or PT above 10 mils).
- Flameout ( $T_{5.4}$  less than 400°F after PT fuel manifold pressure becomes greater than 50 psig and after an GTE run signal is obtained).

The meter in the VIBRATION subsection is always reading the vibration on the GTE at the position selected by the switch. The switch is a four-position switch. It allows you to look at the two different vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibration. A tracking filter for each pickup separates GG vibration from PT vibration depending on vibration frequency. Limits apply to frequency and not pickup location. The HIGH VIBRATION indicator will illuminate when the vibration on the GG reaches 6 mils or the PT reaches 7 mils. An automatic shutdown occurs when GG vibration reaches 7 mils or PT vibration reaches 10 mils.



**FLAMEOUT.**—The FLAMEOUT indicator (G) will illuminate when  $T_{5.4}$  drops below 400°F after the fuel manifold pressure becomes greater than 50 psig and after a GTE run signal is obtained. When this happens, an automatic shutdown will occur.

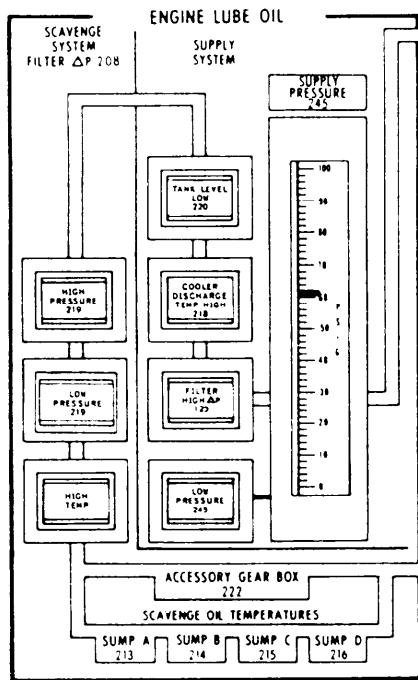
**ENGINE LUBE OIL SECTION.**—The ENGINE LUBE OIL section (H) monitors the operation of the engine's LO supply and scavenge systems. The engine LO section of the panel is only for monitoring purposes and has no control functions. It has a meter and seven indicators used to detect abnormal conditions of the engine LO system.

The left column of three indicators monitors the GTE scavenge oil. Starting at the top of the left column, the first indicator is labeled HIGH PRESSURE. It will illuminate and an alarm will sound when scavenge pressure is above 130 psig. The second indicator is labeled LOW PRESSURE and will illuminate and an alarm will sound when scavenge pressure drops below 5 psig. The third indicator is labeled HIGH TEMP and will illuminate and an alarm will sound when any of the five scavenge temperature RTDs detect a temperature above 300°F. When this alarm sounds, the operator should use one of the DDIs listed at the bottom of the column (ACCESSORY GEAR BOX, SUMP A, SUMP B, SUMP C, or SUMP D) to identify which scavenge temperature is high.

The right column has four indicators and monitors the GTE lube oil supply. The first indicator at the top of the column is labeled TANK LEVEL LOW and is used to monitor the level of the LOSCA lube oil tank. The indicator illuminates and an alarm sounds when the tank level falls to 9.6 gallons. The second indicator is labeled COOLER DISCHARGE TEMP HIGH. It monitors the outlet temp of the oil leaving the LOSCA cooler. It illuminates and an alarm sounds if the temperature of the oil exceeds 250°F. The third indicator is labeled FILTER HIGH AP. This indicator illuminates and an alarm sounds when the differential pressure across the LO supply filter exceeds 20 psid.

The SUPPLY PRESSURE meter displays the supply pressure of the LO. Associated with the meter is the LOW PRESSURE alarm indicator. This indicator illuminates and an alarm sounds when the engine LO pressure drops to 15 psig.

(Remember, an auto shutdown will occur if LO pressure drops to 6 psig.)



**POWER TURBINE SECTION.**—The PT section (I) monitors the operation of the PT. It has two meters, two push buttons, and five indicators.

The first meter is the INLET TEMP ( $T_{5.4}$ ) meter. It displays the temperature of the gas entering the PT. Associated with this meter is the INLET TEMP HIGH alarm indicator for high  $T_{5.4}$ . It has an alarm set point of 1500°F. An automatic shutdown will occur if  $T_{5.4}$  reaches 1530°F and battle override is not on.

The second meter, the PT SPEED meter, shows the speed of the PT. The meter is fed from two sensors mounted on the rear frame of the turbines that sense PT speed.

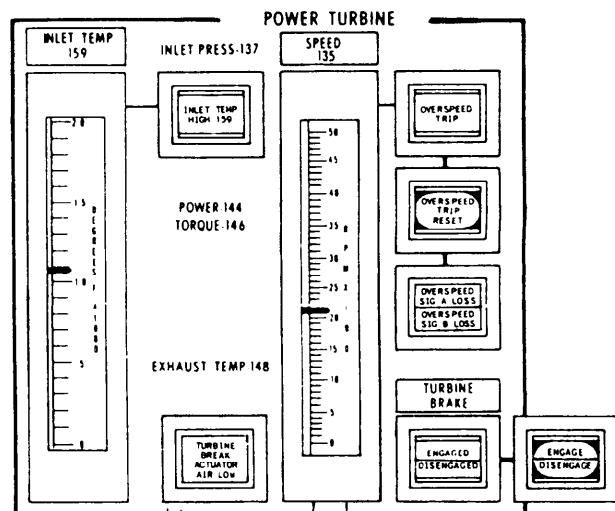
To the right of this meter is an OVERSPEED TRIP indicator. It illuminates if either of the sensors senses a PT speed greater than  $3960 \pm 40$  rpm. This causes the GTE to shut down because the fuel shutdown valves are de-energized.

Directly below the OVERSPEED TRIP indicator is the OVERSPEED TRIP RESET push button. It is used to reset the overspeed trip and to latch the fuel valves during manual starts.

Below the OVERSPEED TRIP RESET push button is a split-legends indicator. It is labeled OVERSPEED SIG A LOSS/OVERSPEED SIG B LOSS. These indicators will illuminate when the PT speed drops below 100 rpm or a malfunction

in either speed circuit occurs. When the PT speed becomes less than the loss-of-signal setting on both speed signal input channels or greater than the overspeed setting on either speed signal input channel, the fuel shutdown valves de-energize (the GTE will shut down). If the PT speed loss signal occurs on only one channel, the GTE will continue to run.

The bottom part of this section has a legend above it labeled TURBINE BRAKE and is used to control and monitor the operation of the turbine brake. The TURBINE BRAKE ACTUATOR AIR LOW indicator, located at the bottom between the meters, will display when the air pressure to the brake actuator is too low. It illuminates when brake air pressure is less than 70 psig. The turbine brake indicator is a split-legends indicator that displays the actual status of the brake, either ENGAGED or DISENGAGED. The momentary-contact push button/indicator next to it is used to control the brake. This push button will illuminate to show the operator command to the brake. Depressing it will either ENGAGE or DISENGAGE the brake assembly. The turbine brake will not engage unless the PT speed is below 250 rpm.



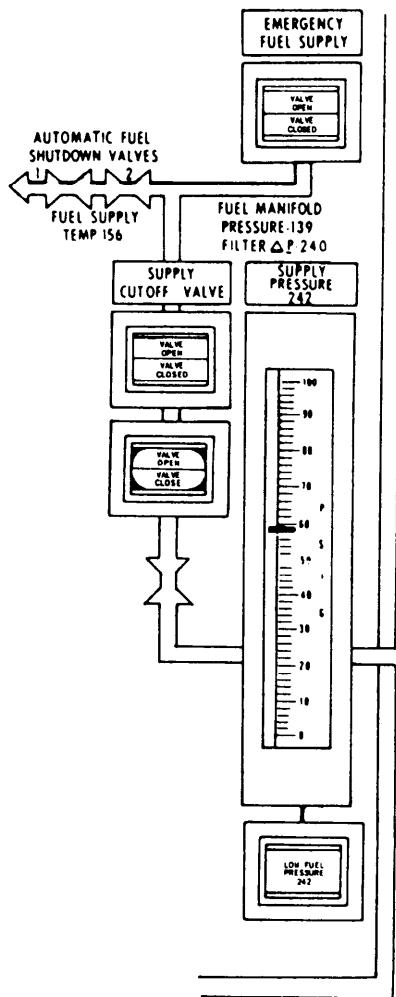
**ENGINE FUEL SUPPLY SECTION.**—The ENGINE FUEL SUPPLY section (J) has the control and monitor components used to operate the fuel supply to the GTE.

Starting at the top, which is labeled EMERGENCY FUEL SUPPLY, is a split-legends indicator labeled VALVE OPEN/VALVE CLOSED. It monitors the actual valve status of the emergency JP-5 supply valve. This valve's normal position is closed. It is held closed

electrically. Upon loss of power the emergency JP-5 valve will open. This allows the GTEs to run on JP-5 from a 350-gallon head tank.

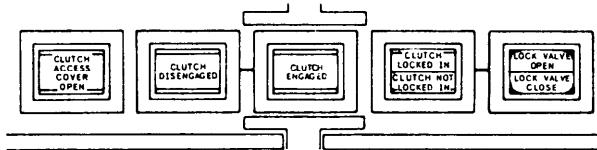
Under the emergency fuel supply indicator is a meter labeled SUPPLY PRESSURE. It displays the pressure of the fuel from the fuel service system to the GTE. Under this meter and associated with it is the LOW FUEL PRESSURE alarm indicator. It illuminates and sounds an alarm at 8 psig. Fuel supply pressure is sensed after the fuel supply cutoff valve.

The PCC has an indicator and control for the FUEL SUPPLY CUTOFF VALVE. The split-legends indicator is labeled VALVE OPEN/VALVE CLOSED. It illuminates to indicate the actual position of the valve, either open or closed. The split-legends, push-button control is labeled VALVE OPEN/VALVE CLOSE. It illuminates to indicate the operator's command, either open or closed.



**CLUTCH SECTION.**—The clutches on the FFG-class ship are synchronized self-shifting. The only operator action required to engage and disengage them is the removal of the brake and operation of the throttle.

The CLUTCH section (K) of the panel has four indicators and one push button. The first indicator is labeled CLUTCH ACCESS COVER OPEN. This indicator illuminates if the access door to the clutch is open. The next two indicators display the clutch status and are labeled CLUTCH DISENGAGED and CLUTCH ENGAGED. The fourth indicator is a split-legends indicator labeled CLUTCH LOCKED IN/CLUTCH NOT LOCKED IN. This indicator displays the status of the lock-in/lock-out mechanism of the clutch. Locking out the clutch provides for operation of the GTE without turning the MRG. For normal operation the clutch must be locked in. The last indicator is a split-legends, push-button control labeled LOCK VALVE OPEN/LOCK VALVE CLOSE. This indicator was a design feature originally installed, but never used. It performs no function.



### Fuel Oil Service System Panel

Located between the two engine panels is the fuel oil service system panel (fig. 6-8). The panel is divided into two identical sections labeled FUEL SYSTEM 2 and 1. Each section has controls and indicators used to operate the fuel system on either No. 1 or No. 2 tank, pump, heater, prefilter, or filter/sePARATOR. The system can be cross-connected to allow one tank and pump combination to supply either or both GTEs.

An operator can monitor the FO service tank by using the split-legends alarm indicator (A) at the top of the panel labeled HIGH/LOW. It alerts the operator when a tank is either full or needs refilling. The meter (B) labeled TANK LEVEL (1 or 2) indicates the actual level (in gallons) of the tank. The FO tank suction and return valve's split-legends indicator (C) labeled OPEN/CLOSED

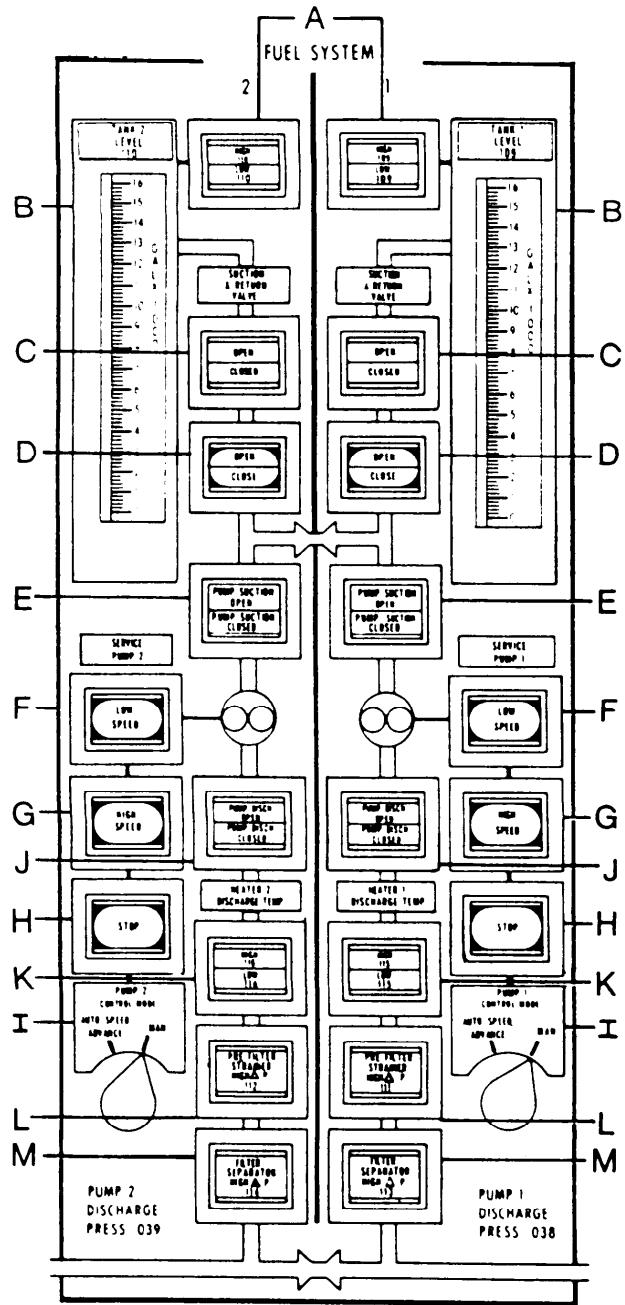


Figure 6-8.—Fuel oil service system panel.

shows the actual status of both valves. Both valves must be in the same position for this indicator to illuminate. These valves determine the tank that is supplying fuel to the fuel pump and where the excess fuel is returned. The valves are operated by the split-legends, push-button indicator (D) labeled OPEN/CLOSE. It will illuminate to show the operator's command to the valves.

The next split-legends indicator (E) labeled PUMP SUCTION OPEN/PUMP SUCTION CLOSED is for the pump suction valves (one per pump). It illuminates to indicate the actual position of the valve. These valves are electrically interlocked with the pump start/stop push buttons to ensure the valves are open before the pump starts.

Three push buttons and a control mode switch control the two service pumps. The three push buttons are labeled LOW SPEED (F), HIGH SPEED (G), and STOP (H). They will illuminate to indicate the actual status of the pump. The pump (1 or 2) CONTROL MODE switch (I) is used to set the pumps in the MAN (manual) mode or the AUTO SPEED ADVANCE mode. Each pump is a two-speed pump. In the manual mode the operator selects the speed of the pump (low or high) by depressing the proper push button. In the automatic mode, a drop in fuel pressure will shift the pump from low to high. If low speed is again desired, the operator must shift the speed back to low. The pump discharge valve indicator (J) is labeled PUMP DISCH OPEN/PUMP DISCH CLOSED. The valve is equipped with a limit switch to send a signal to the PCC which will illuminate the indicator to show the actual position of the valve. This valve is operated manually at the valve.

The HEATER DISCHARGE TEMP HIGH/LOW alarm (K) is a split-legends indicator alarm for high or low temperature. If the temperature of the fuel leaving the heater exceeds 110°F, the high indicator illuminates and an alarm sounds. Likewise, if the temperature drops below 60°F, the low indicator illuminates and an alarm sounds.

A fuel prefilter is used in the system to remove large particulate matter. If its  $\Delta P$  exceeds 10 psid, the PREFILTER STRAINER HIGH  $\Delta P$  indicator (L) illuminates and an alarm sounds. A second filter, called the FILTER/SEPARATOR, is used to separate smaller particles and water. If this becomes clogged and the DP is 12 psid or higher, the FILTER/SEPARATOR HIGH  $\Delta P$  indicator (M) illuminates and an alarm sounds.

### Gear Lube Oil Panel

The gear LO panel (fig. 6-9) is used to control and monitor the flow of LO to the MRG.

The first indicator (A) is labeled SUPPLY HIGH TEMP and illuminates if the MRG LO temperature exceeds 130°F. If the MRG hydraulically most remote bearing pressure drops to 9 psig, the indicator (B) labeled REMOTE

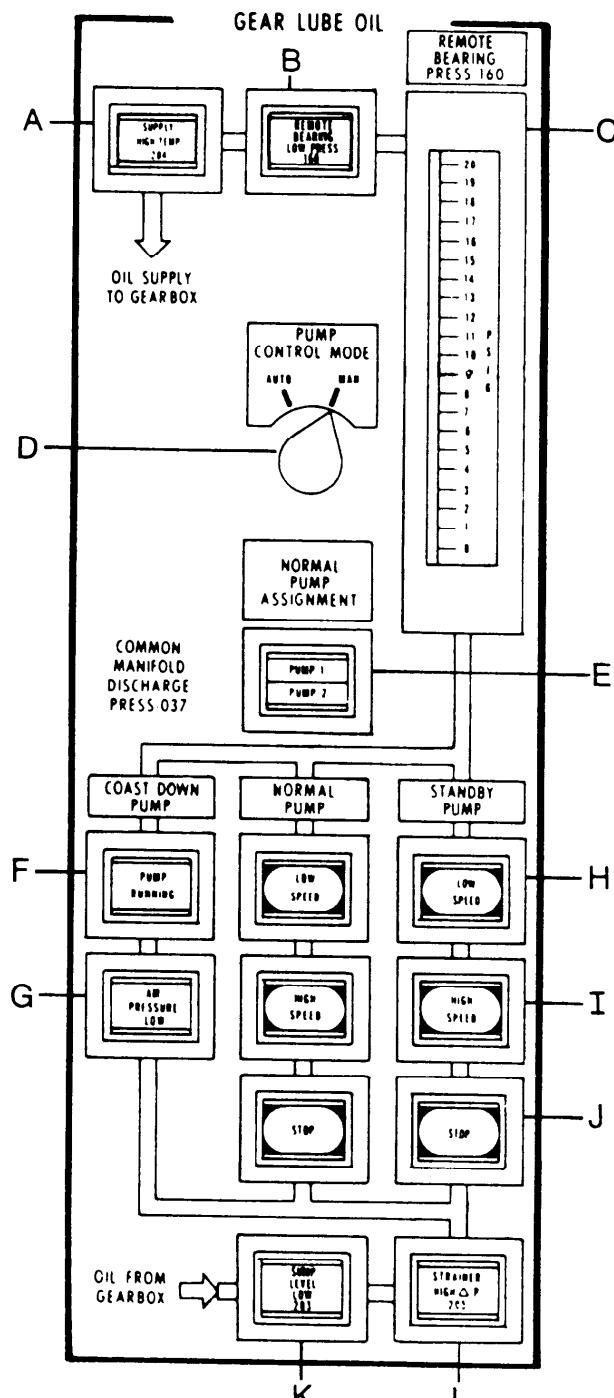


Figure 6-9.—Gear lube oil panel.

BEARING LOW PRESS illuminates and an alarm sounds. The operator can monitor the LO pressure at the PCC by using the hydraulically most remote bearing pressure on the meter (C) labeled REMOTE BEARING PRESS.

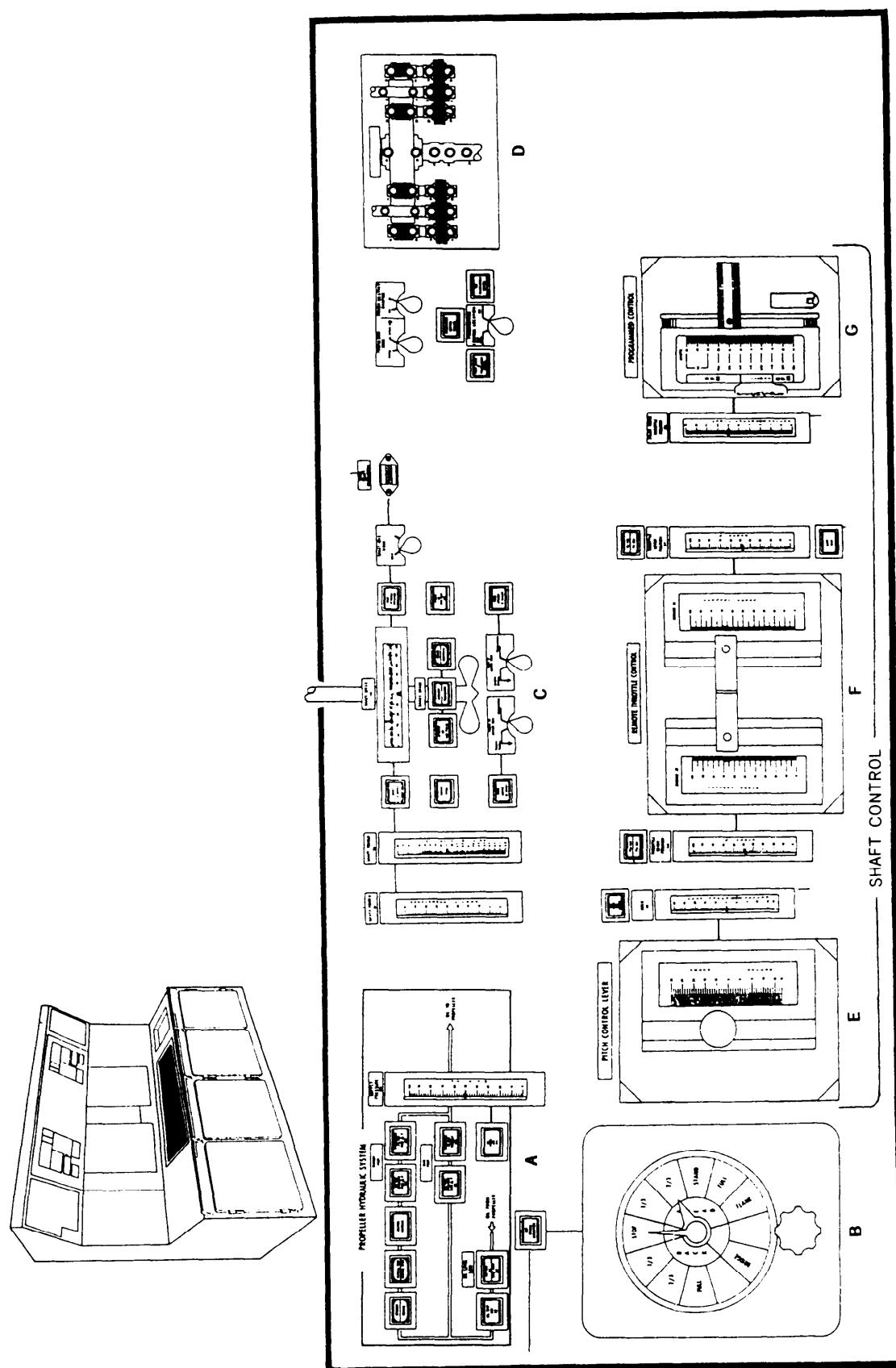
Control is available from the PCC for the two motor-driven, two-speed pumps. The rotary

two-position switch (D) labeled PUMP CONTROL MODE is used to select either the AUTO or MAN (manual) control mode. The next split-leg legend indicator (E) labeled PUMP 1 and PUMP 2 illuminates to indicate which pump is assigned the NORMAL position. Normal and standby pump assignment is done by a switch on the LO pump controller in the engine room.

If the LO pressure drops to 9 psig, or if both electric pumps lose power, a third air-driven pump provides oil to the MRG. This pump is called a COAST DOWN PUMP. It has an indicator (F) labeled PUMP RUNNING on the PCC to show when it is running. The coastdown pump will only run if the shaft is turning. Also, it will stop if the LO pressure exceeds 15 psig. The next indicator down (G) is labeled AIR PRESSURE LOW. It illuminates and sounds an alarm to alert the operator when the air supply to the coastdown pump is low. It activates at 2700 psig.

The speed control push buttons are used for manual speed control of the electric LO pumps. They are labeled LOW SPEED (H), HIGH SPEED (I), and STOP (J). They will illuminate to indicate the status of the pump(s). The operator may use these push buttons in the manual mode to STOP, run in HIGH SPEED, or run in LOW SPEED the normal or standby LO pumps. First, the NORMAL PUMP is selected (its selection is shown by the NORMAL PUMP ASSIGNMENT PUMP 1/PUMP 2 indicator (E)). Then, the operator manually starts the selected pump to start the LO system. After the LO system is started, the operator may put the system in automatic by placing the PUMP CONTROL MODE switch (D) to AUTO. In the AUTO mode, the pumps cycle up in speed in response to pressure decreases. If the pressure drops to 15 psig, the NORMAL PUMP shifts from LOW SPEED to HIGH SPEED. A drop in pressure to 13 psig causes the STANDBY PUMP to start in LOW SPEED. A further decrease in pressure to 11 psig causes the standby pump to go to HIGH SPEED. When system pressure returns, the pumps must be manually cycled to lower speeds or off.

The next indicator (K) labeled SUMP LEVEL LOW, alerts the operator when the level of the MRG oil sump drops below 870 gallons. The indicator (L) next to SUMP LEVEL LOW is the STRAINER HIGH AP. If the differential pressure across the LO strainer exceeds 12 psid, this indicator illuminates and an alarm sounds.



**Figure 6-10.—Propulsion control panel.**

## Propulsion Control Panel

The propulsion control panel (fig. 6-10) is the bottom panel of the PCC. This panel has the controls and indicators for the propeller hydraulic system, shaft speed and propeller pitch, MRG monitoring, and control transfer.

**PROPELLER HYDRAULIC SYSTEM SECTION.**—This section (A) has a meter, eight indicators, and two control push buttons. They are used to operate the hydraulic system of the controllable pitch propeller.

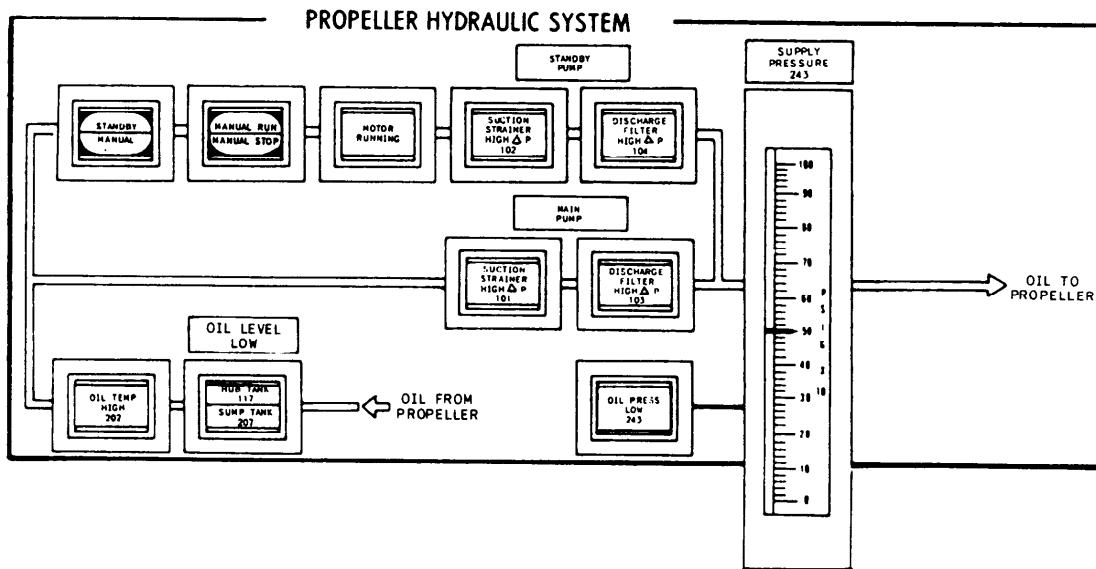
Normally, the hydraulic pressure is supplied to the system by the pump that is driven by the reduction gear (main pump). When this pump cannot provide the proper pressure, it must be augmented by the standby motor-driven pump. Two control push buttons are used to operate the motor-driven pump. The split-legends, push-button indicator labeled STANDBY/MANUAL is used to select the mode of operation. If the standby mode is selected and illuminated, when the shaft speed drops to about 105 srpm, the motor-driven pump starts. When the push button is placed in the manual mode, the motor-driven pump must be started by the operator. To start the pump, the operator uses the split-legends, push-button indicator labeled MANUAL RUN/MANUAL STOP. When the motor-driven pump is running, the indicator labeled MOTOR RUNNING illuminates. Both pumps have suction strainers in the pump suction lines and discharge filters in the pump discharge lines. These filters are monitored by indicators labeled SUCTION

STRAINER HIGH DP and DISCHARGE FILTER HIGH DP. They will illuminate and activate an alarm when either the suction strainer or discharge filter are in an alarm condition.

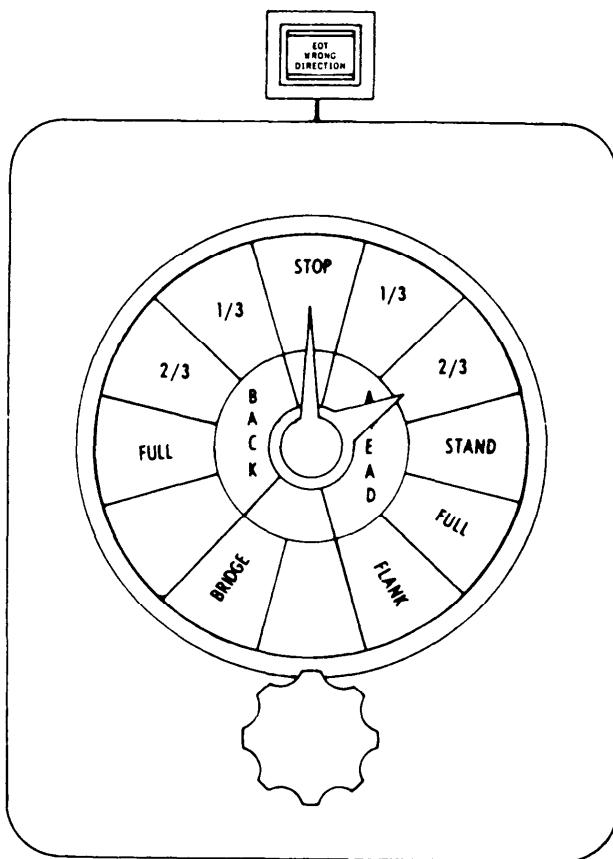
The SUPPLY PRESSURE meter monitors the CPP hydraulic supply pressure. Associated with this meter is the indicator labeled OIL PRESS LOW. If supply oil pressure drops to 40 psig, this indicator illuminates and sounds an alarm.

The next indicator is labeled OIL TEMP HIGH. It illuminates and sounds an alarm to alert the operator that the oil temperature in the system has exceeded 160°F. Under the label OIL LEVEL LOW is the next split-legends indicator labeled HUB TANK/SUMP TANK. This indicator monitors the oil level of the sump and head tanks. If the level in the head tank falls to 35 gallons, the HUB TANK indicator illuminates and sounds an alarm. If the sump tank level drops below 425 gallons, the SUMP TANK indicator illuminates and sounds an alarm.

**ENGINE ORDER TELEGRAPH (EOT) SECTION.**—Located below the propeller hydraulic section, is the EOT section (B). This is used to relay engine orders from the bridge to the PCC. When the bridge orders a change of speed, one of the pointers in the EOT will point to the requested speed. The PCC operator, to acknowledge the order, moves the other pointer to match the bridge pointer. This is done using the knob below the EOT. If the pitch of the propeller and the EOT indicate opposite



directions (ahead and astern), the EOT WRONG DIRECTION indicator at the top of the EOT illuminates and sounds an alarm.



**SHAFT PERFORMANCE MONITORING SECTION.**—Located to the right of the propeller hydraulic system panel are the indicators used to monitor the propeller shaft performance. This section (C) has three meters used to monitor shaft horsepower, torque, and speed; shafting indicators; shaft brake controls; and indicators and engine mode select controls.

The SHAFT POWER edgewise meter displays shaft power. It displays in horsepower and receives its input from the processor. The next edgewise meter is used to display SHAFT TORQUE. This parameter is also sent from the processor and is displayed in ft-lb. The third meter is a horizontal edgewise meter that shows SHAFT SPEED. Associated with the shaft speed meter and to the left of it is the SHAFT STOPPED indicator. It illuminates when the shaft is rotating less than 1/5 rpm. To the right side of the shaft speed meter is the SHAFT REVERSE ROTATION indicator. It illuminates when the propeller shaft is rotating in the reverse (counter-clockwise) direction. Next to this indicator is the

SHAFT IDLE MODE switch. This switch is not functional in this system and has only one position (NORM). To the right of the switch is the TOTAL SHAFT REVOLUTIONS counter. This counter shows total shaft revolutions of the propeller.

The ASTERN PITCH indicator illuminates when the pitch of the propeller is in the astern direction.

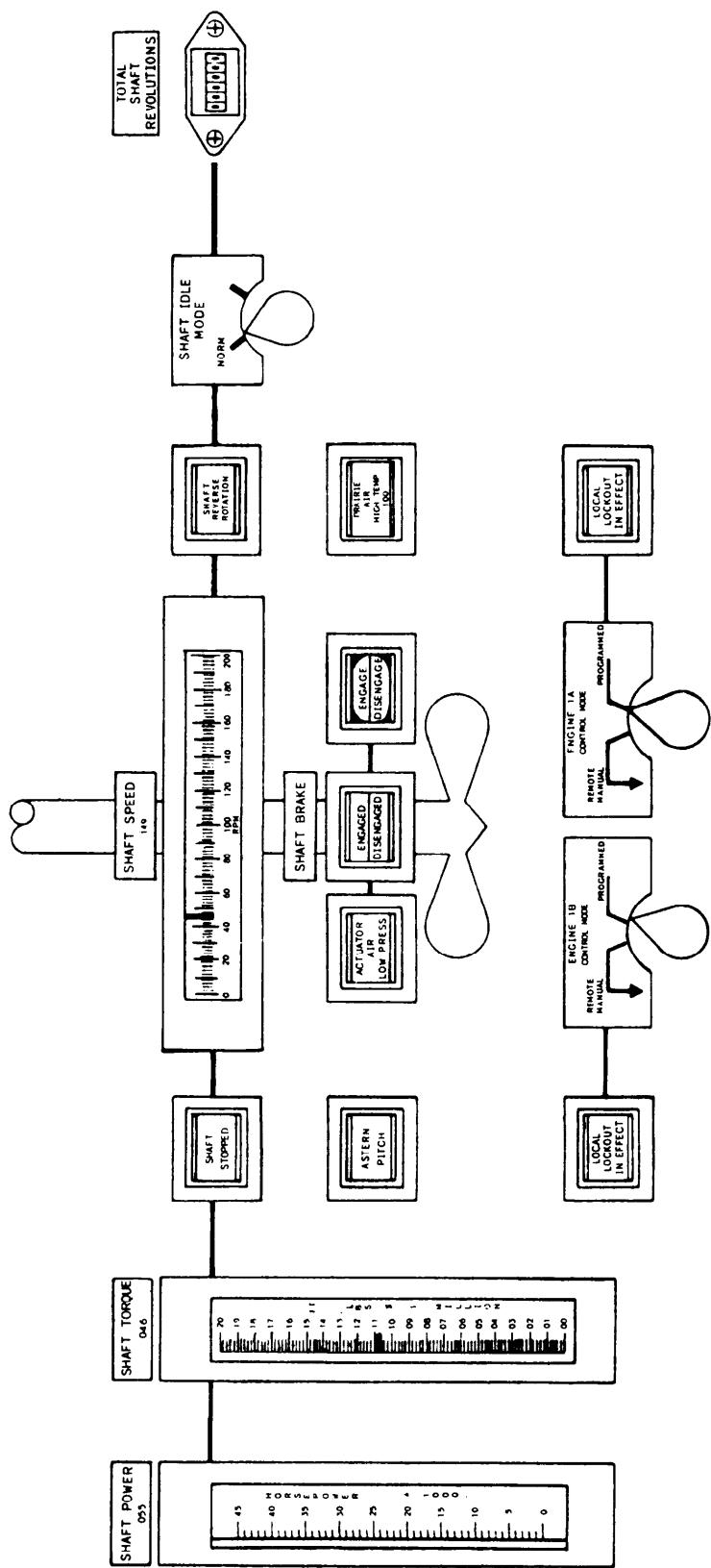
The shaft brake subsection is located below the SHAFT SPEED meter. One control push button and two indicators are used to display conditions of the shaft brake. The shaft brake ACTUATOR AIR LOW PRESS alarm indicator alerts the operator if the air pressure used to operate the shaft brake drops below 1150 psig. The split-legends indicator labeled ENGAGED/DISENGAGED is for the shaft brake and illuminates to show the actual status of the shaft brake. The split-legends, push-button indicator labeled ENGAGE/DISENGAGE is used to apply and release the shaft brake. It will illuminate to indicate the operator command to the brake. It may only be applied if the following conditions are met:

- Shaft speed is less than 75 rpm.
- Throttles are at idle.
- Pitch is at zero.
- Only the station in control of the GTE(s) may apply the shaft brake electrically.

When these permissives are met, the control push button activates the shaft brake. If one of these permissives is lost, the shaft brake will release.

The next indicator is labeled PRAIRIE AIR HIGH TEMP. It will illuminate and sound an alarm when prairie air temperature exceeds 135°F.

Below the shaft brake subsection are two indicators, one per GTE, labeled LOCAL LOCK-OUT IN EFFECT. The indicator on the left is for the 1B GTE and the indicator on the right is for the 1A GTE. When either of these indicators are illuminated, it means control of that GTE is at the LOP. In this subsection are two GTE control mode rotary switches, one per GTE. These switches are used to place the GTEs in either REMOTE MANUAL or PROGRAMMED mode. The remote manual mode is used when a GTE is started or stopped. It is also an alternate method of operating the throttle/pitch combination if programmed control fails. Programmed control is the normal operating throttle mode used after the GTE is started.



**MODE SETTING AND REDUCTION GEAR MONITORING SECTION.**—This section (D) is located to the right of the shaft performance section and is used to set propulsion modes and programmed control locations and to monitor the reduction gear bearings.

The first control switch is used only in programmed mode and is labeled PROPULSION MODE. This switch has two positions, POWER and SPEED. When placed in the POWER position, the processor automatically adjusts the pitch and PLA commands to provide a consistent load on the GTE. To do this, the processor uses the torque computer. At powers above full pitch, an almost linear relationship between the position of the programmed control lever and steady state srpm exists. In the power mode, the GTE or GTEs are kept at a steady power level. In some sea states and/or under some maneuvering conditions, the srpm will vary above or below a normal value. This variation in the power mode is normal and expected.

The other position of the PROPULSION MODE switch is the SPEED mode. When operating in the speed mode, the processor automatically adjusts the propeller pitch signals and the PLA actuator signals to provide a constant propeller srpm. To do this, the processor uses built-in power schedules and propeller srpm feedback. The programmed control lever gives the operator fine control of srpm. The operator can make careful adjustments to ship's speed in relatively calm seas and during alongside evolutions.

Just to the right of the propulsion mode switch is the ROUGH WEATHER DAMPING switch. This is an ON/OFF switch. This switch is only operative when operating in programmed 'control

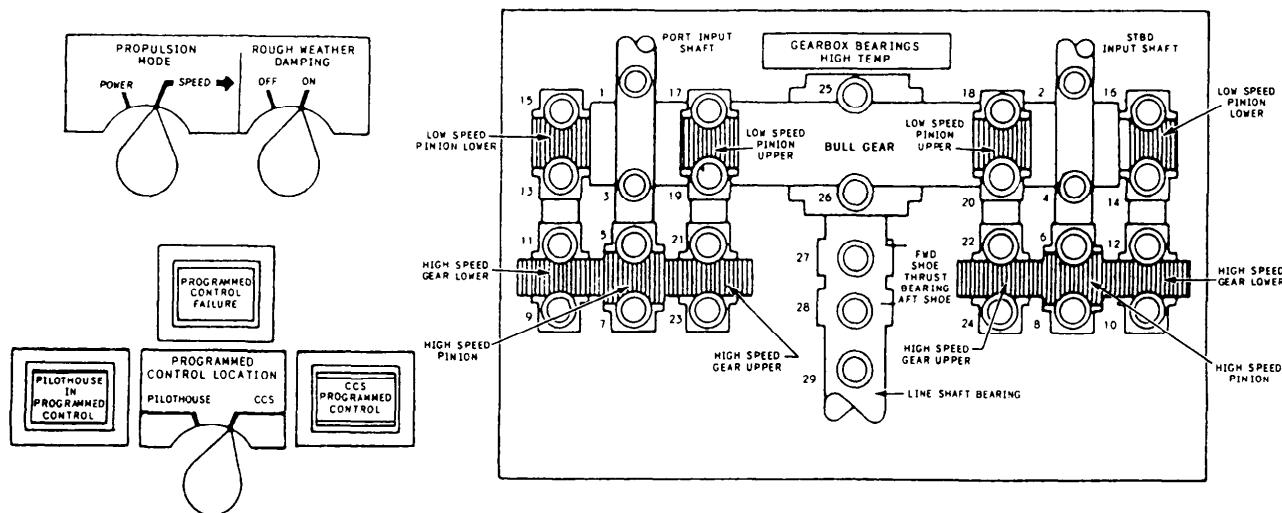
mode and the PROPULSION MODE is set in the SPEED mode. When the rough weather damping circuit is used, the processor attempts to even out PLA actuator command signals during rough sea conditions. This is to reduce hunting (fluctuation) of the propeller srpm.

The next section has 29 LEDs to monitor reduction gear bearing high temperature, one for each bearing in the MRG and the line shaft bearing. Associated with each LED is a number, 1 to 29; placing zeros in front of these numbers makes three-digit numbers. You will then have the DDI number for that bearing. If you use these numbers as reference numbers, 1 to 26 are for the babbitt bearings; the sensors are in the babbitt and are sensing babbitt temperature. Numbers 27 and 28 are for the thrust bearings; number 29 is for the line shaft bearing.

Under the control switches is an indicator labeled PROGRAMMED CONTROL FAILURE. This indicator illuminates and sounds an alarm when the processor has failed or has not made a complete cycle and has stopped. If this occurs, the processor will have to be restarted. Until the processor is restarted, the DDIs and the loggers may not be operating properly.

The next indicator is labeled PILOTHOUSE IN PROGRAMMED CONTROL. When this indicator illuminates, the control of the propulsion system is at the pilot house.

Below the PROGRAMMED CONTROL FAILURE indicator is a two-position PROGRAMMED CONTROL LOCATION switch. It determines the location of the programmed control. The programmed control location rotary switch, when positioned to CCS, shows that the control of the programmed mode is at the PCC. The other switch position is PILOTHOUSE. With



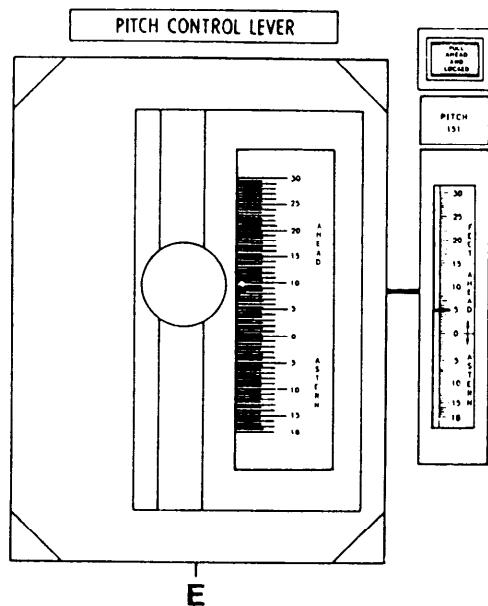
the switch in this position, control of programmed control is at the pilot house (SCC).

On the right-hand side of the PROGRAMMED CONTROL LOCATION switch is an indicator labeled CCS PROGRAMMED CONTROL. When this indicator is illuminated, the control of the propulsion system is at the PCC.

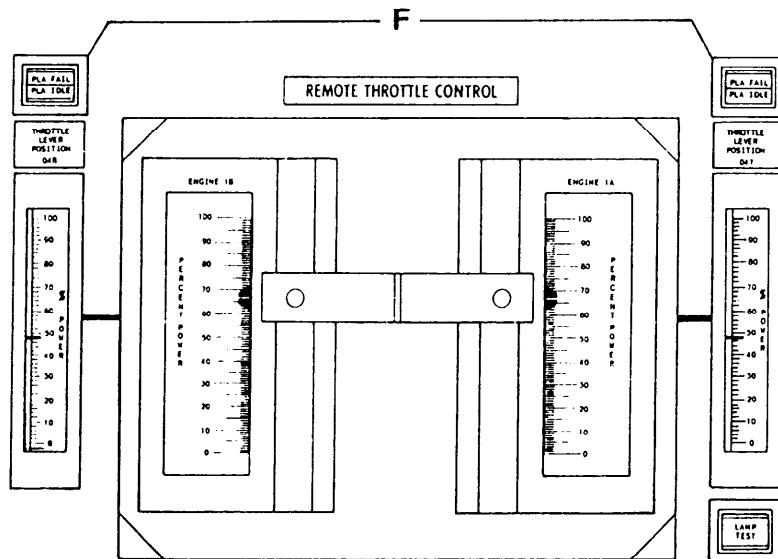
**SHAFT CONTROL SECTIONS.**—The lower sections of the propulsion control panel (E, F, and G) have the levers and indicators used to

operate and monitor the speed and pitch of the propeller shaft.

The section to the left (E) is the PITCH CONTROL LEVER. It controls propeller pitch in the remote manual mode. To the right of this lever is an edgewise meter labeled PITCH. It shows the actual pitch position. Above this meter is an indicator labeled FULL AHEAD AND LOCKED. This indicator illuminates when the pitch of the propeller is full ahead and mechanically locked at the OD box.

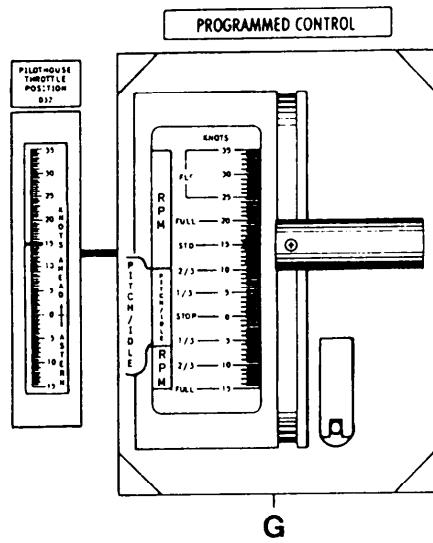


The next section labeled REMOTE THROTTLE CONTROL (F) has two levers for controlling the speed of the GGs, one lever for each GG. These levers can be locked together so that when the GTEs operate together, their speed will be the same. On either side of the REMOTE THROTTLE CONTROL levers are edgewise meters labeled THROTTLE LEVER POSITION, one for each GTE. The meters are always showing the position of the throttle in percentage of power. This is regardless of how the GTE or GTEs are being controlled. Above each edgewise meter is a split-legends indicator. The upper half reads PLA FAIL, the lower half reads PLA IDLE. When the PLA IDLE indicator illuminates, the throttles are setting at the idle position; the idle position is 13 degrees of PLA. When the PLA FAIL indicator illuminates, the throttle is at some position less than 13 degrees of PLA, or a processor failure has occurred.



The last section (G) to the right is the PROGRAMMED CONTROL lever. This lever is only functional when the engine control mode switch of either GTE is in the PROGRAMMED position. The programmed control mode is the primary mode of operation. The propulsion system can be operated in the programmed control mode using either one or both GTEs.

The last edgewise meter on this panel is labeled PILOTHOUSE THROTTLE POSITION. It indicates the actual position of the pilot house throttle lever and is used by the PCC operator to ensure the PROGRAMMED CONTROL LEVER at the pilot house is in the same position as the PROGRAMMED CONTROL LEVER at the PCC prior to transferring control.



### Operational Adjustments Panel

The last panel on the PCC is the operational adjustments-panel (fig. 6-11). It is located behind the second door from the left in the front of the PCC. The operational adjustments panel is subdivided into four sections. From left to right these sections are ENGINES, SHAFT TURNS, PITCH TRIM, and TIME SET.

the second door from the left in the front of the PCC. The operational adjustments panel is subdivided into four sections. From left to right these sections are ENGINES, SHAFT TURNS, PITCH TRIM, and TIME SET.

**ENGINES SECTION.**—This section has six recessed, screwdriver adjustable potentiometers. They provide calibration parameters for engine and propeller subroutines of the software program.

At the top is the BIAS subsection with two adjustment potentiometers. These are used to adjust the output of each GTE to 20,500 hp when the GTEs are operating in the power mode in programmed control with the programmed control lever set at full power.

The next subsection in the engines section is for the WASH SPEED. It has two indicators; the upper potentiometer is for setting the UPPER LIMIT speed at which the starter will be turned OFF during a water wash. The lower potentiometer is for setting the LOWER LIMIT speed at which the starter will be turned ON during a water wash.

The last subsection in the engines section is RPM MODE. It also has two adjustment potentiometers; both of the potentiometers are associated with operating the plant in programmed control with the propulsion mode switch in the speed position. The upper potentiometer is for adjusting the LOOP TIME CONSTANT. In other words, it provides an adjustment to change the response time of the subroutine when the GTE is operating in the RPM (speed) MODE. The lower potentiometer is for adjusting the LOOP GAIN CONSTANT. It provides an adjustment to change the amount of feedback used in computing the throttle commands in the RPM MODE.

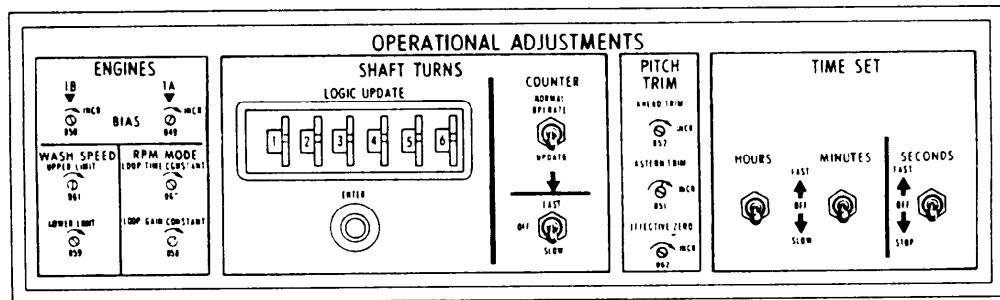


Figure 6-11.—Operational adjustments panel.

**SHAFT TURNS SECTION.**—This section has two subsections. The LOGIC UPDATE subsection has six thumbwheels. They are used to update the logic used by the processor to print the total number of shaft turns on the bell logger. Below these thumbwheels is a push-button switch labeled ENTER. When this switch is depressed, it loads the value dialed on the logic update thumbwheels into the applicable registers. Located next to the LOGIC UPDATE subsection is the COUNTER subsection. It has two toggle switches. Both switches are spring-loaded. The upper switch is used to control logic that drives the mechanical TOTAL SHAFT REVOLUTIONS counter (fig. 6-10, section C). The upper switch is used with the lower switch to update the counter prior to the ship getting underway. When the switch is at the rest (NORMAL OPERATE) position, the counter (on the PCC panel) will count as a function of the shaft revolution sensor. When the switch is held in the UPDATE position, the counter will count as a function of the FAST/OFF/SLOW (lower) toggle switch. The FAST/OFF/SLOW spring-loaded, toggle switch is enabled when the NORMAL OPERATE/UPDATE toggle switch is in the update position. The switch position at OFF (middle or rest) will not allow the counter to count. When the switch is held in the FAST (upper) position, the counter will count at the rate of 10 revolutions per second. When the switch is held in the SLOW (lower) position, the counter will count at the rate of one revolution per second.

**PITCH TRIM SECTION.**—The next section of the operational adjustments panel is the PITCH TRIM section. This section has three recessed, screwdriver adjustable potentiometers. They allow compensation between the propeller pitch subroutine of the software program and the equipment that performs the propeller pitch adjustment. The top potentiometer is for AHEAD TRIM. It is adjusted to give 23.5 feet pitch, when operating in programmed control, with a command equal to or greater than ahead 2/3. The middle potentiometer is for ASTERN TRIM. It is adjusted to give - 14.7 feet pitch, when operating in programmed control, with a command equal to or greater than back 1/3. The bottom potentiometer is for EFFECTIVE ZERO. It is used to adjust pitch to zero thrust, when operating in programmed control, with a command of stop.

**TIME SET SECTION.**—The last section of this panel is the TIME SET section. It is used by

the operator to set the clock on the DEMANDS panel. It has three spring-loaded toggle switches. From left to right, the toggle switches are labeled HOURS, MINUTES, and SECONDS. These switches are three-position, toggle switches. The center position is labeled OFF. In the OFF position, the clock will display and count automatically. Moving the HOURS switch up or to the FAST position and holding it there causes the hour portion of the clock to increment at the rate of 10 hours per second. Moving the switch to the lower or SLOW position and holding it there causes the clock to update at the rate of 1 hour per second. The middle switch is for MINUTES. Its positions are also labeled FAST/OFF/SLOW. With the switch in the OFF (middle or rest) position, the clock will count automatically. Moving and holding the switch in the up or FAST position causes the minute portion of the clock to update at the rate of 1 minute per second. Moving and holding the switch in the down or slow position causes the minutes portion of the clock to update at the rate of 1 minute every 3 seconds. The last switch is for SECONDS. This switch in the OFF (middle or rest) position allows the clock to operate automatically. Moving the switch to the up or FAST position causes the clock to update at the rate of 10 seconds per second. Moving the switch to the down or STOP position stops (or freezes) the clock.

## PCC CONTROL MODES

The PCC controls the operation of the propulsion system in the programmed control mode or the remote manual control mode.

### Programmed Control Mode

The programmed control mode is the primary mode for controlling the propulsion system. In this mode the operator controls a single (PROGRAMMED CONTROL) lever. This lever provides an input to the processor. The processor uses this input to set the pitch of the propeller blades and the speed of the GTE(s).

Two methods of control are used in the programmed mode. They are power control and speed control. In the power control mode, the pitch of the propeller is set to maximum. The GTEs are operated at their lowest possible speeds. The power mode is an open-loop, temperature-compensated mode using the torque computer in the FSEE to maintain constant GTE loading. Power control is also used for low-noise

operations. When better maneuvering response is needed, the throttle is operated in the speed control mode. In this mode the ship's speed is changed by changing the propeller pitch up to maximum with srpm remaining constant. In the speed mode, srpm remains constant while built-in power schedules of the program vary GTE speed. The speed mode is also called closed-loop, constant shaft speed mode.

### CAUTION

The programmed control mode must not be used when the propeller blade pitch is being controlled from the OD box or when it has been locked in the full-ahead position. Since no input has been made to the processor that the propeller blade pitch is being operated manually or has been locked in the full-ahead position, the processor would continue computing and transmitting propeller pitch commands. This will result in damage to the equipment.

### Remote Manual Mode

The remote manual mode at the PCC is used when a GTE is started from the PCC. It is also an alternate method of operating the propulsion equipment if a programmed control failure occurs. This method requires the operation of three levers, one for propeller pitch and one for the speed of each GTE. Normally, a combination of programmed control and remote manual control is used only when GTEs are started or stopped, when maintenance is performed, or when damage has occurred. When one GTE is in programmed control and the other is in remote manual, the remote manual pitch lever is inoperative. The pitch is controlled by the programmed control lever.

### GTE STARTING AND STOPPING

You can start a GTE from the PCC in the automatic or manual mode. In the automatic mode, the operator initiates the start at the PCC. The start/stop sequencer in the FSEE will start the GTE. The sequencer also provides the status indications for the operator to follow the start sequence. Automatic starting is inhibited if the 18 prestart permissives have not been met and the READY TO START indicator at the PCC is extinguished.

Manual starts from the PCC require the operator to activate circuits and sequence the start manually. The start/stop sequencer provides

status indications of the start sequence to the operator. The start/stop sequencer will prohibit a start until the prestart permissives have been met and the READY TO START indicator on the PCC start panel is illuminated.

You can shut down (secure) the GTE by selecting one of the three operator-initiated modes. The fourth mode is a processor-generated shutdown. The modes of stopping are as follows:

- Normal stop—operator initiated
- Manual stop—operator initiated
- Emergency stop—operator initiated
- Automatic shutdown—logic initiated

Normal stops are performed in the remote manual mode. The operator, following the EOSS, must bring the GTE to idle. When the normal stop push button is depressed, it initiates a normal stop sequence, performed by the start/stop sequencer. This allows the GTE to run for 5 minutes at idle before fuel valve closure, which allows the GTE temperatures to equalize (cool). This cooldown period lengthens GTE life. A normal stop sequence may be cancelled by the operator moving the throttle control lever off idle momentarily.

The PCC operator may perform manual stops from the PCC in the remote manual mode. The operator is required to sequence this stop. The GTE should be run at idle for 5 minutes before the GTE is manually stopped.

The PCC operator may activate the emergency stop at any time and in any operating mode, regardless of the console in control. You can initiate the emergency stop by depressing the emergency stop push button. This causes the GTE's fuel valves to close.

Automatic shutdowns may occur during starts or when the GTE is running. The automatic shutdowns de-energize the fuel valves, causing the GTE to shut down. The conditions during start that cause an automatic shutdown are as follows:

- $N_{GG}$  fails to reach 1200 rpm within 20 seconds after start is initiated.
- Failure to reach 400°F  $T_{5.4}$  within 40 seconds after the fuel valves are energized.
- $N_{GG}$  fails to reach 4500 rpm within 90 seconds after start is initiated.
- Engine LO pressure is below 6 psig 45 seconds after start is initiated or GTE speed is above  $4500 \pm 200$  rpm.

During GTE operation, the following conditions cause an automatic shutdown:

- GG flameout— $T_{5.4}$  is below 400°F with fuel manifold pressure above 50 psig.
- $T_{5.4}$  is above 1530°F.
- $N_{pt}$  is above  $3960 \pm 40$  rpm.
- GTE lube oil pressure is less than 6 psig.
- GG vibration is above 7 mils.
- PT vibration is above 10 mils.

**NOTE:** If BATTLE OVERRIDE is applied, it inhibits all automatic shutdowns except flameout and PT overspeed.

## LOCAL OPERATING PANEL

As we discussed previously, the engine-room consoles are the primary operating stations for the LM2500 GTE. The primary purpose of the engine-room consoles is to allow you to operate an engine room independent of all other control points. If the SCC or CCS is damaged, you could still control the GTEs from the engine room. These consoles are also used as maintenance stations for operations, such as water washing and as a central monitor for many engine-room parameters.

The LOP (fig. 6-12) is the engine-room console on the FFG-class ship. It is located on the starboard side, upper level of the engine room,

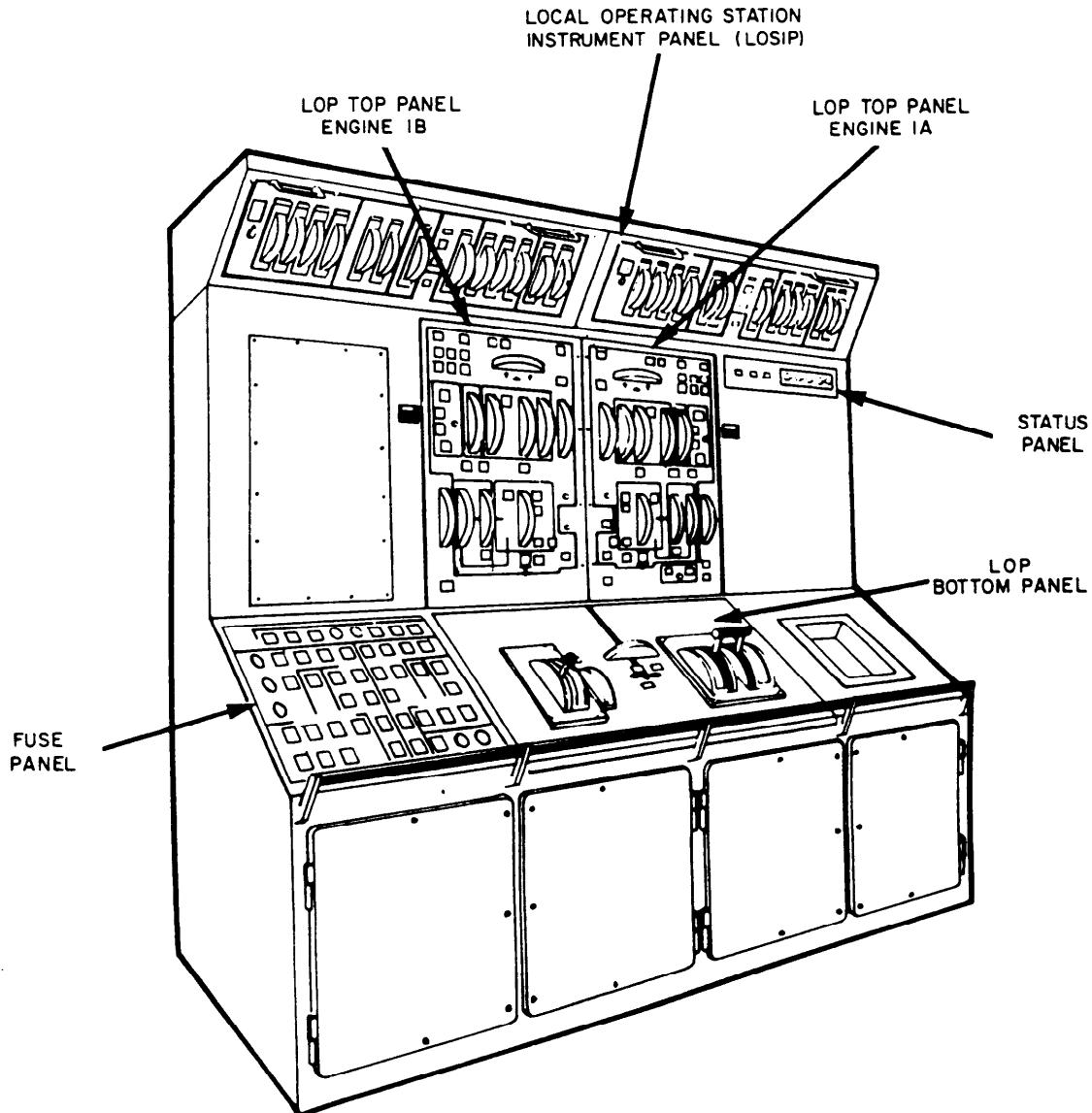


Figure 6-12.—LOP controls and displays.

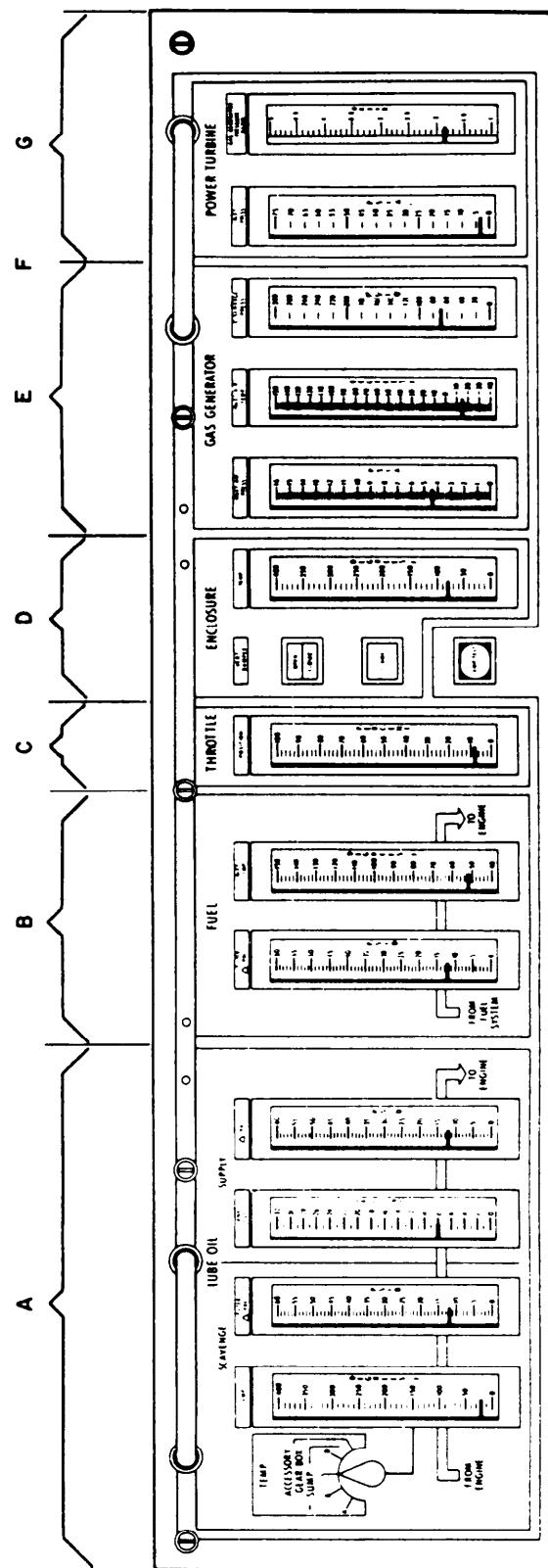


Figure 6-13.—Local operating station instrumentation panel.

near the propulsion equipment. The LOP has the necessary controls and indicators to permit direct local (manual) control of the propulsion equipment. The direct local mode of control, although still electronic, permits operation of the equipment independent of the programmed sequence from the computer. It is normally an unmanned console. However, you can use it if an emergency occurs or for control during maintenance. You may find it easier to understand the operational procedures for the LM2500 GTE by following the operation of the programmed sequence. For this reason, we discussed the FFG LM2500 operational procedures when we discussed the PCC.

The LOP is divided into the following six sections:

1. Local operating station instrument panel (LOSIP)
2. LOP top panel engine 1A
3. LOP top panel engine 1B
4. Status panel
5. LOP bottom panel
6. Fuse panel

## **LOCAL OPERATING STATION INSTRUMENT PANEL**

The LOSIP (fig. 6-13) is located at the top of the LOP. The LOSIP is divided into two sections, one for each GTE. Their layouts are identical. The LOSIP is only a monitoring panel and has no control functions. It is used to monitor conditions of the systems of the LM2500 GTE and selected parameters.

From left to right the monitoring sections are LUBE OIL, FUEL, THROTTLE, ENCLOSURE, GG, and PT. The parenthetical letters referenced in the text are shown on figure 6-13 and indicate the six sections of the LOSIP.

### **LUBE OIL Section**

The LO section (A) is used to monitor the parameters associated with the LM2500 GTE LO system. It has a five-position rotary selector switch and four edgewise meters. The TEMP selector switch on the left is labeled A, B, C, D, and ACCESSORY GEAR BOX. It is used to select the scavenging temperature to be monitored. By rotating the selector switch to the desired position, you may monitor the selected parameter on the first edgewise meter, labeled TEMP. The second edgewise meter, labeled FILTER  $\Delta P$ , is used to monitor the scavenging filter (located on the LOSCA) differential pressure. The third edgewise meter, labeled TANK, indicates the LOSCA tank

level. The fourth edgewise meter, labeled  $\Delta P$ , is used to indicate differential pressure across the LO supply filter (located in the GTM).

### **FUEL SYSTEM Section**

The FUEL section (B) monitors the fuel system of the GTE and has two meters. The first meter is labeled FILTER DP and monitors fuel filter (the GTE-mounted filter) differential pressure. The second edgewise meter is labeled SUPPLY TEMP and monitors the fuel supply temperature.

### **THROTTLE Section**

The THROTTLE section (C) has one edgewise meter, labeled POSITION. It indicates the throttle position in percentage of GTE power in increments of 0 to 100 percent.

### **ENCLOSURE Section**

The ENCLOSURE section (D) has two indicators and an edgewise meter. The first split-leg indicator is labeled OPEN/CLOSED and is used to monitor the actual status of the vent damper. The second indicator is labeled FLAME and, when illuminated, indicates that a flame (fire) has been sensed in the module. It receives its signal from the UV sensors in the enclosures. The edgewise meter is labeled TEMP and indicates the temperature of the enclosure. A momentary-contact push button, labeled LAMP TEST (not considered part of the enclosure section), is located below the two indicators. It is used to test the proper operation of the bulbs in the two indicators of the enclosure section.

### **GAS GENERATOR Section**

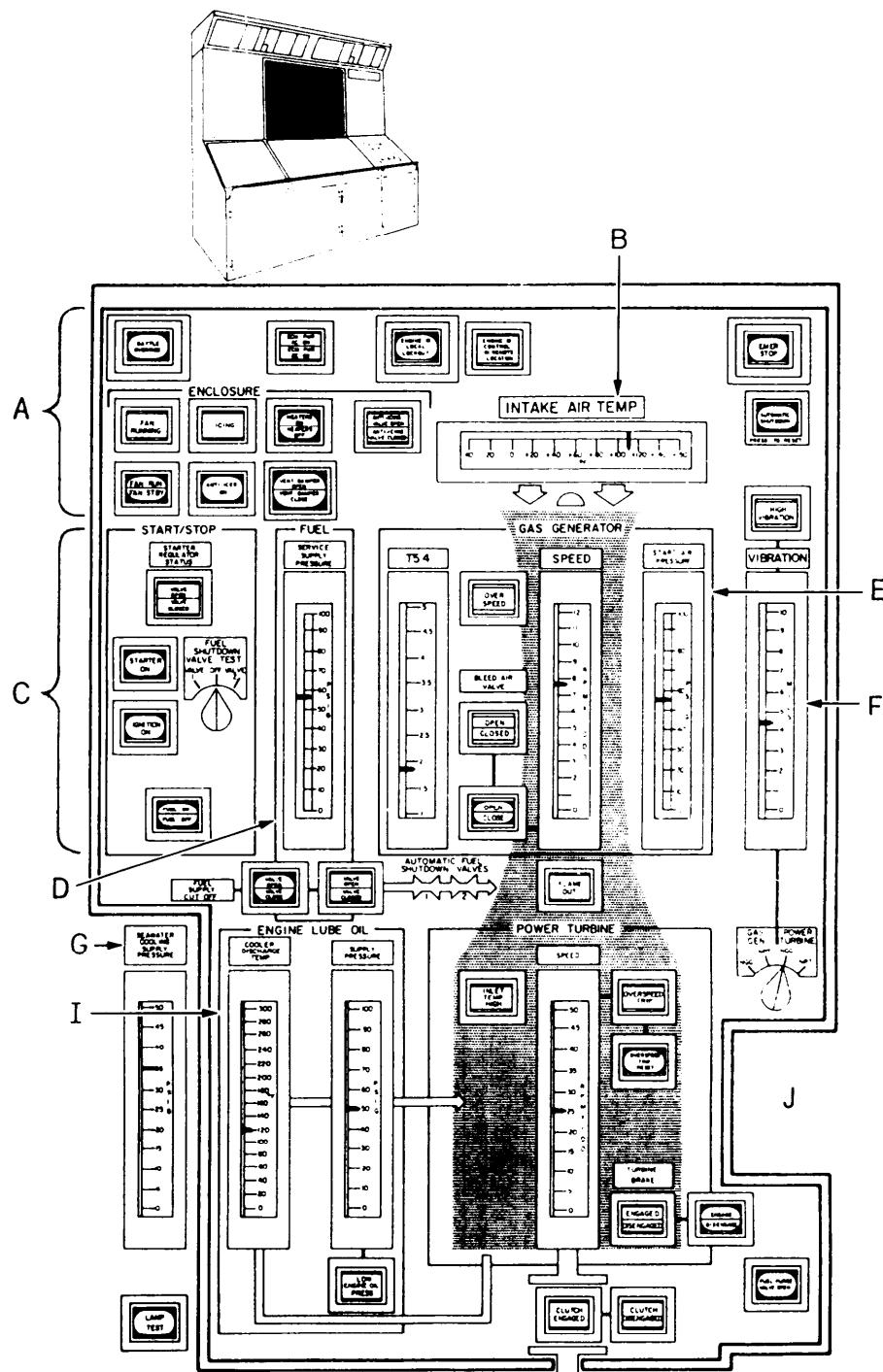
This section (E) is used to monitor the GG. It has three edgewise meters. The first meter, labeled INLET AIR PRESS, monitors GG inlet air pressure ( $P_{t,2}$ ), the pressure of the air entering the compressor. The center edgewise meter, labeled INLET AIR TEMP, monitors the compressor air inlet temperature ( $T_2$ ). The right edgewise meter, labeled DISCHARGE PRESS, monitors the CDP.

### **POWER TURBINE Section**

This section (F) has two edgewise meters used to monitor PT parameters. The left edgewise meter, labeled INLET PRESS, is used to measure PT inlet pressure ( $P_{t,4}$ ). The second edgewise meter, labeled GAS GENERATOR PRESSURE RATIO is used to monitor GG pressure ratio.

### **LOP TOP PANEL**

The LOP top panel (fig. 6-14) is used to control either, or both, of the GTEs. Although



ENGINE 1B

**Figure 6-14.—LOP top panel.**

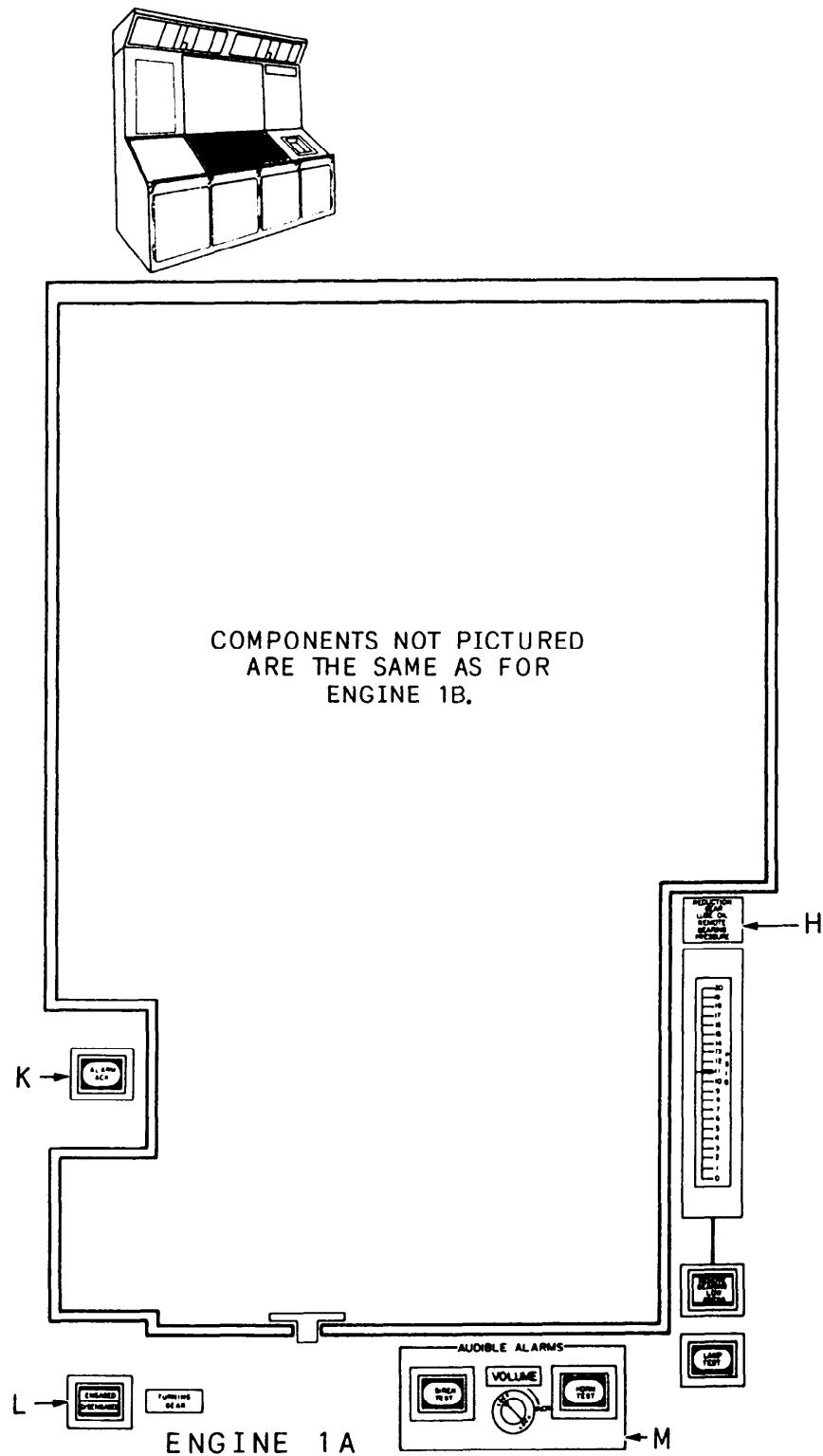


Figure 6-14.—LOP top panel—Continued.

the GTEs are controlled from this panel, the operations are in the manual mode. The LOP has no computer functions. The LOP top panel is divided into two sections, the engine 1A and engine 1B sections. These engine sections are almost mirror images of each other. The differences in the two panels will be pointed out as we cover the related area. As we did with the PCC, we will cover the LOP from left to right, top to bottom.

The first indicator at the top left is labeled BATTLE OVERRIDE. It is a guarded, illuminated push button. It can be manually activated at any time, regardless of the station in control. Normally, you must have the commanding officer's permission to activate BATTLE OVERRIDE. Refer to your ship's standing orders for events which will allow you to activate this switch automatically without the commanding officer's permission. This requirement is mandated because this switch overrides the following safety shutdowns:

1. GTE LO pressure is low.
2. GTE vibration is high.
3.  $T_{5.4}$  is high.
4. PLA failure for the following conditions:
  - a. PCS command signal is out of limits.
  - b. PT shaft torque is out of limits.
  - c. PT speed is out of limits.

BATTLE OVERRIDE does not override a flameout or a PT overspeed trip.

The next indicator is a split-legends type labeled ECM PWR AC ON/ECM PWR DC ON. The upper half of the indicator indicates ac power is on to the FSEE. This ac power is used for the igniters, the anti-icing valves, and the fire detection sensors. The lower half of the indicator indicates dc power is on. This dc power is used for the FSEE electronics and the GTE fuel valve control circuit.

The third push-button indicator is labeled ENGINE 1B(1A) LOCAL LOCKOUT. It is used to place the LOP in control of the associated

GTE. It is a guarded type of push button used to take control from the PCC. By re-depressing it, you can transfer the control to the PCC. When the GTE control is at the PCC, the fourth indicator labeled ENGINE 1B CONTROL IN REMOTE LOCATION will illuminate.

The fifth indicator is a guarded type of push button labeled EMER STOP. This push button is used to stop the GTE in an emergency. You can activate the emergency stop push button at the LOP regardless of what station has control. This push button closes both GTE fuel valves and causes the GTE to shut down.

## ENCLOSURE Section

The ENCLOSURE section (A) monitors the module cooling and air intake system. It has three indicators and four control switches. The first indicator is labeled FAN RUNNING. When it is illuminated, it indicates the enclosure fan is operating. The second indicator is labeled ICING. When it is illuminated, it indicates the intake air is below 41°F and the humidity is above 70 percent. The third indicator is a split-legends push button labeled HEATERS ON/HEATERS OFF. It is used to turn the enclosure heater on or off. When it is illuminated, it indicates the actual status of the heaters. The last indicator across in this column is a split-legends indicator labeled ANTI-ICING VALVE OPEN/ANTI-ICING VALVE CLOSED. When it is illuminated, it shows the actual status of the anti-icing valve.

The first indicator across the second column is a split-legends, push-button indicator labeled FAN RUN/FAN STBY. It is used to turn the enclosure cooling fan on or return it to a standby condition (off). When it is illuminated, it indicates the status of the enclosure fan. The next indicator is a push button labeled ANTI-ICER ON. It illuminates to indicate a command has been sent to open the anti-icing valve. When this button is depressed again, it will close the anti-icing valve. The last indicator in the enclosure section is a split-legends push button labeled VENT DAMPER OPEN/VENT DAMPER CLOSE. The illuminated portion of this indicator shows the operator command to the vent damper.

The horizontal edgewise meter (B) labeled INTAKE AIR TEMP is used to monitor the

temperature of the outside air in °F. This meter is located above the GG section (E) of the LOP top panel.

To the right of the meter is a push-button indicator labeled AUTOMATIC SHUTDOWN (PRESS TO RESET). It illuminates to indicate an emergency shutdown has occurred on the related GTE. The automatic shutdowns are as follows:

- PT inlet temp ( $T_{5.4}$ ) high—above 1530°F
- Engine LO pressure low—below 6 psig
- GG vibration high—above 7 mils
- PT vibration high—above 10 mils
- Flameout:  $T_{5.4}$  less than 400°F with fuel manifold pressure above 50 psig

When one of these conditions is met, the automatic shutdown circuitry closes the two main fuel valves. You depress the AUTOMATIC SHUTDOWN button to reset the automatic shutdown circuitry, once the GTE has come to a complete stop.

### START/STOP Section

The START/STOP section (C) contains the controls to start and stop the GTE. It has one indicator, three push-button indicators, and a rotary switch. The split-legends indicator labeled VALVE OPEN/VALVE CLOSED is the STARTER REGULATOR STATUS indicator. It illuminates to display the open or closed status of the starter regulator valve. The first push-button indicator, labeled STARTER ON, is a momentary switch. When it is depressed, it opens the starter regulator valve and closes it when released. The second push-button indicator is labeled IGNITION ON. It is also a momentary-type switch. When it is depressed, it turns the GTE ignitors on; when it is released, the ignitors are turned off. The last indicator is a split-legends push button labeled FUEL ON/FUEL OFF. It illuminates to show the operator command to energize or de-energize the fuel shutdown valves. By depressing it once, you can open the fuel valves. Re-depressing it closes the valves. You must always keep the push button in the FUEL OFF position when control is at the PCC.

The rotary switch is labeled FUEL SHUT-DOWN VALVE TEST. It is used to test each fuel valve. The switch is spring-loaded to the OFF position. To test an individual valve, you must turn the switch to the desired valve and hold it. You must keep the switch held to that position until the  $N_{GG}$  is at zero. Then depress the FUEL ON/FUEL OFF push button to close the other valve and keep both valves closed.

### FUEL Section

The FUEL section (D) contains a meter, an indicator, and a push button associated with the GTE fuel supply. The edgewise meter, labeled SERVICE SUPPLY PRESSURE, displays the fuel supply pressure from the ship's fuel system. The split-legends push button, labeled VALVE OPEN/VALVE CLOSE, controls and illuminates to display the status of the module fuel cutoff valve located under the enclosure. The split-legends indicator, labeled VALVE OPEN/VALVE CLOSED, illuminates to show the actual fuel supply valve status.

### GAS GENERATOR Section

This section (E) monitors parameters associated with the GG. It contains three edgewise meters, two indicators, and an illuminated push button.

The first edgewise meter is labeled INLET TEMP. This meter displays the  $T_{5.4}$  of the PT. You have to multiply the number displayed by 1000 to determine the actual temperature.

The indicator is labeled OVERSPEED. It will illuminate and activate an alarm when the speed of the GG exceeds  $9700 \pm 100$  rpm. The split-legends indicator, labeled OPEN/CLOSED, displays the status of the GTE's 16th-stage BLEED AIR VALVE. The bleed air push-button indicator, labeled OPEN/CLOSE, controls the operation of the GTE bleed air valve. It will illuminate either open or close, depending on the command that is selected.

The second edgewise meter is labeled SPEED. This meter monitors  $N_{G,G}$ . The readings from this meter are multiplied by 1000 to determine GG speed. The third edgewise meter is labeled START AIR PRESSURE. It displays the pressure of the air available to start the GTE.

## **VIBRATION Section**

This section has an alarm indicator, an edgewise meter, and a rotary selector switch. The alarm indicator, labeled HIGH VIBRATION, illuminates and sounds an alarm when a GTE vibration exceeds the maximum set point. These maximum set points are GG at 4 mils and PT at 7 mils. An automatic shutdown occurs when GG vibration reaches 7 mils or PT vibration reaches 10 mils. The edgewise meter, labeled VIBRATION, will display the vibration on the GTE at the position selected by the rotary switch. The rotary selector switch, labeled GAS GEN/POWER TURBINE, is a four-position switch. It allows you to look at the two different vibration pickups. One of the pickups is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibration. A tracking filter for each pickup separates GG vibration from PT vibration, depending on vibration frequency.

## **SEAWATER COOLING SUPPLY PRESSURE and REDUCTION GEAR LUBE OIL REMOTE BEARING PRESSURE Meters**

These edgewise meters are mirror images of each other as to location, but not to function. The edgewise meter (G) labeled SEAWATER COOLING SUPPLY PRESSURE is located on the engine 1B panel and is used to display the seawater supply pressure to the reduction gear cooler. Below this edgewise meter is a push-button indicator labeled LAMP TEST. It is used to test the lamps in the engine 1B section of the LOP. The edgewise meter (H) labeled REDUCTION GEAR LUBE OIL REMOTE BEARING PRESSURE is located on the engine 1A panel. It displays the MRG most remote bearing pressure. Below this meter on the engine 1A panel is an alarm indicator labeled REMOTE BEARING LOW PRESS. This indicator illuminates and sounds an alarm which alerts the operator if the most remote bearing pressure falls below 9 psig. The LAMP TEST push button below the indicator tests the lamp status for the engine 1A panel.

## **ENGINE LUBE OIL Section**

The ENGINE LUBE OIL section (I) has two edgewise meters and an indicator to monitor the

engine LO supply. The first edgewise meter, labeled COOLER DISCHARGE TEMP, monitors the temperature of the LOSCA cooler outlet. The second edgewise meter, labeled SUPPLY PRESSURE, monitors the engine LO supply pressure. The indicator, labeled LOW ENGINE OIL PRESS, illuminates and sounds an alarm when the engine LO pressure is below 15 psig.

## **POWER TURBINE and OUTPUT Section**

This section (J) has six indicators, an edgewise meter, and three push-button indicators. The first indicator, labeled FLAME OUT, illuminates and sounds an alarm to alert you if conditions for a flameout exist. This condition occurs if  $T_{5.4}$  drops below 400°F when the fuel manifold pressure is above 50 psig. It also initiates an automatic shutdown. The second indicator, labeled INLET TEMP HIGH, illuminates and sounds an alarm to alert the operator of a high  $T_{5.4}$ . This will occur at 1500°F PT inlet temperature.

The edgewise meter, labeled SPEED, is used to monitor the speed of the PT. Associated with this meter is an indicator and push button. The indicator, labeled OVERSPEED TRIP, illuminates when an overspeed trip occurs. The indicator is set at  $3960 \pm 40$  rpm. The push-button indicator, labeled OVERSPEED TRIP RESET, is used to reset the overspeed trip circuitry after an overspeed trip occurs.

## **CAUTION**

Do not depress the OVERSPEED TRIP RESET until the GG has come to a complete stop. The fuel valves can re-open, causing a post-shutdown fire.

The next indicator is a split-legends type labeled ENGAGED/DISENGAGED. It illuminates to display the actual position of the turbine brake. The second push-button indicator is a split-legends type, also. It is labeled ENGAGE/DISENGAGE and controls the operation of the PT brake. The indicator illuminates to indicate the signal that is being sent to the turbine brake.

The bottom two indicators illuminate to display the status of the GTE clutch. These indicators are labeled CLUTCH ENGAGED and CLUTCH DISENGAGED.

The third push-button indicator, labeled FUEL PURGE VALVE OPEN, operates the GTE's fuel purge valve. When this push button is depressed, it opens the fuel purge valve to allow about 3 gallons of cold fuel to drain from the GTE system. In this way, cold fuel is drained from the GTE before starting. The fuel purge valve is operated only when motoring the GTE.

With the exceptions noted in the previous sections (two edgewise meters, one alarm indicator, and the LAMP TEST push button), all of the indicators, push buttons, edgewise meters, and rotary switches described on the LOP top panel are identical on both the engine 1A and engine 1B panels. The following indicators, push buttons, and rotary switch are located on the engine 1A panel and are NOT on the engine 1B panel.

- A push-button indicator (K), labeled ALARM ACK, is located on the engine 1A panel at the position shown. It is a momentary-contact push button used by the operator to acknowledge an alarm. When it is depressed, it will cause the flashing alarm indicator to illuminate in a steady state and silence the alarm.
- A split-type indicator (L), labeled EN-GAGED/DISENGAGED, illuminates to indicate the status of the MRG turning gear. The turning gear must be engaged and disengaged manually at the MRG.

- A section (M), labeled AUDIBLE ALARMS, has two push-button indicators and a rotary switch. The first push-button indicator, labeled SIREN TEST, is depressed by the operator to test the alarm siren. The rotary switch, labeled VOLUME, is actually a rheostat used to adjust the volume of the audible alarms. The second push-button indicator, labeled HORN TEST, is depressed by the operator to test the alarm horn.

## LOP STATUS PANEL

The LOP status panel (fig. 6-15) is located to the right of the 1A GTE top panel. It contains three illuminated indicators for the LOP power supplies and five fuse holders for the 115 volts ac for the console heaters and blowers.

The first indicator is a split-leg indicator, labeled 115 VAC SS AVAILABLE/+28 VDC UPS AVAILABLE. It displays the status of 115-volt ac ship's service power and 28-volt dc power. These indicators will illuminate when each source of power is available. The second indicator is also a split-leg type, labeled 115 VAC UPS AVAILABLE/HEATERS ON. It illuminates to indicate 115-volt ac UPS is available and when the console heaters are on. The third indicator, labeled OVERTEMP, illuminates and sounds an alarm to indicate console overtemperature.

The 115 VAC fuse section contains the fuses for the power and return for the heater relay, power and return for the heaters and blowers, and a spare fuse holder.

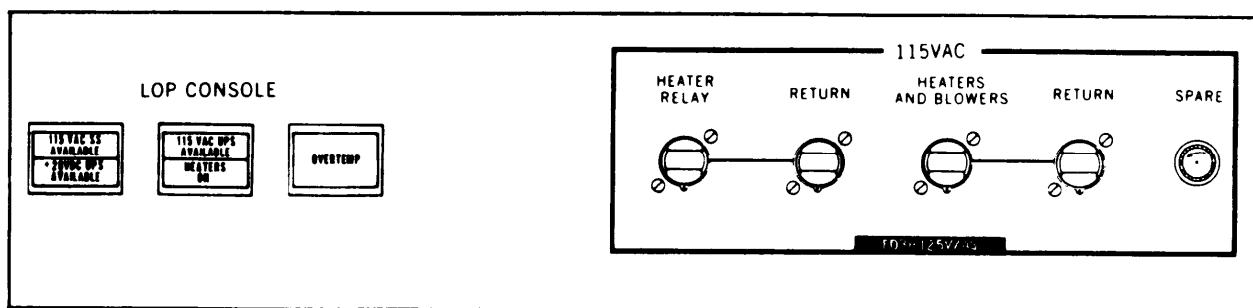


Figure 6-15.—LOP status panel.

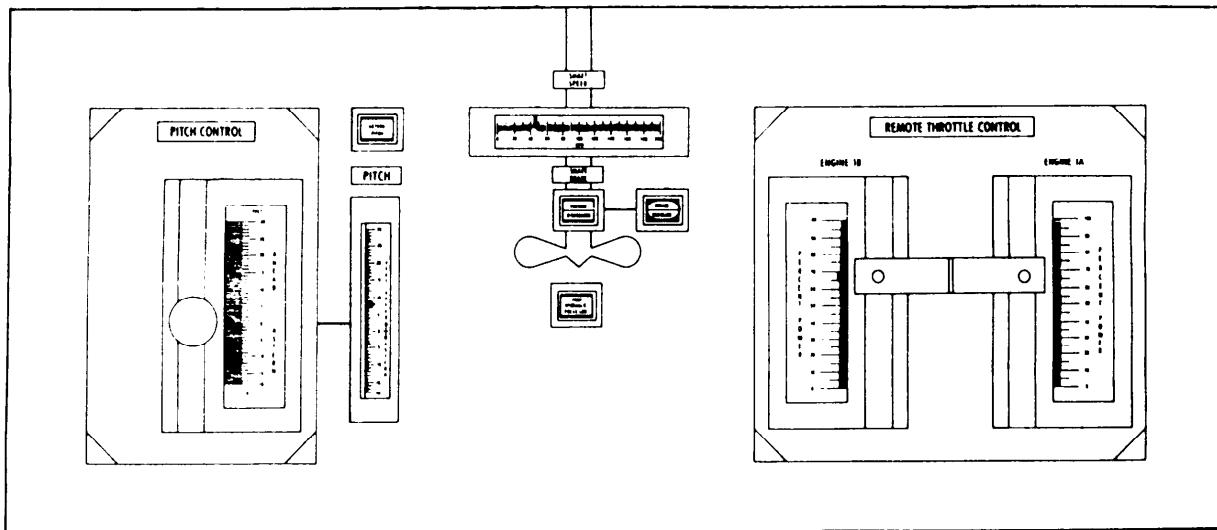


Figure 6-16.—LOP bottom panel.

## LOP BOTTOM PANEL

The LOP bottom panel (fig. 6-16) has a pitch control lever, two edgewise meters, three indicators, a push-button indicator, and two throttle control levers. Only manual throttle and pitch control is available at the LOP.

The first lever, labeled PITCH CONTROL, controls the pitch of the propeller. It is only operative when the LOP is in control of both GTEs. An indicator, labeled ASTERN PITCH, illuminates when the propeller pitch is actually in the astern direction. The first edgewise meter, labeled PITCH, displays the actual propeller pitch. The second edgewise meter is horizontal and labeled SHAFT SPEED. It displays the speed of the shaft in rpm. The second indicator, labeled ENGAGED/DISENGAGED, and the push-button indicator, labeled ENGAGE/DIS-ENGAGE, control and monitor the SHAFT BRAKE. When you depress the shaft brake control push button, it will illuminate the command selected. The shaft brake will only activate when the following permissives are met:

- Pitch at zero
- Shaft speed below 75 rpm
- Throttles at idle
- Station in control

The shaft brake indicator will illuminate to display the actual status of the shaft brake, either ENGAGED or DISENGAGED.

The third indicator, labeled PROP HYDRAULIC PRESS LOW, will alert you when the CPP hydraulic system pressure is below 40 psig.

The two REMOTE THROTTLE CONTROL levers, labeled ENGINE 1B and ENGINE 1A respectively, control the power level of each GTE. The throttles are controlled in increments of percent power.

## LOP FUSE PANEL

The LOP fuse panel (fig. 6-17) is located on the lower left section of the LOP. It contains the 28-volt dc fuses for the LOP, the enclosures, and the transducers that input to the LOP.

## SUMMARY

This chapter has introduced you to the operation of the FFG-class ship engineering plant from the PCC in the CCS and the LOP in the MER. Most GSs assigned to an FFG-class ship will stand watches at one time or another in the CCS. For this reason, you should be very familiar with the capabilities of these consoles. Like all other material in this TRAMAN, this chapter was written to form a basis to start your qualifications at watch stations on your ship. Even if you are not assigned to an FFG-class ship, your knowledge of this material will help you advance in rate and make you more valuable to the Navy.

In no way is this material meant to be a one-stop source for qualifying you as an FFG watch stander. You should use the EOSS, the PQS, ship information books, and technical manuals for this process. By combining

these sources, you should have no problem becoming a qualified watch stander. Remember, before you attempt any operation at these consoles, you must be familiar with and use the EOSS.

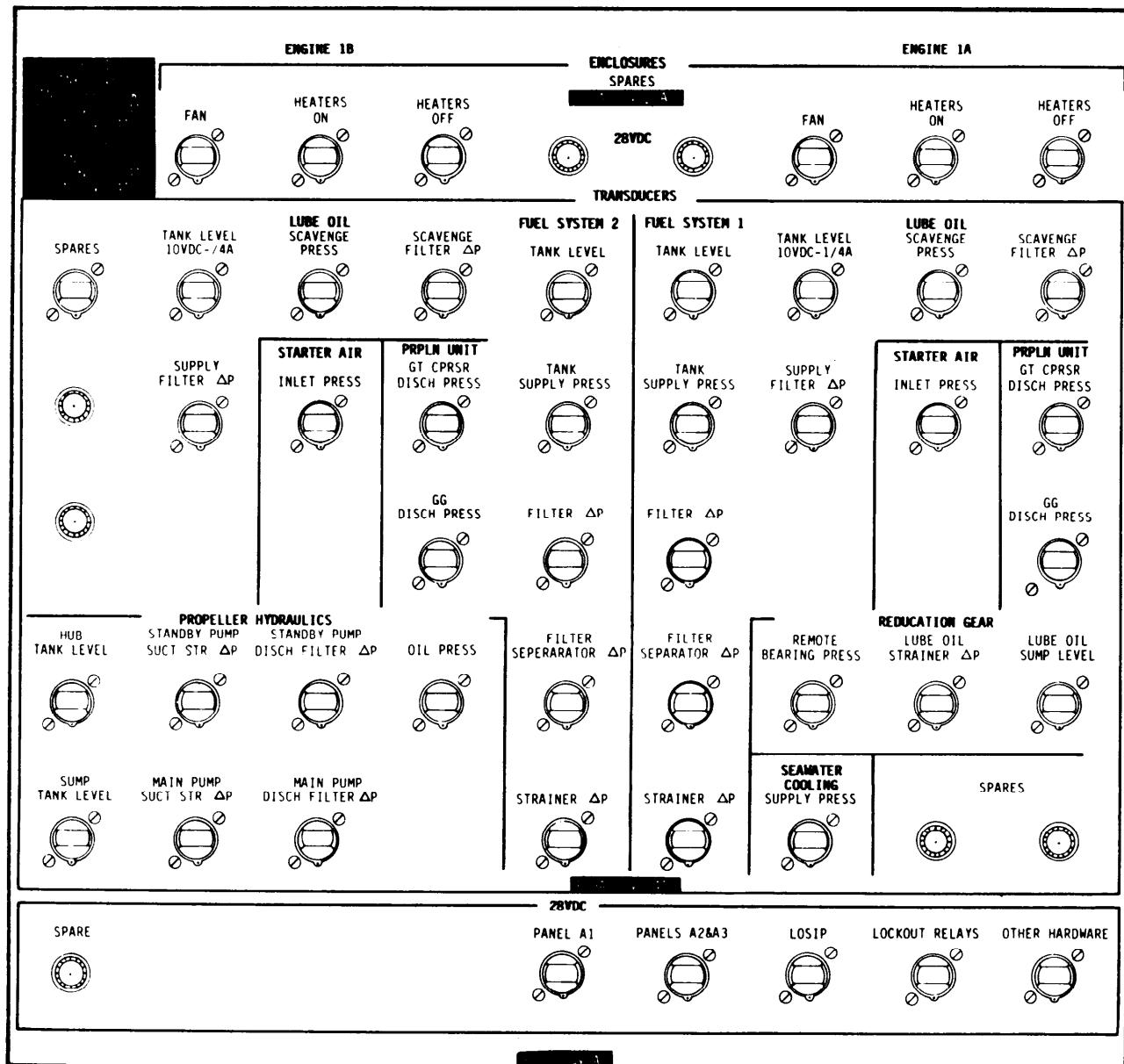


Figure 6-17.—LOP fuse panel.



# CHAPTER 7

## MACHINERY CONTROL SYSTEM FOR DDG-51 CLASS SHIPS

Up to this point we have discussed operation, construction, and control of the gas turbine engineering plant on the Perry-, Spruance-, and Kidd-class ships. One of the revolutionary aspects of the gas turbine plant is its ability to be operated from a central, remote location. This central point is known on all classes of gas turbine ships as the central control station (CCS). The CCS is the primary control watch station for operating nearly all major engineering equipment. Systems that are not controlled in the CCS may at least be monitored from there. This allows for reduced watch standing outside the CCS as opposed to older ships that required watch standers throughout the plant. Also, the EOOW and propulsion, electrical, and damage control watch standers have a quicker look at all vital parameters associated with plant operation.

Currently, three major designs exist for gas turbine CCSSs; one for the Perry-class frigates, one for the Spruance and Kidd classes, and one for the Arleigh Burke class. In this chapter we discuss the Arleigh Burke-class ship's machinery control system (MCS) in CCS.

After reading this chapter and completing the associated NRTC, you should have a good understanding of the function of the CCS. This material is meant for training purposes only. It is not meant to replace the EOSS or technical manuals.

With the help of an experienced GSE and by using the knowledge gained in this chapter, following the EOSS, and completing PQS requirements, you should have no problem qualifying in all aspects of CCS operations.

### MACHINERY CONTROL SYSTEM (DDG-51)

The DDG-51 Arleigh Burke-class ship's MCS provides centralized and remote monitoring and

control of the propulsion, electrical, auxiliary, and damage control systems. The major units of the MCS are shown in figure 7-1. The four consoles located in CCS are the PACC, the EPCC, the DCC, and the engineering officer of the watch/logging unit (EOOW/LU). The shaft control unit 1 (SCU 1) and the SCU 2 are located in main engine room (MER) 1 and MER 2, respectively. The repair station console (RSC) is located in repair station 2.

The MCS is the newest system the Navy has for controlling the GTE-powered engineering plant. In this chapter we will describe only the controls and monitoring provided by the EOOW/LU, the PACC, and the SCUs. The EPCC will be described in chapter 8, and the DCC and RSC will be discussed in chapter 9 of this TRAMAN.

### ENGINEERING OFFICER OF THE WATCH/LOGGING UNIT

The EOOW/LU (fig. 7-2) has two panel assemblies (A1 and A2) and a keyboard control section. It is located in the CCS and is the watch station for the EOOW. This console is a see-over console that has two plasma display assemblies (described later in this chapter). Although, only a bulkhead can be seen over the console, the EOOW/LU was chosen to be see-over, in case during the design of CCS, the console would be centrally located and the EOOW would need the view. These displays are used by the EOOW to obtain the current status of the machinery plant. The console also has a bell logger, a bubble memory unit, and an AN/USH-26(V) cartridge tape unit installed in the front. The bell logger is a high-speed printer that can print bell commands as well as changes in propulsion system status.

Embedded in each of the MCS consoles is an AN/UYK-44 computer that performs centralized

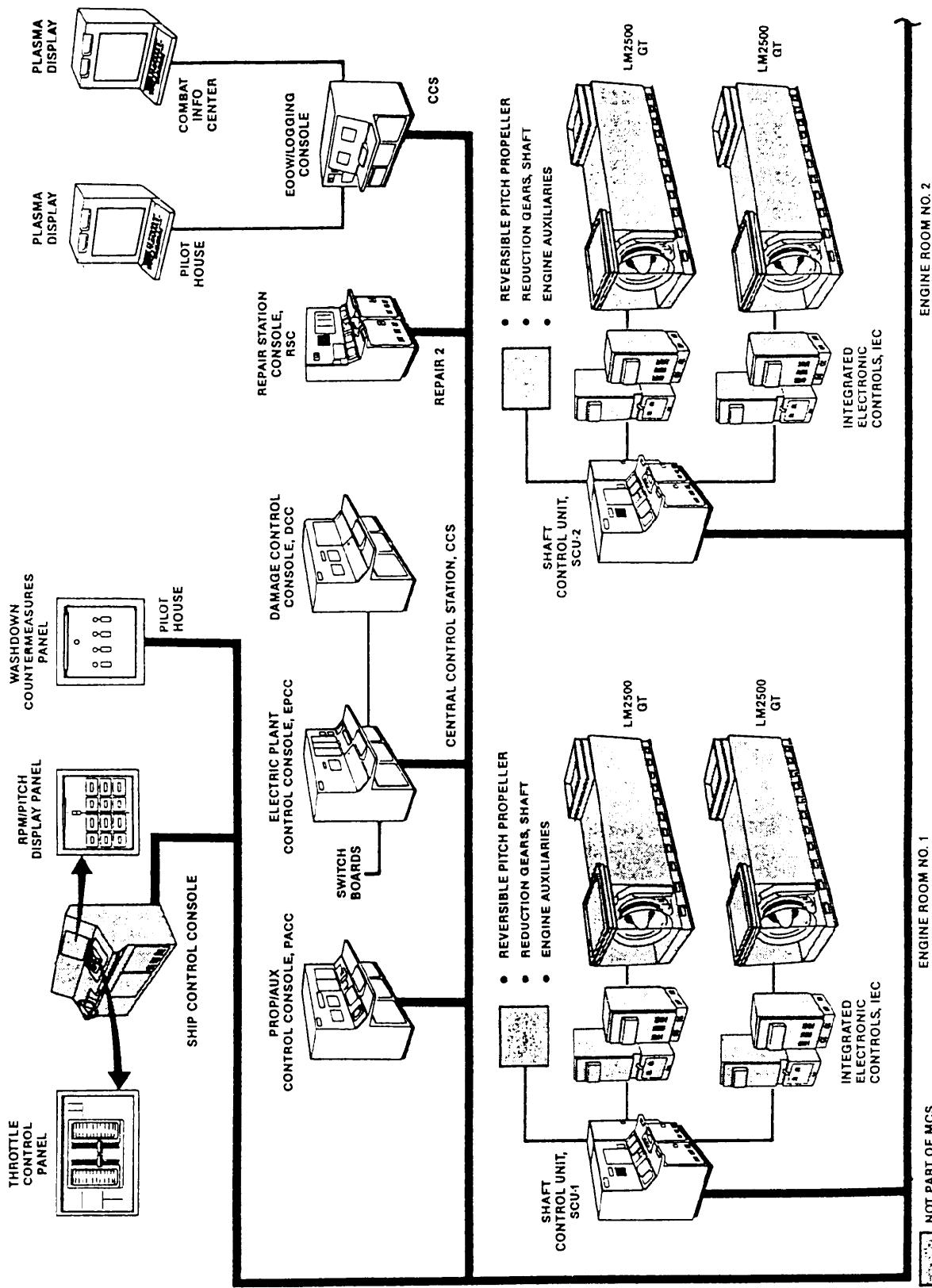


Figure 7-1.—DDG-51 machinery control system.

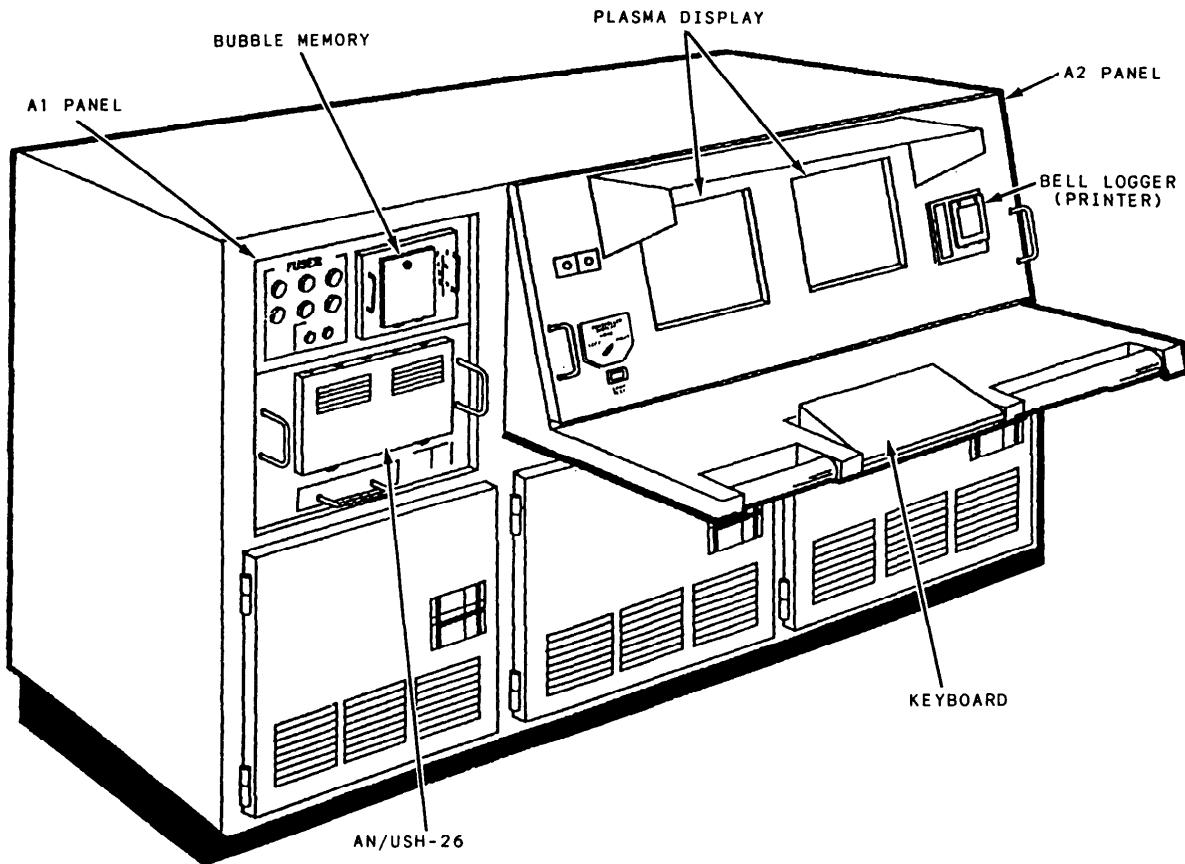


Figure 7-2.—Overall view of the EOOW/LU (door removed).

monitoring and controlling functions for the console. Through multiplexers, the computer monitors plant status and generates control commands. Through panel distributors, the computer lights lamps, sounds sirens, and detects button actions. The bubble memory in the consoles serve the same function as the disk drives on a personal computer: it holds data. The principle function of the bubble memory units for all consoles is to store the computer program that "runs" the console. The bubble memory unit is also used to load programs into the bubble memory cassettes that store the programs for the computers in the consoles. A detailed description of the bubble memory is discussed later in this chapter.

The AN/USH-26(V) tape unit is used as a data logger to record machinery status changes and alarm conditions for the MCS. This tape unit is also used in the bubble memory loading operations.

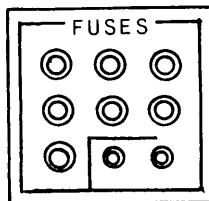
## PANEL ASSEMBLY A1

The A1 panel is divided into three sections. These sections have the controls and indicators for the fuse assembly, the bubble memory, and the AN/USH-26(V) tape unit.

### Fuse Assembly Section

The fuse assembly section has nine 28-volt dc power loss indicator/fuse holders. Each indicator illuminates white to indicate a loss of power to its respective unit. Starting at the left on the top row, the first fuse is for the console cooling fans. The next two fuses are for the left and right plasma screens, respectively. On the second row, the first fuse is for the transformers. The second fuse is for the bridge control unit (BCU) plasma display, and the third fuse is for the combat information center (CIC) plasma display. On the third row, the first fuse

is for the console indicators and relays. The next two fuses are spares.



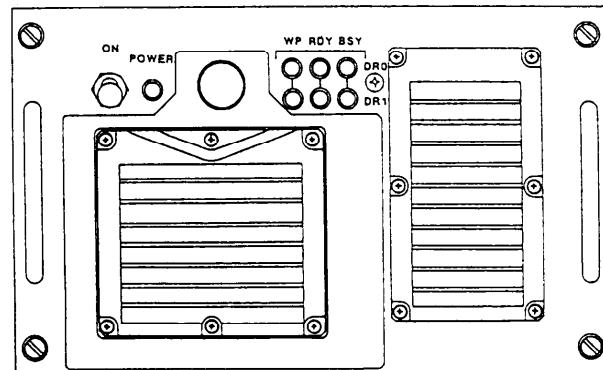
### Bubble Memory Section

The bubble memory system stores digital data, like a floppy or hard disk of a personal computer. In the DDG-51 MCS, the data is the computer program that operates the console. When the console is powered up, the computer automatically loads the program from the bubble memory cartridges. (This "bootstrap" function of the computer is equivalent to a personal computer's AUTOEXEC program.) A lot of computer data is stored magnetically—such as on floppy and hard disks. In the bubble memory, the data bits are stored as magnetic bubbles. Bubbles improve reliability because they are moved, stored, read, or written electrically; there are no mechanical, moving parts. The bubbles do not have to move past a read/write head, as opposed to the floppy or hard disk. The main advantage of the bubble memory is its resistance to electromagnetic interference.

The bubble memory cassettes store a unique program for each of the AN/UYK-44 computers. The cassettes are loaded from the AN/USH-26 magnetic tape unit in the EOOW/LU using the AN/UYK-44 input/output controller, the bubble memory drive, and the work station plasma display and keyboard in the EOOW/LU.

The bubble memory is contained in an enclosure of welded aluminum alloy. The major items of the unit are two 256K-byte (256 thousand) memory cassettes, interface and control circuit card assemblies, and a dc power supply. These units (not shown) are enclosed behind the access doors in the front of the panel. The front panel has a power on/off switch and seven LED indicators. The power on/off switch is a two-position toggle switch (normally on) that controls power to the bubble memory drive. The first LED, labeled POWER, illuminates green to show power is turned on to the bubble memory drive. The top row of three LEDs, labeled DRO (at the right), are for memory drive No. 0. The first LED in the top row, under the label WP,

illuminates red to show the write protect function is operating. The second LED, under the label RDY, illuminates yellow to show main power has been applied to the cassette drive and it is ready to read/write. The third LED, under the label BSY, illuminates yellow to show data is being transferred. The second row of three LEDs are for memory drive No. 1 (DR1) and are identical to the first row.



### AN/USH-26 Section

Figure 7-3 shows the AN/USH-26 with the door removed for clarity. It is a data cartridge magnetic tape storage and data transfer device. It is used with the AN/UYK-44 computer in the EOOW/LU for loading bubble memory cassettes and for logging data associated with the DDG-51 machinery. It operates under the control of the AN/UYK-44 and, during normal on-line operation, requires minimal operator interface. The tape unit contains two tape drive assemblies, a card cage assembly, power supplies, a maintenance panel, and front panel controls and indicators.

The two tape drive assemblies, labeled DRIVE 0 and 1, respectively, are identical and have identical controls and indicators. Each tape drive has an alarm indicator, a two-position toggle switch, a rotary switch, and four LEDs. We will describe only the controls and indicators for drive 0.

Starting at the top left of the tape drive assembly is the alarm indicator, labeled HOT. It is an incandescent bulb with a red cover lens. When the bulb is illuminated, it shows the tape drive assembly temperature > 165°F. It will also illuminate when the ALARM/ENABLE/TEST switch (described later), located at the lower right of the control panel, is set to the TEST position.

Below the alarm indicator is the two-position toggle switch, labeled ON LINE/OFF LINE. It

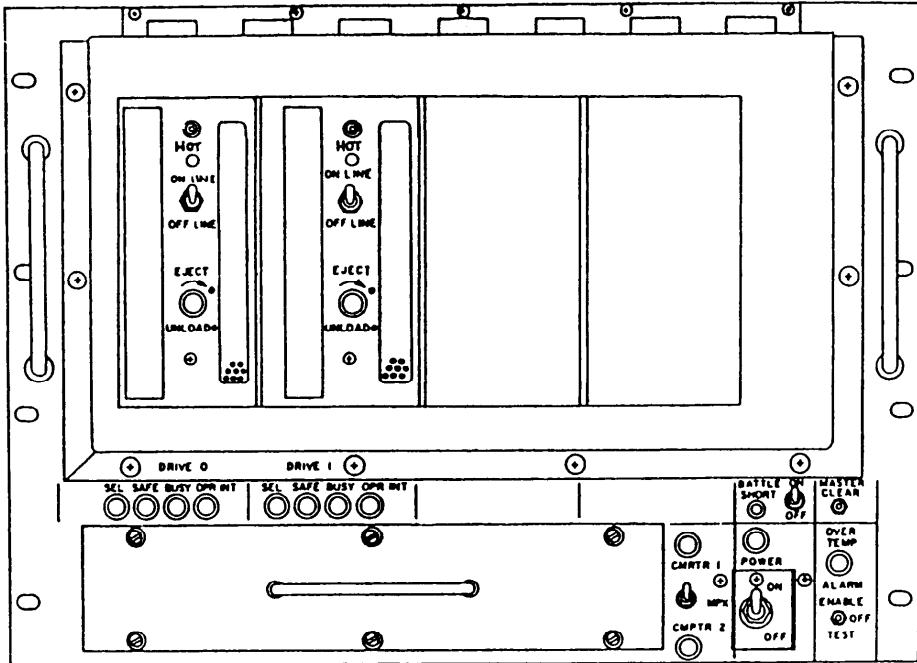


Figure 7-3.—AN/USH-26 front panel controls and indicators (door removed).

is used to place the tape drive in the operational (on line) or non-operational (off line) condition. Below this toggle switch is a rotary switch labeled EJECT/UNLOAD. The rotary switch is used by the operator to unload or mechanically eject the tape cartridge from the tape drive assembly.

At the bottom of each tape drive assembly is a horizontal row of four LEDs. The first LED at the left, labeled SEL, has a clear lens and illuminates to show the respective tape drive has been selected. The second LED, labeled SAFE, illuminates to show the respective tape drive is file protected (cannot be written over). The third LED, labeled BUSY, illuminates to show the respective tape drive is performing a motion command. The last LED, labeled OPR INT, illuminates to show that some form of operator intervention is required for the respective tape drive.

Located towards the bottom right corner of the unit, and mounted vertically, is a three-position toggle switch and two LEDs. The toggle switch positions are labeled CMPTR1 /MPX/ CMPTR2. When the toggle switch is in the CMPTR1 position, the top LED illuminates to show the AN/USH-26(V) is operating with computer 1. In the MPX position, the AN/USH-26(V) is operating with computer 1 or computer 2, or with both computers 1 and 2 (multiplex). In the CMPTR2 position, the bottom LED

illuminates to show the AN/USH-26(V) is operating with computer 2.

To the extreme right of the four LEDs for drive No. 1 is an LED, labeled BATTLE SHORT, and a two-position toggle switch, labeled ON/OFF. When the toggle switch is in the ON position, the overtemperature shutdown is disabled and the LED illuminates red. When the toggle switch is in the OFF position, the overtemperature shutdown is enabled. To the right of the BATTLE SHORT toggle switch is a two-position return-to-neutral toggle switch, labeled MASTER CLEAR. When activated to either position, it resets the AN/USH-26(V) electronics.

Below the LED labeled BATTLE SHORT is an LED labeled POWER and a two-position toggle switch labeled ON/OFF. When set to the ON position, it enables primary power to the AN/USH-26(V) and the LED labeled POWER illuminates. In the OFF position, primary power to the AN/USH-26(V) is disabled.

To the right of the POWER toggle switch and LED is the last LED and a three-position toggle switch. The LED is labeled OVERTEMP and illuminates red when the ambient temperature within the AN/USH-26(V) > 140°F. The three-position toggle switch is labeled ALARM ENABLE/OFF/TEST. When set to the ENABLE position, the audible alarms are enabled. In the OFF position, the audible alarms are disabled.

When set to the TEST position, the audible alarms sound and all the LEDs labeled HOT and OVERTEMP illuminate.

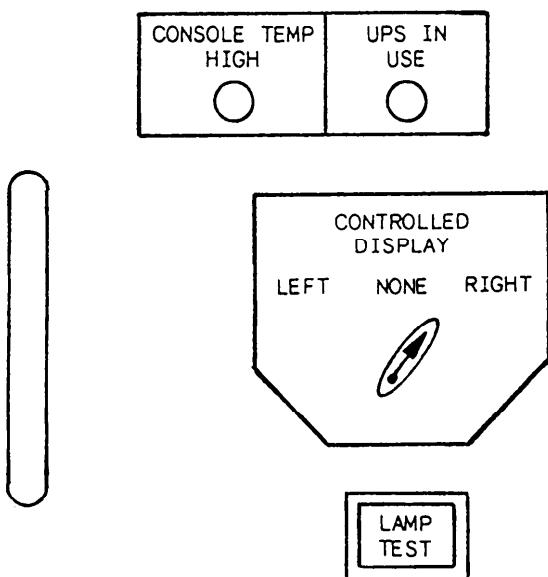
## PANEL ASSEMBLY A2

The A2 panel is used by the EOOW to monitor selected parameters of the engineering plant. There are basically three sections on this panel; the console section, which has two LEDs, a three-position rotary select switch, and a momentary-contact push button; the plasma display section, which has two plasma displays; and the printer section, which has a thermal printer and its controls and indicators.

### Console Section

The two LEDs are mounted at the top and to the left of the left plasma display. The first LED is labeled CONSOLE TEMP HIGH. It illuminates red to show an overtemperature condition exists in either of the console power supplies. The second LED is labeled UPS IN USE. It illuminates to show the console is operating on battery power.

Below the two LEDs is the three-position rotary switch labeled CONTROLLED DISPLAY. The three positions of this switch are labeled LEFT, NONE, and RIGHT. This switch is used to connect the plasma display keyboard to the left, right, or neither plasma display. Beneath the CONTROLLED DISPLAY rotary switch is the momentary-contact push button labeled LAMP TEST. When depressed, it performs an operational test of the two LEDs labeled CONSOLE TEMP HIGH and UPS IN USE.



## Plasma Display Section

The plasma display provides the operator with machinery status and alarm information required to control and monitor the propulsion machinery. This section contains two plasma displays, which use the keyboard, located on the keyboard control section, to request various displays. At any one time, only one of the plasma displays functions as a controllable display. The plasma display provides operator information in two display modes called status/alarm and summary. In addition, up to nine lines of analog status information may be displayed on the lower portion of the display. The display is driven by the AN/UYK-44 computer over a 16-bit parallel data channel. The operator controls the data presented on the controllable display by typing commands into a keyboard that is switchable between the plasma displays.

### Printer Section

The bell logging function for the MCS is implemented by a medium-speed, microcomputer-controlled thermal printer that mounts to the front of the EOOW/LU. The printer accepts ASCII-coded character data from the AN/UYK-44 computer and prints the characters in a 40-column format at a rate of 160 lines per minute. The characters print out on 4 1/4-inch wide heat sensitive paper. The printer forms each character by printing predetermined dots within a 7 by 9 dot matrix.

The logger prints bell commands as well as changes in the propulsion system status. The bell log printout is initiated when any of the following events occur:

- A change in control station for either shaft
- A change in bridge order mode
- When the BCU is in the rpm/pitch ordering mode and there is a change in an ordered shaft speed or ordered propeller pitch
- When the BCU is in the maneuvering bells mode and the BCU programmed control lever is moved to a new order band

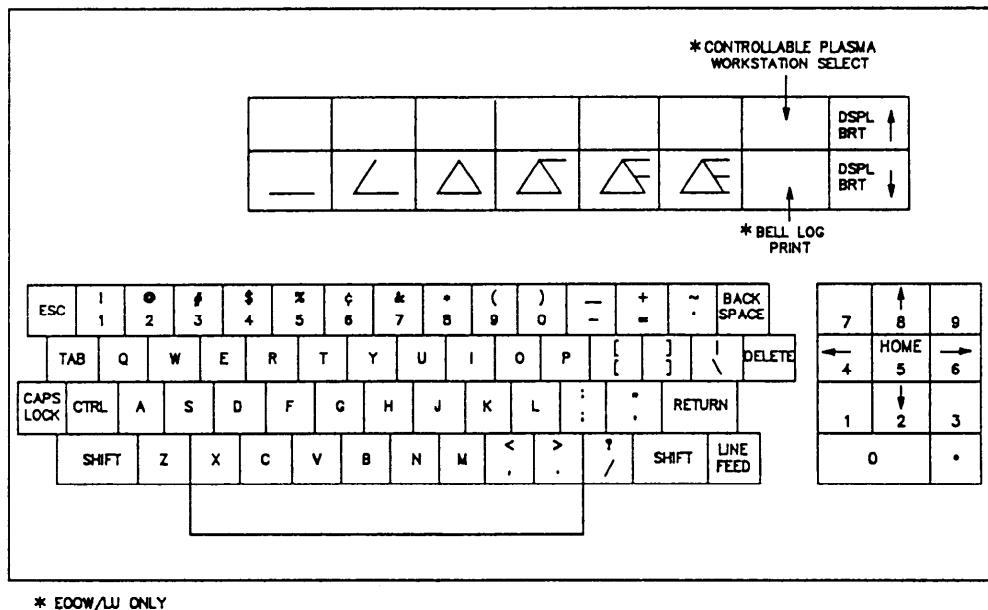


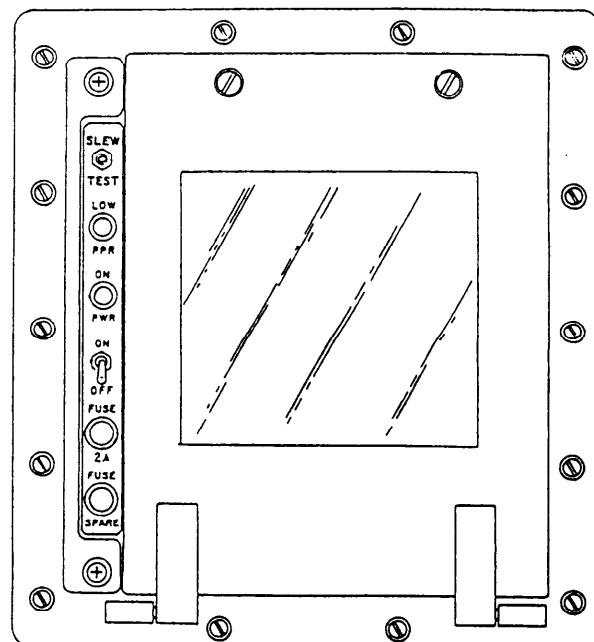
Figure 7-4.—Plasma display keyboard.

- Automatically every hour on the hour
- When the BELL LOGGER PRINT push button on the PACC or BCU or the special function key on the EOOW/LU keyboard is depressed

Mounted vertically down the left side of the printer are two toggle switches, two LEDs, and two fuse holders. The first toggle switch, labeled SLEW/TEST, is a three-position return-to-center type. When placed in the SLEW position, it causes the paper to advance through the printer. In the TEST position, the printer will print a repetitive test pattern. Each pattern is a full character set of the printer. The LED indicator below this toggle switch is labeled LOW PPR. It illuminates green to show that less than 15 feet of paper remain on the supply roll.

Below the LOW PPR indicator is another LED labeled PWR ON. This LED works with the two-position ON/OFF toggle switch located directly below it. When the switch is in the ON position, the LED illuminates green to indicate power is available at the printer. In the OFF position, power is secured to the printer and the LED is not illuminated. The two fuse holders are labeled 2A FUSE and SPARE. The first fuse holder contains the 2-amp fuse that provides overcurrent protection for the printer power

supply circuits. The other fuse holder has a spare 2-amp fuse for repairs.



#### KEYBOARD CONTROL SECTION

The operator at the EOOW/LU uses this section to input commands to the plasma display assemblies. The keyboard assembly (fig. 7-4)

consists of a standard keyboard with 16 function keys and arrow and home keys imbedded in a numerical keypad. We will describe the function keys, standard keyboard, and the arrow/home keys from left to right and top to bottom.

## Function Keys

These keys are arranged in two rows of eight keys each across the top of the keyboard. The first six keys across the top row are not used. The seventh key is labeled CONTROLLABLE PLASMA WORKSTATION SELECT. When depressed, it switches the plasma display connected to the keyboard from controllable plasma display to work station plasma display or vice versa. The eighth key is labeled DISPL BRT $\uparrow$ . The operator uses this key to increase the brightness of the plasma display in fixed steps with each activation of the key.

The first six keys in the second row are used by the operator to enter damage control symbols in the manual entry and edit message. The seventh key is labeled BELL LOG PRINT. When depressed, it causes a bell log to be printed on the thermal printer. The eighth key in the second row is labeled DISPL BRT $\downarrow$ . The operator uses this key to decrease the brightness of the plasma display in fixed steps with each activation of the key.

## Standard Keys

Because most of the standard keys are self-explanatory, we will describe only the keys that have special functions. The first key on the top row, labeled ESC, is used to terminate a command function and return to the menu list. The third key, labeled 2, is used during alarm table modification to decrease alarm delays. For delays between 1 and 30 seconds, each activation of this key decreases the delay by 1 second. For delays between 30 seconds and 10 minutes, each activation of this key decreases the delay by 5 seconds. The ninth key, labeled 8, is used during alarm table modification to increase alarm delays. For delays between 1 and 30 seconds, each activation of this key increases the delay by 1 second. For delays between 30 seconds and 10 minutes, each activation of this key increases the delay by 5 seconds. The last key on the first row, labeled BACK SPACE, serves as an erase function by moving the cursor back one space with each activation when in the manual entry and edit mode.

The last key on the third row, labeled RETURN, is used by the operator interchangeably with the last key on the fourth row, labeled LINE FEED, to enter a manual entry message. The first key and the next-to-last key on the fourth row are both labeled SHIFT. While depressed, either key enables entry of the upper character on dual-character keys. It has no effect when used with the single-character keys.

## Arrow/Home Keys

Only four of these keys are used by the operator. They are used in conjunction with either of the SHIFT keys to perform the following functions:

- SHIFT  $\rightarrow_6$ .—Scrolls the plasma display one line at a time from the current display toward the most recent log entry.
- SHIFT  $\leftarrow_4$ .—Scrolls the plasma display one line at a time from the current display toward the oldest log entry.
- SHIFT  $\downarrow_2$ .—Advances from the present CURRENT STATUS LOG displayed to the next newest CURRENT STATUS LOG (advances in time).
- SHIFT  $\uparrow_8$ .—Advances from present the CURRENT STATUS LOG displayed to the next oldest CURRENT STATUS LOG (backwards in time).

The operator may also use the  $\downarrow_2$  and the  $\uparrow_8$  (without the SHIFT key) to perform the same time delay modifications of the 2 and 8 keys on the standard keyboard.

## PROPELLION AND AUXILIARY CONTROL CONSOLE

The PACC operates in conjunction with the SCU 1 (in MER 1) and the SCU 2 (in MER 2). The SCUs provide the local control for four GTEs that drive the port and starboard shafts, and they provide the interfaces with the auxiliary machinery plant. The PACC communicates with the SCUs and with other consoles in the MCS over the ship's data multiplexing system (DMS).

The majority of panels and controls are identical on the PACC and the SCUs. The major difference in the two consoles is in the quantity

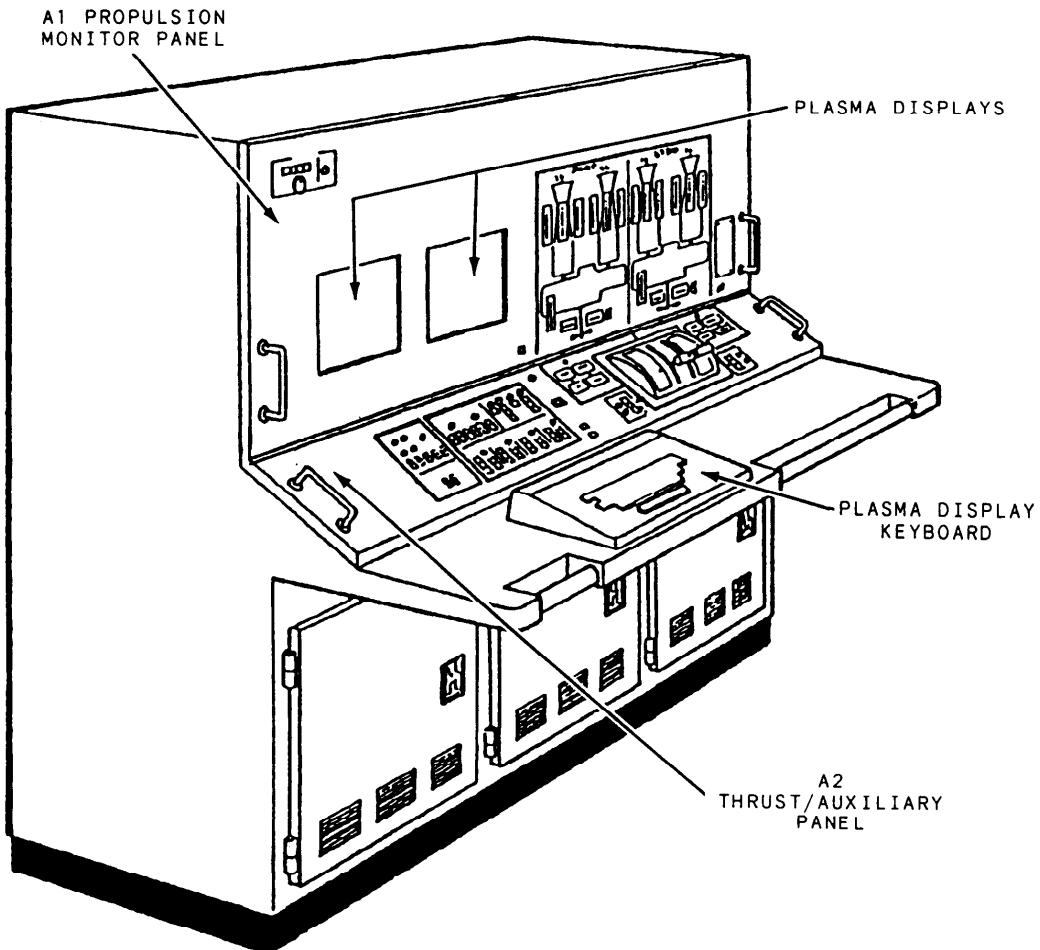


Figure 7-5.—PACC.

of equipment monitored. The PACC is designed to monitor four GTEs, two MRGs, and their associated auxiliary systems. The SCU is designed to monitor two GTEs, one MRG, and their associated auxiliary systems. Where the section being described on the PACC is identical to a section on the SCU, we will place an (\*SCU). Later in this chapter we describe the SCUs covering only the areas of the consoles that are different from those on the PACC.

The PACC provides for centralized control and monitoring of all propulsion engines, the reduction gears, the shafts, and the propellers. The PACC also provides control and monitoring for auxiliary machinery, such as air conditioning, chilled water cooling, potable water supply, and the firemains. The control of the propulsion engines and propulsion auxiliaries is normally at the PACC when the ship is underway. The PACC (fig. 7-5) on the DDG-51-class ship is divided into three panels (\*SCU), PROPULSION MONITOR PANEL (A1), THRUST/AUXILIARY

PANEL (A2), and PLASMA DISPLAY KEYBOARD PANEL (A3).

#### **PROPULSION MONITOR PANEL (A1)**

The operator uses this panel to monitor and control the propulsion GTEs, the MRGs, and their support systems. The panel is basically divided into three sections. For ease of description we will call them the CONSOLE, PLASMA DISPLAY, and PROPULSION sections.

##### **Console Section**

The operator uses the console section (\*SCU) to test the console audible alarms and to monitor the console power supplies. It has four momentary-contact push buttons, a rotary control switch, and two LEDs.

The four momentary-contact push buttons are located horizontally under the heading AUDIBLE ALARMS TEST and are labeled SIREN, HORN, BELL, and BUZZER, respectively. The operator

uses these push buttons to test the respective audible alarm. The rotary control switch is located directly below these audible alarm test push buttons. It is used by the operator to adjust the volume of the audible alarms.

The two LEDs are located to the right of the alarm test push buttons and are labeled TEMP HIGH and UPS IN USE, respectively. The TEMP HIGH indicator will illuminate amber to show power supply temperature is excessive. The UPS IN USE indicator will illuminate red to show the

console is operating on the emergency power source.

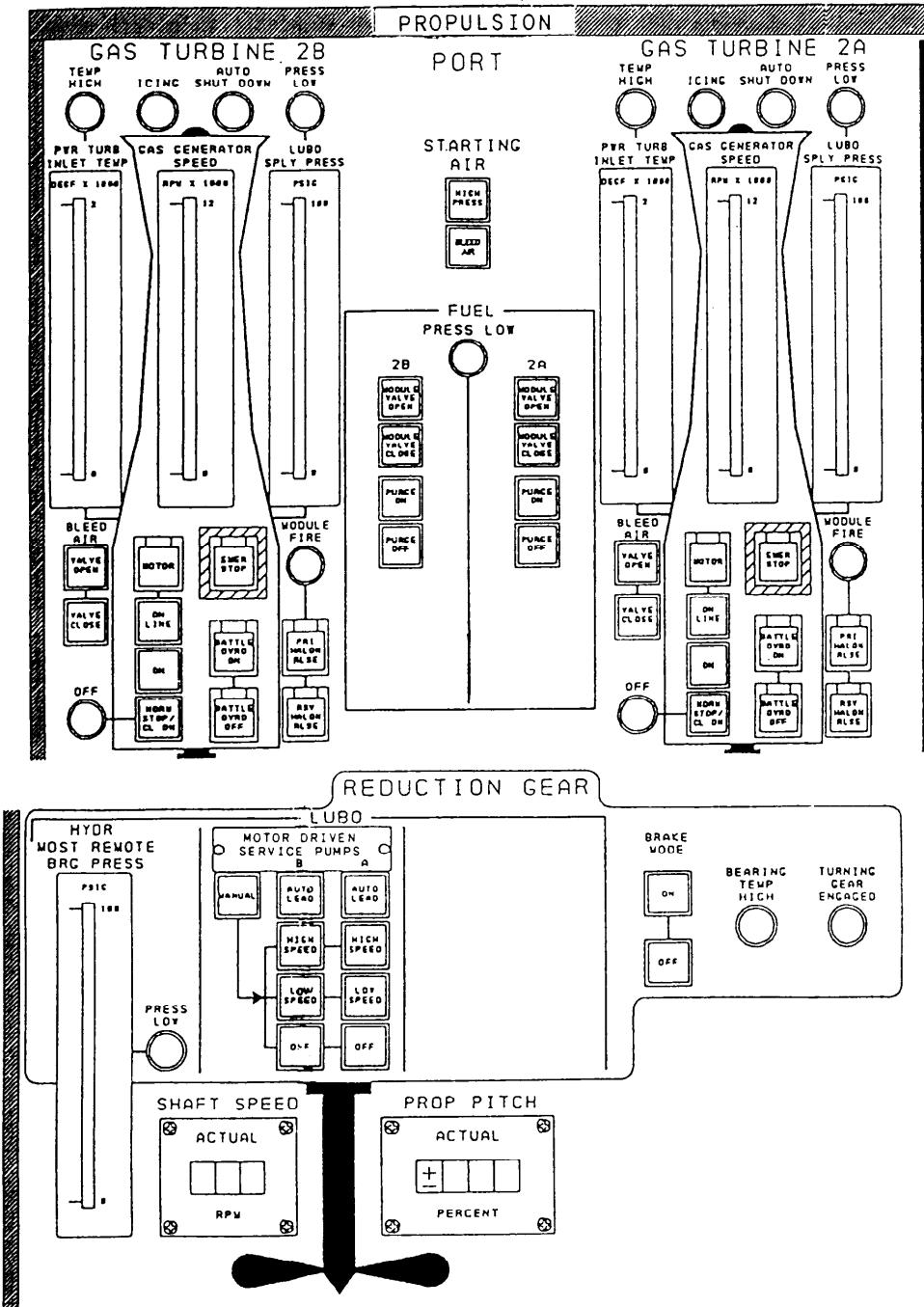
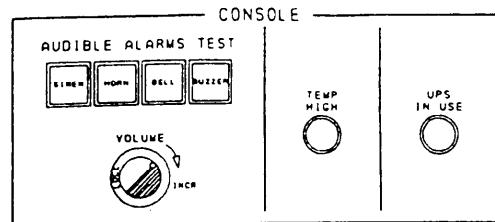


Figure 7-6.—A1 panel propulsion section.

## Plasma Display Section

The plasma display section contains two alphanumeric plasma displays. They display up-to-date system status in the form of status/alarm, summary groups, and demand displays. The plasma displays are identical to the units (discussed previously) on the EOOW/LU.

## Propulsion Section

The operator uses the propulsion section (fig. 7-6) for the actual monitor and control of the propulsion GTEs, the MRGs, and their support systems. Again, for ease of description, we will break the section down to four subsections called GAS TURBINE, STARTING AIR, FUEL OIL, and REDUCTION GEAR subsections.

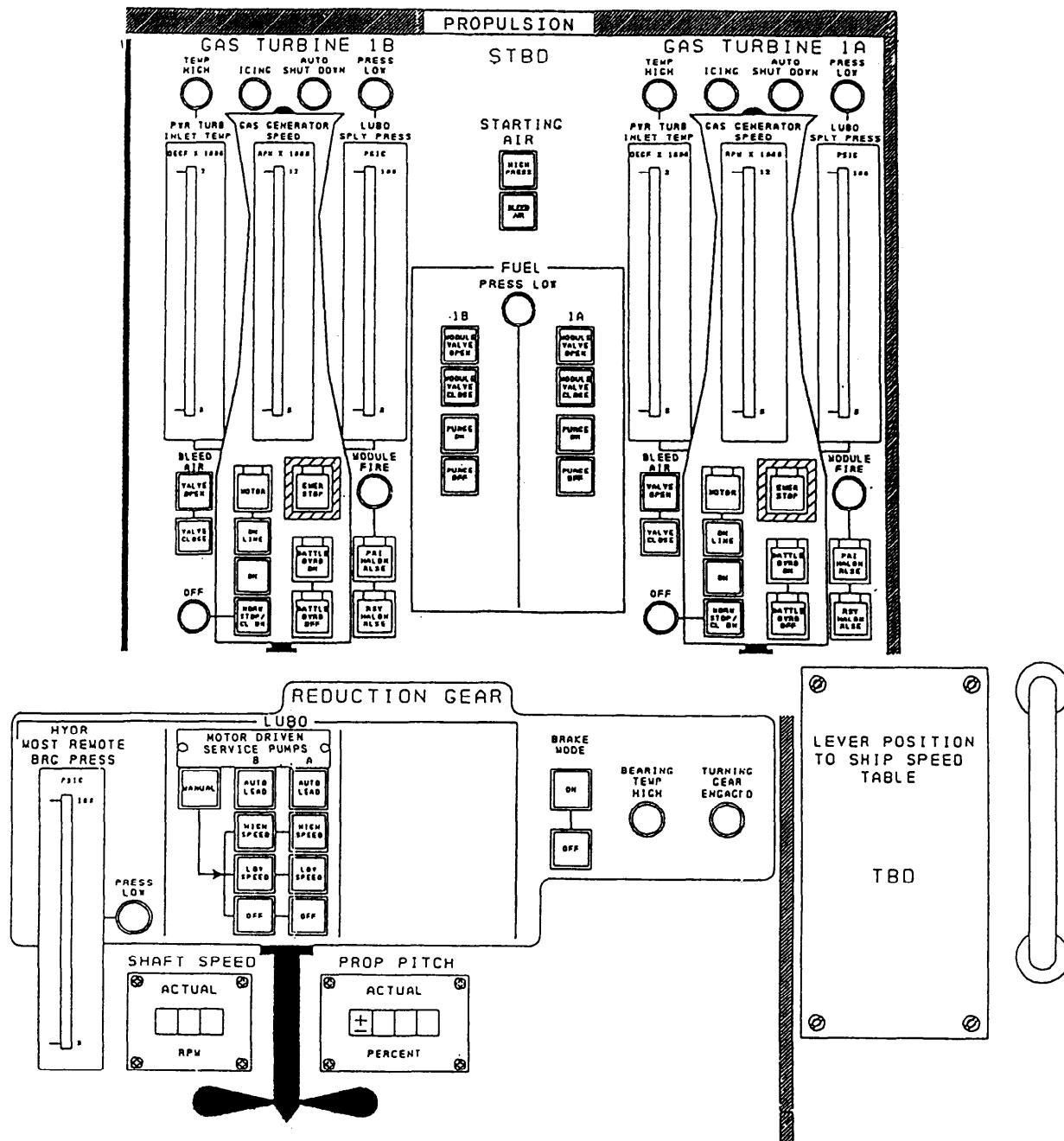


Figure 7-6.—A1 panel propulsion section—Continued.

**GAS TURBINE SUBSECTION.**—In this subsection we will describe only the controls and indicators for GTE 2B. The controls and indicators for GTE 2A, 1A, and 1B are a mirror image. There are 6 LEDs, 3 LED meters, and 11 push buttons for each GTE in this subsection.

Starting at the top left below the heading GAS TURBINE 2B is a horizontal row of four LEDs. The first LED, labeled TEMP HIGH, illuminates red to show  $T_{5.4}$  has exceeded the alarm set point. The second LED, labeled ICING, illuminates amber to show icing conditions exist at the gas turbine inlet. The third LED, labeled AUTO SHUT DOWN, illuminates red to show an automatic shutdown of the GTE has been initiated. The last LED, labeled PRESS LOW, illuminates red to show the GTE LO supply pressure has fallen below the alarm set point.

Located below the four LEDs are three LED meters. The meter to the left is labeled PWR TURB INLET TEMP. It illuminates to display the actual  $T_{5.4}$  in °F. This meter has a range of 0 to 2000. The center LED meter is labeled GAS GENERATOR SPEED. It has a range of 0 to 12,000 and illuminates to show the actual  $N_g$ . The last LED meter is labeled LUBO SPL<sup>Y</sup> PRESS. It has a range of 0 to 100 and illuminates to show the actual GTE LO supply pressure.

Mounted vertically below the  $T_{5.4}$  LED meter are two push buttons for the bleed air. They are labeled VALVE OPEN and VALVE CLOSE, respectively. These push buttons are used by the operator to open/close the GTE bleed air valve and will illuminate individually to show the valve status.

To the right of the two bleed air push buttons is a vertical row of four push buttons. The top push button is labeled MOTOR. When depressed by the operator, it illuminates amber and places the GTE in a motor state. The second push button, labeled ON LINE, illuminates green when depressed to bring the GTE to the on line state. The third push button, labeled ON, illuminates green to bring the GTE to the on state. The last push button in the row is labeled NORM STOP/CL DN. When depressed, it illuminates green to bring the GTE automatically to the cool down and then to the off state. To the left of this push button is an LED labeled OFF.

The LED illuminates green (after a 5-minute cool-down period) when the off state is reached.

To the right of the four vertical push buttons is a vertical row of three push buttons. The top push button, labeled EMER STOP, is a guarded-type push button used by the operator to emergency stop the GTE in the event of an unsafe condition. When depressed, it illuminates red and causes the GTE to go directly to off and bypass the cool-down period. Below the EMER STOP push button are two push buttons labeled BATTLE OVRD ON (illuminates amber) and BATTLE OVRD OFF (illuminates green). The operator uses these push buttons to activate or deactivate the battle override feature of the control electronics. When activated, battle override prevents all auto shutdowns (except overspeed) and speed limiting during critical operating conditions.

To the right of these three push buttons and below the LUBO SPL<sup>Y</sup> PRESS LED meter is an LED and two push buttons. The LED illuminates red to show a fire has been detected in the GTE module. The push button, labeled PRI HALON RLSE, is a red backlit guarded type. When depressed, it initiates the primary halon release sequence to the GTE module. It illuminates to indicate the sequence has started. During the release sequence, a PRI HALON ACTUATED message is displayed on the plasma display. Several seconds later, the PRI HALON RLSE indicator illuminates to indicate the Halon system has been pressurized. The push button, labeled RSV HALON RLSE, is a red backlit guarded type. When depressed, it initiates the secondary halon release sequence to the GTE module. It illuminates to indicate the sequence has started.

**STARTING AIR SUBSECTION.**—This subsection is used by the operator to select which system will be used to start the GTE. It has two push buttons. The top push button is labeled HIGH PRESS. When depressed, it illuminates amber to indicate the operator has selected HP air for the GTE start. The second push button is labeled BLEED AIR. When depressed, it illuminates green to indicate the operator has selected bleed air for the GTE start.

**FUEL OIL SUBSECTION.**—The operator uses this section to control the GTE FO valves.

It has one LED and four identical pairs of push buttons used to monitor/control the two fuel systems (1B and 1A). Each system has a vertical column of four push buttons. The LED is common to both systems. We will only describe the four push buttons for the 1B system.

At the top of this subsection is an LED, labeled PRESS LOW, which monitors both systems. It illuminates red to show a low fuel pressure condition exists on a running GTE. The first two push buttons are labeled MODULE VALVE OPEN (illuminates green) and MODULE VALVE CLOSE (illuminates amber), respectively. The operator uses these push buttons to open/close the module fuel valve, which permits or shuts off fuel flow to the module. When depressed, they will illuminate appropriately. The next two push buttons are labeled PURGE VALVE ON (illuminates amber) and PURGE VALVE OFF (illuminates green), respectively. The operator uses these push buttons to open/close the GTE fuel purge valve when purging the fuel system. When depressed, they will illuminate appropriately.

**REDUCTION GEAR SUBSECTION.**—This subsection has two mirror image MRG mimics. It is used to monitor the port and starboard MRGs. Each mimic has an LED meter, 4 LED indicators, 11 push buttons, and 2 digital indicators. We will describe only the port MRG mimic.

The LED meter, labeled HYDR MOST REMOTE BRG PRESS, is located on the left side of each mimic. It has a range of 0 to 100 psig and is used to indicate actual LO pressure at the MRG most remote bearing. Associated with this LED meter, and located to the right of it, is an LED labeled PRESS LOW. When illuminated, it indicates pressure at the most remote bearing is at or below the alarm set point. To the right of this LED indicator, under the heading MOTOR DRIVEN SERVICE PUMPS, are nine push-button indicators. They are used to control the LO pumps. The push button labeled MANUAL is common to both 1B and 1A LO systems. It is an amber backlit push button that, when depressed, allows the operator to have manual control of the LO pumps speed.

Eight of the push buttons (four for each system) are pairs that are identical as to function.

We will describe only the four push buttons for the 1B LO system pumps. The first push button, labeled AUTO LEAD, is a green backlit push button used to select pump 1B(1A) as the lead pump in automatic control mode. The second push button, labeled HIGH SPEED, is a green backlit push-button indicator the operator uses to place pump 1B(1A) in high speed (manual mode) and illuminates to indicate pump speed in the automatic mode. The third push button, labeled LOW SPEED, is a green backlit push-button indicator the operator uses to place pump 1B(1A) in low speed (manual mode) and illuminates to indicate pump speed in the automatic mode. The last push button for the LO pumps, labeled OFF, is a green backlit push-button indicator the operator uses to stop pump 1B(1A).

The last two of the 11 push buttons on the mimic are under the heading BRAKE MODE. They are labeled ON (illuminates amber) and OFF (illuminates green), respectively. These push buttons are used by the operator to control the PT brakes. When the push button labeled ON is depressed, it causes the GTEs to go to idle, PT brakes to engage (if NPT is below 2300 rpm), and propeller pitch to go to zero. Depressing the BRAKE MODE OFF push button when the brake mode is on causes the PT brakes to release, removes the idle speed and zero pitch command and allows these commands to return to the demand set on the programmed control lever.

To the right of these two push buttons are the last two LED indicators on the mimic. The first LED, labeled BEARING TEMP HIGH, illuminates red to indicate a reduction gear bearing temperature is at or above its alarm set point. The operator identifies the specific bearing causing the alarm on the plasma display. The LED, labeled TURNING GEAR ENGAGED, illuminates amber to show the turning gear is engaged.

The first of the two digital indicators is located below and to the left of the nine push buttons used to control the motor-driven LO pumps. It is under the heading SHAFT SPEED and labeled ACTUAL RPM. It has a range of 0 to 200 rpm and displays the actual shaft rpm. To the right of this indicator, under the heading PROP PITCH, is the second digital indicator. It is labeled ACTUAL PERCENT and indicates actual propeller pitch in percentage of maximum design for ahead (+) and astern (-) pitch.

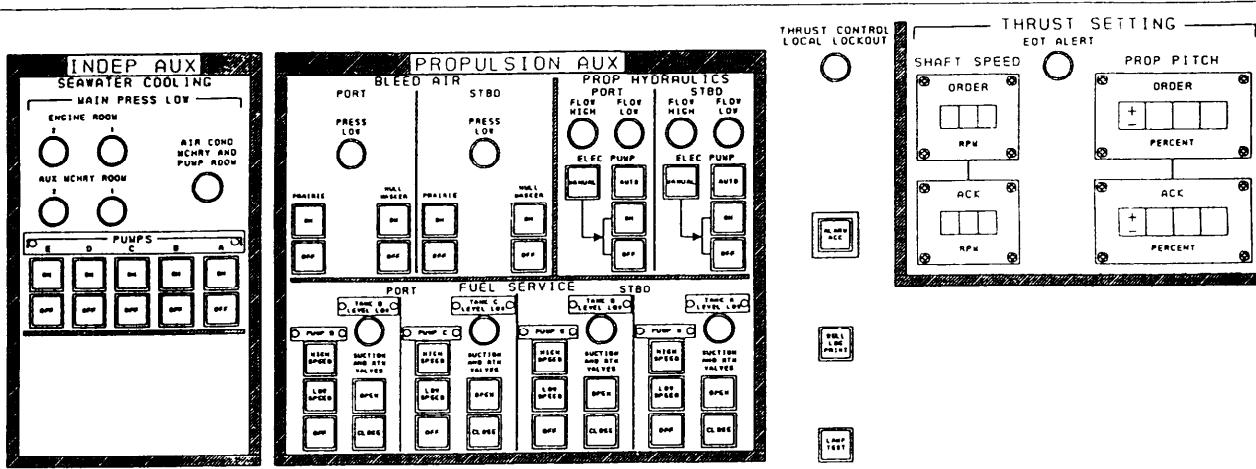


Figure 7-7.—A2 panel.

## THRUST/AUXILIARY PANEL (A2)

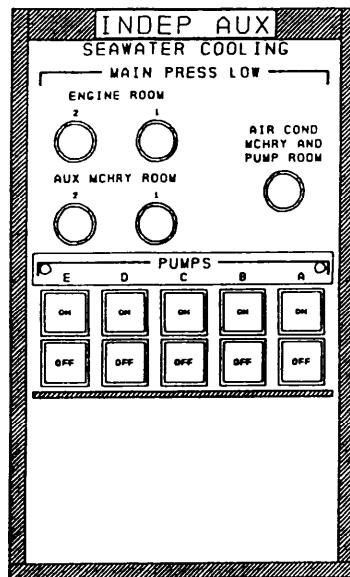
The operator uses this panel (fig. 7-7) to control and monitor auxiliary and propulsion auxiliary systems. For ease of explanation, we will divide the panel into sections and describe each section individually. These sections are the INDEPENDENT AUX, PROPULSION AUX, CONSOLE, THRUST SETTING, CONTROL LOCATION, and PROGRAMMED CONTROL LEVER.

### Independent Aux Section

This section is used to control and monitor the seawater cooling system. It has five LEDs and ten push buttons. The LEDs are used to alert the operator when the seawater cooling system pressure in a monitored space is at or below its alarm set point. The spaces monitored by these LEDs are engine rooms #1 and #2, auxiliary machinery rooms #1 and #2, and the air conditioning machinery and pump room.

The ten push buttons are five sets of identical pairs. Each push button of the pair is labeled ON or OFF, respectively. These push buttons are used to start or

stop the respective seawater cooling pump from the PACC. The pumps are labeled left to right #5, #4, #3, #2, and #1.



### Propulsion Auxiliaries Section

The operator uses this section of the panel to monitor and control the BLEED AIR (port and starboard), PROP HYDRAULICS (port and starboard), and FUEL SERVICE (port and starboard) systems.

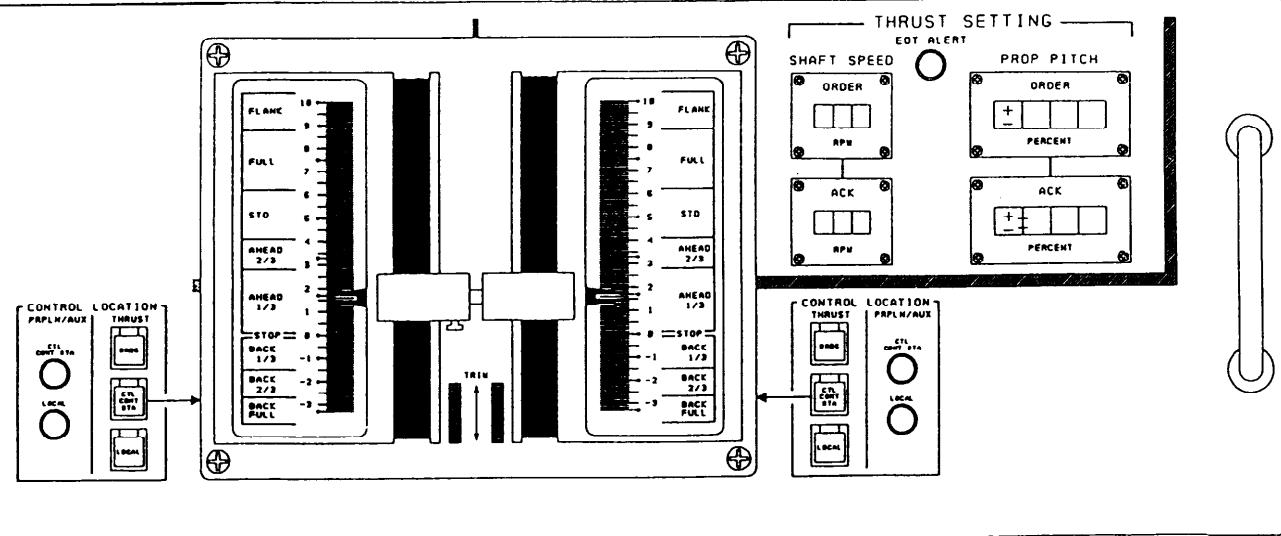
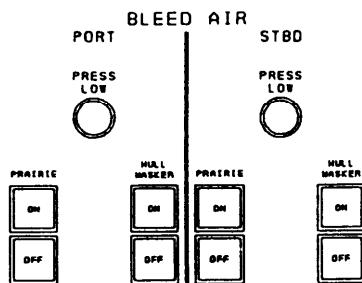


Figure 7-7.—A2 panel—Continued.

**BLEED AIR.**—Under the heading BLEED AIR, there is an LED indicator and four push buttons for each (port and starboard) bleed air system. The LEDs, labeled PRESS LOW, illuminate amber if the respective bleed air header pressure falls below its alarm set point. The first two push buttons are for the PRAIRIE AIR valve. They are labeled ON and OFF, respectively, and illuminate green to indicate the status of or operator's command to the valve. The last two push buttons are for the HULL MASKER valves. They are labeled ON and OFF, respectively, and illuminate green to indicate the status of or operator's command to the valve.

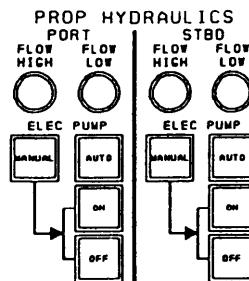


**PROP HYDRAULICS.**—Under the heading PROP HYDRAULICS, there are two LED indicators and four push buttons for each (port and starboard) propeller hydraulic system.

The two LEDs are located under the heading PORT(STBD). The first LED, labeled FLOW HIGH, illuminates amber when the respective propeller hydraulic oil flow rate is at or above the

preset alarm limit. The second LED is labeled FLOW LOW. It illuminates amber when the respective propeller hydraulic oil flow rate is at or below the preset alarm limit.

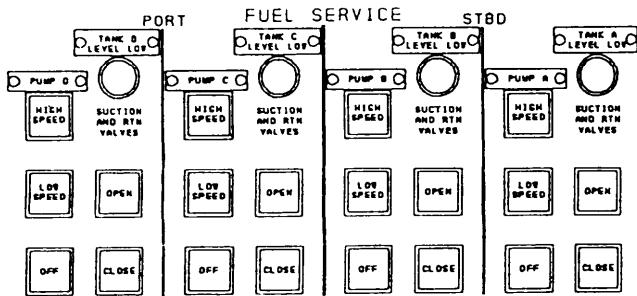
Mounted vertically and below the two LEDs are the four push buttons under the heading ELEC PUMP. The first push button is labeled MANUAL. When depressed, it illuminates amber to indicate the operator has manual control of the electric LO pump. The second push button is labeled AUTO. When depressed, it illuminates green to indicate the pump is in the automatic mode. The third push button is located under the AUTO push button and is labeled ON. It illuminates green to indicate the pump status or operator command to the pump. This push button is active in the MANUAL or AUTO control mode. The last push button is labeled OFF. It illuminates green to indicate the pump status or operator command to the pump. This push button is also active in the MANUAL or AUTO control mode.



**FUEL SERVICE.**—Under the heading FUEL SERVICE are the controls and indicators used by the operator to monitor the port and starboard fuel service system. It has an LED, three push buttons for pump control, and two push buttons for valve control for each of the four systems. The systems and pumps are labeled PORT (2-B and 2-A) and STBD (1-B and 1-A). As the controls and indicators for each system are identical, we will describe only the port 2-B system.

The LED is located under the heading TANK 2-B LEVEL LOW. It illuminates amber when the FO level in the service tank is below the alarm set point. The first three push buttons are located vertically under the heading PUMP 2-B. They are labeled HIGH SPEED, LOW SPEED, and OFF, respectively. Each push button illuminates green when the pump is in the state indicated either as a result of the automatic control feature or operator actuation.

The last two push buttons are located under the heading SUCTION AND RTN VALVES. They are labeled OPEN and CLOSE, respectively. These push buttons are used by the operator to open and close the FO service tank suction and return valves. When depressed, the push buttons illuminate green when both valves are in the position commanded (full open or full closed).



### Console Section

This section is located between the PROPULSION AUX section and the port THRUST SETTING section. It has three push buttons mounted vertically. The first push button, labeled ALARM ACK, is used by the operator to silence audible alarms, cause flashing alarm indicators for active alarms to go to a steady state, and plasma display alarm messages to change from unacknowledged to acknowledged state. The second push button, labeled BELL LOG PRINT is used by the PACC operator to obtain a bell log printout at the EOOW/LU. The last push button, labeled LAMP TEST, is used by the

PACC operator to test control panel indicators. When depressed, all indicators light, all LED meter segments light to indicate full scale, and digital displays will indicate all 8's.

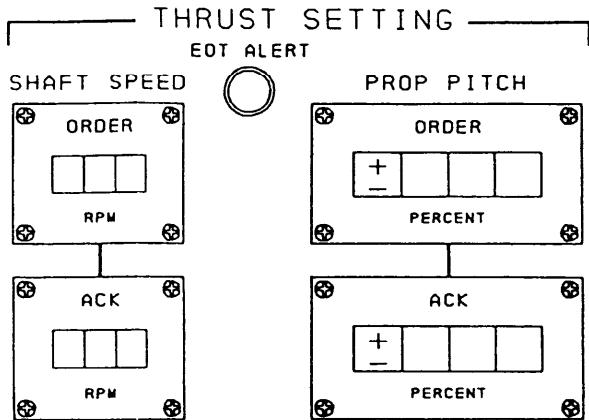


### Thrust Setting Section

There is a thrust setting section for each shaft (port and starboard). The sections are mirror image so we will describe only the port thrust setting section. These sections are located to the upper left and upper right side of the programmed control levers. Each section has an LED and four digital displays. The LED, under the heading EOT ALERT, illuminates amber to indicate a difference exists between the BCU port program control lever (order) setting and the PACC program lever (actual) setting. Two of the digital indicators are located under the heading SHAFT SPEED. The first indicator is labeled ORDER RPM. It is a three-digit display that indicates the port shaft speed (order) as determined by the setting of the BCU programmed control lever. The second indicator is labeled ACK RPM. It is a three-digit display that indicates the port shaft speed (actual) demand output as determined by the position of the PACC programmed control lever.

The other two digital indicators are located under the heading PROP PITCH. The first indicator is labeled ORDER PERCENT. It is a sign plus three-digit display that indicates the ordered port propeller pitch as determined by the setting of the BCU programmed control lever. The second indicator is labeled ACK PERCENT. It is a sign plus three-digit display that indicates the port propeller pitch (actual) demand output as

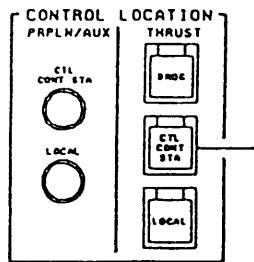
determined by the position of the PACC programmed control lever.



### Control Location Section

There is a control location section for each shaft (port and starboard). The sections are mirror image so we will describe only the port control location section. These sections are located to the lower left and lower right side, respectively, of the programmed control levers.

Each control location section has three LEDs and three push buttons. The first LED is labeled THRUST CONTROL LOCAL LOCK-OUT. It illuminates red when either SCU MODE SELECTOR (on the SCU) is in the LOCKOUT manual position. It indicates control is at the SCU. The other two LEDs are located under the heading PRPLN/AUX. The first LED, labeled CTL CONT STA, illuminates green to indicate control of the port propulsion unit and propulsion auxiliaries is at the PACC. The second LED, labeled LOCAL, illuminates green to indicate control of the port propulsion unit and propulsion auxiliaries is at SCU-2.

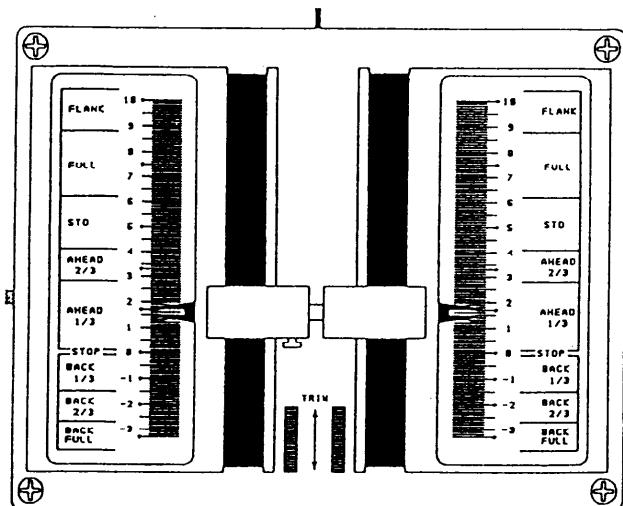


### Programmed Control Lever Section

The programmed control levers on the PACC provide power commands to the gas turbine

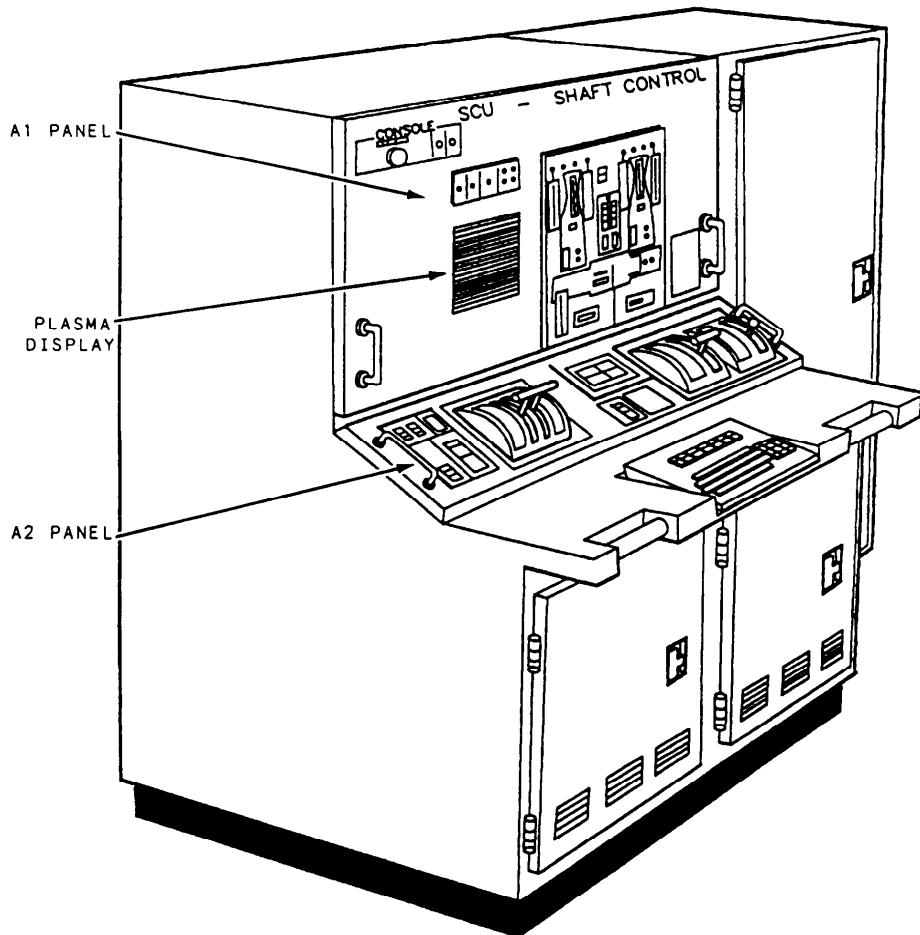
propulsion engines and propeller pitch commands through the DMS and the SCU. These commands from the control levers are synchro analog signals. The analog signals are then converted to digital data for transmission over the DMS network. The processor in the SCU outputs the digital commands to digital-to-analog converters in the input/output multiplexer. (The multiplexer is in the SCU.) The analog signals are then used to control the gas turbine propulsion engine speed, then the shaft rpm, and finally the propeller pitch.

This section has two control levers used to control speed of the GTEs and propeller pitch for each shaft. The left lever controls the port shaft, GTE 2B, and GTE 2A. The right lever controls the starboard shaft, GTE 1B, and GTE 1A. The movement of either lever results in engine speed and propeller pitch demand outputs to control ship speed. Linear scales alongside each lever are marked with a 10, corresponding with maximum speed ahead, a -3.3 with maximum speed astern, and 0 to zero thrust. The levers may be mechanically locked together for simultaneous control of both levers.



### PLASMA DISPLAY KEYBOARD PANEL (A3)

This panel is identical to the keyboard control panel on the EOOW/LU described previously. The keyboard is common to all the propulsion consoles in the MCS.



**Figure 7-8.—SCU.**

## SHAFT CONTROL UNIT

The SCUs (fig. 7-8) are operationally identical and only minor panel nomenclature makes them physically different. The SCU is divided into three panels: the propulsion monitor panel (A1), the thrust/auxiliary panel (A2), and the horizontal keyboard panel.

The descriptions provided in this section are applicable to both SCU 1 and SCU 2. Where the nomenclature is different, SCU 2 nomenclature will be indicated in parentheses. As in previous chapters, the description of the controls and indicators on the console panels will be covered from left to right, top to bottom.

There are two SCUs, one located in MER 1 and one located in MER 2. Each of these consoles interfaces with two LM2500 GTEs and their associated integrated electronic control (IEC) cabinets. The IEC cabinet performs basically the same functions as the FSEE on the other classes

of GTE-powered ships. The starboard shaft is driven by the GTEs in MER 1 and is controlled and monitored by the SCU 1. The port shaft is driven by the GTEs in MER 2 and is controlled and monitored by the SCU 2. Both SCUs monitor and control the propulsion plants for their respective shaft, including auxiliary systems such as bleed air, fuel service, propeller hydraulics, and LO. Control levers mounted on the SCU provide the thrust setting ability when GTE control is at the SCU.

## PROPELLSION MONITOR PANEL (A1)

The controls and indicators on this panel (fig. 7-9) are identical to the controls and indicators on the PACC propulsion monitor panel, with the exception being quantity. As previously stated, the PACC has the controls and indicators to monitor all four GTEs and both MRGs, while the SCU has the controls and

indicators to monitor only two GTEs and one MRG.

Other than the quantity of controls and indicators, the only major differences in the SCU and the PACC propulsion monitor panel is it has only one plasma display and the addition of a SUMMARY ALARMS section on the SCU. This section has nine LEDs, each of which monitors multiple systems. The first LED, labeled BLEED AIR, illuminates amber to indicate any one of the alarms related to the bleed air system has been activated. The second LED, labeled PROP HYDR, illuminates amber to indicate any one of the seven alarms related to the propeller hydraulics has been activated. The third LED, labeled REDUCTION GEAR AND SHAFTING, illuminates amber to indicate any one of 36 alarms related to the MRG and shafting has been activated. The fourth and fifth LEDs are mounted vertically and are for ENGINE ROOM 1(2). The top LED, labeled LUBO, illuminates amber to indicate an alarm related to the LO system in the engine room has been activated. The bottom LED, labeled FUEL OIL, illuminates amber to indicate any one of nine alarms related to the fuel system has been activated.

The last four LEDs are for the GAS TURBINE (two for each GTE in the engine room). They are grouped vertically in pairs for GTE 1B(2B) and GTE 1A(2A). We will describe only the two LEDs for GTE 1B(2B). The top LED, labeled VITAL, illuminates amber to indicate any one of 23 vital alarms related to GTE 1B(2B) has been activated. The bottom LED, labeled NON VITAL, illuminates amber to indicate any one of 19 non-vital alarms related to GTE 1B(2B) has been activated.

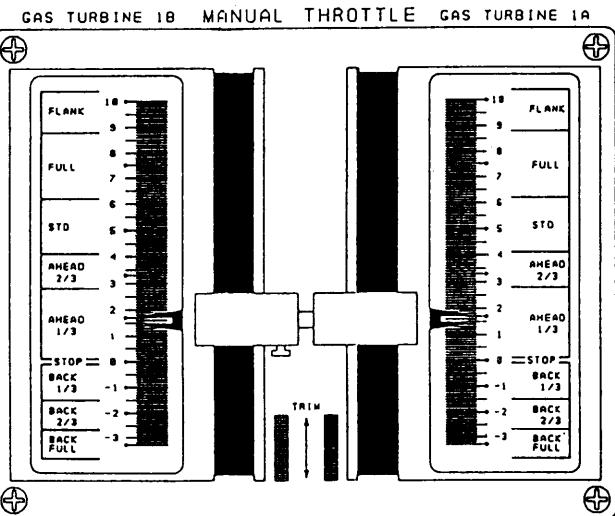
## THRUST AUXILIARY PANEL (A2)

This panel (fig. 7-10) has the identical controls and indicators found on the PACC thrust/auxiliary panel.

The major differences between the SCU panel and the PACC panel are as follows:

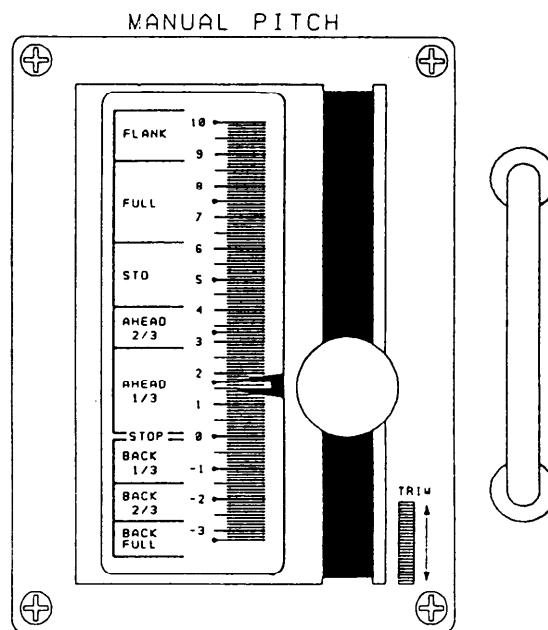
- Only one PROGRAMMED CONTROL lever for control of the GTEs and shaft for the applicable engine room
- The addition of two manual throttle control levers (located between the PROPULSION AUX and the THRUST

SETTING section) for individual control of the GTEs



- One pitch control lever (located to the right of the PROGRAMMED CONTROL lever) for manual control of propeller pitch
- A MODE select switch added to the CONTROL LOCATION section

The throttle control levers have been described on the PACC and will not be covered again. The pitch control lever is used when the SCU is in the manual mode to vary pitch from 0 to full ahead (+25 feet) or 0 to full astern (- 17 feet). It also has a vernier thumbwheel, labeled TRIM, which is used to make fine adjustments to the pitch setting.



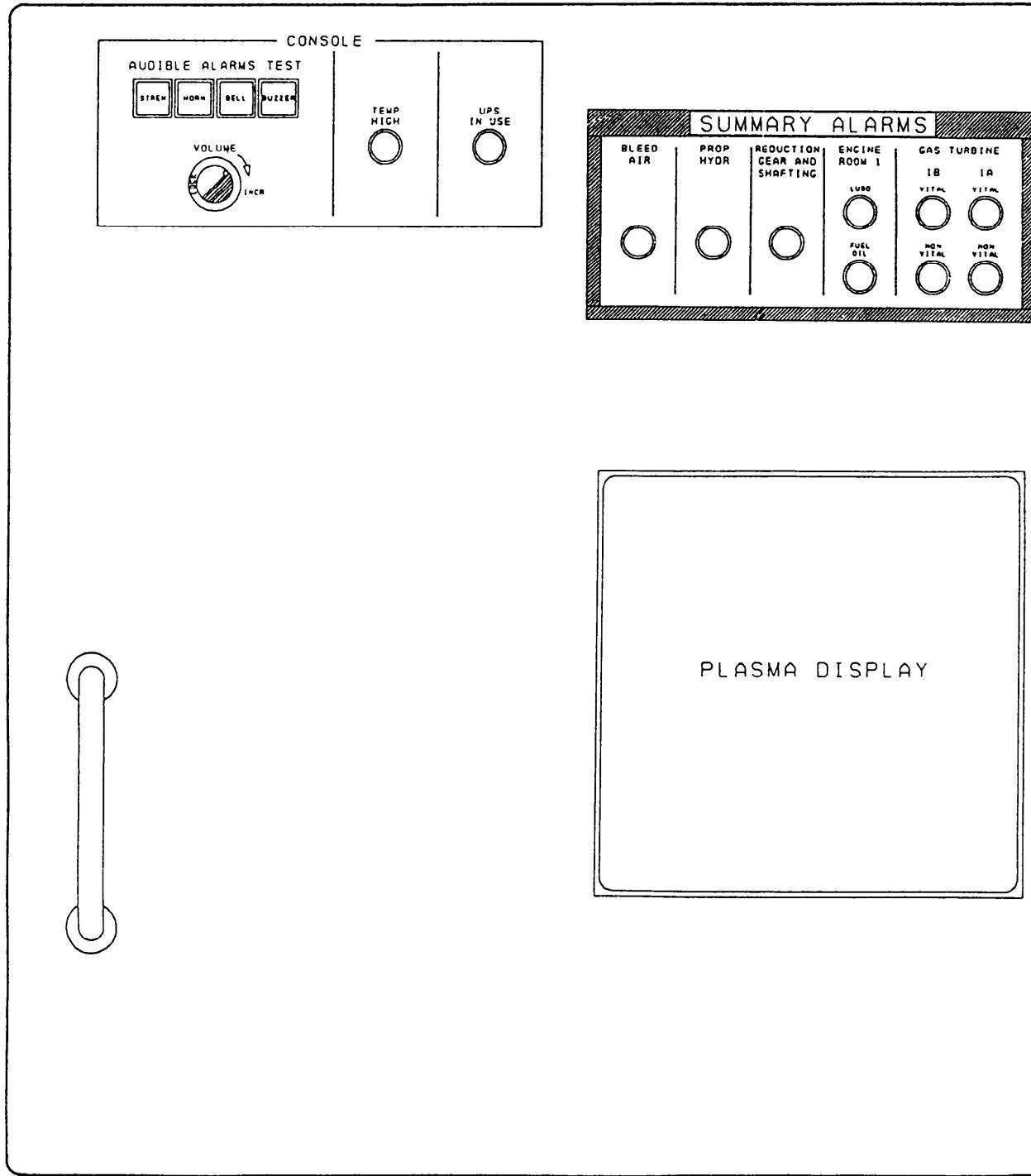


Figure 7-9.—SCU propulsion monitor panel.

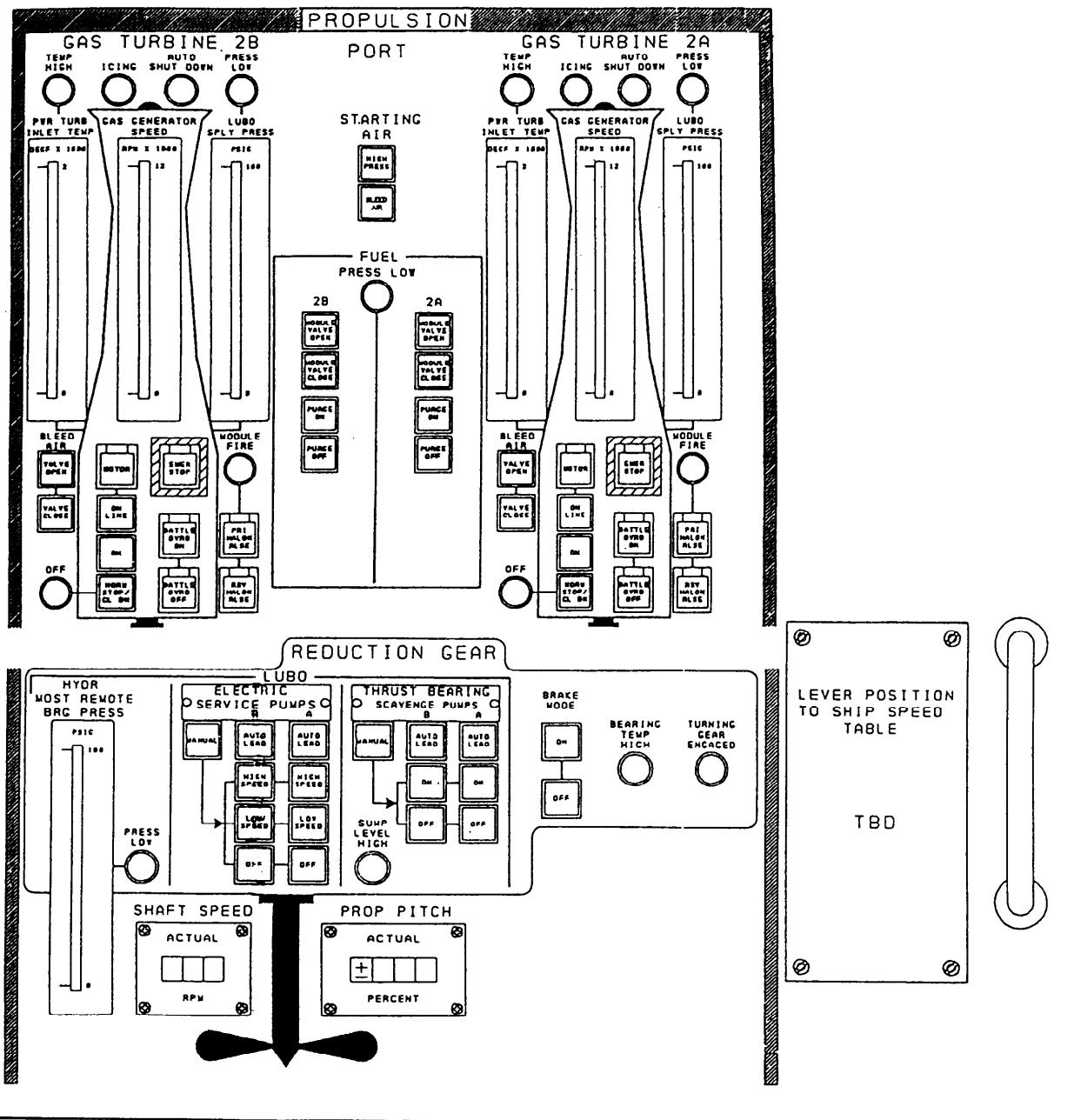


Figure 7-9.—SCU propulsion monitor panel—Continued.

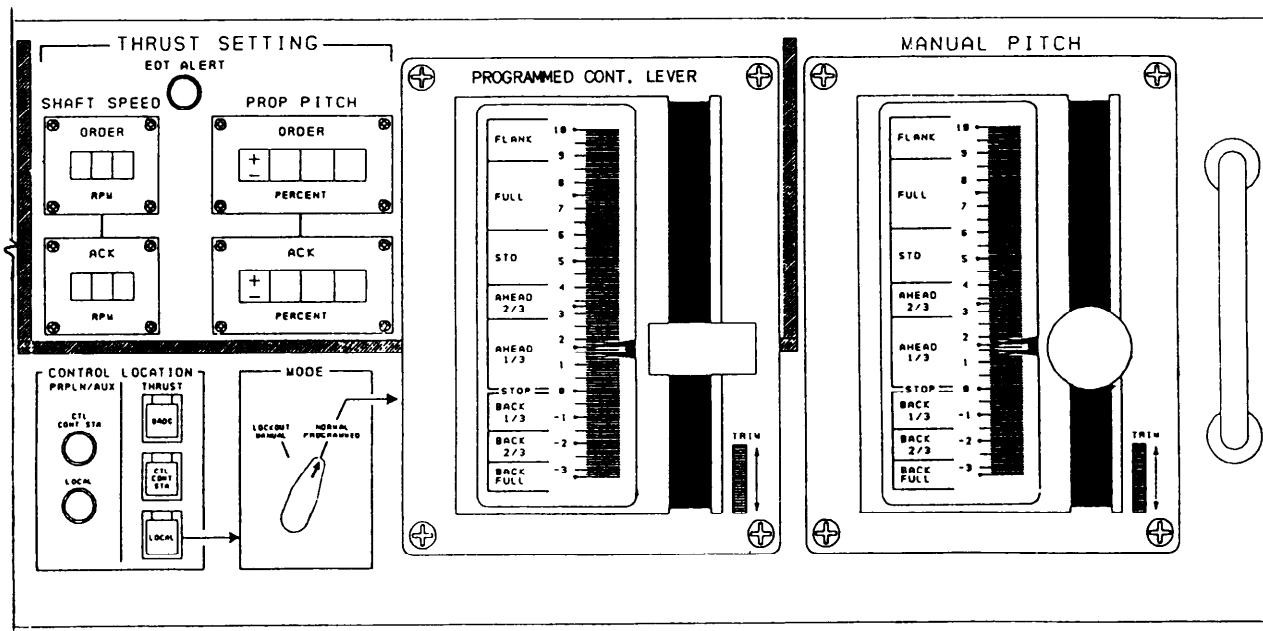
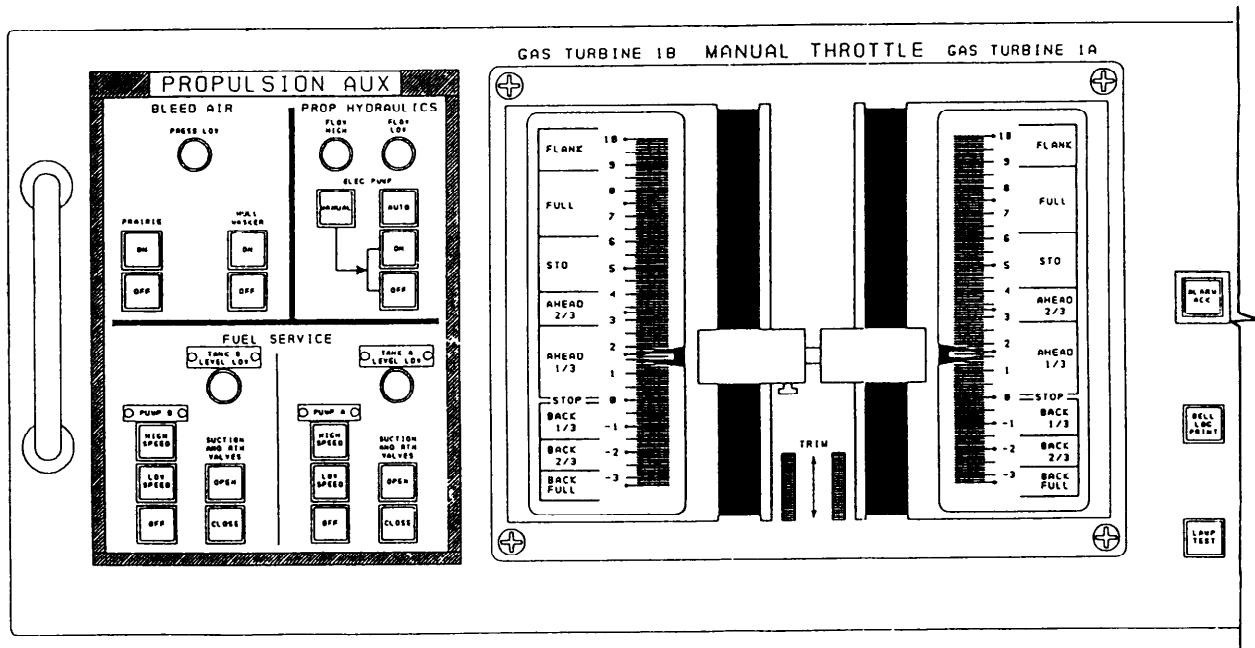
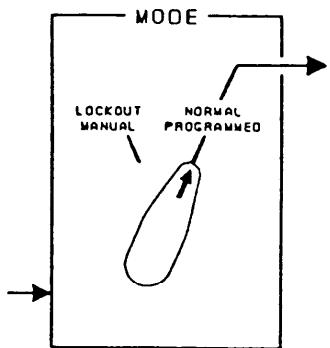


Figure 7-10.—SCU thrust/auxiliary panel.

The MODE select switch is located to the right of the LEDs and push buttons of the CONTROL LOCATION SECTION. It is a two-position rotary switch used to select either the LOCK-OUT MANUAL or NORMAL PROGRAMMED mode. The SCU operator uses this switch to place the GTEs and propeller pitch control in the programmed control mode after starting the GTEs.



### HORIZONTAL KEYBOARD PANEL

This panel is identical to the keyboard control panel on the EOOW/LU described

previously. The keyboard is common to all the propulsion consoles in the MCS.

### SUMMARY

This chapter was written to familiarize you with the consoles of the MCS of the Arleigh Burke-class ships, it is not enough information for operational or troubleshooting purposes. This material is provided to give you, a junior GS, enough knowledge to begin qualifying in your assigned watches, using the PQS applicable to the watch station you are learning.

The knowledge gained by reading this chapter should also give you enough information to assist a qualified technician in the repair of this important equipment. Only technical manuals can give you the in-depth procedures as to how to troubleshoot and repair the MCS equipment. Never try to work on this equipment without the proper manuals and supervision by a qualified technician.



# CHAPTER 8

## ELECTRICAL PLANT OPERATION

Each class of gas turbine powered ships has its own distinct EPCC. They are located in the CCS. The EPCC provides the capability of remote operation and monitoring of the electrical plant. In this chapter we will describe the EPCC for each class of gas turbine-powered ships.

The information in this chapter will help you know the location of the controls and indicators on the consoles. This will help you operate the consoles faster since you will know where to reach for the control switches. Also, when an indicator illuminates, you will know what it means. Studying this chapter will also help you qualify as an operator of the EPCC. However, the information in this chapter is for training purposes only. You should NEVER operate any console without following the EOSS procedures.

### ELECTRIC PLANT CONTROL CONSOLE (DD-CLASS SHIPS)

The EPCC on the DD-class ships contains the controls and indicators used to operate and monitor the ship's service power generators and distribution systems remotely. The control system on the DD-class ships is the EPCE (fig. 8-1). It consists of an EPCC and an electric plant control electronics enclosure (EPCEE). In this section we will discuss the EPCC. The EPCC is subdivided into four panels, and each panel is dedicated to a particular type of control and monitoring. The panels are the alarm/status panel, the generator status panel, the mimic panel, and the system control panel. We will discuss each panel of the console and point out the purpose or the function of each indicator, switch/indicator, or switch. We will also discuss the TOPS, load centers, and the different system configurations.

### ALARM/STATUS PANEL

The ALARM/STATUS panel is the upper left panel (fig. 8-2). It contains the alarm/status indicators, 60/400-Hz converter, emergency power, switchboard, main switchboard ground detection, load shedding, synchronizing indication, GTGs demand display, and alarm acknowledge sections.

### ALARM/STATUS Section

The ALARM/STATUS indicators section is divided into three subsections, one for each

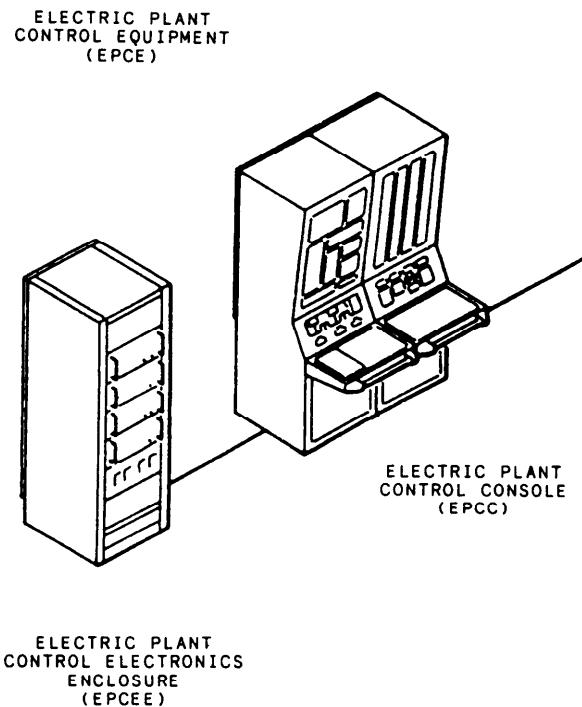


Figure 8-1.—EPCE (DD-class ships).

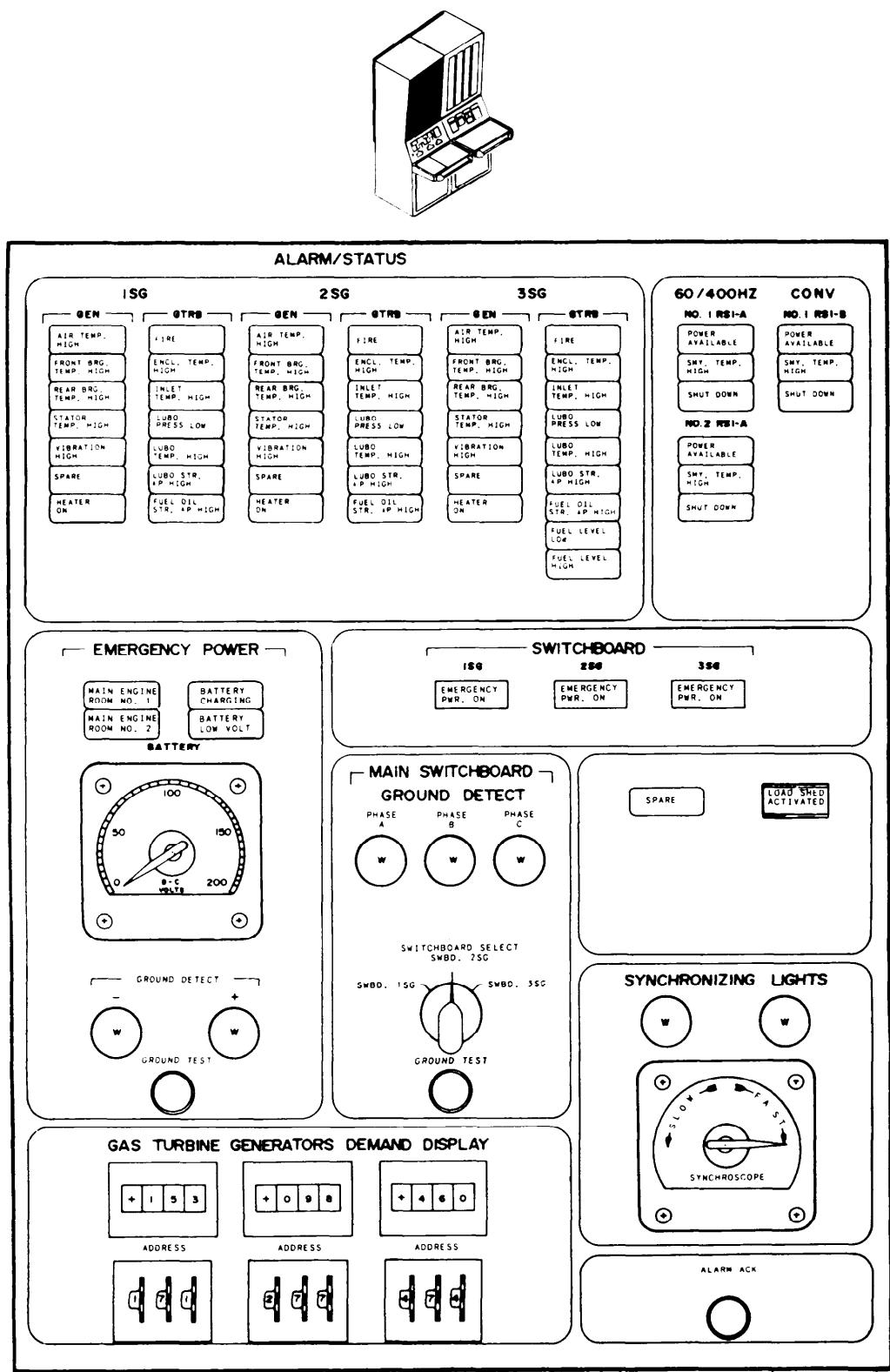
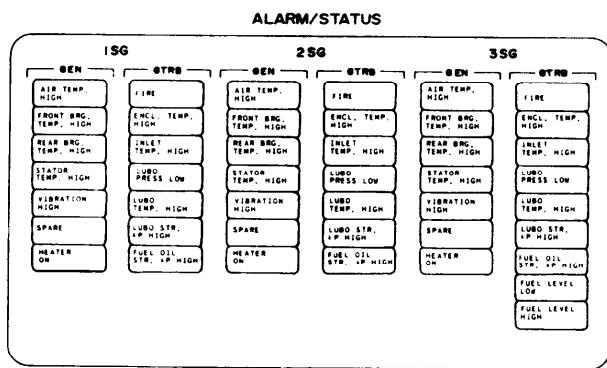


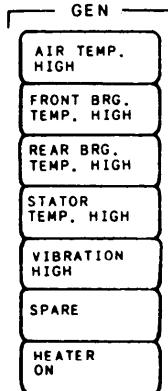
Figure 8-2.—ALARM/STATUS panel.

SSGTGS. All are the same except No. 3. It has two extra alarm indicators. We will discuss the alarms/indicators from the top to the bottom of the columns, the GEN column first and then the GTRB column.



**GENERATOR COLUMN.**—This column has the following alarm/indicators:

- AIR TEMP. HIGH indicates the temperature of the air exiting the generator is too high.
- FRONT BRG. TEMP. HIGH indicates the temperature sensed in the babbitt of the front bearing is above the set limit.
- REAR BRG. TEMP. HIGH indicates the temperature sensed in the babbitt of the rear bearing is above the set limit.
- STATOR TEMP. HIGH indicates the temperature in the generator stator windings have exceeded the preset limit.
- VIBRATION HIGH indicates the vibration on the GTE has exceeded the preset limit.



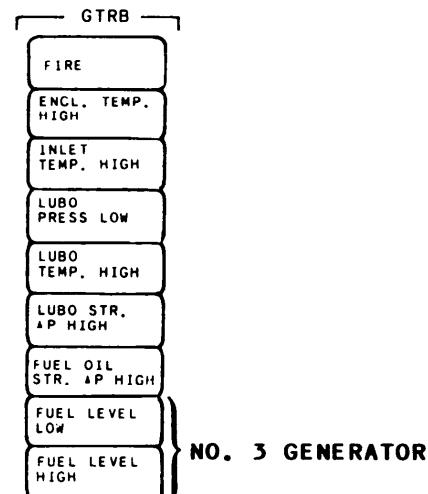
- SPARE indicator.
- HEATER ON indicates the heater in the generator enclosure is energized.

**GAS TURBINE AND REDUCTION GEARS COLUMN.**—This column has the following indicators:

- FIRE indicates that a fire is being sensed in the acoustical enclosure.
- ENCL. TEMP. HIGH indicates the temperature in the enclosure exceeds the preset limit.
- INLET TEMP. HIGH indicates the temperature of the gases going into the turbine section is above the set point.
- LUBO PRESS LOW indicates the lube oil pressure to the GTE or the reduction gear has dropped below the set limit.
- LUBO TEMP. HIGH indicates the temperature of the GTE lube oil is above the set point.
- LUBO STR. DP HIGH indicates the differential pressure on the GTE lube oil strainer is above the set point.
- FUEL OIL STR. DP HIGH indicates the differential pressure on the fuel oil strainer is above the set point.

The No. 3 generator has two more indicators directly below the indicators just described.

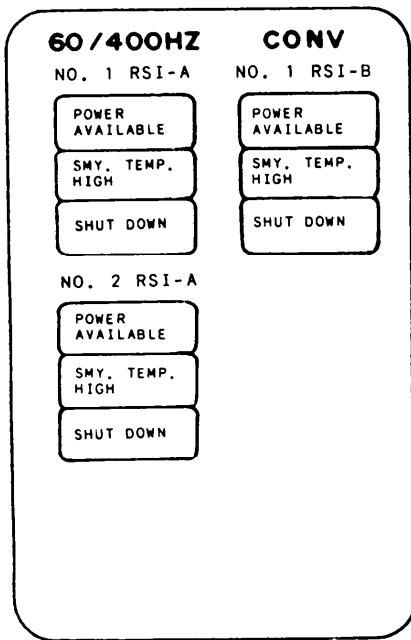
- FUEL LEVEL LOW indicates the fuel level in the tank has exceeded the low level limit.



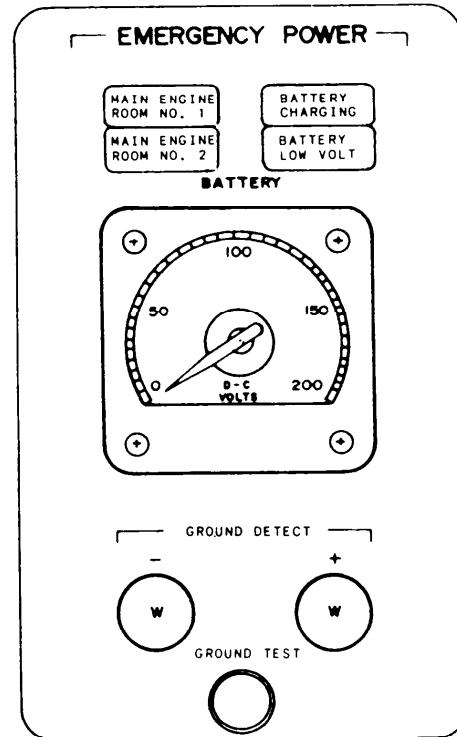
- FUEL LEVEL HIGH indicates the fuel level in the tank has exceeded the high level limit.

## 60/400HZ CONV Section

The ship has three 60/400-Hz converters. This section has a set of identical indicators for each converter. The top indicator is POWER AVAILABLE, which illuminates when the converter is online. The middle indicator is SMY. TEMP. HIGH, which illuminates when the temperature in the converter exceeds the preset limit. The bottom indicator is SHUT DOWN, which illuminates when the converter is or has been secured.



output by the UPS battery bank is below the preset limit. Below the indicators is the D-C VOLTS meter. It indicates the output voltage of the UPS battery bank. Located at the bottom is the GROUND DETECT section. It has two indicators that should be of equal brilliance. The left indicator is for the negative lead of the UPS circuitry. The right indicator is for the positive lead of the UPS circuitry. The GROUND TEST push-button switch is located below the indicators. When you depress the switch, a dimming or extinguishing of an indicator indicates a ground on that side of the circuitry.

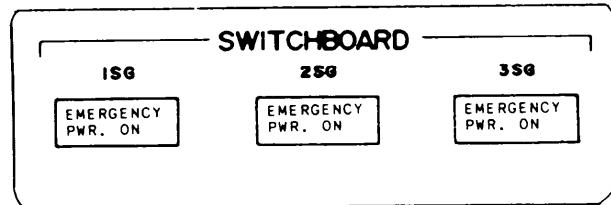


## EMERGENCY POWER Section

This section has four indicators, one meter, and two ground detect indicators with a switch. The top left indicator is labeled MAIN ENGINE ROOM NO. 1. It will illuminate when the ship control system in engine room No. 1 is operating on the UPS system. The bottom left indicator, MAIN ENGINE ROOM NO. 2, functions the same but is for the No. 2 engine room. The top right indicator is labeled BATTERY CHARGING. It will illuminate when the UPS battery bank is on charge. The bottom right indicator, BATTERY LOW VOLT, illuminates when the voltage

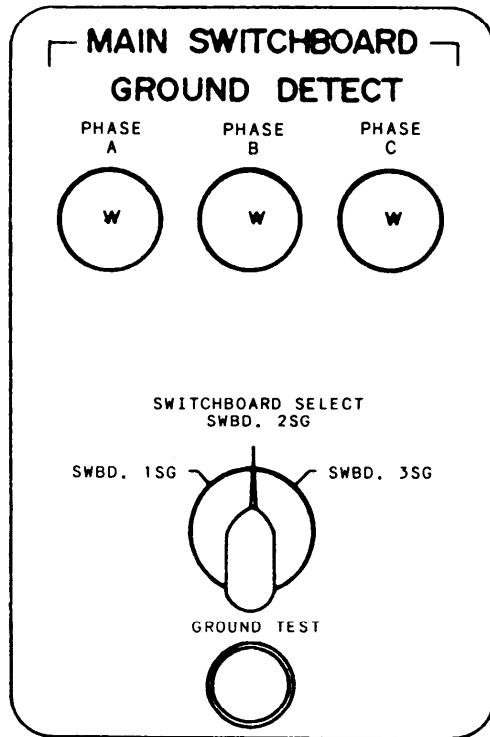
## SWITCHBOARD Section

This section has three indicators, one for each SWBD. Each indicator, EMERGENCY PWR. ON, will illuminate when its related SWBD's power supply fails. When this condition occurs, power is supplied to the SWBD by a set of its own 24-volt dc emergency batteries.



## MAIN SWITCHBOARD GROUND DETECT Section

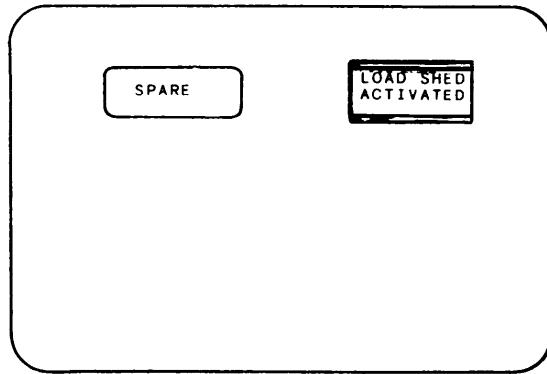
This section has three indicator lights across the top, PHASE A, PHASE B, and PHASE C. These indicators are normally of equal brilliancy. Below the indicator lights is the SWITCHBOARD SELECT rotary switch. It selects the SWBD that is being checked. At the bottom of the section is the GROUND TEST push-button switch. When it is depressed, it connects the selected SWBD to the indicator lights. A grounded condition is indicated by one of the lights going out and the other two lights glowing brighter. The light that goes out is the phase that is grounded.



## Load Shedding Switch/Indicator

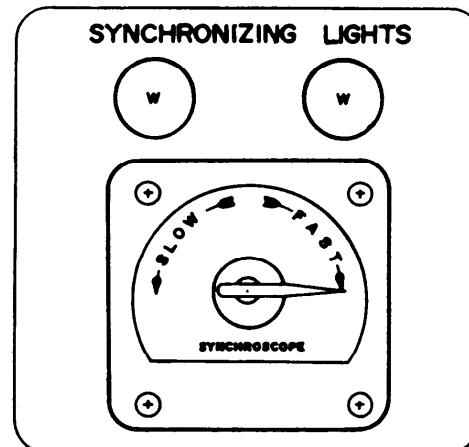
The LOAD SHED ACTIVATED switch/indicator, when depressed, will output a command to trip the load shedding breakers. The illumination of the indicator will result when the load shedding breakers are opened. This may be by the

operator or the ship's electric plant circuitry. A SPARE indicator is located to the left of the load shed activated switch/indicator.



## SYNCHRONIZING LIGHTS Section

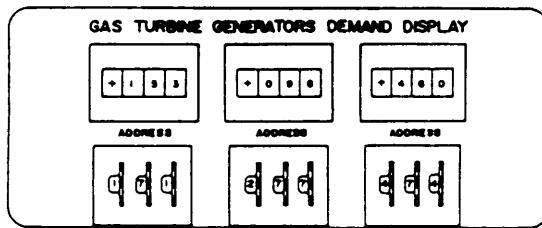
This section contains two indicator lights and a synchroscope meter. The SYNCHRONIZING LIGHTS will be dark when the generators are in phase. The brilliancy of the lights will vary according to differences in the phases. On the SYNCHROSCOPE, the direction of rotation of the synchroscope pointer indicates that the frequency of the on-coming generator is FAST or SLOW with respect to the on-line generator. The speed of rotation is an indication of the amount of difference in the frequency. When the pointer is at the 12 o'clock position, the generators are in phase with each other.



## GAS TURBINE GENERATORS DEMAND DISPLAY Section

This section contains three sets of displays and thumbwheel switches. The upper portion is the display and it will display the parameter

that is addressed by the thumbwheel switch just below it.



### Alarm Acknowledge

The ALARM ACK push-button switch, when depressed after an alarm has been received, will silence the audible alarm and change the flashing alarm indicator to a steady light. The following indicator lights will continue to flash even after the ALARM ACK switch has been depressed: EMERGENCY POWER for the SWBDs, BATTERY CHARGING, EMERGENCY POWER for ENG RM NO. 1 and ENG RM NO. 2 (located on this panel), and the EMERGENCY indicator in the POWER section located on the system control panel (discussed later in this DD-class ship section).



### GENERATOR STATUS PANEL

The GENERATOR STATUS panel is the upper right panel (fig. 8-3). It has three sections, one with meters and indicators for continuous monitoring of each generator, a shore power section, and a bus tie and SWBD section.

#### Generators Section

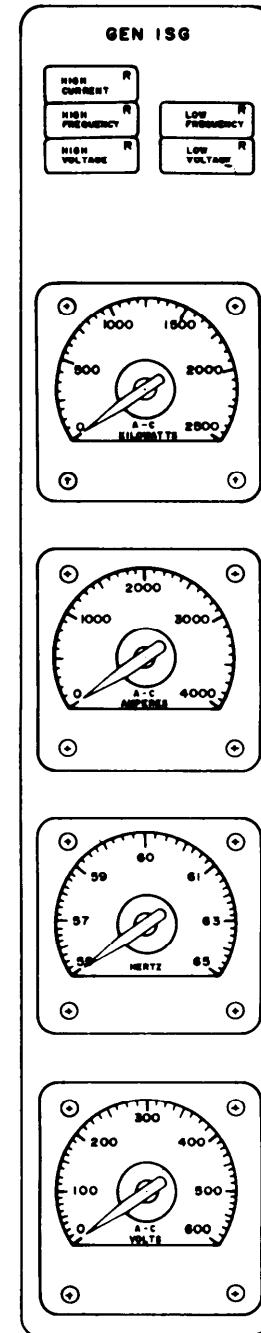
This section has three subsections, one for each generator. The subsections are labeled GEN 1SG, GEN 2SG, and GEN 3SG. Since all these subsections are identical, we will describe only one.

**ALARM INDICATORS.**—The alarms/indicators for the generator are as follows:

- HIGH CURRENT indicates the current exceeds the preset limit.
- HIGH FREQUENCY indicates the frequency exceeds the preset limit.

- HIGH VOLTAGE indicates the voltage exceeds the preset limit.
- LOW FREQUENCY indicates the frequency has dropped below the preset limit.
- LOW VOLTAGE indicates the voltage has dropped below the preset limit.

**METERS.**—The four meters in this section are the KILOWATTS, AMPERES, HERTZ, and VOLTS meters.



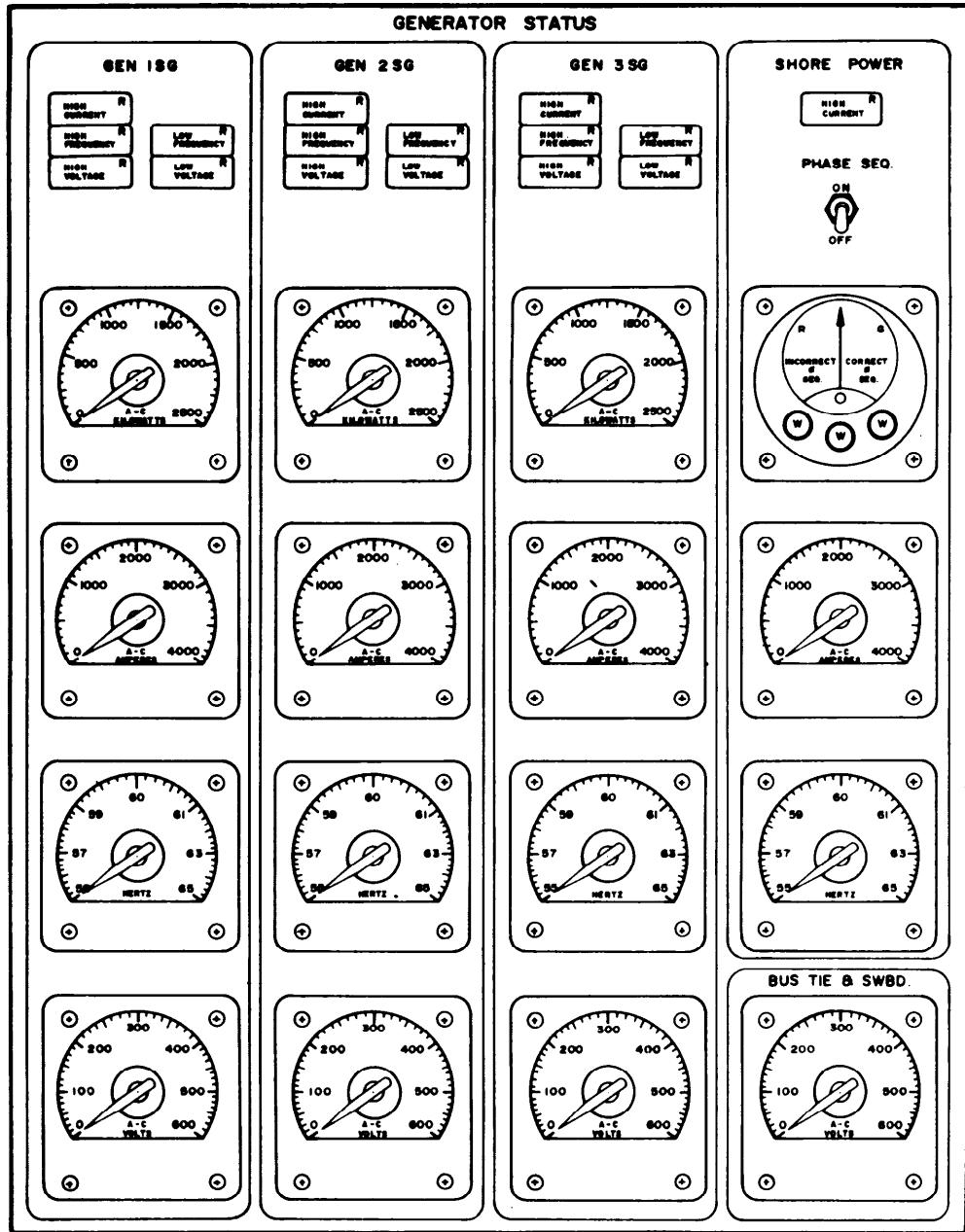
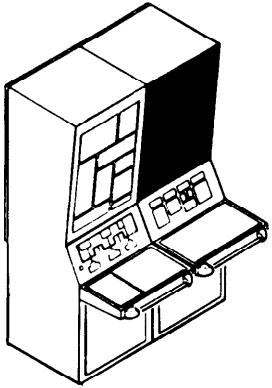


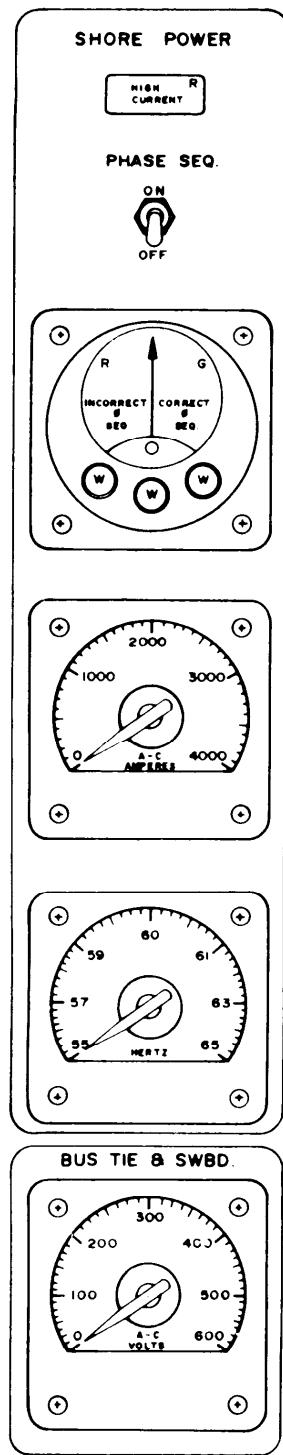
Figure 8-3.—Generator status panel.

### SHORE POWER Section

This section contains one indicator, one switch, and three meters. Starting at the top, the first item is an alarm indicator for HIGH CURRENT. It will illuminate when the current on the shore power exceeds the preset limit. Below this indicator is the PHASE SEQ. toggle switch. When it is in the OFF or down

position, it disconnects the power from the PHASE SEQ. meter. With the switch in the ON or up position, it connects the power to the PHASE SEQ. meter. Below this switch is the PHASE SEQ. meter. It is operative when the PHASE SEQ. switch is ON. The PHASE SEQ. meter indicates that the phase sequence of the shore power is incorrect or correct and that all three phases are present. The next meter is the

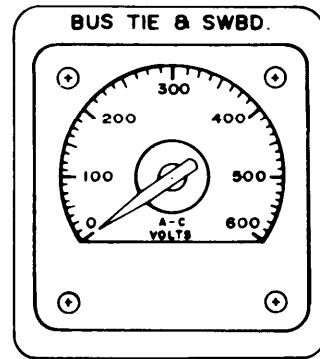
AMPERES meter. The last meter in this section is the HERTZ meter.



### BUS TIE & SWBD Section

This section has a VOLTS meter. The input to this meter is controlled by the BUS TIE &

SWBD VOLTAGE SELECT switch located on the system control panel.

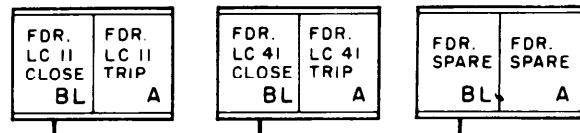


### MIMIC PANEL

The MIMIC panel is the lower left panel (fig. 8-4). It contains a mimic bus depicting the physical arrangement of the SWBD and bus ties. The panel has the controls for the following circuit breakers: generators, bus ties, load centers, and shore power. It also has the manual start and stop controls for the SSGTGSs and the plant control indicators.

### Circuit Breaker Switches/Indicators

All circuit breaker switches/indicators on this panel are alternate action push-button switches and indicators. Across the top of the panel are the switches/indicators for the load centers. When the FDR. LC11 CLOSE indicator is illuminated, it indicates the breaker is closed and feeding power to the load center. When the FDR. LC11 TRIP switch is depressed, it will cause the breaker to trip and the FDR. LC11 TRIP indicator will illuminate, indicating the breaker is tripped and no power is being fed to the load center. When the FDR. LC11 TRIP indicator is illuminated and the FDR. LC11 CLOSE switch is depressed, it will cause the breaker to close and feed power to the load center. The other indicators are for different load centers and some spares are provided.



The next circuit breaker switches below the circuit breakers/indicators for the load

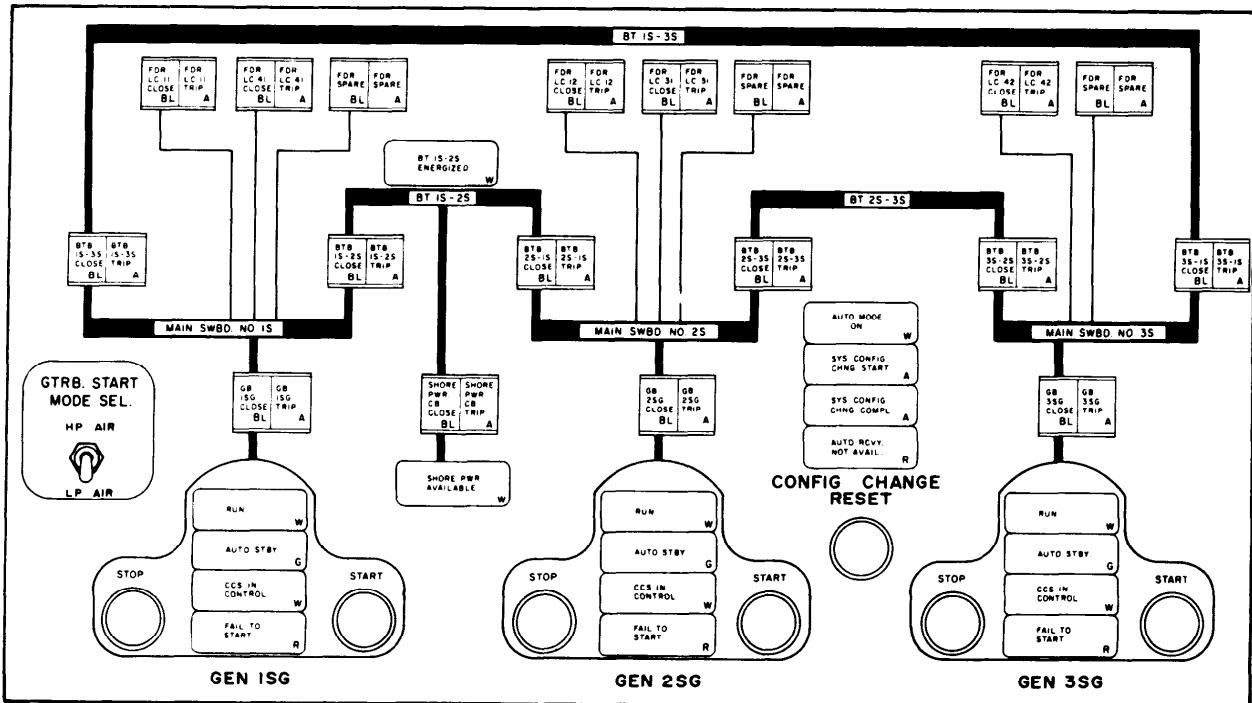
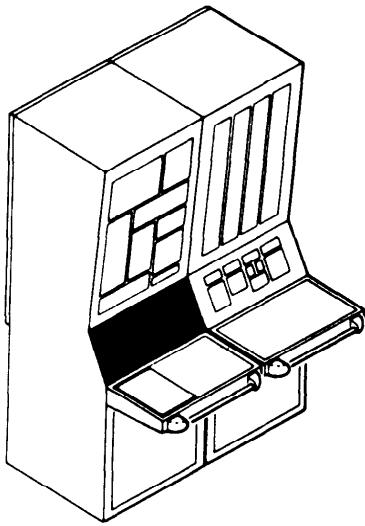
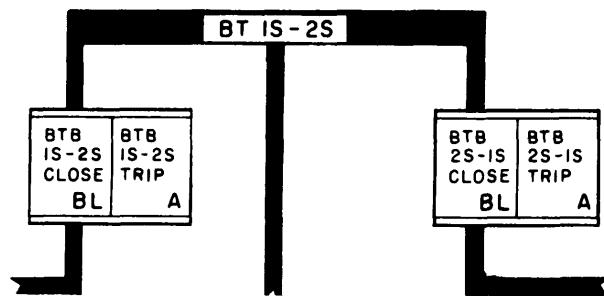
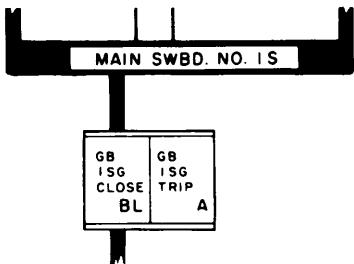


Figure 8-4.—MIMIC panel.

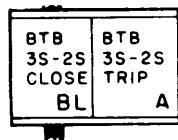
center are the bus tie breakers (BTBs). These are labeled BTB 1S-2S CLOSE/BTB 1S-2S TRIP. The label identifies the location of the BTBs. The first number is the SWBD the breaker is located on and the second number is the SWBD it will connect with. They work the same as the load center breaker switches, except these switches control the bus ties that connect the SWBD buses together.



The next circuit breaker switches are for the generator circuit breaker (GB). These are labeled GB 1SG CLOSE/GB 1SG TRIP. This label identifies these as the GB on the No. 1 SWBD. These switches are used to control the breaker that connects the generator to the SWBD bus and feeds power to the ship. These switches also work the same as the load center breaker switches.



The last circuit breaker switches are for the shore power. They are labeled SHORE PWR. CB CLOSE/SHORE PWR. CB TRIP. They control the shore power circuit breaker that connects shore power to the ship. They work the same as the load center circuit breaker switches.



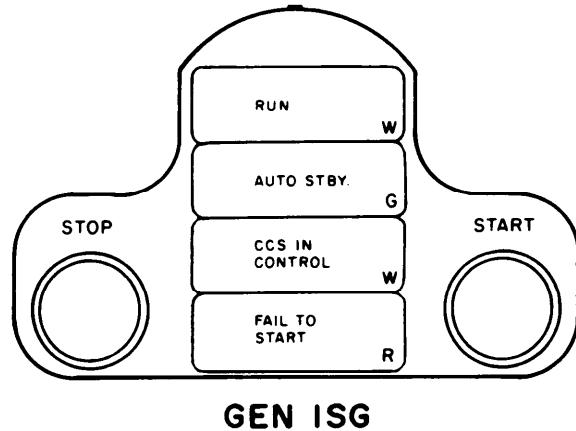
## Generators Section

This section has the controls for each generator, labeled GEN 1SG, GEN 2SG, and GEN 3SG. For each generator there are four indicators and two push-button switches. The indicators from top to bottom are as follows:

- RUN indicates that the generator is running.
- AUTO STBY. indicates that the generator is not online but is available for standby/emergency operation.
- CCS IN CONTROL indicates that CCS is in control of the generator.
- FAIL TO START is not used.

The switch on the right side is the START switch. It is a momentary push-button switch. When it is depressed, it initiates a start command

through the GTRB START MODE SEL switch to the appropriate generator. The left switch is the STOP switch. It is a momentary push-button switch. When it is depressed, it will initiate a stop command to the appropriate generator.



**GEN 1SG**

## Gas Turbine Start Mode Selector

Located on the left-hand side of the panel is the GTRB. START MODE SEL. switch. It is a two-position toggle switch labeled HP AIR and LP AIR. The switch is spring loaded to the LP AIR position and must be held in the HP AIR position. You use this switch to select the type of air pressure used to start the GTE.



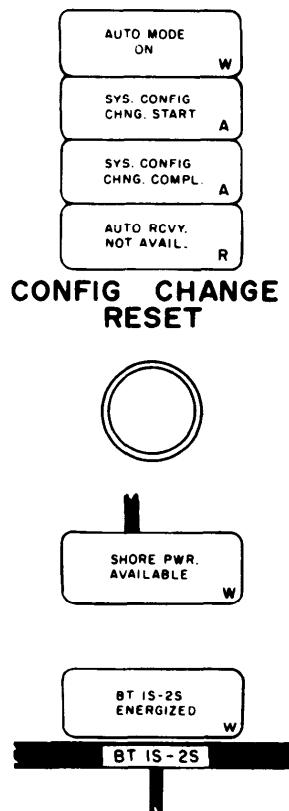
## Miscellaneous Indicators

Located to the right of center on the panel are four indicators in a column. These indicators from top to bottom are as follows:

- AUTO MODE ON indicates that the OP MODE SEL switch, located on the system control panel, is set to the AUTO position. This means that all VOLTAGE REG and GOV MODE selector switches are set to the NORMAL position.
- SYS. CONFIG CHNG. START indicates the ship's electric plants have started an automatic configuration change.

- SYS. CONFIG. CHNG. COMPL. indicates the automatic configuration change has been completed.
- AUTO RCVY. NOT AVAIL. indicates the EPCE does not have automatic recovery capability.

Another indicator on this panel is the SHORE PWR. AVAILABLE indicator. It will illuminate when shore power is connected to the ship. The last indicator is the BT 1S-2S ENERGIZED indicator. It will illuminate when the 1S or 2S SWBD is energized or shore power is applied to BT 1S-2S.



## SYSTEM CONTROL PANEL

The system control panel is the lower right panel (fig. 8-5). It contains the following sections: generators, bus tie and SWBD voltage select, synchronizing select and console mode control, system frequency and voltage control, power, malfunction, logic self-test, test, and auto paralleling.

### Generators Section

This section has the indicators and controls for the governor and voltage regulator mode and

for the frequency and voltage of each generator. These indicators and controls are labeled GEN 1SG, GEN 2SG, and GEN 3SG from left to right.

**GOVERNOR MODE SWITCH/INDICATOR.**—This switch/indicator is an alternate action push-button switch and indicator, labeled GOV. MODE. The normal indication is with the NORMAL portion illuminated. It indicates the generator governor control mode is in the normal operating mode. Depressing this switch will output a command to the governor to change the control mode to droop and the DROOP portion of the indicator will illuminate, meaning the governor control mode is in the droop mode. When the DROOP indicator is illuminated, depressing the switch will output a command to the governor to change the control mode to normal, and the NORMAL indicator will illuminate.

**FREQUENCY CONTROL SWITCH.**—This switch is located next to the governor mode switch/indicator and is labeled FREQ. It is a three-position switch, spring loaded to center position. The center position is labeled OFF, which is the normal position of the switch. When the switch is turned to the right or the RAISE position, it will cause the frequency of the generator to increase. When the switch is turned to the left or the LOWER position, it will cause the frequency of the generator to decrease.

**VOLTAGE REGULATOR MODE SWITCH/INDICATORS.**—Both of these switch/indicators are alternate-action push-button switches and indicators. They are labeled VR. MODE. The top switch/indicator is AUTO/MANUAL. When AUTO is illuminated, it indicates the generator voltage regulator control mode is in the automatic operating mode. Depressing this switch will output a command to change the voltage regulator control mode to manual. It will cause the MANUAL indicator to illuminate, meaning the voltage regulator control mode is in the manual mode. When the MANUAL indicator is illuminated, depressing the switch will output a command to the voltage regulator to change to the automatic operating mode.

The bottom switch/indicator is NORMAL/DROOP. When the NORMAL indicator is illuminated, it indicates the generator voltage regulator control mode is in the normal mode of operation. Depressing this switch will output a command to change the voltage regulator control

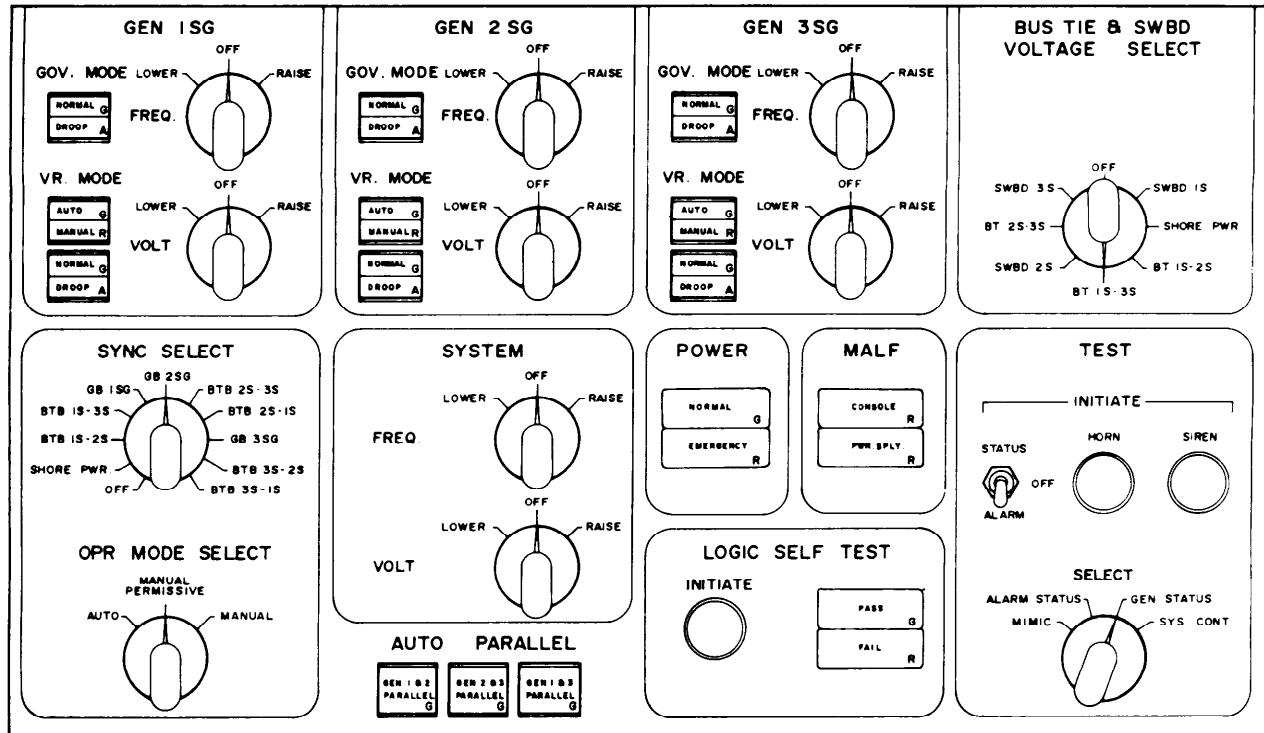
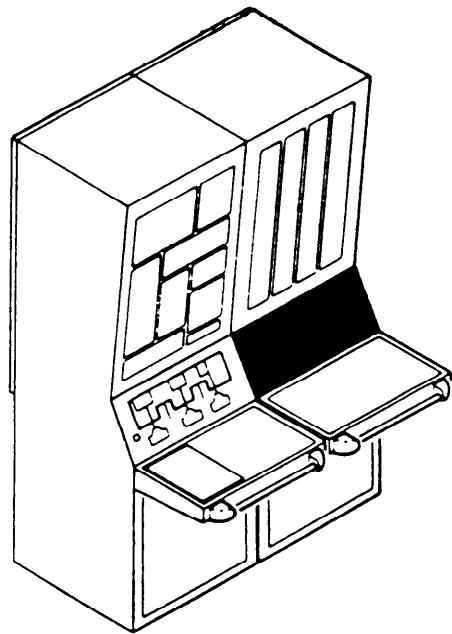
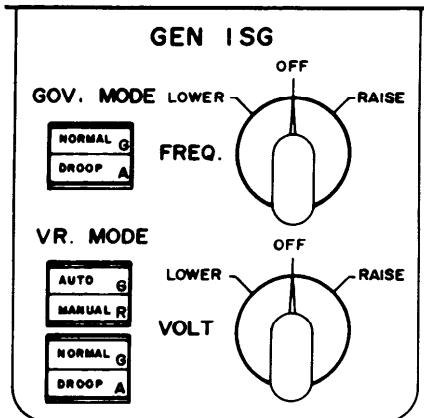


Figure 8-5.—System control panel.

mode to droop. It will cause the DROOP indicator to illuminate, meaning the voltage regulator control mode is in the droop mode. When the DROOP indicator is illuminated, depressing the switch will output a command to the voltage regulator to change to the normal mode of operation.

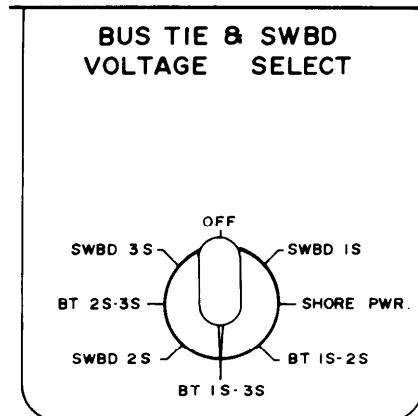
**VOLTAGE REGULATOR CONTROL SWITCH.**—This switch is located next to the voltage regulator control mode switch/indicators and is labeled VOLT. It is a three-position switch, spring loaded to the center position. The center position is labeled OFF, which is the normal position of the switch. When the switch is turned to the right or the RAISE position, it will cause the voltage of the generator to increase. When the switch is turned to the left or the LOWER position, it will cause the voltage of the generator to decrease.



### BUS TIE & SWBD VOLTAGE SELECT Section

This section is located in the upper right-hand corner of the panel. It is labeled BUS TIE & SWBD VOLTAGE SELECT. It has one rotary switch. This switch is used to select from what location the BUS TIE & SWBD voltmeter located on the generator status panel will receive its input. The top position is labeled OFF. When the switch is in this position, the meter is OFF. Clockwise around the switch, SWBD 1S is the No. 1 SWBD; SHORE PWR. is for the shore power cables; BT 1S-2S is for the bus tie cable between the 1S and 2S SWBDs; BT 1S-3S is for the bus tie cable between the 1S and 3S SWBDs; SWBD 2S is for the No. 2 SWBD; BT 2S-3S is for the

bus tie cable between the 2S and 3S SWBDs; and SWBD 3S is for the No. 3 SWBD.



### Synchro Control Section

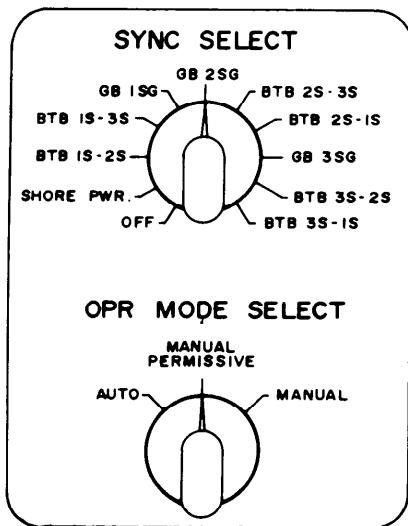
This section is located in the lower left-hand corner of the panel. It has two select switches. The top switch controls the input to the synchroscope and synchronizing lights and the bottom switch controls the mode of operation of the console and the paralleling device. These switches are labeled SYNC SELECT and OPR MODE SELECT, respectively.

**SYNC SELECT SWITCH.**—This is a rotary switch used to select between the GBs, the BTBs, or the shore power circuit breaker. It connects the inputs from both sides of the selected breaker to the synchroscope and synchronizing lights, located on the alarm/status panel. This switch also allows the breaker selected to receive a manual close command when it is operated in the MANUAL PERMISSIVE mode.

The switch has an OFF position and a position for each GB, each BTB, and the shore power circuit breaker. When the switch is in the OFF position, it will prevent all breakers from responding to a manual close command while in the MANUAL PERMISSIVE mode.

**OPR MODE SELECT SWITCH.**—This is a rotary switch used to select the mode of operation of the console and the automatic paralleling device. When the switch is turned to the left, it is in AUTO. In this position it enables the automatic recovery capability and generator paralleling control device. The middle position is MANUAL PERMISSIVE. In this position it routes the close command through the synchronizing monitor to the breaker selected by

the SYNC SELECT switch. The right position is MANUAL. When this position is selected, it routes the close command directly to the breaker selected by the SYNC SELECT switch.



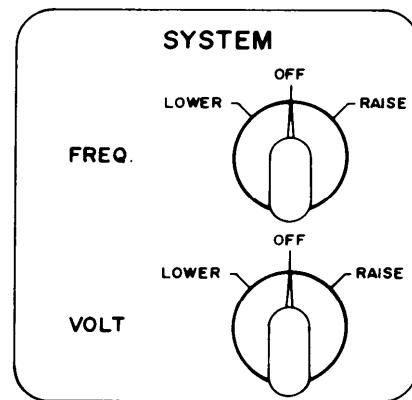
### SYSTEM Section

This section has two switches, one for frequency and one for voltage. These switches will adjust the frequency or the voltage of all generators operating in parallel, providing the governor and voltage regulator of the generators are in the NORMAL mode of operation.

**FREQUENCY SWITCH.**—This switch controls the frequency of the system and is labeled FREQ. It is a three-position switch, spring loaded to the center position. The center position is labeled OFF, which is its normal position. When the switch is turned to the right or the RAISE position, it will cause the frequency of the generators to increase. When the switch is turned to the left or the LOWER position, it will cause the frequency of the generators to decrease.

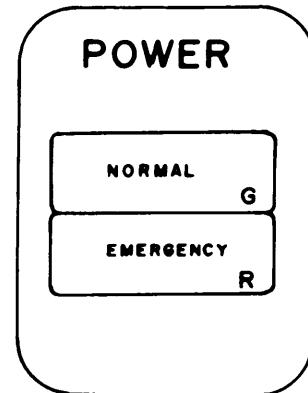
**VOLTAGE SWITCH.**—This switch is used to control the voltage of the system and is labeled VOLT. It is a three-position switch, spring loaded to the center position. The center position is labeled OFF, which is the normal position of the switch. When the switch is turned to the right or the RAISE position, it will cause the voltage of the generators to increase.

When the switch is turned to the left or the LOWER position, it will cause the voltage of the generators to decrease.



### POWER Section

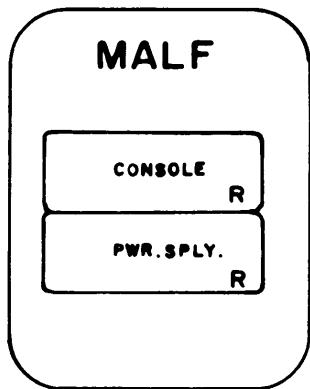
This section has two indicators. The top indicator is labeled NORMAL. When it is illuminated, the EPCE is using ship's power or shore power as the normal power. The bottom indicator is labeled EMERGENCY. When it is illuminated, it flashes. This indicates that the EPCE is using UPS power.



### MALF Section

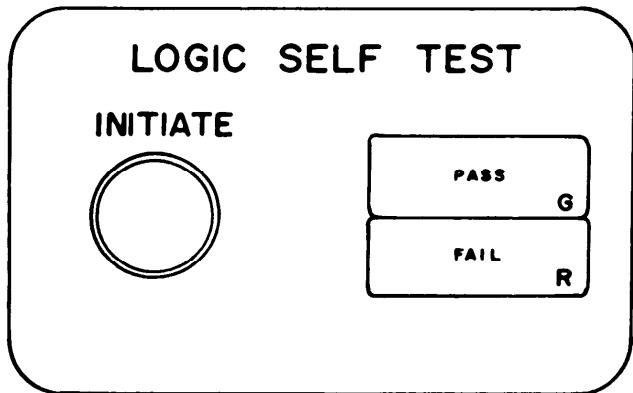
This section is labeled MALF and has two indicators. The top indicator is labeled CONSOLE. When it is illuminated, it indicates a malfunction in the EPCC continuity interlock circuit or that a card self-test circuit has activated the card fault output. The bottom indicator is labeled PWR. SPLY. When it

is illuminated, it indicates a malfunction in the EPCEE power supply.



### LOGIC SELF TEST Section

This section contains one push-button switch and two indicators. The push-button switch is labeled INITIATE and is enabled only when the OPR MODE SWITCH is in the MANUAL PERMISSIVE or the MANUAL mode of operation. When this switch is depressed, it will initiate a self-test program to test selected EPCC internal logic. The top indicator is labeled PASS and will illuminate after the successful completion of the EPCC self-test. The bottom indicator is labeled FAIL and will illuminate when a malfunction is detected during a self-test.

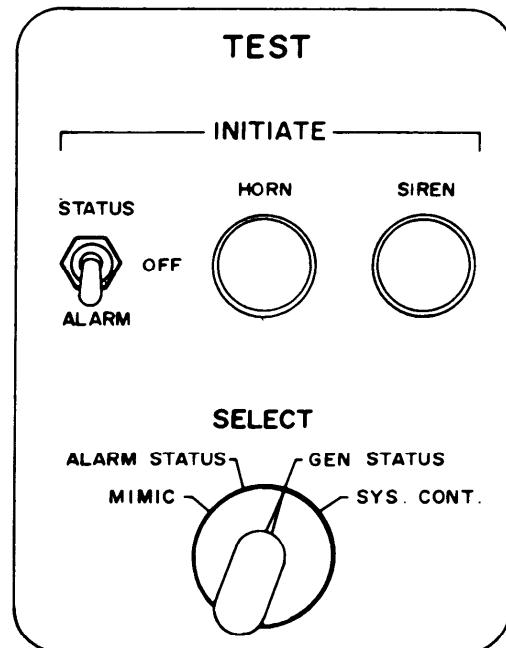


### TEST Section

This section has two subsections, labeled INITIATE and SELECT. The switches in these subsections are used to test collectively the operation of the status and alarm indicators on the console and the operation of the horn and siren.

**INITIATE.**—The INITIATE subsection has three switches. The left switch is a toggle switch with three positions. The top position is labeled STATUS. In this position, all the status indicators on the panel selected by the SELECT switch will illuminate. The middle position is labeled OFF. In this position, no test is being done. The bottom position is labeled ALARM. In this position, all the alarm indicators on the panel selected by the SELECT switch are illuminated. The middle switch is a momentary push-button switch labeled HORN. When this switch is depressed, a horn will sound. The right switch is also a momentary push-button switch labeled SIREN. When this switch is depressed, a siren will sound.

**SELECT.**—The SELECT subsection has a rotary switch labeled SELECT used with the three-position toggle switch. The switch positions are labeled MIMIC, ALARM STATUS, GEN STATUS, and SYS. CONT. Each position is for one of the panels on the EPCC. When one of these positions is selected, that panel's indicators or alarm indicators will be tested.



### AUTO PARALLEL Section

This section has three push-button switch/indicators. The switches are labeled GEN 1 & 2 PARALLEL, GEN 2 & 3 PARALLEL, and GEN 1 & 3 PARALLEL. The switches are enabled only

when the OPR MODE SELECT switch is in the AUTO position. The indicator portion is illuminated when that condition exists. When one of the switches is depressed, it will cause the indicated generators to be paralleled.



## TURBINE OVERLOAD PROTECTION SYSTEM

The TOPS is an automatic protection system to prevent an overload/overtemperature condition from developing on the remaining SSGTGS should one of the paralleled generators fail. Primary power is 120 volts ac and is converted into the required dc voltages needed for operation. The system has an internal battery to provide a backup source on power failure.

The TOPS control unit receives analog inputs from the PAMISE, such as SSGTGS inlet temperature, rpm, and kilowatt. The control unit also receives digital inputs from the EPCC, such as GB, BTB, and shore power circuit breaker status. The control unit will process the signals and provide a listing, or menu, to the display unit. The display unit is essentially a video display terminal with a pressure-sensitive surface. The operator touches the surface to select the menu to be displayed.

Another series of output signals from the control unit go directly to the SSGTGS, SWBD, and the load shed relay. Based upon the results of the analysis of the data, the control unit will issue the commands to close the bleed air valves, open GBs, and/or initiate load shed. This is done individually or in combination. The control unit will initiate whatever action is needed to maintain the vital electrical load.

## LOAD CENTERS

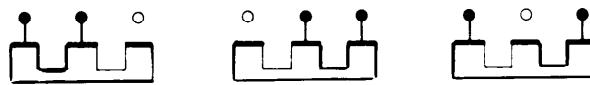
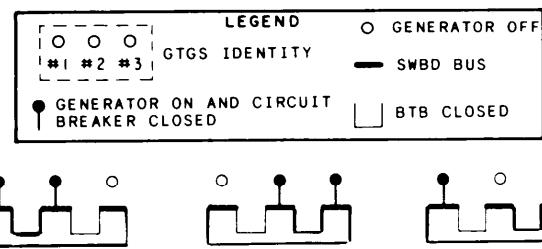
The load centers are very similar to the distribution section of a main SWBD. They are sometimes referred to as load center SWBDs. They are located at remote locations from the main SWBDs. The load center uses the same type of breakers as the main SWBDs to feed the loads.

## SYSTEM CONFIGURATION

The electrical system is designed so that two generators can supply all electrical loads. The third SSGTGS can be put on standby. Then it can automatically be started and synchronized to the bus if one or both of the on-line generators should fail. Automatic failure detection and recovery is available only when the EPCC is in control and in automatic mode. Also, the electric plant must be in a standard parallel plant or standard split-plant configuration. The different types of configurations are the standard parallel-plant configurations, the standard split-plant configurations, the nonstandard plant configurations, and the emergency configurations.

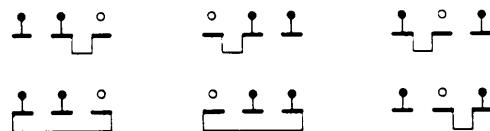
### Standard Parallel-Plant Configurations

A standard parallel-plant configuration consists of two generators online and paralleled, with all BTBs closed, connecting the three main SWBDs in a loop system. Configuration status logic at the EPCC identifies the on-line generators for auto recovery control.



### Standard Split-Plant Configurations

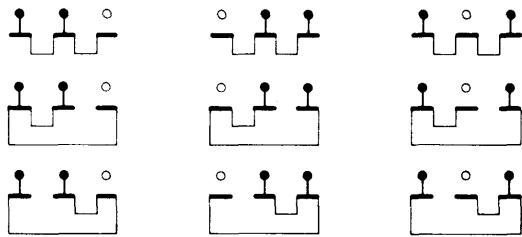
A standard split-plant configuration consists of two generators online, but not paralleled. The off-line generator SWBD is energized through the bus tie connection to one of the on-line generator SWBDs. The remaining bus ties are not energized. The configuration status logic at the EPCC can identify any of these configurations by monitoring the open and closed status of the GBs and BTBs.



### Nonstandard Plant Configurations

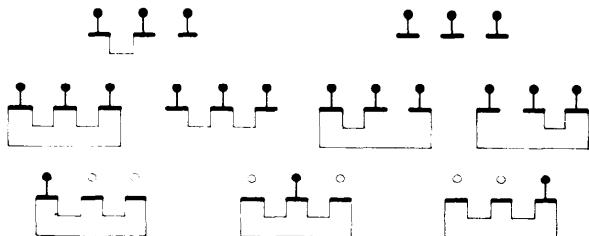
A nonstandard plant configuration is an open loop configuration which energizes all three

SWBDs from two generators operating in parallel. These configurations are operator selected, or they are the result of a failure. All electrical distribution functions are provided with these configurations. However, automatic recovery capability is not available.



### Emergency Configurations

An emergency configuration can occur when two generators are inoperative, and one generator must energize the three SWBDs. Other emergency configurations may have all three generators online, with all, two, or none in parallel.



### ELECTRIC PLANT CONTROL CONSOLE (CG CLASS SHIPS)

The EPCCs on the CG- and the DDG-class ships (fig. 8-6) are very similar to those on the DD-class ships. We will only discuss the differences in the consoles in this section. This console has two more panels than the DD consoles. They are for the 60/400 Hz converters.

### ALARM/STATUS PANEL

The alarm/status panel (fig. 8-7) is the upper left panel. It contains the following sections: alarm/status indicators, emergency power, generator and gas turbine lube oil meters, synchronizing indication, SWBD emergency power and main SWBD ground detection, alarm acknowledge, and demand displays.

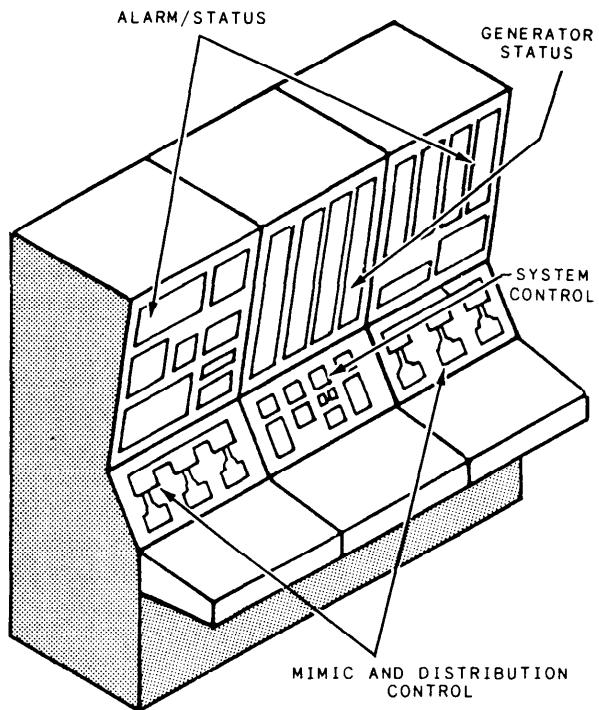


Figure 8-6.—EPCC (CG- and DDG-class ships.)

### Alarm/Status Indicator Section

The alarm/status indicator section is divided into three subsections, one for each SSGTGS. These subsections are identical. The only alarms/indicators we will discuss are the ones that are added or different from the DD-class ships.

**GENERATOR COLUMN.**—The indicators in this column, labeled GEN, are the same as those on the DD consoles except the location of a few of the indicators on the panel and the addition of the LUBO PRESS LOW indicator, which indicates the lube oil pressure in the generator drops below the preset limit. All other indicators were explained in the description of the DD consoles.

**GAS TURBINE AND REDUCTION GEARS COLUMN.**—The indicators in this column, labeled GTRB, are the same as those on the DD consoles except the location of a few of the indicators on the panel and the addition of more indicators.

- **BLOW-IN DOOR OPEN** indicates the blow-in doors are open.

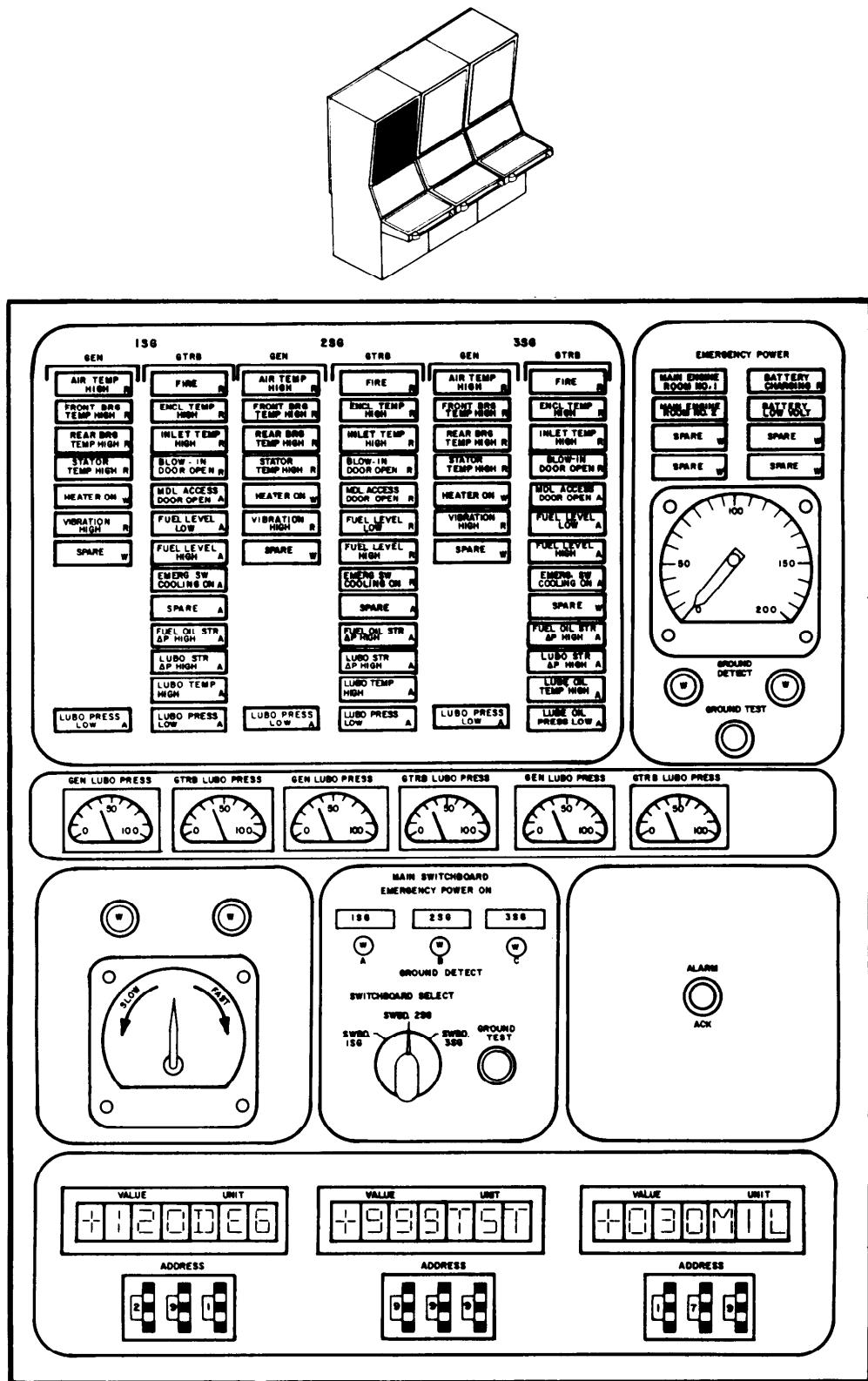
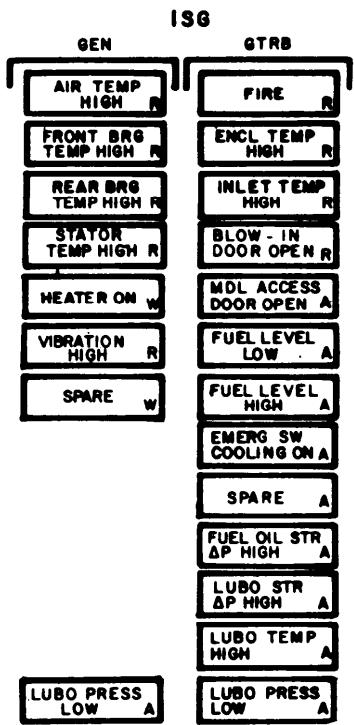


Figure 8-7.—Alarm/status panel.

- MDL ACCESS DOOR OPEN indicates the door to the module is open.
- EMERG SW COOLING ON indicates the emergency cooling water is being supplied to the SSGTGS cooling water system.

All other indicators were explained in the DD-class ship section.

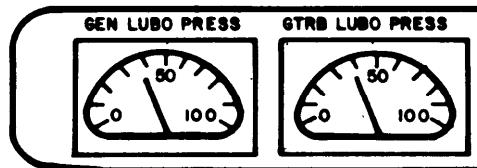


### Emergency Power Section

The indicators in this section are identical to those on the DD console. However, there are four additional indicators that are all labeled SPARE.

### Generator and Gas Turbine Lube Oil Meters Section

The three sets of identical meters in this section provide a means for continuous monitoring of lube oil pressure. The meters are labeled GEN LUBO PRESS and GTRB LUBO PRESS, one for each SSGTG.



### Synchronizing Indication Section

The indicators in this section are the same as the synchronizing indication section on the DD console.

### Switchboard Emergency Power and Main Switchboard Ground Detection Section

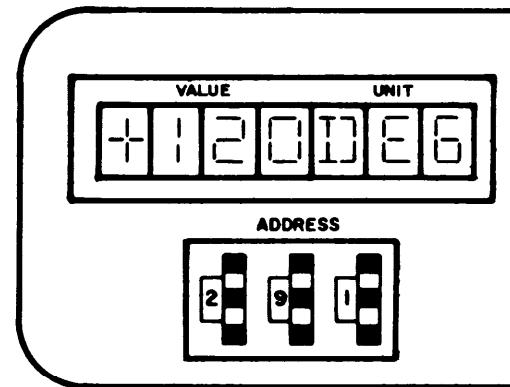
This section is a combination of the SWBD emergency power section and the main SWBD ground detection sections of the DD console. This section operates the same as the DD console.

### Alarm Acknowledge

This section is the same as the alarm acknowledge section of the DD console.

### Demand Display Section

This section is basically the same as the demand display section of the DD console, except it also shows the unit of measure for the parameter being displayed.



### GENERATOR STATUS PANEL

The generator status panel is the upper middle panel of the console. It is identical to the generator status panel on the DD console.

### 400-HZ ALARM/STATUS PANEL

This panel and the panel below it, discussed later, are for the 400-Hz converters. The addition of these two panels to the EPCC is the greatest difference in the EPCCs on the different class

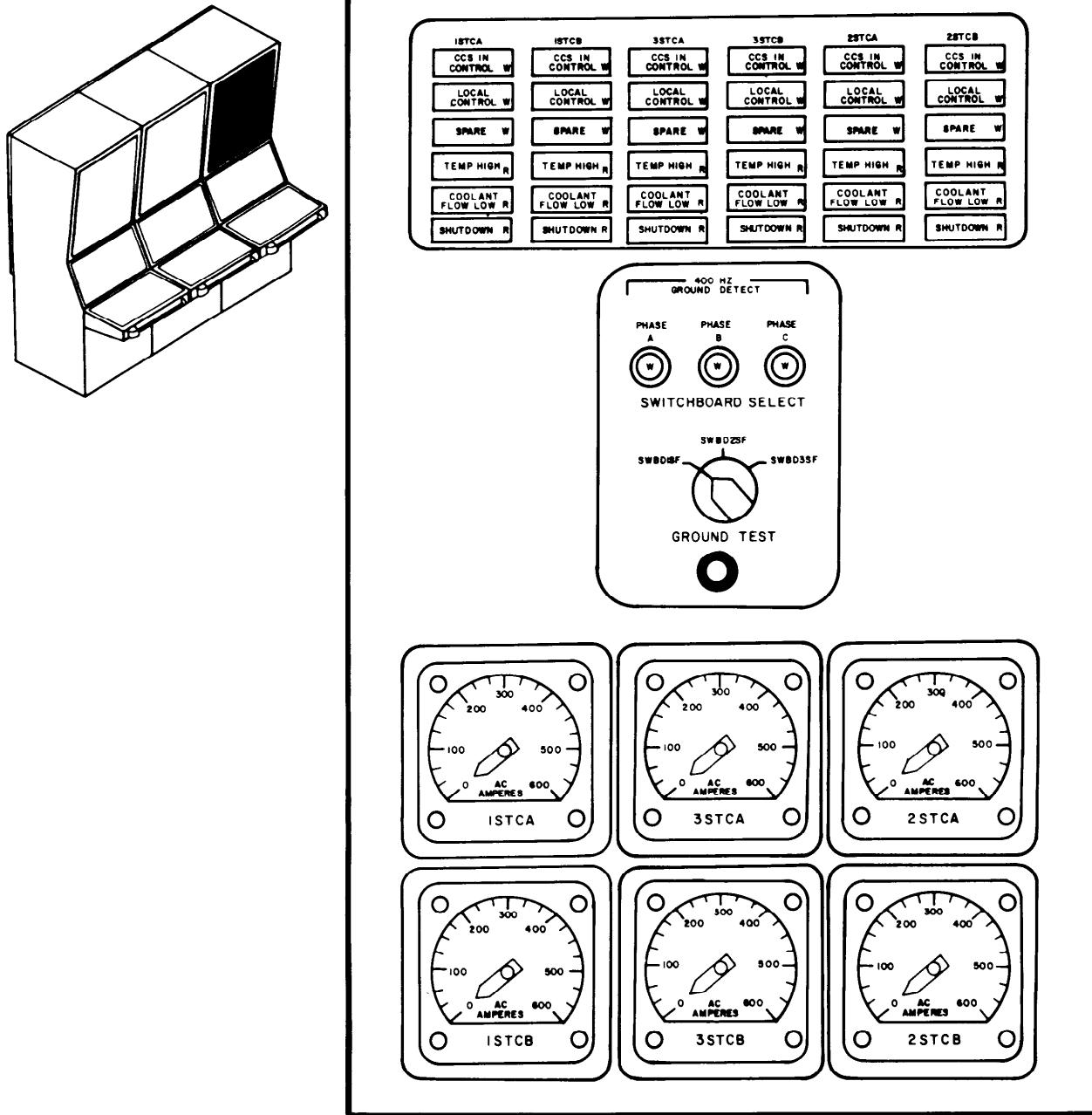


Figure 8-8.—400-Hz alarm/status panel.

ships. This panel (fig. 8-8) is divided into three sections, the alarm/status indicator, ground detection, and meter sections.

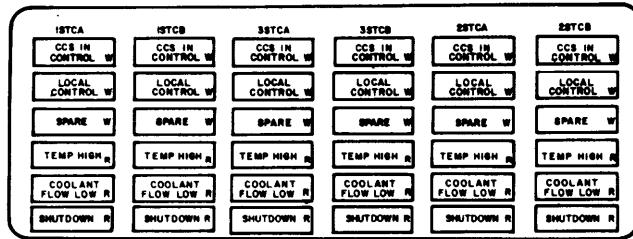
#### 400-Hz Alarm/Status Indicator Section

This section has six columns of indicators, one for each 400-Hz converter. All the columns are identical. The columns are labeled from left to

right 1STCA, 1STCB, 3STCA, 3STCB, 2STCA, and 2STCB. The indicators from top to bottom are as follows:

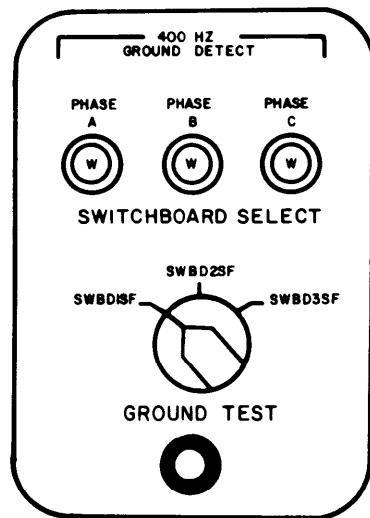
- CCS IN CONTROL indicates the control of the converter is at the EPCC.
- LOCAL CONTROL indicates the control of the converter is at the converter.

- SPARE.
- TEMP HIGH indicates the temperature in the converter exceeds the preset limit.
- COOLANT FLOW LOW indicates the flow of the coolant in the cooling system is not within limits.
- SHUTDOWN indicates the converter is or has been secured.



#### 400 HZ GROUND DETECT Section

This section contains three indicator lights, labeled PHASE A, PHASE B, and PHASE C. Under the indicators is the SWITCHBOARD SELECT three-position rotary switch. It is used to select the specific 400-Hz SWBD that is going to be tested for a ground. The bottom switch is a push-button switch that is labeled GROUND TEST. When this switch is depressed, it will connect the selected SWBD to the indicator lights to test that SWBD for a grounded condition.



#### Meter Section

The meter section contains six ampere meters, one for each 400-Hz converter.

#### MIMIC PANEL

The MIMIC panel (fig. 8-9) is basically the same as the MIMIC panel on the DD console. It contains the LOAD SHED ACTIVATED indicator/switch and the generator control section has more indicators and a little different layout. The only section we are going to discuss is the generator control section because everything else functions the same as the DD console.

The generator control sections have eight indicators and two push-button switches. The switches are located on the left side of the section. The top switch is the START switch. It is a momentary push-button switch. Depressing this switch initiates a start command through the GTRB START MODE SEL switch to the appropriate generator. The bottom switch is the STOP switch. It is a momentary push-button switch. When the STOP switch is depressed, it will initiate a stop command to the appropriate generator. The two columns of indicators have the same indicators as the MIMIC panel on the DD console. The indicators are as follows:

- RUN.
- AUTO STBY.
- CCS IN CONTROL.
- SPARE.
- FAIL TO START.
- FAN “A” ON indicates the “A” fan is running.
- FAN “B” ON indicates the “B” fan is running.
- STBY FAN TRANSFER indicates the control of the standby fan is at the EPCC.

#### SYSTEM CONTROL PANEL

The system control panel (fig. 8-10) is almost the same as the system control panel on the DD

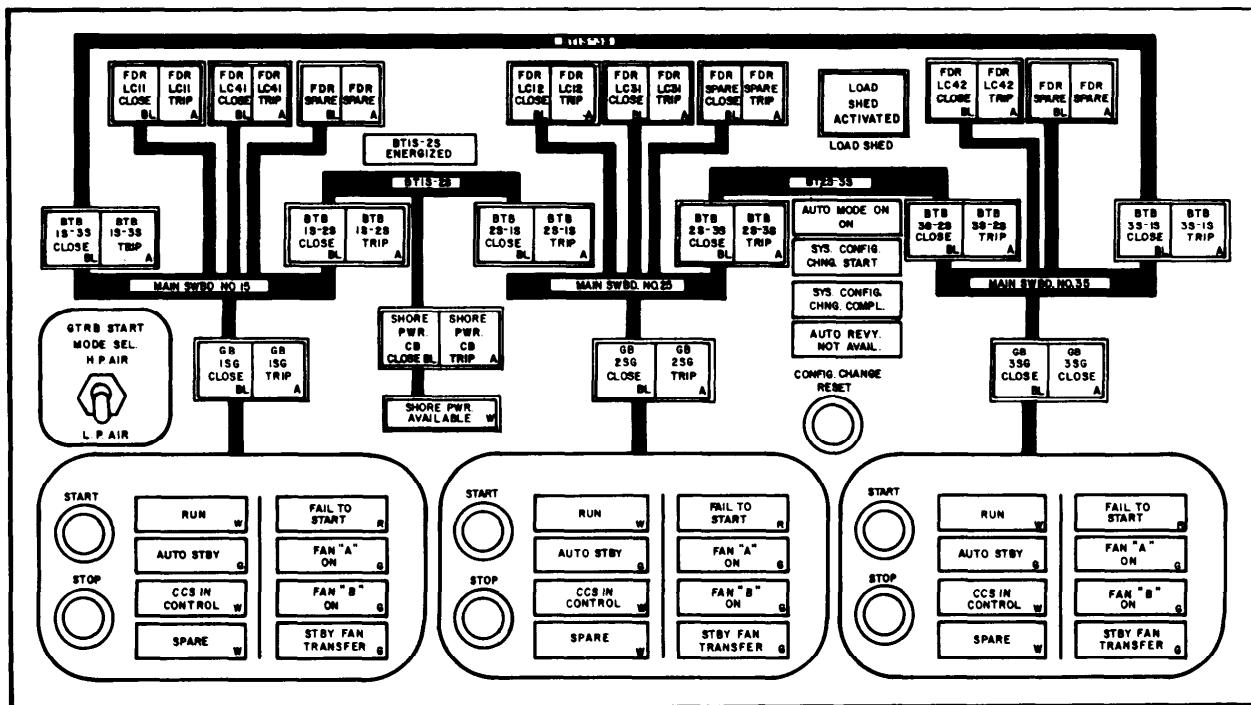
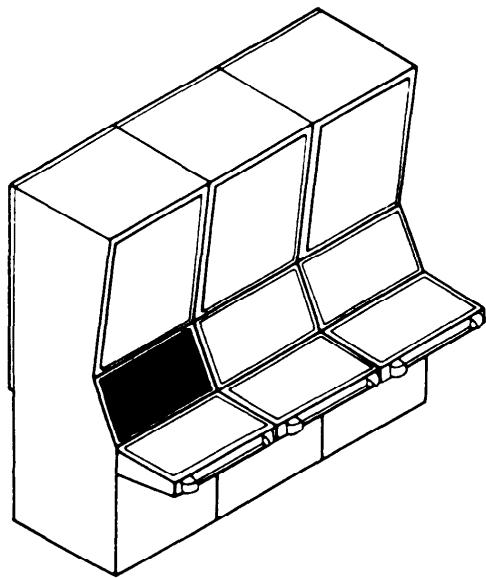


Figure 8-9.—MIMIC panel.

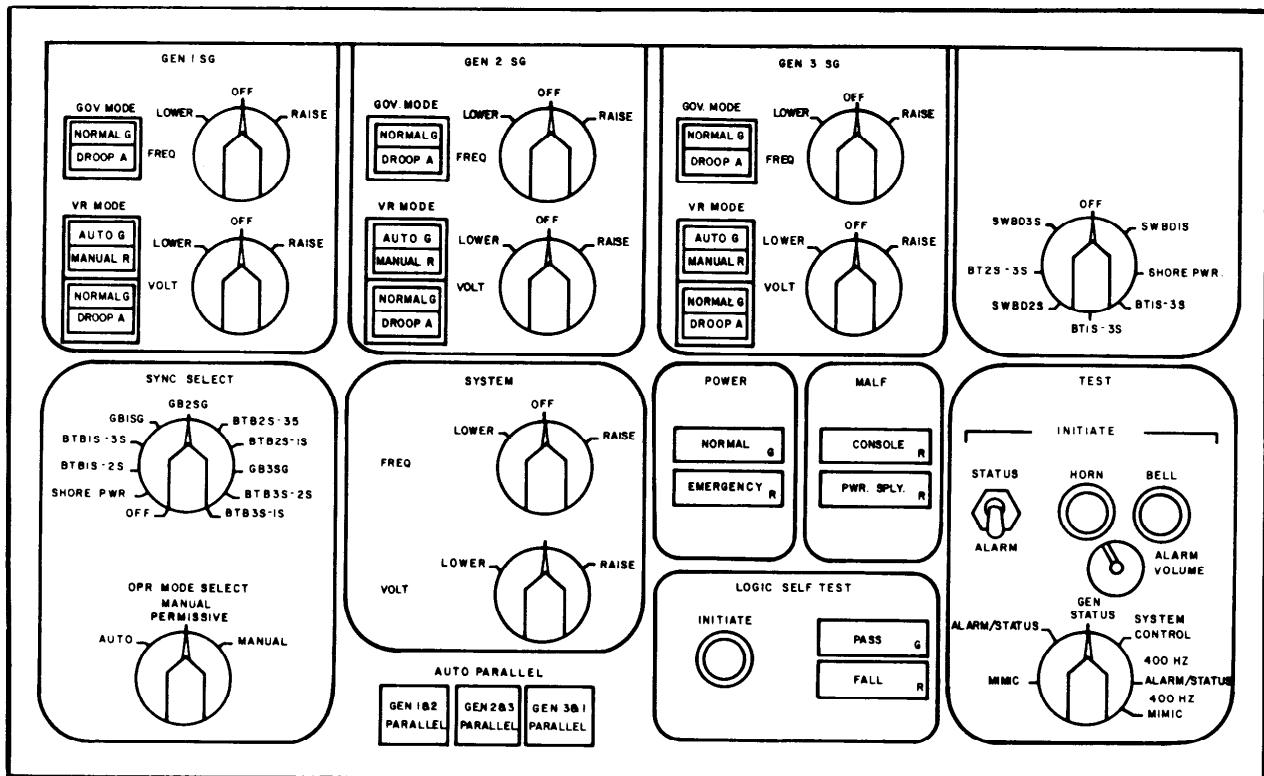
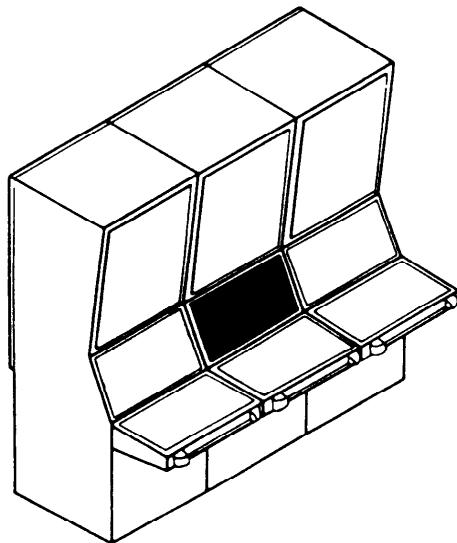


Figure 8-10.—System control panel.

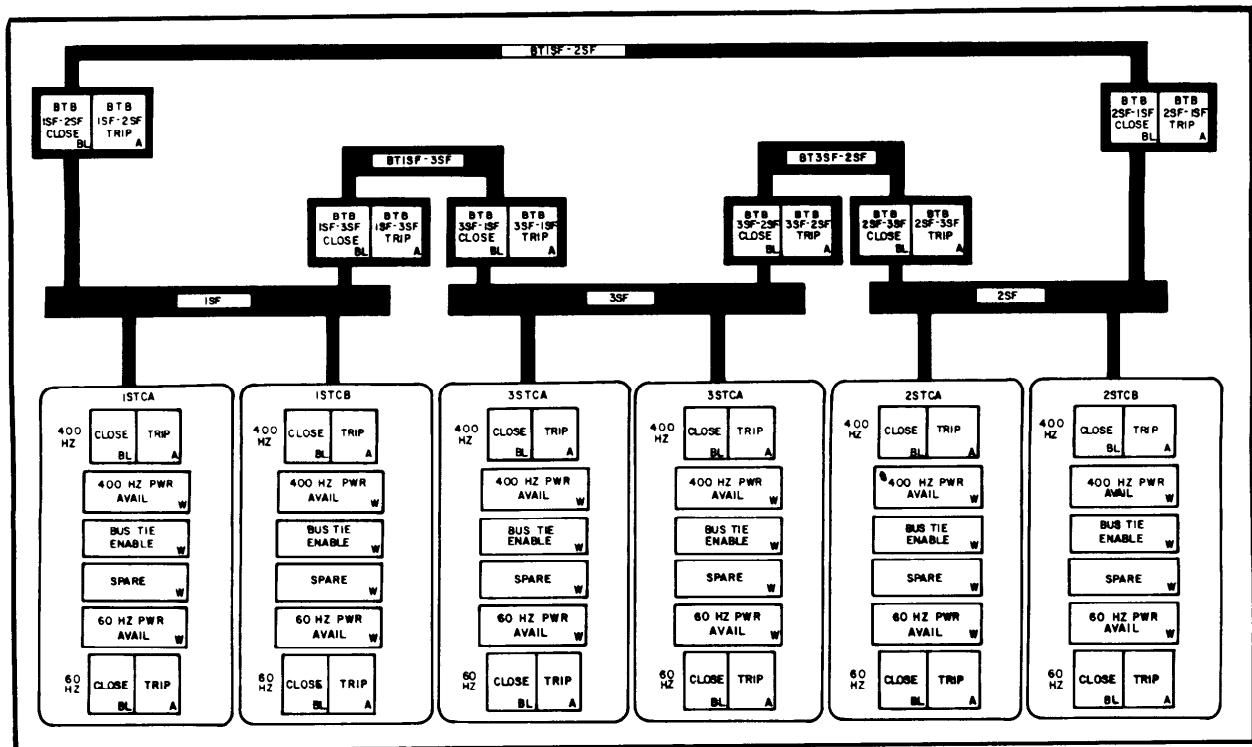
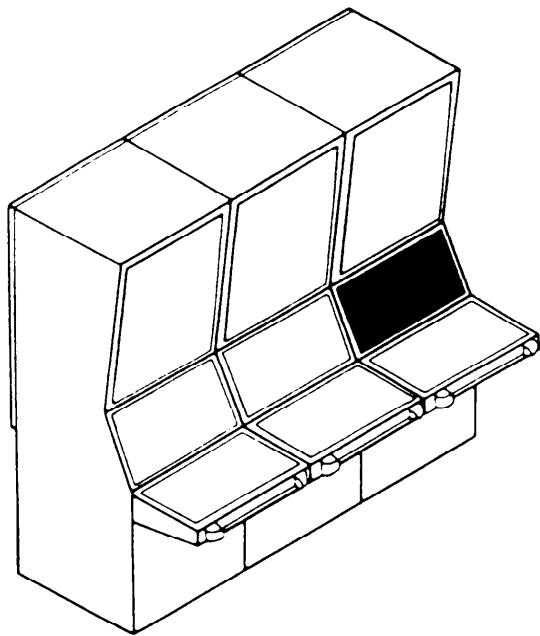


Figure 8-11.—400-Hz MIMIC panel.

console. It has the TEST section with a control knob for the ALARM VOLUME. It is located under the HORN and BELL test switches. The alarm siren has been changed to a bell. The SELECT switch has two added positions for the two 400-Hz panels.

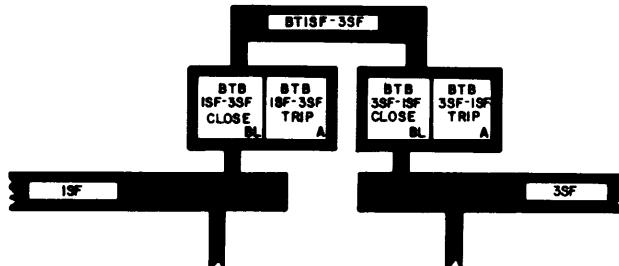
## 400-HZ MIMIC PANEL

The 400-Hz MIMIC panel (fig. 8-11) is the lower right-hand panel. It has a mimic drawing of the ship's 400-Hz system at the top of the panel. The bottom of the panel contains controls and indicators to operate the converters.

### Mimic Section

The mimic section contains a mimic bus depicting the physical arrangement of the SWBD and bus ties. This section of the panel has controls/indicators for the BTBs. The BTB switch/indicators are alternate action push-button switches and indicators. The first number in the legend on the indicator is the SWBD the breaker is located on. The second number is the SWBD the breaker connects.

When the BTB 1SF-3SF CLOSE indicator is illuminated, it indicates the breaker is closed between the 1SF and 3SF SWBDs. Depressing the BTB 1SF-3SF TRIP indicator will cause the breaker to trip (open) and the BTB 1SF-3SF TRIP indicator will illuminate. When the BTB 1SF-3SF TRIP indicator is illuminated, you can close the breaker by depressing the BTB 1SF-3SF CLOSE switch.



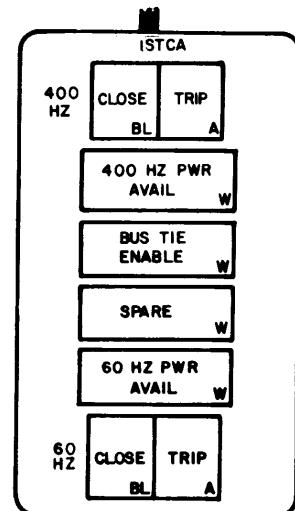
### Converter Control Section

This section contains six identical subsections. The subsections are labeled from left to right 1STCA, 1STCB, 3STCA, 3STCB, 2STCA,

and 2STCB. At the top of the section is a switch/indicator that is an alternate action push-button switch/indicator. The switch/indicator is labeled 400 HZ at the left of the switch/indicator. The switch/indicator is labeled CLOSE/TRIP. When the CLOSE portion is illuminated, it indicates the breaker is closed and feeding power to the SWBD. When the TRIP switch is depressed, it causes the breaker to trip and the TRIP indicator will illuminate. When the TRIP indicator is illuminated and the CLOSE switch is depressed, the breaker will close.

Next is the 400 HZ PWR AVAIL indicator. When it is illuminated, the converter is operating. BUS TIE ENABLE is the next indicator. When it is illuminated, it means close/trip power is available to the breaker. A SPARE indicator is located below the BUS TIE ENABLE indicator. Below the SPARE indicator is the 60 HZ PWR AVAIL indicator. When it is illuminated, 60 Hz power is available to the converter.

At the bottom of this section is a switch/indicator that is an alternate action push-button switch/indicator. The switch/indicator is labeled 60 HZ at the left of the switch/indicator. The switch/indicator is labeled CLOSE/TRIP. When the CLOSE portion is illuminated, it indicates the breaker is closed and feeding power to the converter. Depressing the TRIP switch will cause the breaker to trip and the TRIP indicator will illuminate. When the TRIP indicator is illuminated and the CLOSE switch is depressed, the breaker will close.



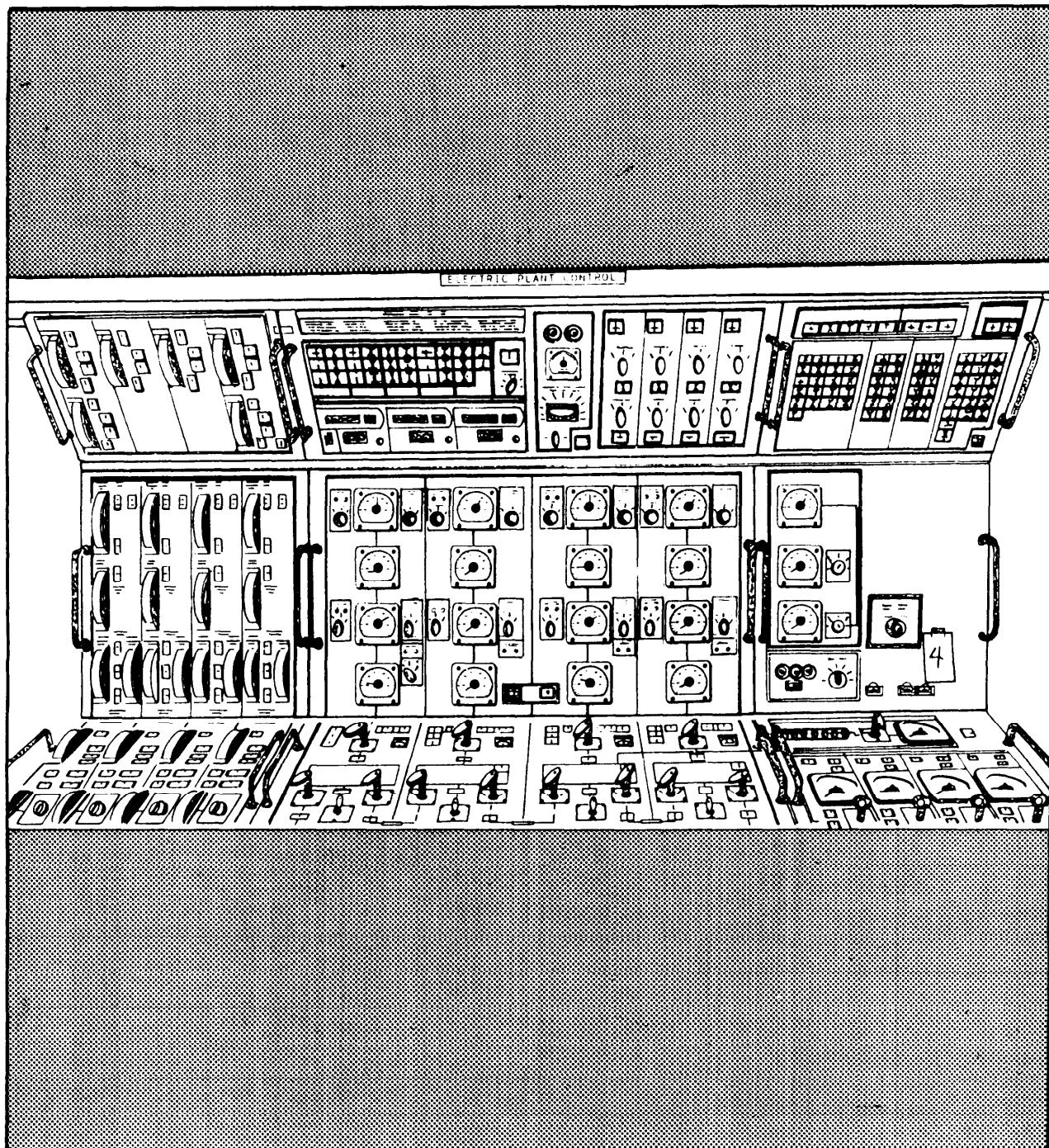


Figure 8-12.—EPCC (FFG-class ships).

## ELECTRIC PLANT CONTROL CONSOLE (FFG-CLASS SHIPS)

The EPCC on the FFG-class ships contains the controls and indicators used to remotely operate and monitor the SSDGs and power distribution system.

The EPCC (fig. 8-12) is subdivided into nine panels and each panel is dedicated to a particular type of control and monitoring. The panels are the engine fuel systems panel (A-1), supervisory control status(SCS)/parameters/synchronization/paralleling panel (A-2), console power status/console

vital power feeder circuit breaker status panel (A-3), SSDG panels (A-4 and A-7), SSDG output and distribution panels (A-5 and A-8), system output monitor/ground status test/generator 4 voltage control panel (A-6), and shore power/generators panel (A-9). The lower portion of the EPCC contains three fuse panels.

### ENGINE FUEL SYSTEMS PANEL (A-1)

The ENGINE FUEL SYSTEMS panel (A-1) (fig. 8-13) is the upper left panel. It contains a meter for each fuel tank with associated high- and

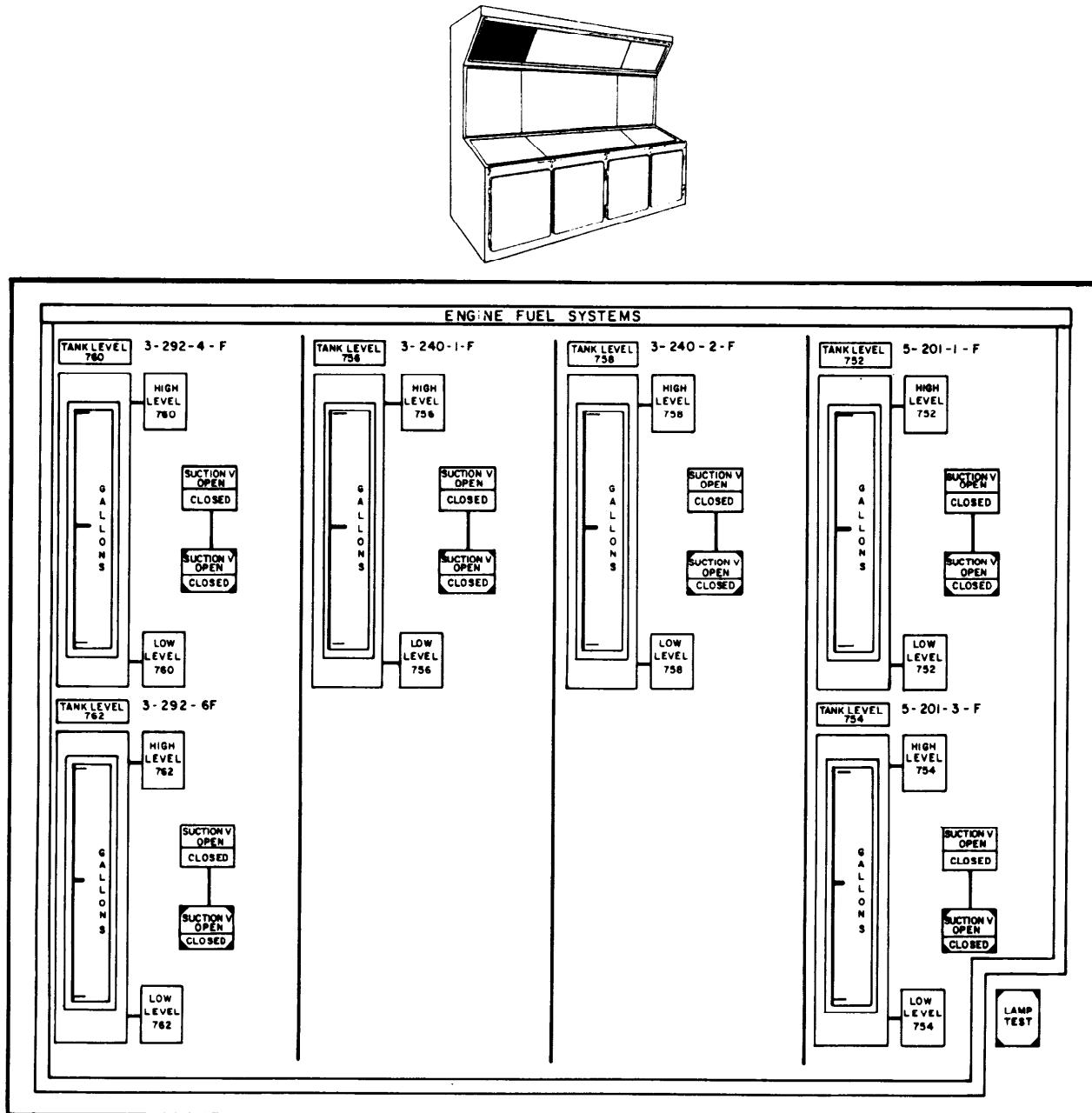


Figure 8-13.—Engine fuel systems panel (A-1).

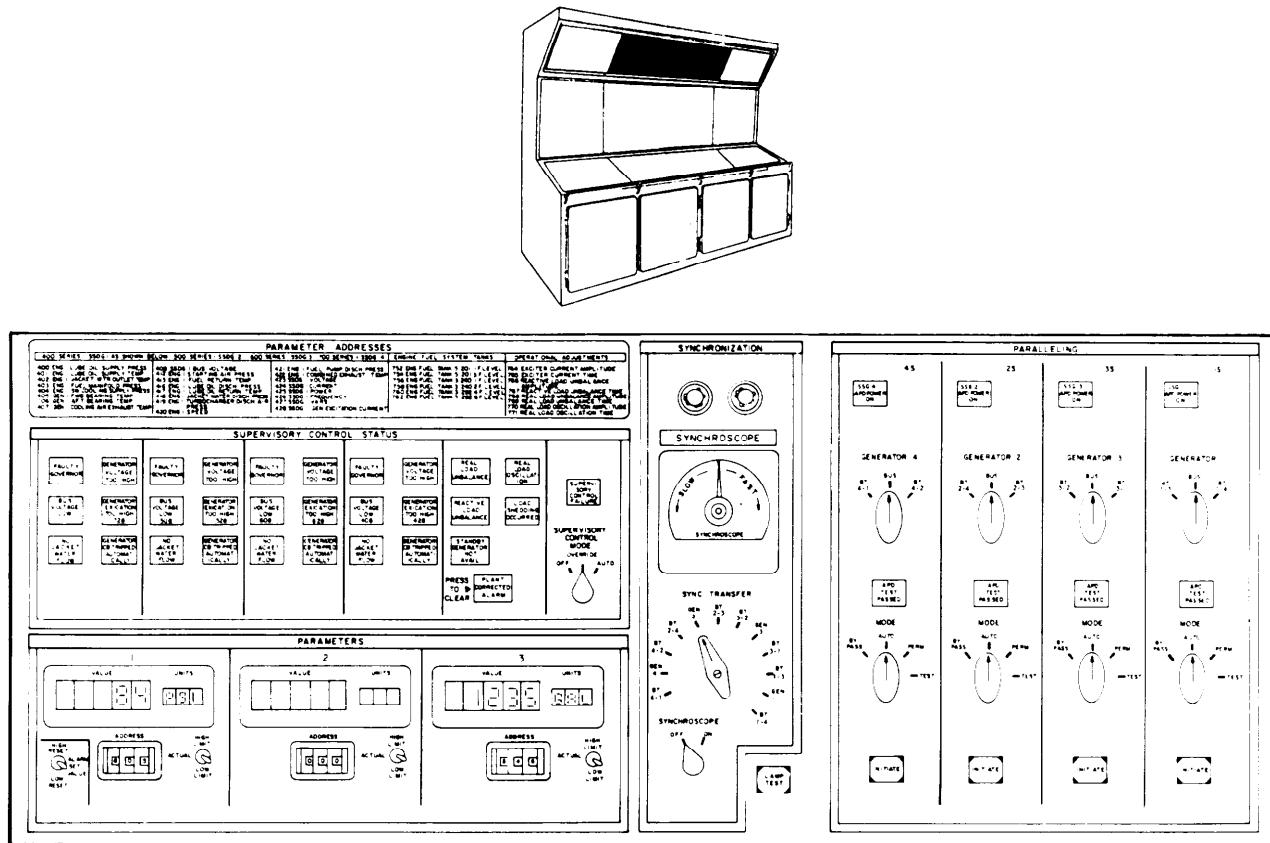


Figure 8-14.—SCS/synchronization/paralleling/parameters panel (A-2).

low-level alarms. The panel also has push-button switches to control the suction valve on each tank and an indicator to show the position of each valve.

Tanks 5-201-1-F and 5-201-3-F are for No. 1 SSDG, tanks 3-240-1-F and 3-240-2-F are for No. 2 and No. 3 SSDGs, and tanks 3-292-4-F and 3-292-6-F are for No. 4 SSDG. All tanks have the same layout, a meter with indicators at the top, the bottom, and to the right of the meter. The indicators are the HIGH LEVEL and the LOW LEVEL alarm indicators, respectfully. The alarm indicators also have a 3-digit number on the indicator. This number is the DDI address for that parameter. (When these 3-digit number sequences are next to an indicator/alarm, they will always indicate a DDI address on this class ship). The two indicators in the middle and to the right of the meter are for the suction valve of the respective tank. The top indicator is the position indicator, and the bottom indicator is a push-button switch that is used to control the valve. Both indicators are labeled SUCTION V OPEN/CLOSED. The top indicator shows the actual position of the valve. The bottom indicator

shows the command being sent to the valve from the console.

The LAMP TEST push-button switch is located on the lower right corner. It is used to test the indicator lights on the A-1 panel only.

#### SUPERVISORY CONTROL STATUS/ SYNCHRONIZATION/PARALLELING/ PARAMETERS PANEL (A-2)

This panel (A-2) (fig. 8-14) is the upper middle panel. It has the parameter addresses, SCS, synchronization, paralleling, and parameters sections.

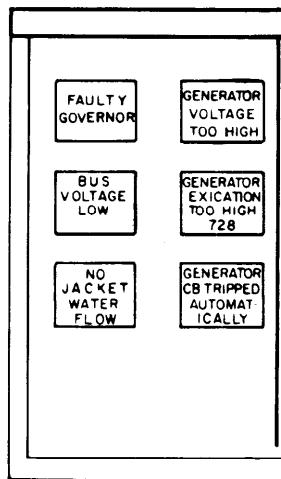
#### SUPERVISORY CONTROL STATUS Section

The SCS section is divided into six subsections. Four are identical, one for each SSDG; the other two are for the overall plant and SCS control switch.

The SSDG subsections each contain six indicators. The indicator circuitry is in operation only when the SUPERVISORY CONTROL

MODE switch is in the OVERRIDE or AUTO position. The six SSDG indicators are as follows:

- FAULTY GOVERNOR indicates a problem with the speed regulation.
- BUS VOLTAGE LOW indicates the voltage on the SWBD is low.
- NO JACKET WATER FLOW indicates the flow of the diesel's jacket water has stopped.
- GENERATOR VOLTAGE TOO HIGH indicates the output voltage of the generator exceeds the preset limit.
- GENERATOR EXCITATION TOO HIGH indicates the ampere level being applied to the generator field exceeds the preset limit.
- GENERATOR CB TRIPPED AUTOMATICALLY indicates the generator circuit breaker (CB) has opened. The operator opening the generator CB can cause this alarm indication.

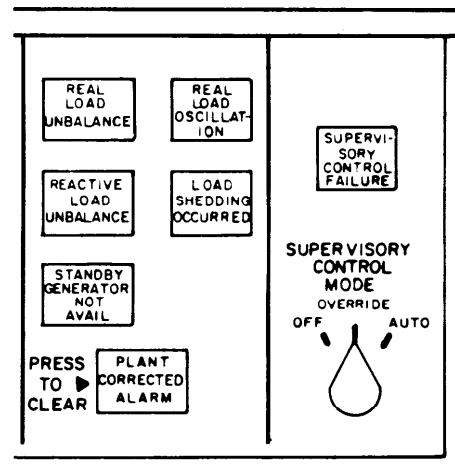


The overall plant section alarms are for conditions that could effect the overall electrical plant operations. These alarms are as follows:

- REAL LOAD UNBALANCE indicates the real or kW load between paralleled generators exceeds the preset limit.
- REACTIVE LOAD UNBALANCE indicates the reactive or ampere load between paralleled generators exceeds the preset limit.

- STANDBY GENERATOR NOT AVAIL indicates the SCS cannot locate a generator setup for automatic operations.
- REAL LOAD OSCILLATION indicates the real or kW load between paralleled generators is oscillating.
- LOAD SHEDDING OCCURRED indicates the electric plant has opened the load shedding circuit breakers.
- PLANT CORRECTED ALARM indicator/push-button switch indicates the SCS has taken action to correct the plant following a malfunction. The indicator will remain illuminated until the PLANT CORRECTED ALARM switch is pressed.

The SUPERVISORY CONTROL FAILURE indicator and the SUPERVISORY CONTROL MODE switch are the last items in this section. The SUPERVISORY CONTROL FAILURE indicator will illuminate when a problem with SCS has been sensed. This could be a hardware or a software problem. The SUPERVISORY CONTROL MODE switch is a three-position switch used to select the operating mode of the SCS. The left position is OFF. In this position the SCS processor has no monitoring or controlling capability. The middle position is OVERRIDE. In this position the SCS will monitor the electrical plant for malfunction but will not take any corrective actions. The right position is AUTO. In this position the SCS will monitor and take corrective action to maintain the electric plant in a standard configuration.



## SYNCHRONIZATION Section

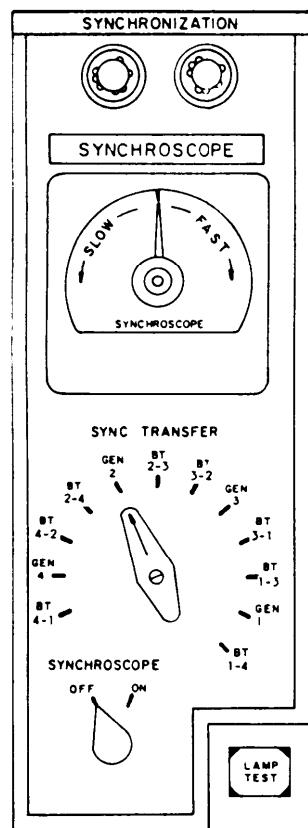
This section contains two indicator lights, a SYNCHROSCOPE meter, a SYNC TRANSFER switch, and an ON/OFF switch.

The indicator lights will be dark when the generators are in phase. The brilliancy of the lights will vary according to differences in the phases.

The SYNCHROSCOPE meter shows the direction and speed of rotation. The direction of rotation of the synchroscope pointer indicates that the frequency of the on-coming generator is FAST or SLOW with respect to the on-line generator. The speed of rotation is an indication of the amount of difference in the frequency. When the pointer is at the 12 o'clock position, the generators are in phase with each other.

The SYNC TRANSFER switch is a rotary switch used to select between the generator CBs or the bus tie (BT) circuit breakers. It connects the inputs from both sides of the selected breaker to the synchroscope and lights. The SYNCHROSCOPE ON/OFF switch is used to turn the synchroscope and lights on and off.

The LAMP TEST push-button switch is located on the lower right corner. It is used to test the indicator lights on the A-2 panel only.



## PARALLELING Section

This section is labeled PARALLELING but is sometimes referred to as the APD section. It has four identical subsections, one for each generator.

The top indicator is labeled APD POWER ON. When it is illuminated, the APD has power applied to it.

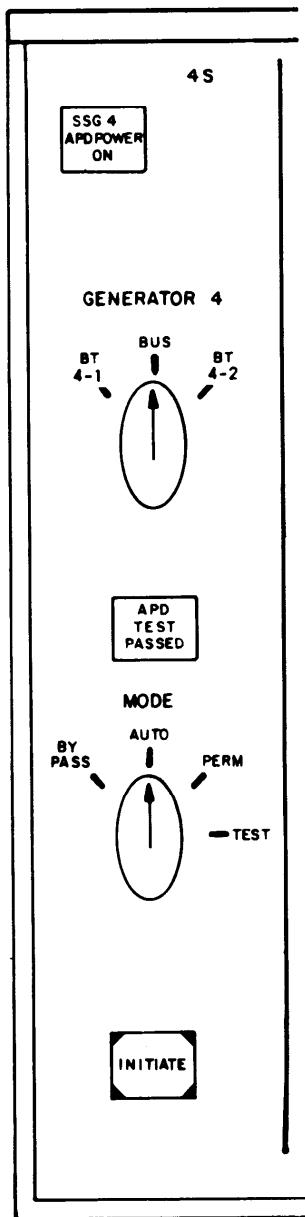
The switch below the APD POWER ON indicator is labeled GENERATOR 4 (1, 2, or 3). It is a three-position rotary switch used to select the breaker on the No. 4 SWBD that the APD will control. The left position is labeled BT 4-1. When the switch is in this position, the APD is connected to the BT that connects the No. 4 and No. 1 SWBDs. The middle position is labeled BUS. This position is for the generator CB. The right position is labeled BT 4-2. It is for the BT that connects the No. 4 and No. 2 SWBDs.

The next indicator down is labeled APD TEST PASSED. This indicator will illuminate at the time the permissives have been met to close the circuit breaker.

The bottom switch is labeled MODE. It is a four-position rotary switch. The MODE switch is used to select the mode of operation of the APD. The left position is labeled BYPASS. This position is used only when the APD is inoperative, when APD permissives cannot be met, or when manual paralleling by the operator is required. This position bypasses the APD's CB closing permissives. The MODE selector switch is spring returned from BYPASS to AUTO. The operator must hold it in the BYPASS position while the CB control switch (not shown) is turned to the CLOSE position. This is done when the two points in the electric plant to be paralleled are synchronized. Also, the operator has to use the APD BYPASS position to close a CB to a dead bus and to the last breaker in a ring bus. The straight up position is labeled AUTO. In this position the APD automatically adjusts the speed of an oncoming generator to synchronize it with an energized portion of the electric system. It then provides a signal to close the designated CB. The next position is labeled PERM. In this position the APD acts as a safety interlock. It prevents the closing of the designated CB unless the required permissives are met. When operated in this mode, the APD functions as a monitoring device, not

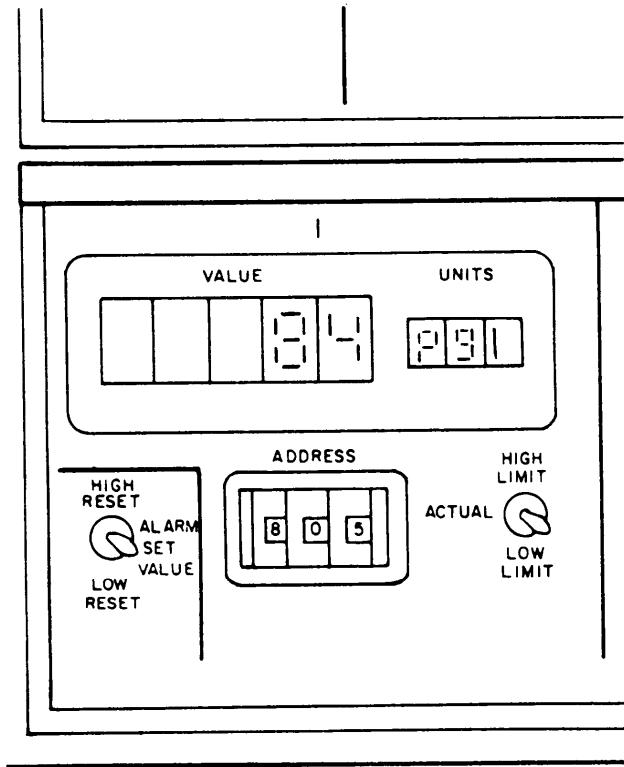
as a controller. The TEST position is the last position. It permits all the features of the APD automatic mode except the signal to close the breaker. Instead, it provides a signal to illuminate the respective APD TEST PASSED indicator light.

The bottom indicator/switch is labeled INITIATE. When this push button is depressed, the APD test sequence is initiated.



## PARAMETERS Section

This section has three digital display subsections. Each contains a display, a thumbwheel, and a toggle switch. The thumbwheel is used to select an address, found on a DDI listing, that calls up the selected parameter. The parameter is displayed with the decimal in the proper position and with the units used to measure the parameter (psi, rpm, and so forth). The toggle switch on the right of each subsection is used to display either the high-alarm limit, the actual value, or the low-alarm limit. Another toggle switch, located at the left side of the first subsection, is used with the other toggle switches. It allows the operator to verify the high/low reset value of the alarm.



## CONSOLE POWER STATUS/ CONSOLE/VITAL POWER FEEDER CIRCUIT BREAKER STATUS PANEL (A-3)

The CONSOLE POWER STATUS/CONSOLE/VITAL POWER FEEDER CIRCUIT BREAKER STATUS panel (A-3) is the upper

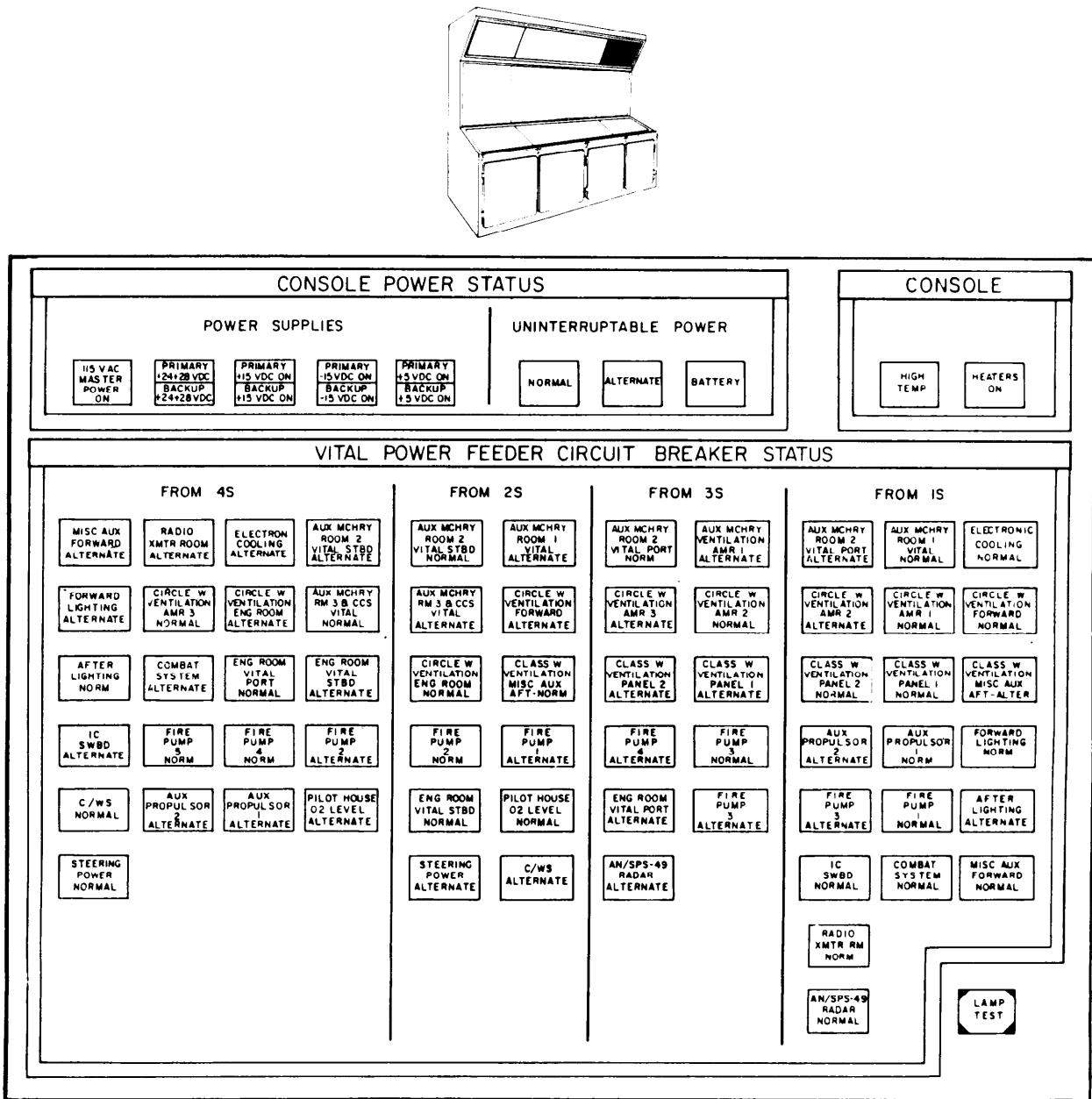


Figure 8-15.—CONSOLE POWER STATUS/CONSOLE/VITAL POWER FEEDER CIRCUIT BREAKER STATUS panel (A-3).

right panel (fig. 8-15). It has the console power status, console, and vital power feeder circuit breaker status sections.

#### CONSOLE POWER STATUS Section

This section contains two subsections, one for the power supplies and the other for the status of the uninterruptable power.

**POWER SUPPLIES.**—This subsection has the indicators that are illuminated when the power supply is operating. The left indicator is 115 VAC MASTER POWER ON. The next four indicators are split-legends indicators, with the upper half of each for the primary power supply and the lower half for the backup power supply. From left to right the power supplies are +24+28 VDC, +15 VDC, -15 VDC, and +5 VDC.

**UNINTERRUPTABLE POWER.**—This subsection has the indicators for the UPS. The left indicator is labeled NORMAL. When it is illuminated, the UPS is operating in a normal manner. The middle indicator is labeled ALTERNATE. When it is illuminated, the power is bypassing the UPS. The right indicator is labeled BATTERY. When it is illuminated, the UPS is operating on the battery power.

## CONSOLE Section

This section contains two indicators. The first indicator is for console HIGH TEMP. When it is illuminated, the console temperature has exceeded a preset value. The HEATERS ON indicator is the right indicator. When it is illuminated, the heaters in the console are on.

## VITAL POWER FEEDER CIRCUIT BREAKER STATUS Section

The illumination of an indicator in this section of the panel shows that a particular CB is open. The layout of the indicators is by SWBD. The indicators are limited to only the vital CBs.

The LAMP TEST push-button switch is located on the lower right corner. It is used to test the indicator lights on the A-3 panel only.

## SSDG PANEL (A-4)

The SSDG panel (A-4) is the middle left panel (fig. 8-16). It is subdivided into four columns. The columns are labeled PRIME MOVER (4, 2, 3, and 1). Each column is identical, one for each SSDG. The indicators from top to bottom are as follows:

- MANIFOLD PRESS meter monitors the pressure of the fuel in the manifold.
- FUEL RETURN HIGH TEMP indicator is at the top and to the right of the meter. It indicates the temperature of the fuel coming out of the fuel cooler is above the preset limit.
- ACOUSTIC CELL FIRE WARNING indicator is to the right of the high

temperature indicator. It indicates the UV sensor in the SSDG enclosure has detected a fire.

- FUEL PRESS FAILURE indicator is at the bottom of the meter. It indicates the pressure in the manifold is below the preset limit.
- ENGINE SPEED meter monitors the speed of the SSDG. It is sensed by the PMA mounted on the aft end of the generator rotor.
- ENGINE TRIP indicator indicates the SSDG has been automatically shut down either by the overspeed trip, low lube oil pressure, Halon release, or corrective action of the SCS.
- RETURN TEMP meter monitors the temperature of the lube oil returning to the sump.
- SUPPLY HIGH TEMP indicator is at the top and to the right of the meter. It indicates the temperature of the lube oil going to the SSDG exceeds the preset limit.
- SUMP LOW LEVEL indicator is the middle indicator. It indicates the level of the lube oil sump is low.
- SUPPLY PRESS meter monitors the pressure of the lube oil going to the SSDG.
- SUPPLY LOW PRESS indicator is at the bottom of the meter. It indicates the pressure of the lube oil going to the SSDG is below the preset limit.

## SSDG OUTPUT AND DISTRIBUTION PANEL (A-5)

The SSDG OUTPUT AND DISTRIBUTION panel (A-5) is located in the center of the EPCC (fig. 8-17). This panel contains four identical columns, one for each SSDG (4, 2, 3, and 1). The controls and indicators on this panel are used to monitor and control the output of the generator. The sections on this panel are the meter, governor control, voltage regulator control, and alarm acknowledge and processor generated alarm sections.

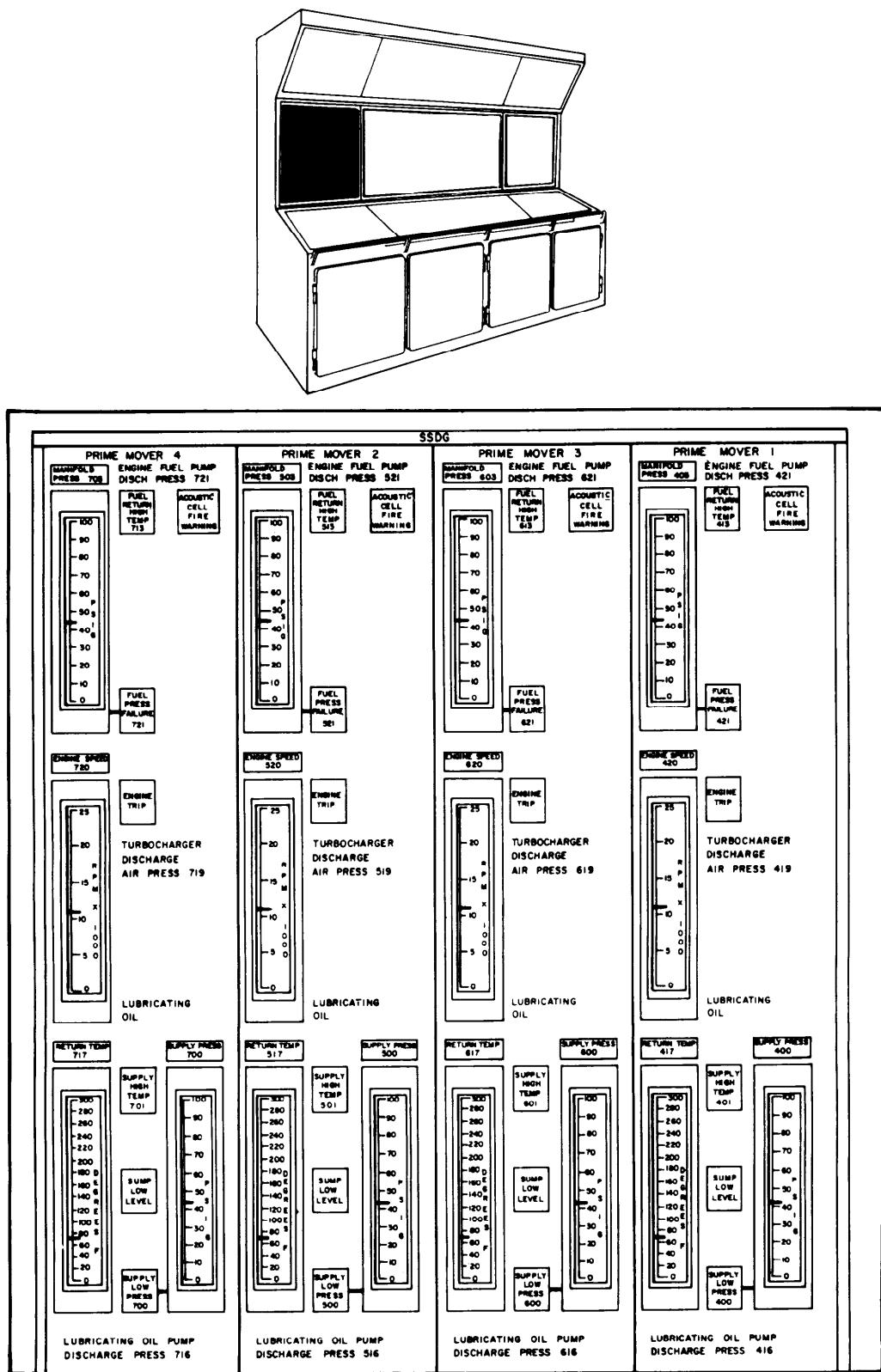


Figure 8-16.—SSDG panel (A-4).

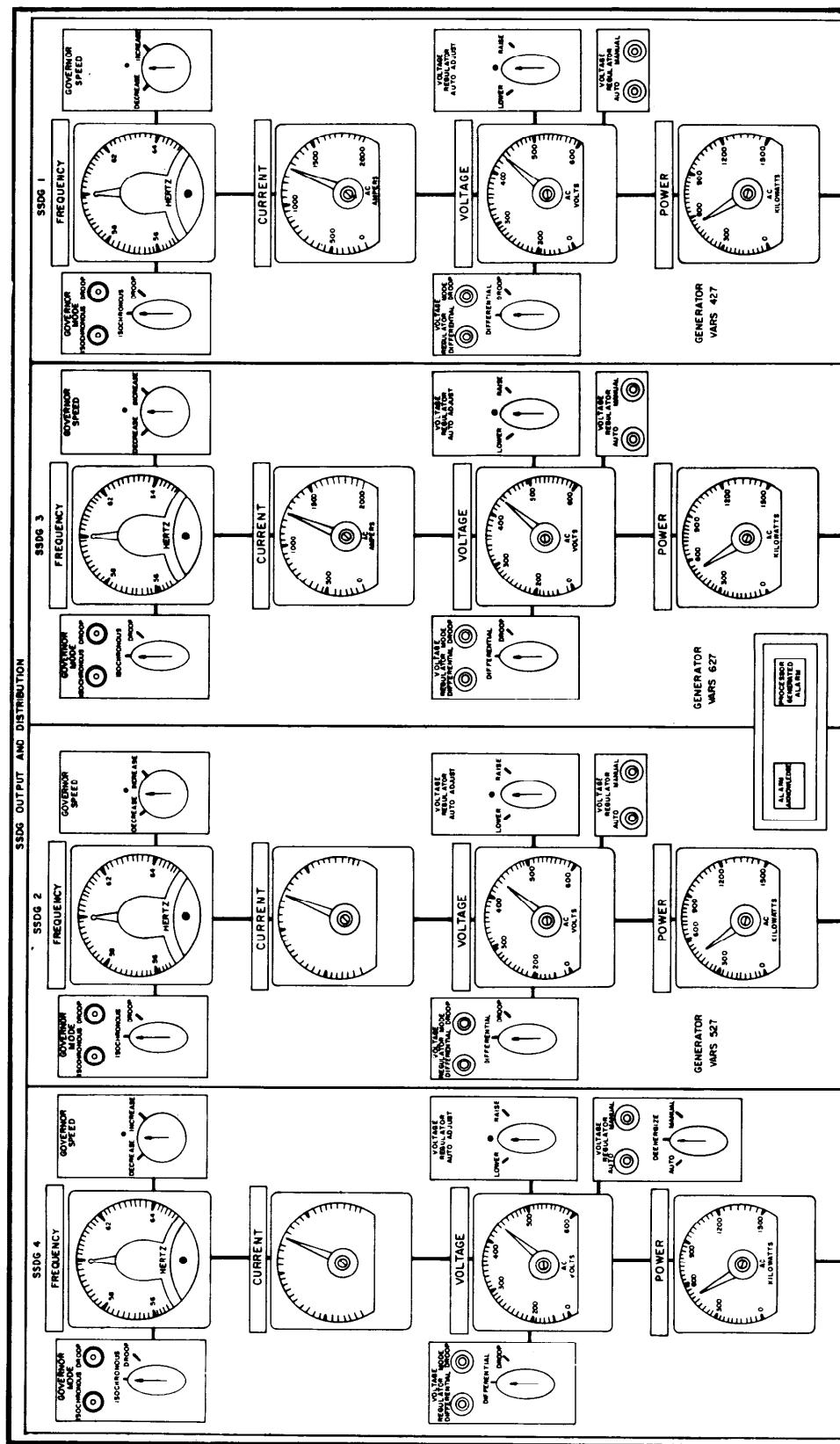
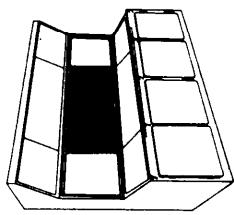


Figure 8-17.—SSDG OUTPUT AND DISTRIBUTION panel (A-5).

## Meter Section

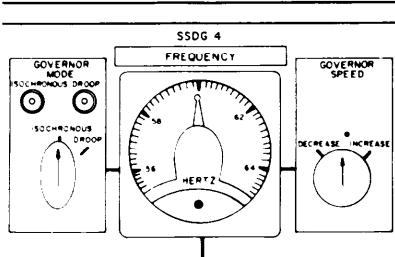
The meters on this panel are used to monitor the FREQUENCY, CURRENT, VOLTAGE, and POWER. These meters are directly wired to the SWBD they monitor.

## Governor Control Section

This section has two switch/indicators for the governor mode and the governor speed. The GOVERNOR MODE switch/indicator controls the governor's mode of operation. The GOVERNOR SPEED switch controls the speed of the SSDG.

**GOVERNOR MODE SWITCH.**—The GOVERNOR MODE control switch and indicators are located to the left of the FREQUENCY meter. The lights are labeled ISOCHRONOUS and DROOP. The indicator light that is illuminated indicates the mode of operation the governor is using. In the ISOCHRONOUS mode, the generators maintain constant speed through load changes. In the DROOP mode, the speed of the generator set varies indirectly with the load. Below the indicator lights is the governor mode selector switch with two positions, ISOCHRONOUS and DROOP. It is used to select the governor's mode of operation.

**GOVERNOR SPEED SWITCH.**—The GOVERNOR SPEED switch is located to the right of the FREQUENCY meter. It is a three-position switch, spring loaded to the center position. When the switch is turned to the right or the INCREASE position, it will cause the frequency of the generator to increase. When it is turned to the left or the DECREASE position, it will cause the frequency of the generator to decrease.



## Voltage Regulator Control Section

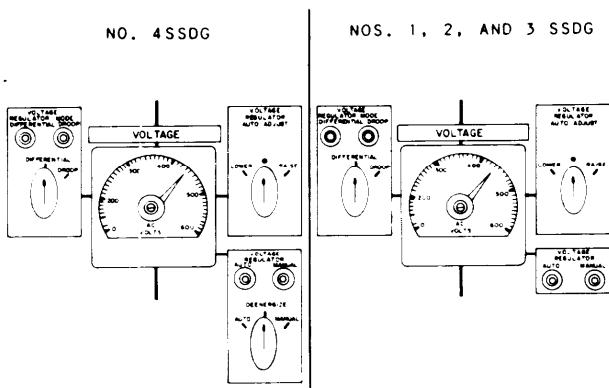
The voltage regulator control section has three separate controls for the VOLTAGE REGULATOR MODE, the VOLTAGE REGULATOR AUTO ADJUST, and the VOLTAGE REGULATOR. The voltage regulator mode controls the voltage regulator's mode of operation.

The voltage regulator auto adjust section controls the output of the generator voltage. The voltage regulator displays the type of voltage regulation used.

**VOLTAGE REGULATOR MODE.**—The VOLTAGE REGULATOR MODE control indicators and switch are located to the left of the VOLTAGE meter. The lights are labeled DIFFERENTIAL and DROOP. The indicator light that is illuminated indicates the mode of operation the voltage regulator is using. When the DIFFERENTIAL mode light is illuminated, the generators maintain constant voltage through load changes. When the DROOP mode light is illuminated, the voltage of the generator set varies indirectly with the load. Below the indicator lights is the VOLTAGE REGULATOR MODE selector switch with two positions, DIFFERENTIAL and DROOP. This switch is used to select the voltage regulator's mode of operation.

**VOLTAGE REGULATOR AUTO ADJUST.**—The VOLTAGE REGULATOR AUTO ADJUST switch is located to the right of the VOLTAGE meter. It is a three-position switch, spring loaded to the center position. When the switch is turned to the right or the RAISE position, it will cause the voltage of the generators to increase. When the switch is turned to the left or the LOWER position, it will cause the voltage of the generators to decrease.

**VOLTAGE REGULATOR.**—The VOLTAGE REGULATOR indicators are located below the VOLTAGE REGULATOR AUTO ADJUST switch. The two indicator lights are labeled AUTO and MANUAL. The No. 4 SSDG also has a three-position selector switch. This switch functions the same as those in the same sections on the DD consoles. The switch positions are labeled AUTO, DEENERGIZE, and MANUAL. This switch is used to control the type of voltage regulation.

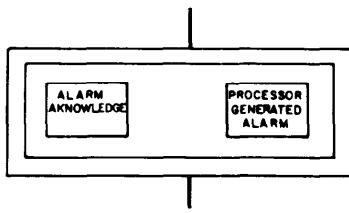


## **Alarm Acknowledge and Processor Generated Alarm Section**

This section has two push-button switches, ALARM ACKNOWLEDGE and PROCESSOR GENERATED ALARM.

When the ALARM ACKNOWLEDGE push-button switch is depressed after an alarm has been received, the audible alarm will be silenced and the flashing alarm indicator will change to a steady light.

The PROCESSOR GENERATED ALARM will occur when an out-of-tolerance condition occurs on equipment being monitored; an alarm is generated in the EPCC by the fault alarm circuit. The status of the parameter is also checked by the processor, a special-purpose computer, located in the EPCC. The processor compares the signal with the alarm set value to determine if an out-of-tolerance condition exists. If the condition does exist, the processor checks the equipment fault alarm circuitry to determine if the fault alarm has been actuated. If the fault alarm has not been actuated but an alarm condition is detected by the processor, the PROCESSOR GENERATED ALARM indicator flashes and an audible alarm sounds.



## **SYSTEM OUTPUT MONITOR/GROUND STATUS TEST/GENERATOR 4 PANEL (A-6)**

The SYSTEM OUTPUT MONITOR/GROUND STATUS TEST/GENERATOR 4 panel (fig. 8-18) is the middle right panel (fig. 8-18). It contains the system output monitor section, ground status test section, generator 4, and audible alarm test switches and rheostat.

### **SYSTEM OUTPUT MONITOR Section**

The SYSTEM OUTPUT MONITOR section contains three meters (FREQUENCY, CURRENT, and VOLTAGE) and two selector switches. The top meter and bottom meter inputs are controlled by the bottom selector switch. The selector switch allows the operator to select which input is applied to the FREQUENCY and VOLTAGE

meters, one of the bus ties, or shore power. The middle meter is a CURRENT meter. The input to this meter is controlled by the upper switch. This selector switch allows the operator to select which bus tie is connected to the CURRENT meter.

### **GROUND STATUS TEST Section**

The GROUND STATUS TEST section has three indicator lights labeled PHASE, and from left to right, A, B, and C. These indicators are normally of equal brilliancy. To the right of the indicator lights is a rotary switch labeled SWITCHBOARD. This switch has four positions, one for each SWBD. At the bottom of this section is a push-button switch labeled BUS GROUND TEST. When this switch is depressed, it connects the selected SWBD to the related indicator lights for testing that SWBD for a grounded condition. A ground will be indicated by one of the lights going out and the other two lights glowing brighter. The light that goes out is the phase that is grounded.

### **GENERATOR 4 Section**

The GENERATOR 4 section has a rheostat and is labeled VOLTAGE REGULATOR MANUAL ADJUST. The rheostat is used to adjust the voltage on the No. 4 SSDG when it is in manual voltage regulation.

### **Audible Test Switches and Rheostat Section**

The audible test switches and rheostat section is located at the bottom of the panel. It contains two push-button switches and a rheostat. The push-button switches are for testing the horn and bell. They are labeled HORN TEST and BELL TEST. The rheostat is for controlling the volume of the audible tones.

The LAMP TEST push-button switch is located at the bottom to the left of the test switches. It is used to test the indicator lights on the A-4, A-5, and A-6 panels only.

### **SSDG PANEL (A-7)**

The SSDG panel (A-7) is the bottom left panel (fig. 8-19). It is subdivided into four columns. The columns are labeled PRIME MOVER (4, 2, 3, and 1). Each column is identical, one for each SSDG. We will describe a column from the top to the bottom.

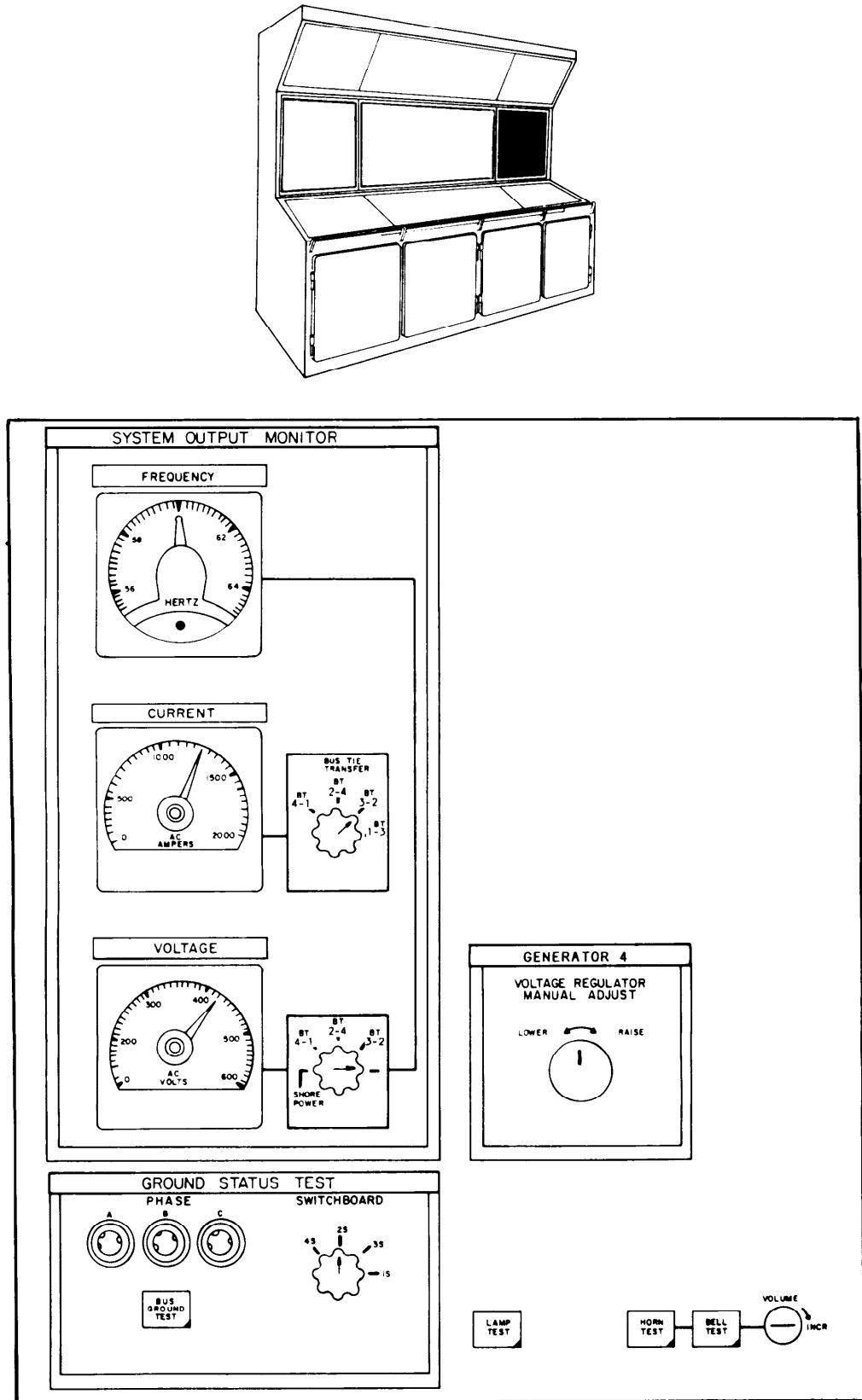


Figure 8-18.—SYSTEM OUTPUT MONITOR/GROUND STATUS TEST/GENERATOR 4 panel (A-6).

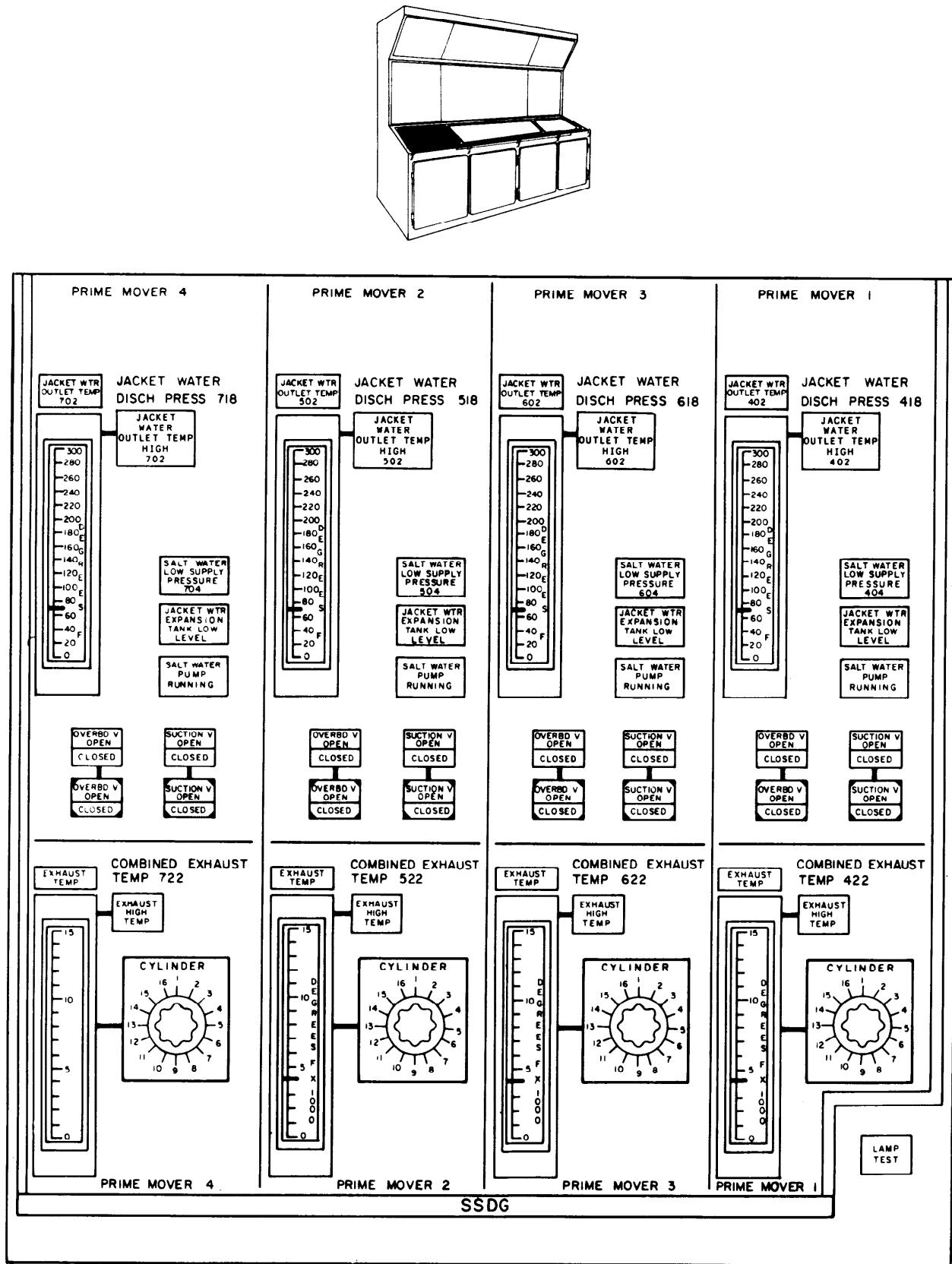


Figure 8-19.—SSDG panel (A-7).

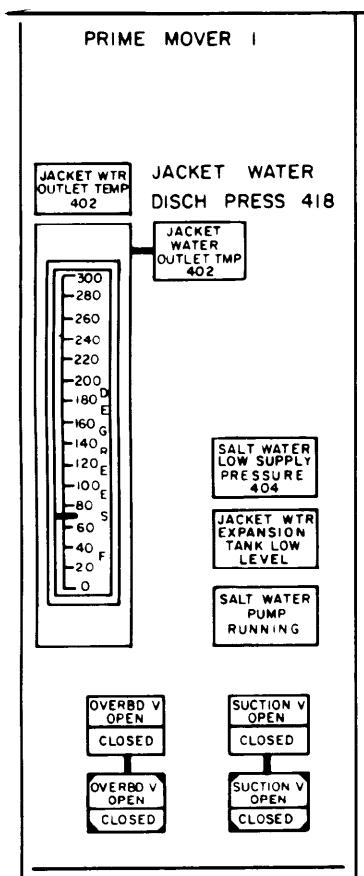
## Jacket Cooling Water System Section

The jacket cooling water system circulates fresh water in the diesel engine jacket. The water is circulated by an engine-driven pump. The top meter, the JACKET WTR OUTLET TEMP, provides a continuous display of the jacket water temperature. The indicator at the top of the meter is the JACKET WATER OUTLET TMP HIGH. It will illuminate when the jacket water outlet temperature exceeds the preset limit. The other indicator for the jacket water system is the JACKET WTR EXPANSION TANK LOW LEVEL indicator. It will illuminate when the water level in the expansion tank falls below the predetermined level.

## Seawater System Section

Each SSDG is provided with a motor-driven seawater circulating pump. The seawater system is used to cool the jacket water system. The following alarm indicators and switch/indicators are for the seawater system:

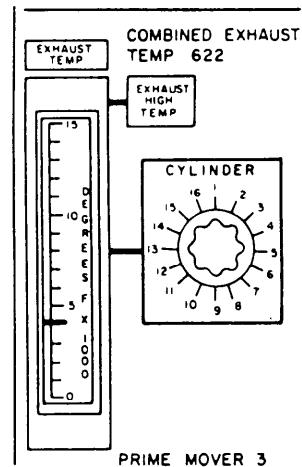
- SALT WATER LOW SUPPLY PRESSURE alarm indicates the pressure in the seawater system is below the preset limit.



- SALT WATER PUMP RUNNING indicator indicates the seawater pump is running.
- OVERBD V OPEN/CLOSED indicator/switch is used to control the seawater overboard discharge valve. The upper indicator shows the actual valve position. The lower indicator/switch is used to control the valve from the EPCC.
- SUCTION V OPEN/CLOSED indicator/switch is used to control the seawater pump suction valve. The upper indicator shows the actual valve position. The lower indicator/switch is used to control the valve from the EPCC.

## Exhaust Temperature Section

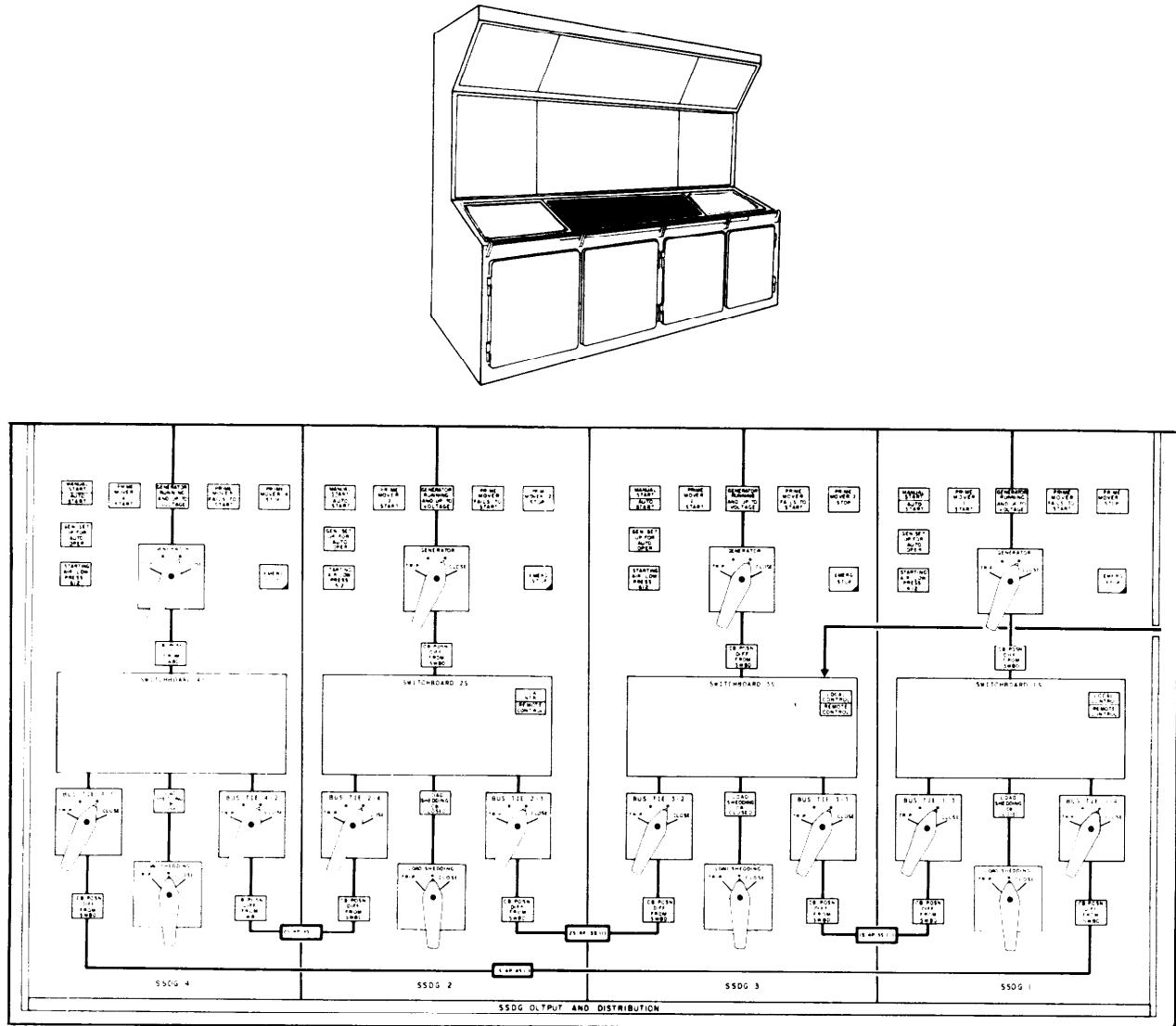
Diesel engine exhaust temperature is measured by thermocouples mounted in each cylinder exhaust manifold and at the outlet of the exhaust manifold. The output from the thermocouples are displayed on the meter labeled EXHAUST TEMP. The switch to the right of the meter is labeled CYLINDER. It is used to select which of the 16 cylinders will be displayed on the meter. When any cylinder temperature reaches a predetermined level, the EXHAUST HIGH TEMP alarm/indicator will illuminate.



The LAMP TEST push-button switch is located on the lower right corner of the panel. It is used to test the indicator lights on the A-7 panel only.

## SSDG OUTPUT AND DISTRIBUTION PANEL (A-8)

The SSDG OUTPUT AND DISTRIBUTION panel (A-8) is the bottom center panel (fig. 8-20).



**Figure 8-20.—SSDG OUTPUT AND DISTRIBUTION panel (A-8).**

It displays a mimic bus depicting the physical arrangement of the electric plant and BTs. The panel is divided into four sections, one for each SSDG (4, 2, 3, and 1). Each section is the same. The panel contains the controls and indicators used to start and stop the SSDG and to control the opening and closing of the generator, BTs, and load shedding CB; it also has an indicator indicating the SWBD control location.

#### Engine Starting and Stopping Section

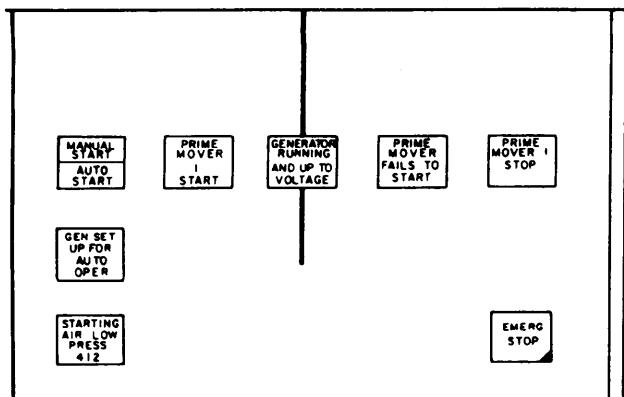
The engine starting and stopping section is located across the top of each section. We will

describe the switch/indicators from the left to right, and then down.

- **MANUAL START/AUTO START** is a split-legends, alternate-action push-button switch. When the MANUAL START position of the indicator is illuminated, the operator must start the SSDG. If the AUTO START position of the indicator is illuminated, the control of starting the SSDG is given to the SCS.
- **PRIME MOVER 1 START** is a push button used to start the SSDG. It is

enabled when the MANUAL START/AUTO START switch is in the MANUAL START position.

- GENERATOR RUNNING AND UP TO VOLTAGE indicates the generator is up to speed and up to voltage.
- PRIMER MOVER FAILS TO START indicates the SSDG failed to start in the required time period.
- PRIME MOVER 1 STOP is a push button used to stop the SSDG.
- GEN SET UP FOR AUTO OPER indicates all the systems and the SWBD are set up for operation of the SSDG in either the manual or auto mode.
- STARTING AIR LOW PRESS indicates the starting air pressure to the SSDG is below the preset limit.
- EMER STOP is a guarded push-button switch. Depressing this switch causes fuel and combustion air to be shut off, thus stopping the SSDG.

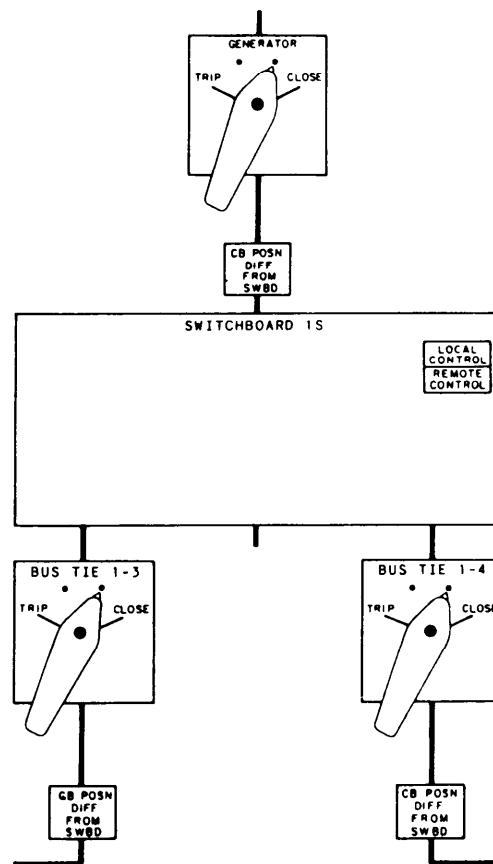


### Circuit Breaker Control and Switchboard Control Sections

Control switches are provided for each generator, BT, and load shedding CB. The control switches for the generator CBs and BTBs are four-position rotary switches. They are spring returned from the outermost position on each side to the adjacent innermost position. The two outermost positions are labeled TRIP and CLOSE. When the switch is placed in these

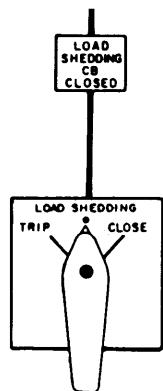
positions, the indicated signal will be sent to the breaker. The two inner positions of the switch set up a circuit through auxiliary contacts on the breaker. The CB POSN DIFF FROM SWBD indicator will illuminate if the switch is in any position different than the actual breaker position. To operate a generator CB or BTB, turn the switch to the desired extreme outermost position, TRIP or CLOSE. Then release the switch handle, which returns to the adjacent innermost position. If the CB POSN DIFF FROM SWBD indicator is illuminated, the switch must be turned to the other innermost position. This will make the switch agree with the CB.

The Nos. 1, 2, and 3 SWBDs have an indicator for local and remote control. When the LOCAL CONTROL indicator is illuminated, control of the SWBD is at the SWBD. When the REMOTE CONTROL indicator is illuminated, control of the SWBD is at the EPCC.



The LOAD SHEDDING CB control switch is a three-position switch, spring loaded to the center position. The left position is labeled TRIP and the right position is labeled CLOSE. A blue LOAD SHEDDING CB CLOSED indicator light

is located above each CB control switch. When it is illuminated, the LOAD SHEDDING CB is closed.



## SHORE POWER/GENERATORS PANEL (A-9)

The SHORE POWER/GENERATORS panel (A-9) is the bottom right panel (fig. 8-21). It has two sections, shore power and generators.

### SHORE POWER Section

This section is located across the top of the panel. It has indicator lights for the shore power circuit breakers, a control switch for the breakers, and a meter for current. The indicator lights will only illuminate when the respective circuit breaker

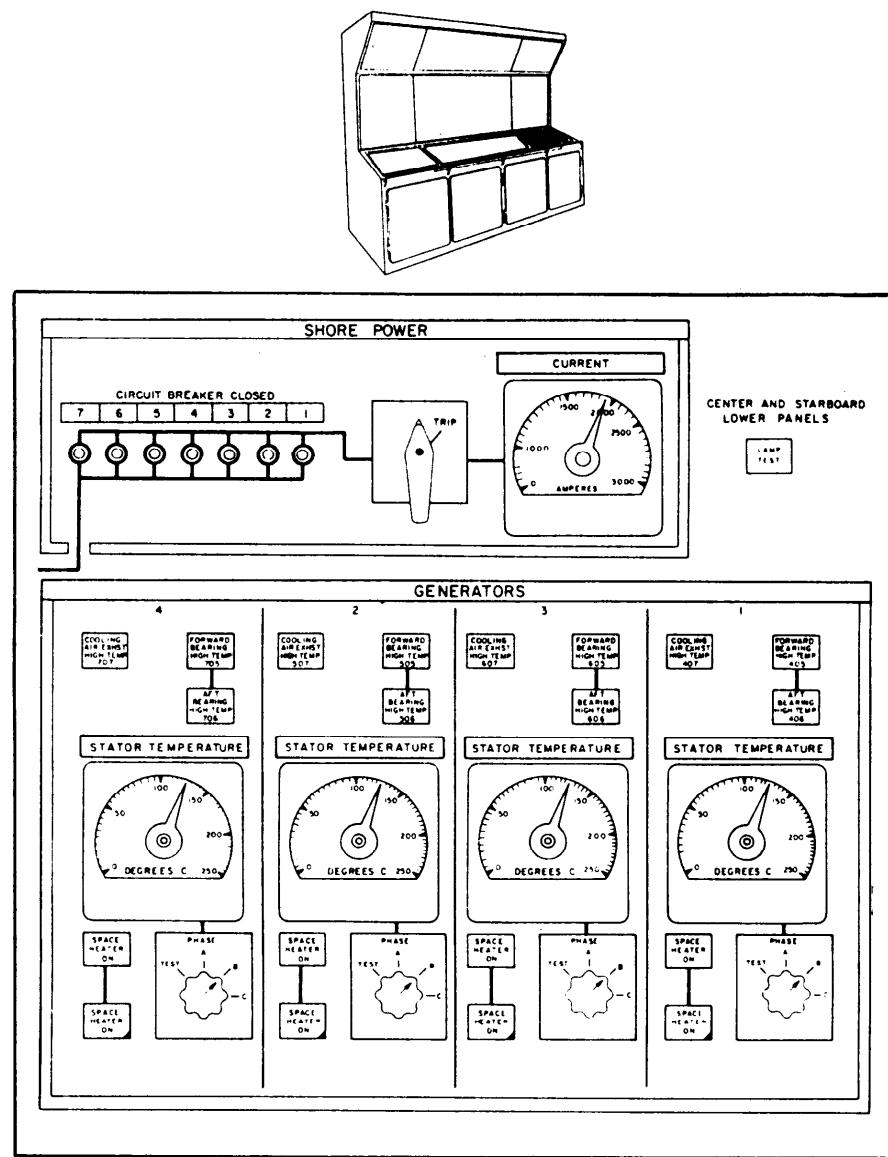
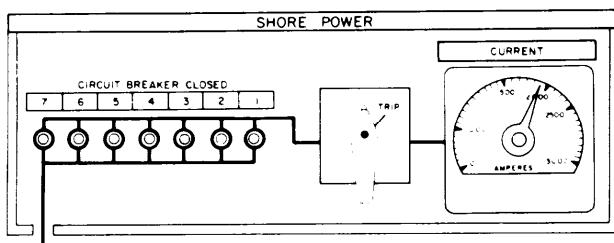


Figure 8-21.—SHORE POWER/GENERATORS panel (A-9).

is closed. The control switch can only trip the shore power circuit breakers. The CURRENT meter provides a continuous display of the amperes the ship is drawing from shore power.

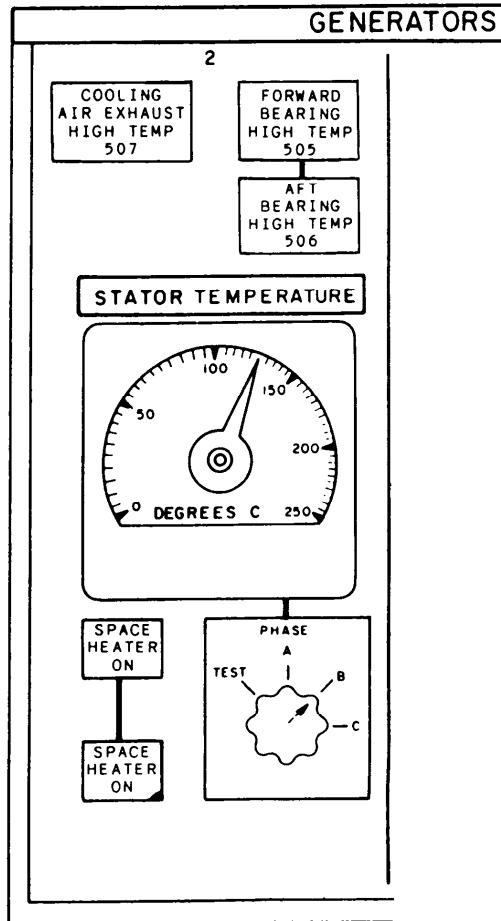


## GENERATORS Section

This section is located across the bottom of the panel. It is subdivided into four identical columns, one for each SSDG (4, 2, 3, and 1). We will cover a column from the top to the bottom. The columns contain the following indicators, meter, and switch.

- COOLING AIR (EXHAUST) HIGH TEMP indicates the air exiting the generator cooler is above the preset limit.
- FORWARD BEARING HIGH TEMP indicates the temperature of the bearing is above the preset limit.
- AFT BEARING HIGH TEMP indicates the temperature of the bearing is above the preset limit.
- STATOR TEMPERATURE meter provides continuous temperature monitoring of the generator windings.
- PHASE rotary switch is used to select the input to the stator temperature meter. It has four positions, TEST, A, B, and C.
- SPACE HEATER ON indicator/switch controls the space heater in the generator. The upper indicator shows the actual status

of the heater. The lower indicator/switch controls the heater from the EPCC.



The LAMP TEST push-button switch is located on the upper right corner of the panel. It is used to test the indicator lights on the A-8 and A-9 panels only.

## ELECTRIC PLANT CONTROL CONSOLE (DDG-51 CLASS SHIP)

The EPCC (fig. 8-22) on the DDG-51 class ship is part of the machinery control system (MCS). It contains the controls and indicators needed to remotely operate and monitor the SSGTGs and power distribution system. It exchanges information with the rest of the MCS.

The EPCC is subdivided into two panels, the output monitor panel (A-1) and the distribution panel (A-2).

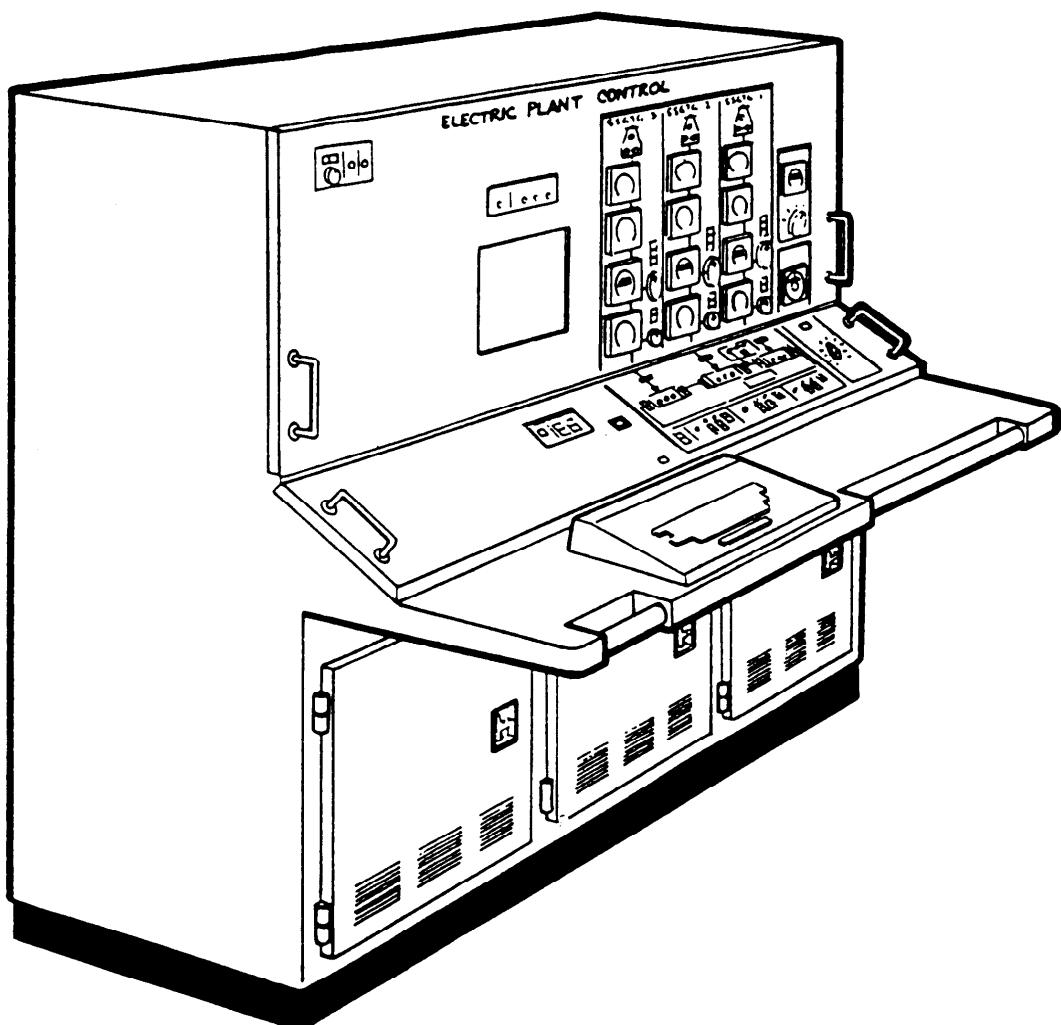


Figure 8-22.—EPCC (DDG-51 class ships).

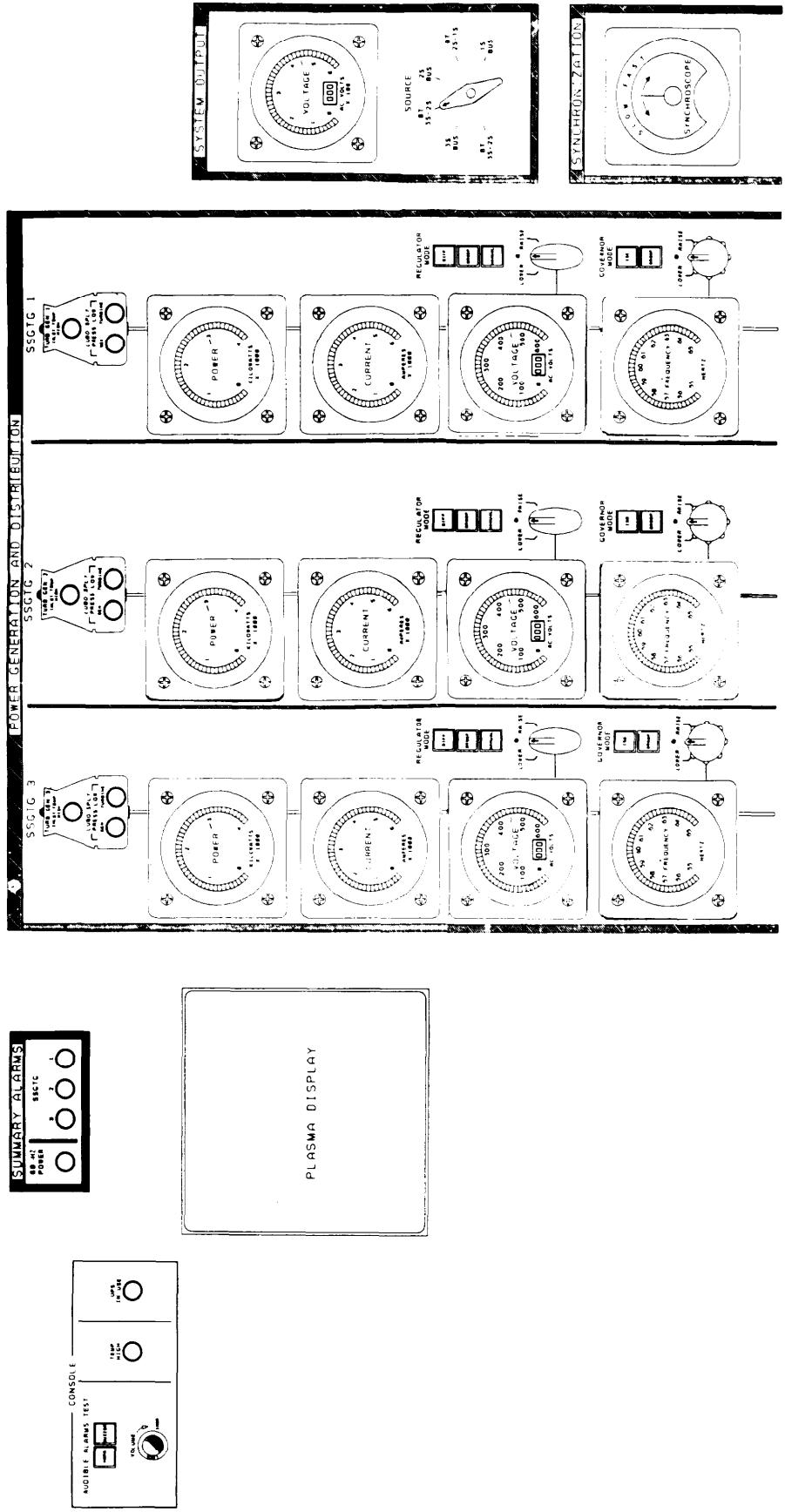


Figure 8-23.—Output monitor panel (A-1).

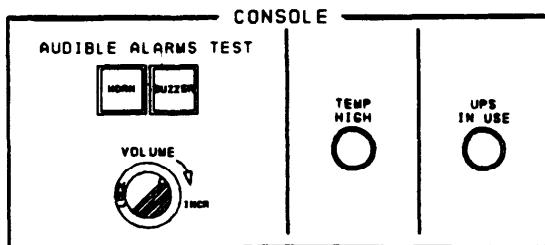
## OUTPUT MONITOR PANEL (A-1)

The output monitor panel (A-1) (fig. 8-23) is the upper panel. It contains the console, summary alarms, plasma display, power generation and distribution, system output, and synchronization sections.

### CONSOLE Section

This section is located at the top left side of the panel. It has the following controls and indicators:

- HORN test push-button switch is used to test the audible alarm.
- BUZZER test push-button switch is used to test the audible alarm.
- VOLUME control knob is used to control the audible alarm volume.
- TEMP HIGH indicator indicates the temperature inside the console is above the preset limit.
- UPS IN USE indicator indicates the console is operating on emergency battery power.



### SUMMARY ALARMS Section

This section is located at the top of the panel and to the right of the console section. Its indicators are summary alarms for the 60 HZ POWER and for each SSGTG.

The 60 HZ POWER indicator is used to indicate that one of the following events has occurred:

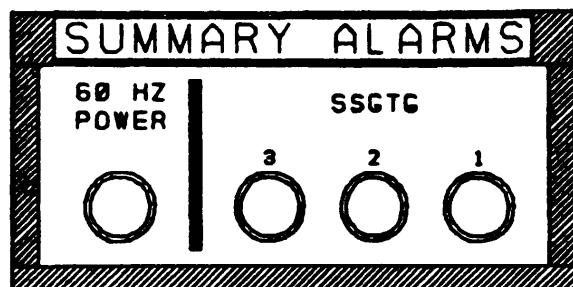
- A generator voltage regulator has shifted from the primary regulator to the backup regulator.
- A generator has high current.
- A SWBD has high ground voltage.

The SSGTG portion contains three indicator lights, one for each SSGTG. The indicator is used to indicate that the following event(s) has occurred:

- Engine control on battery power
- Start air temperature high
- Generator set backup relief valve opened.
- PRI/RSV halon power failure
- Engine speed high
- Engine vibration high
- Engine lube oil supply temperature high
- Generator set firemain backup on
- Engine inlet air icing
- Blow-in door open
- Engine inlet-to-atmosphere differential pressure high
- Engine module temperature high
- Engine module Halon actuated
- Generator cooling air temperature high
- Generator stator phase A temperature high
- Generator stator phase B temperature high
- Generator stator phase C temperature high
- Generator front end bearing temperature high
- Generator aft end bearing temperature high

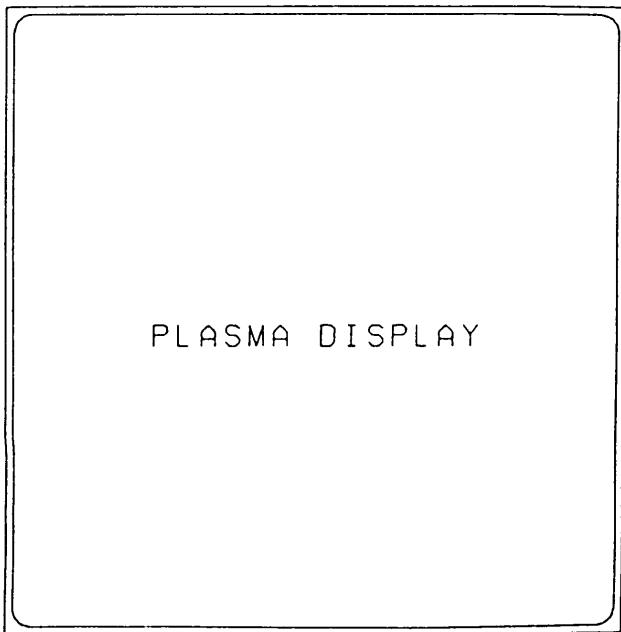
Additionally, the following conditions will cause the SSGTG indicator to illuminate.

- Engine fuel oil gravity feed tank level high
- Engine fuel oil gravity feed tank level low
- GTG 3 head tank level high
- GTG 3 head tank level low
- Generator No. 3 fuel service heater temperature high



## PLASMA DISPLAY Section

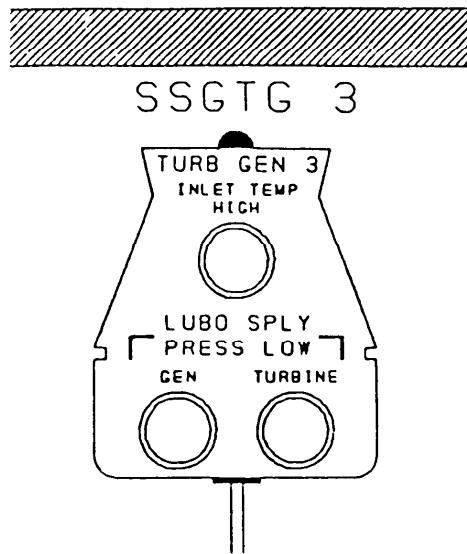
This section is an alphanumeric display device. The plasma display provides the EPCC operator with machinery status and alarm information required to control and monitor the electrical equipment. The plasma display can be operated in two different modes, status/alarm or summary group status. The bottom portion of the display is used for DDI display in both modes. The modes are controlled by the plasma keyboard. The plasma display works the same as the other plasma displays described in chapter 7.



## POWER GENERATION AND DISTRIBUTION Section

This section is divided into three identical sections, one for each SSGTG. The sections are labeled from left to right SSGTG 3, SSGTG2, and SSGTG1. We will discuss the No. 3 SSGTG section. The top indicator is labeled TURB GEN 3 INLET TEMP HIGH. It indicates the temperature of the air at the inlet exceeds the preset limit. The next two indicators are labeled LUBO SPLY PRESS LOW. The left indicator is GEN. This indicator will illuminate when the LO pressure on the generator and reduction gears system is below the preset limit. The right

indicator, TURBINE, is for the LO pressure on the GTE. It indicates the pressure on the GTE is below the preset limit.

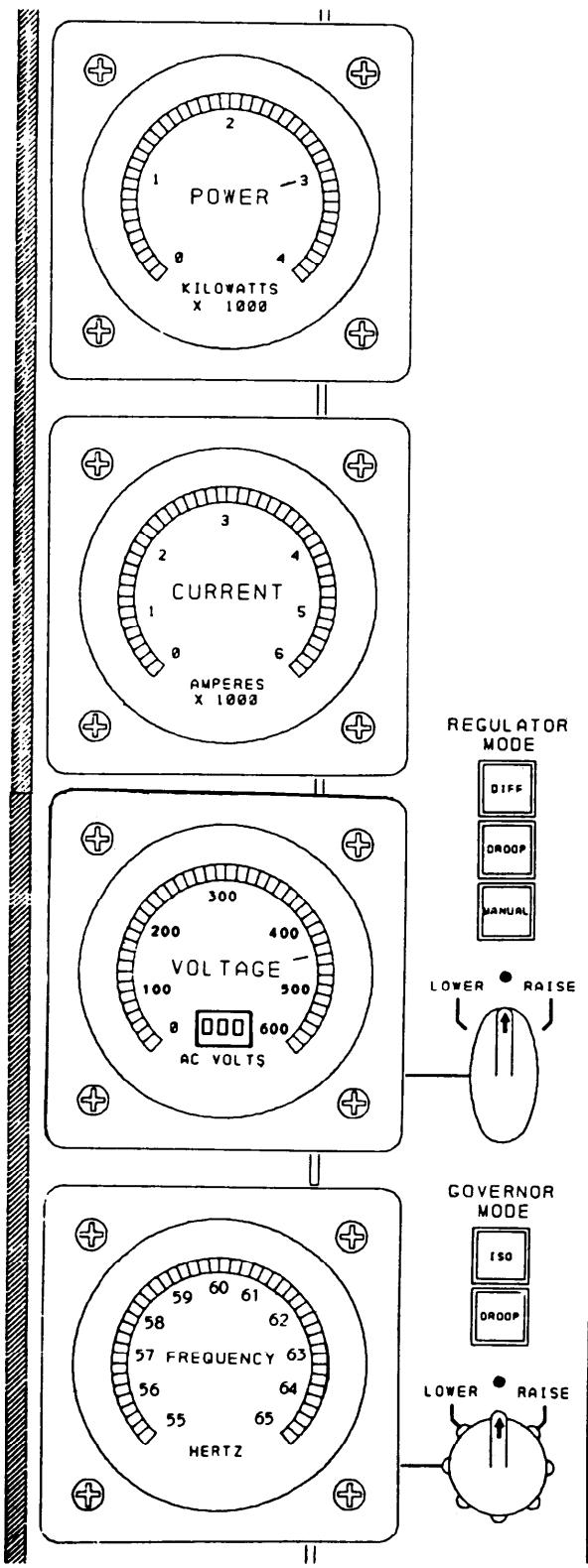


**METERS.**—The meters from top to bottom are POWER, CURRENT, VOLTAGE, and FREQUENCY. The power, current, and frequency meters are 270-degree LED meters. The voltage meter is also a 270-degree LED meter, but it contains a three-digit LED display on the meter. The meters are black in color and the parameter area illuminates red in color. Red area increases around the 270-degree arch as the parameter increases.

**REGULATOR MODE.**—The REGULATOR MODE selector switch/indicators are located to the right of the VOLTAGE meter. The voltage regulator mode switch/indicators are DIFF, DROOP, and MANUAL. The mode that is selected will have its respective indicator illuminated. The rotary switch, below the switch/indicators, is used to RAISE or LOWER the voltage of the generator. It is spring loaded to the center position.

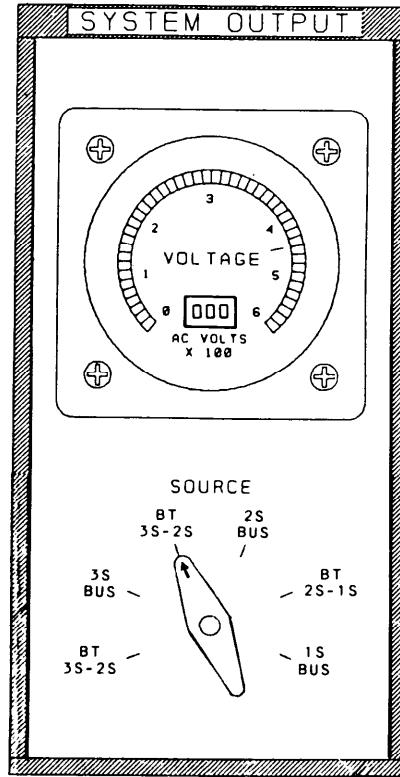
**GOVERNOR MODE.**—The GOVERNOR MODE selector switch/indicators are located to the right of the FREQUENCY meter. The governor mode switch/indicators are ISO and DROOP. The mode that is selected will have its respective indicator illuminated. The rotary switch is used to LOWER or RAISE the frequency of

the generator. It is spring loaded to the center position.



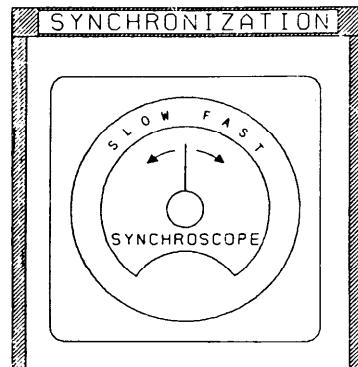
## SYSTEM OUTPUT Section

This section has a VOLTAGE meter and a SOURCE switch. The VOLTAGE meter is the same as the voltage meters on the power generation and distribution section. The SOURCE switch is used to select the input, a bus tie or a bus, to the meter.



## SYNCHRONIZATION Section

This section has a SYNCHROSCOPE meter on this panel, and the selector switch is located on the A-2 panel. The synchroscope functions the same as the synchroscopes on the FFG console.



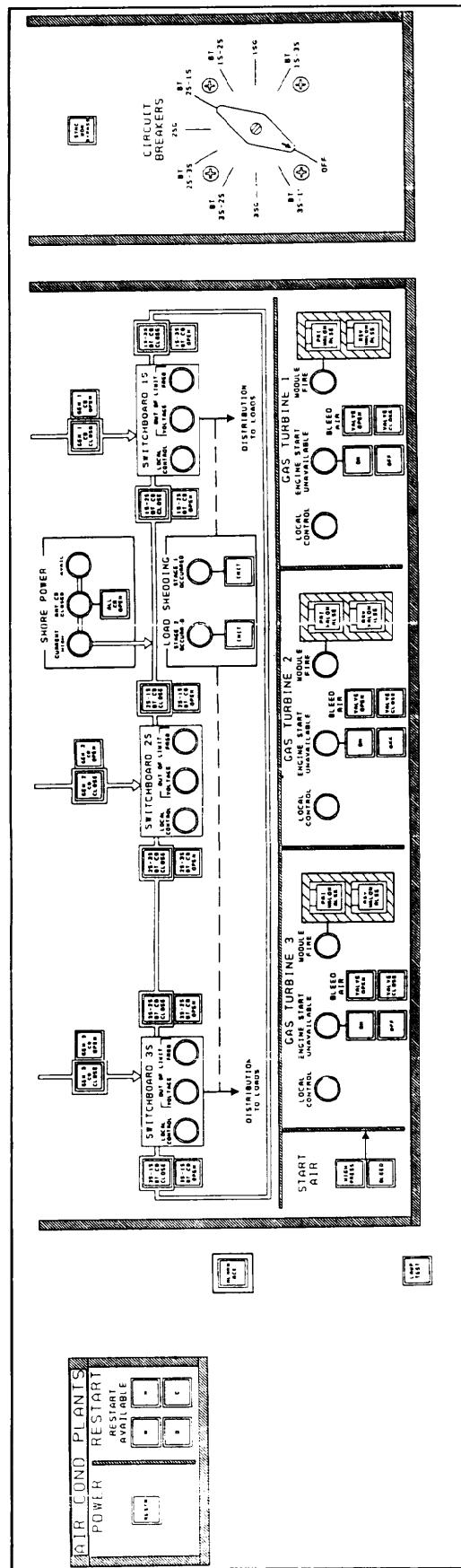


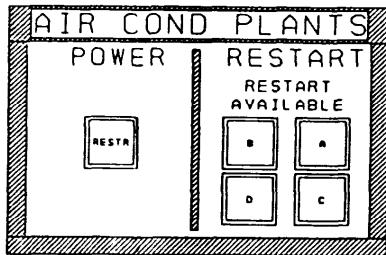
Figure 8-24.—Distribution panel (A-2).

## DISTRIBUTION PANEL (A-2)

The distribution panel (A-2) (fig. 8-24) is the lower panel. It contains the air conditioning (A/C), alarm acknowledge, lamp test, SWBD, shore power, load shedding, start air, gas turbine control, and synchronization sections.

### AIR COND PLANTS Section

This section has two subsections. The POWER section has a RESTR push-button switch. It is used to restore power to A/C plants 1, 2, 3, and 4. The other subsection is RESTART. It has four push-button switches, one for each A/C plant. When a switch is illuminated, it can be used to restart the indicated A/C plant.



### Alarm Acknowledge Section

This section has the ALARM ACK push-button switch. When it is depressed, the following events will occur:

- The audible alarms will be silenced.
- The alarm indicator will go to a steady state.
- The plasma display will indicate acknowledge.

### Lamp Test Section

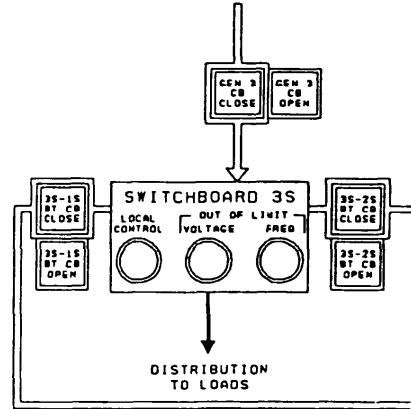
This section has the LAMP TEST push-button switch. When it is depressed, all indicator lights will illuminate and all LED meter segment lights will indicate full scale.

### Switchboard Section

This section is the upper portion of the lower panel. It displays a mimic bus depicting the physical arrangement of the electric plant and BTs. It has the controls for the GBs and the SWBDs.

**CIRCUIT BREAKER CONTROLS.**—The top switch/indicators are for the GBs. When the GEN 3 CB CLOSE indicator is illuminated, the breaker is closed. When the GEN 3 CB OPEN switch/indicator is depressed, it will open the CB and cause the indicator to illuminate. When the GEN 3 CB CLOSE switch/indicator is depressed, it will send a close command to the GB and the indicator will illuminate. The BT CB switch/indicators function the same as the GB switch/indicators. A typical label for a BT is 3S-1S BT CB CLOSE and 3S-1S BT CB OPEN. Each breaker has two switch/indicators.

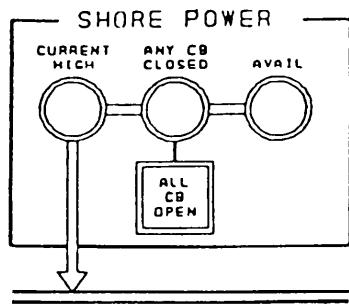
**SWITCHBOARD CONTROLS.**—The SWBD section has three indicator lights. The left indicator is LOCAL CONTROL. It indicates that the control of that SWBD's breakers is at the SWBD. The other two indicators are under the label OUT OF LIMIT. The left indicator is for VOLTAGE. The right is for FREQ. The appropriate indicator will illuminate when the voltage or frequency of the related SWBD is not within the required limits.



### SHORE POWER Section

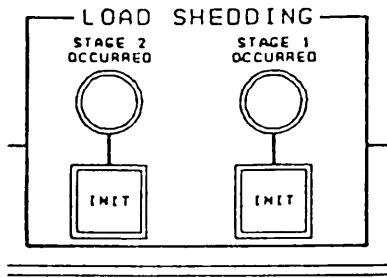
This section has three indicators and one switch/indicator. The left indicator is CURRENT HIGH. It indicates the current on shore power is above the preset limit. The middle indicator is ANY CB CLOSED. It indicates that a shore power circuit breaker is closed. The right indicator is AVAIL. It indicates the shore power cables are connected and energized up to the SWBD. The switch/indicator is ALL CB OPEN. It indicates all shore power

circuit breakers are open. Depressing this switch causes all shore power CBs to open.



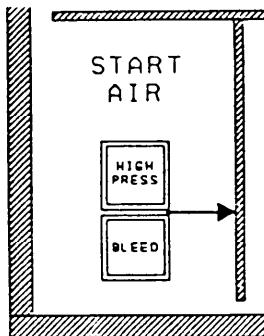
### LOAD SHEDDING Section

This section contains two indicators and two switch/indicators. The left side of the section is for STAGE 2. The right side is for STAGE 1. Each side has an indicator and a switch/indicator. The indicator labeled OCCURRED will illuminate when load shedding has occurred in its respective stage. When depressed, the switch/indicator labeled INIT will illuminate and will initiate its stage of load shedding.



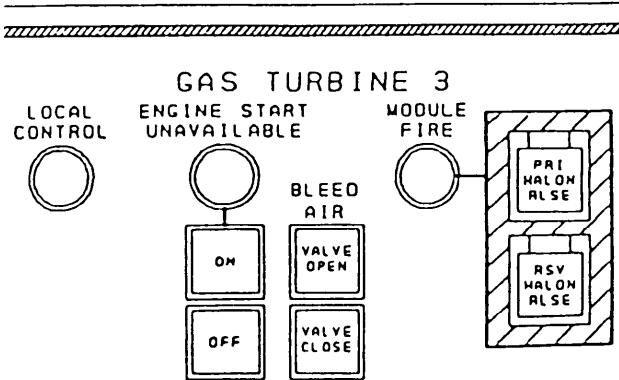
### START AIR Section

This section is located on the lower portion of the A-2 panel. It has two switch/indicators. The upper switch/indicator is for HIGH PRESS air starting of the SSGTG. The lower switch/indicator is for BLEED air starting of the SSGTG.



### GAS TURBINE Section

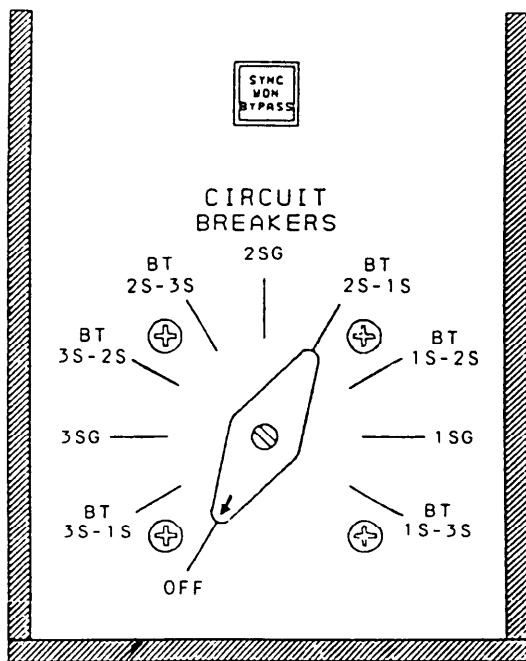
This section is located across the lower portion of the A-2 panel. It has three identical sections, one for each SSGTG. The left indicator is for LOCAL CONTROL. It indicates the control of the SSGTG is not available from the EPCC. The middle indicator is ENGINE START UNAVAILABLE. It indicates the SSGTG is not available to start. The switch/indicator under this indicator is ON. It indicates the GTE is running or in start sequence. The push button is used to initiate a GTE start sequence. The bottom switch/indicator is OFF. It indicates the GTE is secured or in a stop sequence. The two switch/indicators under the BLEED AIR heading are labeled VALVE OPEN and VALVE CLOSED. These switch/indicators function like the GB control switch/indicators. The last indicator in this section is MODULE FIRE. It indicates a fire has been detected in the SSGTG gas turbine enclosure. The last two switch/indicators are guarded push-button switch/indicators. The top one is for PRI HALON RLSE. It is used to activate the primary Halon release. It will illuminate when Halon has been released from any location. The bottom switch/indicator is for RSV HALON RLSE. It functions the same as the primary switch/indicator.



### Synchronization Section

This section is located on the right side of the panel. It contains a switch/indicator and a rotary switch. The switch/indicator, SYNC MON BY-PASS, is used to bypass the synchronizing monitor in the SWBD. The rotary switch is a ten-position switch. It is used to select the circuit

breaker the synchronizing monitor circuit is monitoring.



## SUMMARY

In this chapter we described the controls and indicators of the various class ship's EPCCs. The description of the controls provided in this chapter will help you understand what happens when you depress or turn a control switch. The description of the indicators in this chapter show you the condition or event occurring if that indicator illuminates. As a reminder, always consult the EOSS for the proper operation of these consoles. For additional information on these consoles, refer to *Electric Plant Control Equipment*, Volume 1, NAVSEA S9300-AU-MMA-010, for the CG-class ships; *Electric Plant Control Equipment*, Volume 1, NAVSEA S9234-BS-MMO-010, for the DD-class ships; *DDG-51 Machinery Control System, Electric Plant Control Console*, Volume 1, NAVSEA 9202-AT-MMF-010/16331, for the DDG-51 class ships; and *Electric Plant Control Console*, Volume 1 of 6, NAVSEA 0967-LP-608-4010, for the FFG-class ships.



# CHAPTER 9

## AUXILIARY EQUIPMENT AND CONSOLES

Up to this point we have discussed the construction, indicators, and controls of the main propulsion and electric plant consoles. Also located in the central control station (CCS) of gas turbine-powered ships are important auxiliary equipment and consoles. This equipment allows the CCS watches to monitor and/or control various auxiliary and damage control systems from a central, remote location and provides for the automatic logging of vital parameters and information.

The watches in CCS are responsible for operating and monitoring the ship's engineering plant. For this reason, they must also be familiar with the operation of the auxiliary equipment and consoles. This equipment includes the following units:

- Propulsion and auxiliary machinery information system equipment (PAMISE)
- Fuel system control console (FSCC)
- Auxiliary control console (ACC)
- Damage control console (DCC)
- Bell and data loggers
- Repair station console (RSC)
- Data multiplex system (DMS)

This equipment allows the number of watch standers for the entire engineering plant to be kept to a minimum. Alarms and status indicators keep the CCS operators aware of plant conditions, digital displays and meters show them the vital parameters, and switches and push buttons allow them to control the equipment from a central location.

In this chapter, we will first discuss the operation and control of the auxiliary equipment found on DD-963/993 and CG-47 class ships. We will

then describe the auxiliary equipment found on FFG-7 and DDG-51 class ships. We will describe the indicators and controls associated with each console and related watch-stander responsibilities.

After reading this chapter and completing the associated nonresident training course (NRTC), you should understand the basic functions of the auxiliary equipment and consoles of gas turbine ships. You should also recognize the responsibilities of each watch stander as they relate to the operation and control of this equipment.

The material in this chapter is for training purposes only. It is not meant to replace the Engineering Operational Sequencing System (EOSS) or technical manuals. With the help of an experienced Gas Turbine Systems Technician (Electrical) (GSE) or Gas Turbine Systems Technician (Mechanical) (GSM) and by using the knowledge gained in this chapter, following the EOSS, and completing Personnel Qualification Standards (PQS) requirements, you should have no problem qualifying in all aspects of the auxiliary consoles in CCS.

### PROPELLION AND AUXILIARY MACHINERY INFORMATION SYSTEM EQUIPMENT

The propulsion and auxiliary machinery information system equipment (PAMISE) receives, evaluates, and logs the performance parameters of the propulsion plant, electric plant, and selected ship's auxiliaries. The PAMISE consists of the central information system equipment (CISE), a digital computer, signal conditioning equipment (S/CE), and two line printers. The CISE is located in CCS. A set of S/CE is located in each of the main engine rooms (MERs). Another set is located in CCS. Each signal conditioner functions as a central gathering point for sensory inputs. It processes these inputs so that they will be compatible for computer use and performs alarm signal generation as needed.

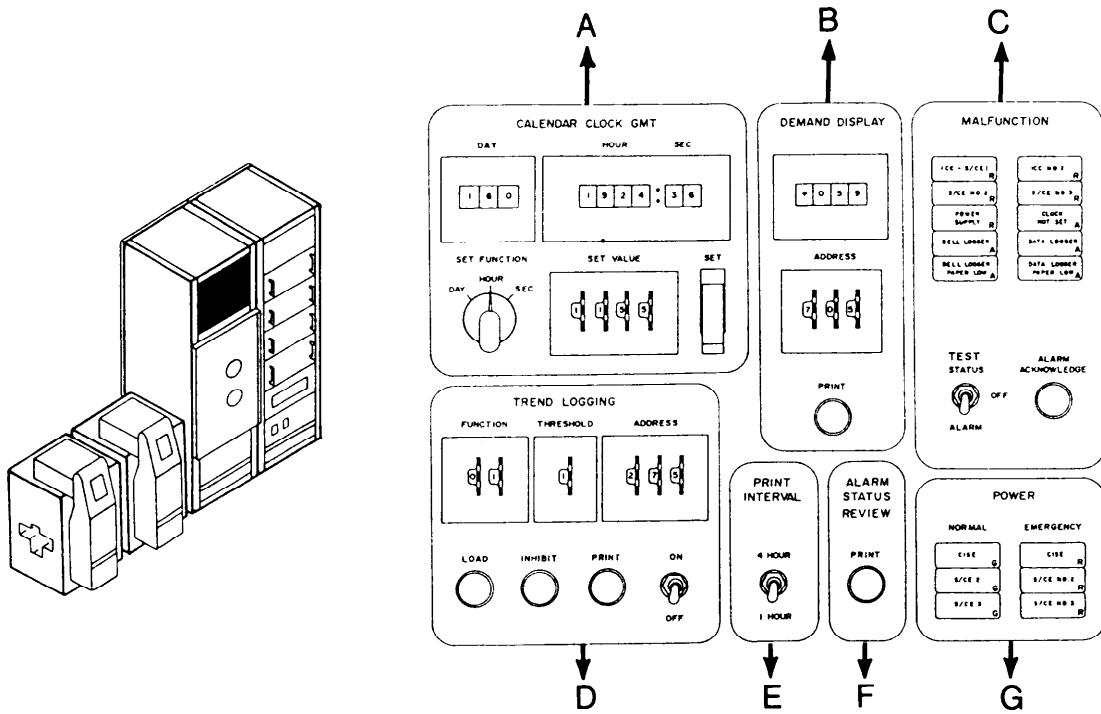


Figure 9-1.—DD monitor and control panel.

## CENTRAL INFORMATION SYSTEM EQUIPMENT

Located in CCS, the CISE is composed of the executive control unit (ECU), S/CE No. 1, a tape reader, two line printers, and associated power supplies.

### Executive Control Unit

The ECU is the main component of the system. It is a special purpose computer that collects, analyzes, and distributes the data that will be used by operators of the engineering plant. The ECU gathers data from the ship's equipment by collecting inputs from the S/CEs, propulsion and auxiliary machinery control equipment (PAMCE), and electric plant control console (EPCC). The data are delivered to operators in the form of alarms, status indicators, printed logs, and digital displays. No propulsion plant control is accomplished by the ECU.

The ECU has a monitor and control panel that allows for operator logging requests, demand display information, and date/time information. This control panel is mounted on the front of the ECU. Another control panel, the ECU test panel, is located on the rear of the ECU. This panel is used for computer maintenance.

## Monitor and Control Panel

On DD-class ships, the monitor and control panel of the CISE is divided into seven sections. (See fig. 9-1.) (On CG-class ships, this panel is divided into six sections.) The sections of the monitor and control panel are as follows:

- CALENDAR CLOCK GMT
- DEMAND DISPLAY
- MALFUNCTION
- TREND LOGGING (not applicable on the CG)
- PRINT INTERVAL
- ALARM STATUS REVIEW
- POWER

### CALENDAR CLOCK GMT SECTION.—

The CALENDAR CLOCK GMT section (A) contains a Julian calendar display, a Greenwich mean time (GMT) digital clock, a three-position rotary switch, and a

spring-loaded, two-position toggle switch. The calendar information is displayed in the light emitting diode (LED) windows under the headings DAY, HOUR, and SEC. The Julian date is continuously displayed in the LED windows under the heading DAY.

#### NOTE

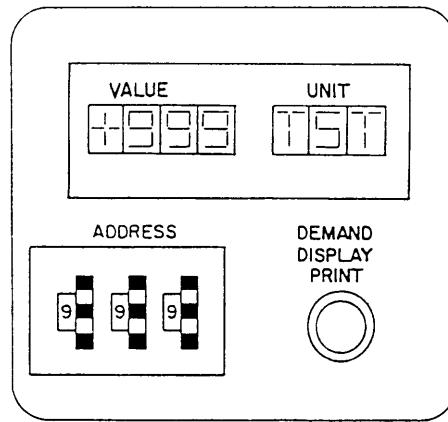
Julian dates are numerically sequential days of the year. For example, January 1 is day 001; January 2 is day 002; December 31 is day 365, except in a leap year when it is day 366.

Under the headings HOUR and SEC, the GMT clock displays the time of day in hours and seconds in the LED windows in the 24-hour clock format. This clock allows logging to be consistent from time zone to time zone without the operators having to note time changes. The rotary switch under the heading SET FUNCTION has three positions: DAY, HOUR, and SEC. The operator uses this switch to select a change in the Julian date, the hour, or the seconds shown in the LED windows. The thumbwheels labeled SET VALUE work in conjunction with the spring-loaded toggle switch labeled SET. The operator uses the thumbwheels to dial up the desired data to be shown in the LED windows and raises the toggle switch to the SET position to load the data into the computer.

**DEMAND DISPLAY SECTION.**—The DEMAND DISPLAY section (B) contains a demand display indicator (DDI), a set of three thumbwheels, and a push-button switch. The DDI display allows operators to display a selected parameter by setting up the address on the thumbwheels. The display on the CG-class ships will also show the unit of measurement of the selected address. You can select and display any plant parameter as long as it has a DDI address.

A PRINT push button (DEMAND DISPLAY PRINT on the CG) is also associated with the DDI. When depressed, this push button causes the parameter selected by the address to be printed on the data log. The DDI index also has special addresses that allow group printouts to be printed on the data log. Printouts of groups include areas such as power train, fuel oil, lube oil, GTM, GTG, and 60-Hz

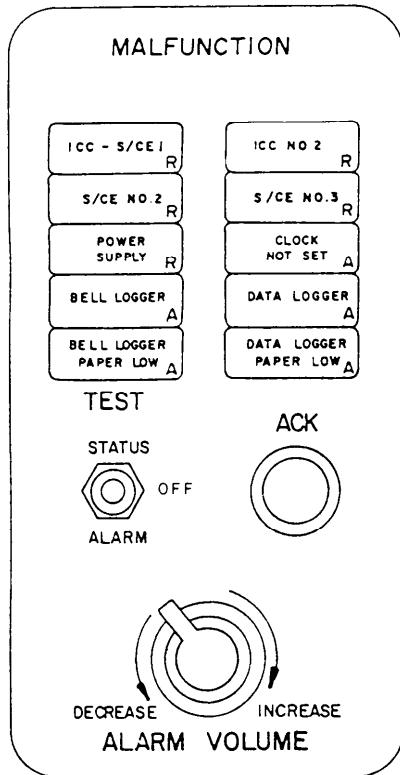
distribution. Consult your ship's DDI index for the addresses of these printouts.



**MALFUNCTION SECTION.**—The MALFUNCTION section (C) has ten alarm indicators, an alarm/status test switch, and an alarm acknowledge push button. The MALFUNCTION section on the CG also has a alarm volume control knob. The alarm indicators illuminate either red or amber to alert the operator when malfunctions occur within the PAMISE system. The first alarm indicator, labeled ICC-S/CE 1, illuminates red to indicate a fault in the information center console (ICC) No. 1 or in the S/CE No. 1. The second alarm indicator, labeled ICC NO. 2, illuminates red to indicate a fault in the ICC No. 2. The third alarm indicator, labeled S/CE NO. 2, illuminates red when a fault in the S/CE No. 2 occurs. The fourth alarm indicator, labeled S/CE NO. 3, illuminates red when a fault in the S/CE No. 3 occurs. The fifth alarm indicator is labeled POWER SUPPLY. It illuminates red to indicate a fault in one of the engineering control and surveillance system (ECSS) power supplies. The sixth alarm indicator is labeled CLOCK NOT SET. It illuminates amber when the calender clock has not reset after a loss of ECU power. The seventh alarm indicator, labeled BELL LOGGER, illuminates amber when the bell logger is not on line or when a fault occurs. The eighth alarm indicator, labeled DATA LOGGER, illuminates amber when the data logger is not on line or when a fault occurs. The ninth alarm indicator, labeled BELL LOGGER PAPER LOW, illuminates amber to indicate that there are about ten blank sheets of paper remaining in the bell logger. The last alarm indicator, labeled DATA LOGGER PAPER LOW, illuminates amber to indicate that there are

about ten blank sheets of paper remaining in the data logger.

When any of these malfunctions occur, the appropriate alarm flashes and a buzzer sounds. Depressing the ALARM ACKNOWLEDGE push button (labeled ACK on the CG) will silence the buzzer and cause the indicator to illuminate steadily. The alarm indicator extinguishes when the malfunction clears. On the CG, the volume of the buzzer can be adjusted by rotating the ALARM VOLUME control knob (this feature does not exist on the DD). The three-position toggle switch allows the operator to test the alarm and status indicators. The three positions of the switch are labeled STATUS, OFF, and ALARM.



**TREND LOGGING SECTION.**—The TREND LOGGING section (D) of the CISE (not applicable on the CG) allows certain parameters to be printed onto the data log when a selected limit is exceeded. The TREND LOGGING section has three groups of thumbwheels, three push buttons, and a two-position toggle switch. The three thumbwheel groups are labeled FUNCTION, THRESHOLD, and ADDRESS. The FUNCTION thumbwheels allow the operator to select 1 of 16 trend logging memory locations. The THRESHOLD thumbwheel allows the operator

to preset the amount of variance of the parameter before printout occurs. This range is set between 1 to 10 percent of full scale. The ADDRESS thumbwheels allow the operator to select the parameter to be trend logged.

The three push buttons labeled LOAD, INHIBIT, and PRINT are used when the operator is setting, securing, and reviewing the trend logging. The two-position switch, labeled ON and OFF, is used to turn on or turn off trend logging functions. The three push buttons are used to program the digital computer for trend logging. After placing the toggle switch to the ON position and setting all the thumbwheels, the operator depresses the LOAD push button to program the selected parameter into trend logging. The PRINT push button signals the data logger to print out all active trend logging parameters. The INHIBIT push button is used to stop the trend logging of a selected parameter. Trend logging is useful for monitoring recently repaired equipment to establish trend data. It is also useful for logging of data during full power and economy trials.

**PRINT INTERVAL SECTION.**—The PRINT INTERVAL section (E) contains a two-position switch labeled 1 HOUR and 4 HOUR. This switch sets the interval when the data logger will automatically print a complete plant printout.

**ALARM STATUS REVIEW SECTION.**—The ALARM STATUS REVIEW section (F) contains a push-button switch labeled PRINT. When depressed, the switch commands the data logger to print out all active alarms in the ECSS. This function is useful to the engineering officer of the watch (EOOW) when reviewing the active alarms and out-of-limits parameters before relieving the watch.

**POWER SECTION.**—The POWER section (G) consists of three status indicators, under the heading NORMAL, and three alarm indicators, under the heading EMERGENCY. These six indicators allow the operator to monitor the status of the power supplies in the PAMISE system. The first indicator, labeled CISE, illuminates green to indicate the CISE is on normal ship's service (SS) power. The second indicator, labeled CISE, illuminates red to indicate the CISE is on the uninterruptible power supply (UPS). The third indicator, labeled S/CE 2, illuminates green to

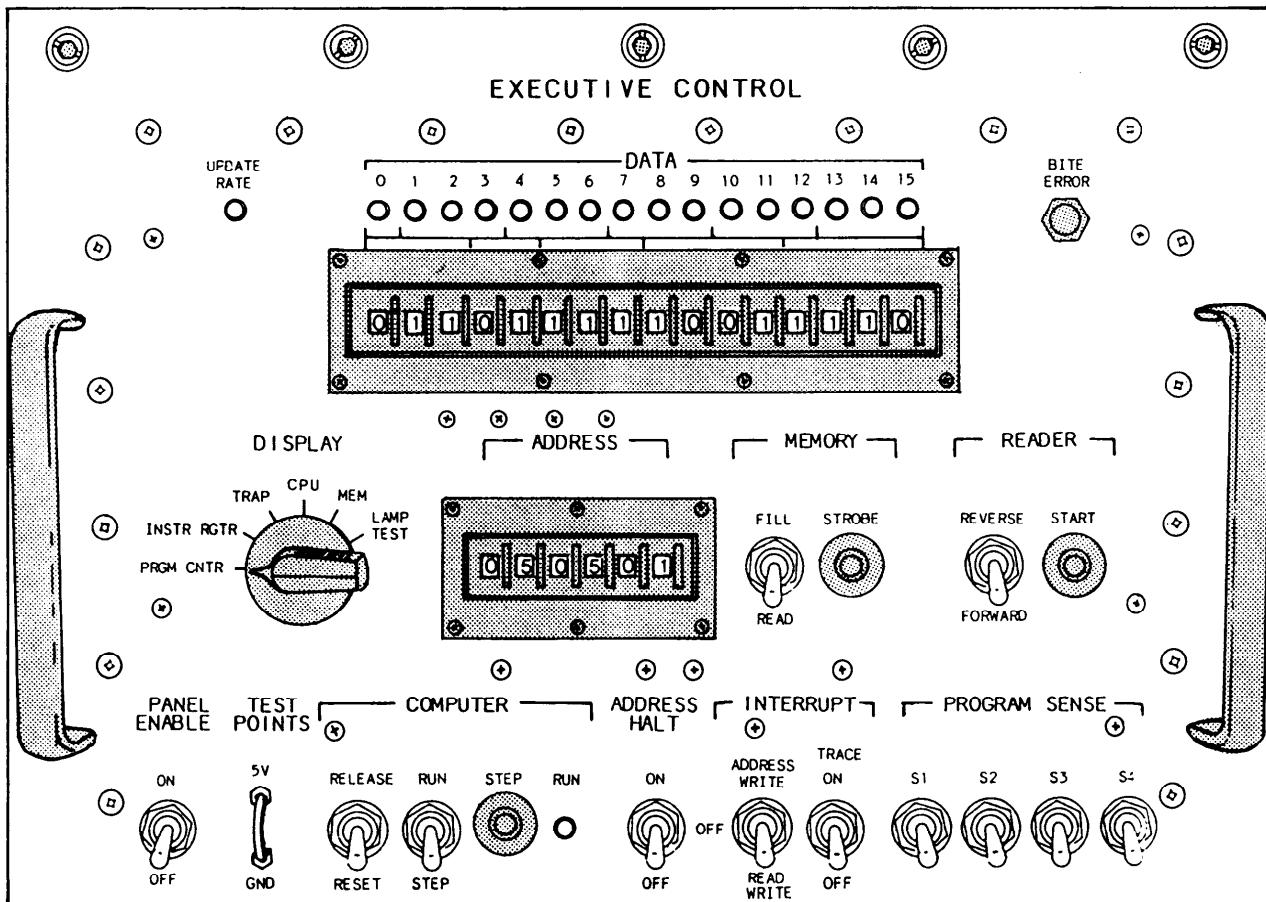


Figure 9-2.—ECU test panel.

indicate the S/CE 2 is on normal SS power. The fourth indicator, labeled S/CE NO. 2, illuminates red to indicate the S/CE No. 2 is on UPS. The fifth indicator, labeled S/CE 3, illuminates green to indicate the S/CE 3 is on normal SS power. The sixth indicator, labeled S/CE NO. 3, illuminates red to indicate the S/CE No. 3 is on UPS.

#### ECU Test Panel

The ECU test panel (fig. 9-2) is located inside the CISE enclosure at the back of the CISE cabinet. The test panel is the primary interface to the ECU. The computer program (operated only by experienced GSEs) is loaded, run, and maintained through this panel. The tape reader panel (not shown) consists of a punched tape reader, two reels, and a two-position toggle switch. The tape reader reads the ECSS program from a prepunched tape and loads the information into the memory core of the ECU.

#### CAUTION

The potential for causing malfunctions to the entire ECSS network is very high if the equipment is operated by inexperienced maintenance personnel. A technician must have a thorough understanding of the serial data networks, binary logic, and digital equipment before operating the ECU test panel. The operation of the ECU test panel is beyond the scope of this training manual (TRAMAN) and will not be covered.

#### SIGNAL CONDITIONING EQUIPMENT

Signal conditioning is done by the PAMISE at the S/CEs No. 1, No. 2, and No. 3. The purpose of these S/CEs is to convert all the sensory inputs into a common electrical range of 0 to 10 volts dc. This conversion makes the inputs compatible with the rest of the ECSS. The S/CE No. 1 monitors the electric plant. The

S/CEs No. 2 and No. 3 monitor the main propulsion parameters. The five basic types of signal conditioning include

1. voltage signal conditioning,
2. current signal conditioning,
3. RTE signal conditioning,
4. tachometer/frequency signal conditioning, and
5. wattmeter signal conditioning.

Each of these conditioners receives a sensor or external signal conditioner voltage, current, resistive, or frequency input, respectively. These inputs are converted to a 0- to 10-volt dc analog signal and are processed by other electronic circuitry of the ECSS for alarm generation, analog meter display, and digital demand displays. The PAMISE is designed so that discrete contact sensor signals are allowed to pass through the signal conditioners unaffected.

The S/CE No. 1 is located in CCS and is a part of the CISE. The S/CE No. 2 is located in MER No. 2, and the S/CE No. 3 is located in MER No. 1. The S/CEs consist of a self-test panel through which the operator interfaces with the ECSS electronics. All three units are basically the same. We will, however, point out any significant differences throughout our discussion.

The self-test panel, shown in figure 9-3 for S/CE No. 1 and in figure 9-4 for S/CEs No. 2 and No. 3, provides a method for the ECU to generate self-test signals to various ECSS

equipment. This panel detects and displays malfunctions that occur within the ECSS and provides for calibration of numerous circuit cards. The serial clock and the system can also be reset at this panel. The self-test panel consists of two sections labeled CALIBRATION and MALFUNCTION. There is one self-test panel on each of the S/CEs.

### CALIBRATION Section

Refer to section A in figure 9-3. The CALIBRATION section (A) consists of 18 LED status indicators, two toggle switches, and a four-position rotary switch. The operator uses this section to calibrate and adjust the set points on various circuit cards and to display the results of these adjustments. The LEDs on this section will visually display the following information:

- Type of calibration
- Card out of slot or wrong slot status
- Adjustment type
- Card type
- Results of adjustments

The first toggle switch is a two-position switch labeled ADJ TYPE. The operator uses this switch to select the type of desired adjustment. The adjustment type can be either ZERO or GAIN. The other toggle switch is a three-position switch. The operator uses this switch to turn the

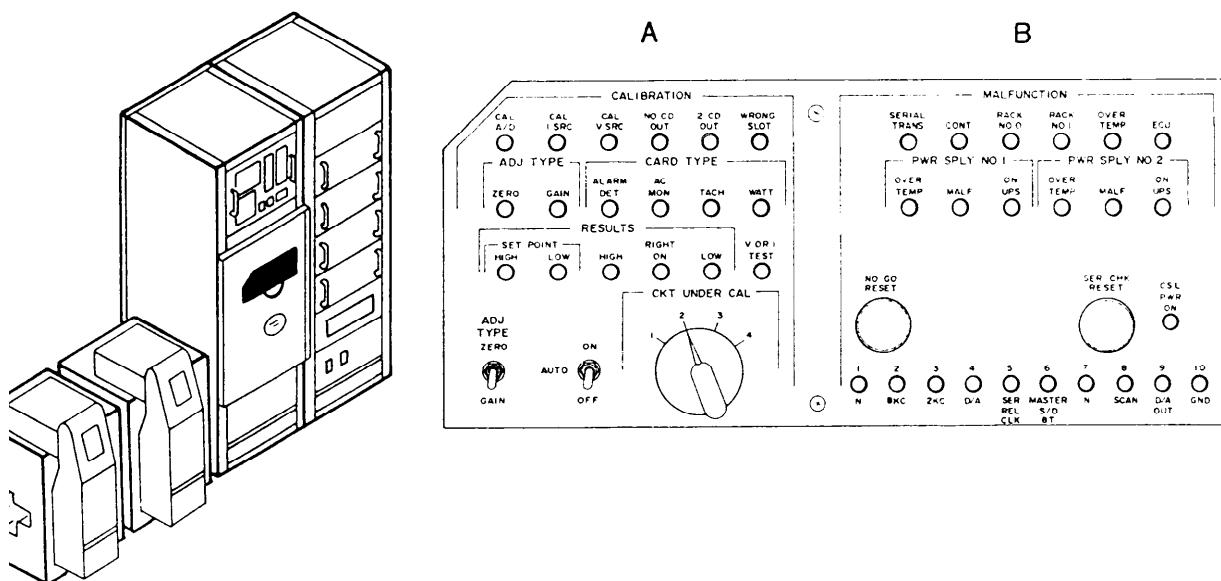


Figure 9-3.—CISE self-test panel.

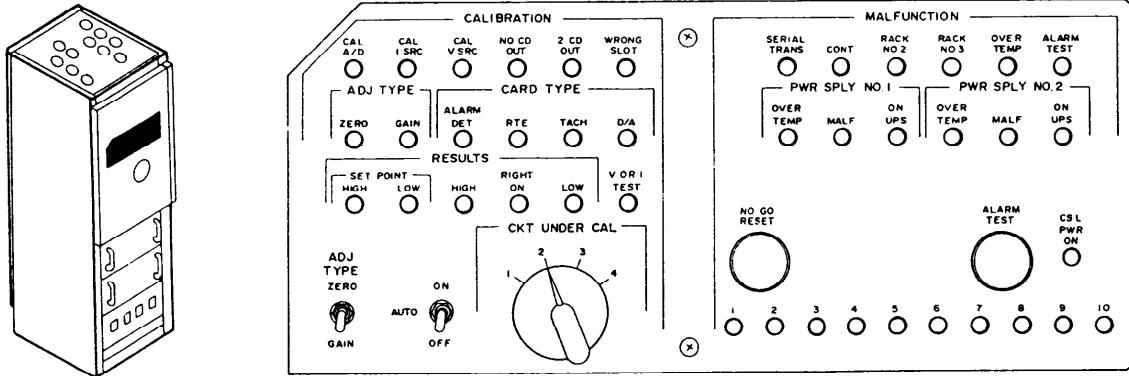


Figure 9-4.—S/CE No. 2 and S/CE No. 3 self-test panel.

calibration panel on or off or to set it for automatic. In the OFF position the calibration panel is disabled. The ON position allows the operator to conduct adjustments and calibrations of the various circuit cards. In the AUTO position, the self-test panel allows for the generation of the self-test signal that is distributed to respective ECSS equipment. The four-position rotary switch, labeled CKT UNDER CAL, allows the operator to select the circuit on the circuit card to be tested.

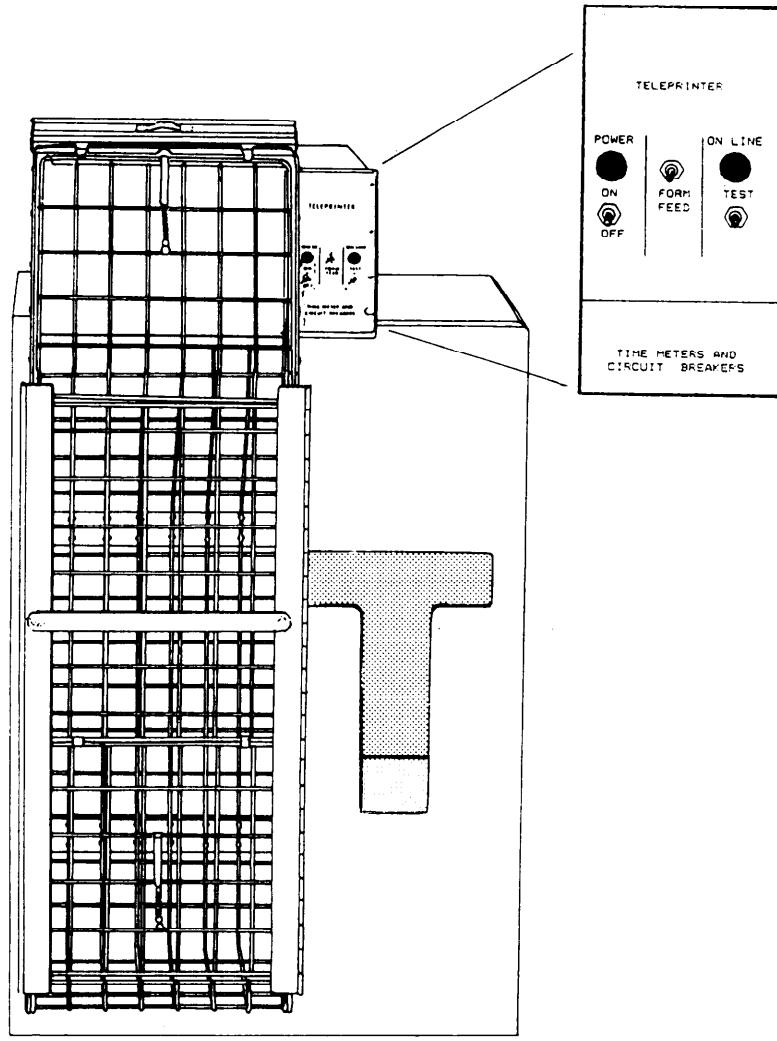
### MALFUNCTION Section

Refer to section B in figure 9-3. The MALFUNCTION section (B) consists of 13 LED status/alarm indicators, two push-button switches and ten test jacks. This section provides the operator with a visual indication of a malfunction within the respective S/CE and the status of that system. The first six LED alarm indicators illuminate red to provide an indication of a malfunction in the S/CE (and the ECU for S/CE No. 1). The first LED, labeled SERIAL TRANS, indicates a malfunction in serial transmission. The second LED, labeled CONT, indicates a break in continuity in the S/CE. The third LED, labeled RACK NO. 0 (RACK NO. 2 on S/CEs No. 2 and No. 3), indicates a malfunction in the respective logic rack. The fourth LED, labeled RACK NO. 1 (labeled RACK NO. 3 on S/CEs No. 2 and No. 3), indicates a malfunction in the respective logic rack. The fifth LED, labeled OVER TEMP, indicates an overtemperature condition within the S/CE. The last LED in the first row, labeled ECU (labeled ALARM TEST on S/CEs No. 2 and No. 3), indicates a malfunction in the ECU (indicates an alarm test on S/CEs No. 2 and No. 3). The next three LED alarm indicators are under the heading PWR SPLY NO. 1. These

indicators are labeled OVER TEMP, MALF, and ON UPS. The first LED, labeled OVER TEMP, illuminates red to indicate an overtemperature condition in power supply No. 1. The second LED, labeled MALF, illuminates to indicate a malfunction within power supply No. 1. The last LED, labeled ON UPS, illuminates red to indicate the power supply is on UPS. The next three LED alarm indicators, under the heading PWR SPLY NO. 2, are identical to the LEDs discussed for power supply No. 1. The first push-button switch located on the left side of the MALFUNCTION section is labeled NO GO RESET. The operator uses this switch to clear the alarms on the CISE or respective S/CE. The other push-button switch, located on the right side of the MALFUNCTION section, is labeled SER CLK RESET (labeled ALARM TEST on S/CEs No. 2 and No. 3). On S/CE No. 1, the operator uses this push button to reset the serial clock. On S/CEs No. 2 and No. 3, the operator uses this push button to conduct tests of the S/CE alarms. The last LED indicator, labeled CSL PWR ON, illuminates red to indicate that CISE console power is on. The 10 test jacks along the bottom of the MALFUNCTION section allow the operator to read various data test points within the S/CE.

### BELL AND DATA LOGGERS

With all the equipment that must be monitored and all the information that must be logged for future reference, it would be nearly impossible for a single operator to operate the console and write in a log. For this reason, two line printers are designed to receive information from an ECU and log this information automatically. These line printers, the bell logger and the data logger, are identical in design and operation. The only difference is in the information the printer is



**Figure 9-5.—Line printer.**

commanded to print. Figure 9-5 shows a detailed view of one of the line printers.

### Bell Logger

The bell logger prints only bell signals and replies to those signals. Bell signals include rpm commands, pitch commands, and station in control status. All other logging functions are done by the data logger.

### Data Logger

The data logger is responsible for all logging functions not performed by the bell logger. These functions include data logging, alarm logging, status change logging, trend logging, and demand print logging.

**DATA LOGGING.**—The data logging function provides a record of the values and/or status of all parameters of interest, either automatically, at selected time intervals, or upon operator demand.

**ALARM LOGGING.**—The alarm logging function provides a permanent record of all changes in alarm conditions as they occur, including both the alarm itself and its acknowledgement or reset.

**STATUS CHANGE LOGGING.**—The status change logging function records nonalarming changes in the discrete status of certain parameters, such as pump on/off or pump fast/slow.

**TREND LOGGING.**—The trend logging function provides continuous and automatic

monitoring of up to 16 operator-selected parameters and automatic printout if a parameter's value changes by more than a preset threshold (percentage).

**DEMAND PRINT LOGGING.**—The demand print logging function provides the operator with a printout of an individual item or a group of items. To accomplish this, the operator dials up the address for the information desired to be printed and depresses the print push button.

If either of the line printers should fail to operate properly, the remaining operable printer automatically assumes all logging duties. In this event, the priorities for logging time, in order of highest to lowest, are as follows:

1. Bell logging
2. Alarm logging
3. Status change logging
4. Trend logging
5. Demand and data logging

The line printer control panel consists of two indicator lights and three toggle switches. The first indicator light, labeled POWER, illuminates green to indicate electrical power is applied to the printer. The first switch is a two-position, spring-loaded toggle switch labeled FORM FEED. It advances the paper in the printer to the next page. The second indicator light, labeled ON-LINE, illuminates green to indicate the printer is ready

to receive data. The second switch, a two-position toggle switch labeled ON/OFF, turns the line printer on and off. The last switch is a two-position, spring-loaded toggle switch labeled TEST. This switch tests the printer operation by printing out a test pattern when the operator raises the switch to the TEST position.

## FUEL SYSTEM CONTROL EQUIPMENT

The fuel system control equipment is not connected to any components of the ECSS. It is, however, an important electronic control console on the DD-963, DD-993, and CG-47 class ships; therefore, it is discussed in this chapter as is the damage control console.

The major components of this system include the fuel system control console (FSCC), two fuel oil (FO) transfer local panels, and the JP-5 local control panel. These consoles and panels are an integrated information and control system. They provide operator control and monitoring from local and remote locations. In most cases, information generated by one unit of its system is shared by one or more of the other units.

## FUEL SYSTEM CONTROL CONSOLE

An FSCC is shown in figure 9-6. This console provides centralized monitoring and control of

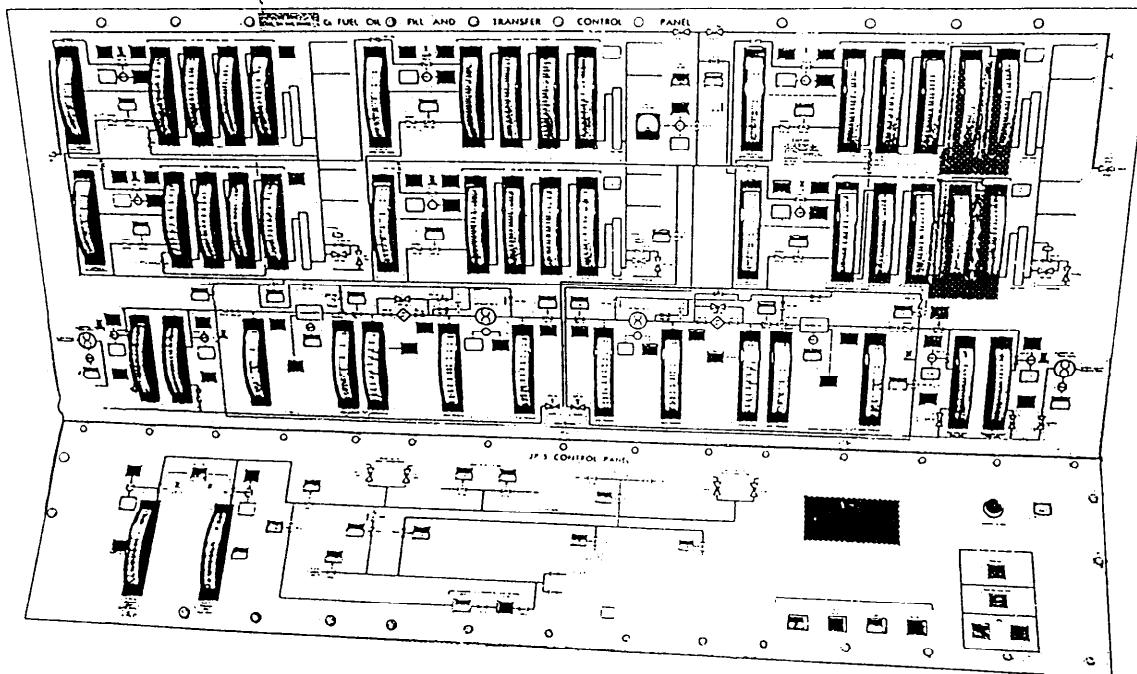


Figure 9-6.—Fuel system control console.

both the FO fill and transfer system and the JP-5 system. The front of the FSCC is divided into two operator panels; the upper panel is the FO fill and transfer control panel, and the lower panel is the JP-5 control panel. (See also fig. 9-7.) These panels have mimics of the associated system, vertical reading meters to display system parameters and tank levels, indicator lights to display system status, and push buttons to remotely control motor-operated equipment.

The FSCC has three main cabinet assemblies (A1, A2, A3), the FO fill and transfer control panel (A4), and the JP-5 control panel (A5). Figure 9-7 shows the console outline and component location. The three main cabinet assemblies contain the power supplies, electronic hardware, and internal wiring of the FSCC. The FO fill and transfer control panel (A4) has the operator controls and indicators for

the FO fill and transfer system. The JP-5 control panel (A5) contains the operator controls and indicators for the JP-5 fill, transfer, and service systems.

The indicators and controls on the front panels of the FSCC will be discussed first, from left to right and top to bottom; followed by the back panels in the same left-to-right, top-to-bottom fashion. Refer to figure 9-7.

### Fuel Oil Fill and Transfer Control Panel

The FO fill and transfer control panel will be discussed in two sections. (See fig. 9-8.) The upper section of the panel will be referred to as the fuel oil fill section; the lower section as the fuel oil transfer section. This system is shown in full in figure 9-8 and in greater detail in figures 9-9

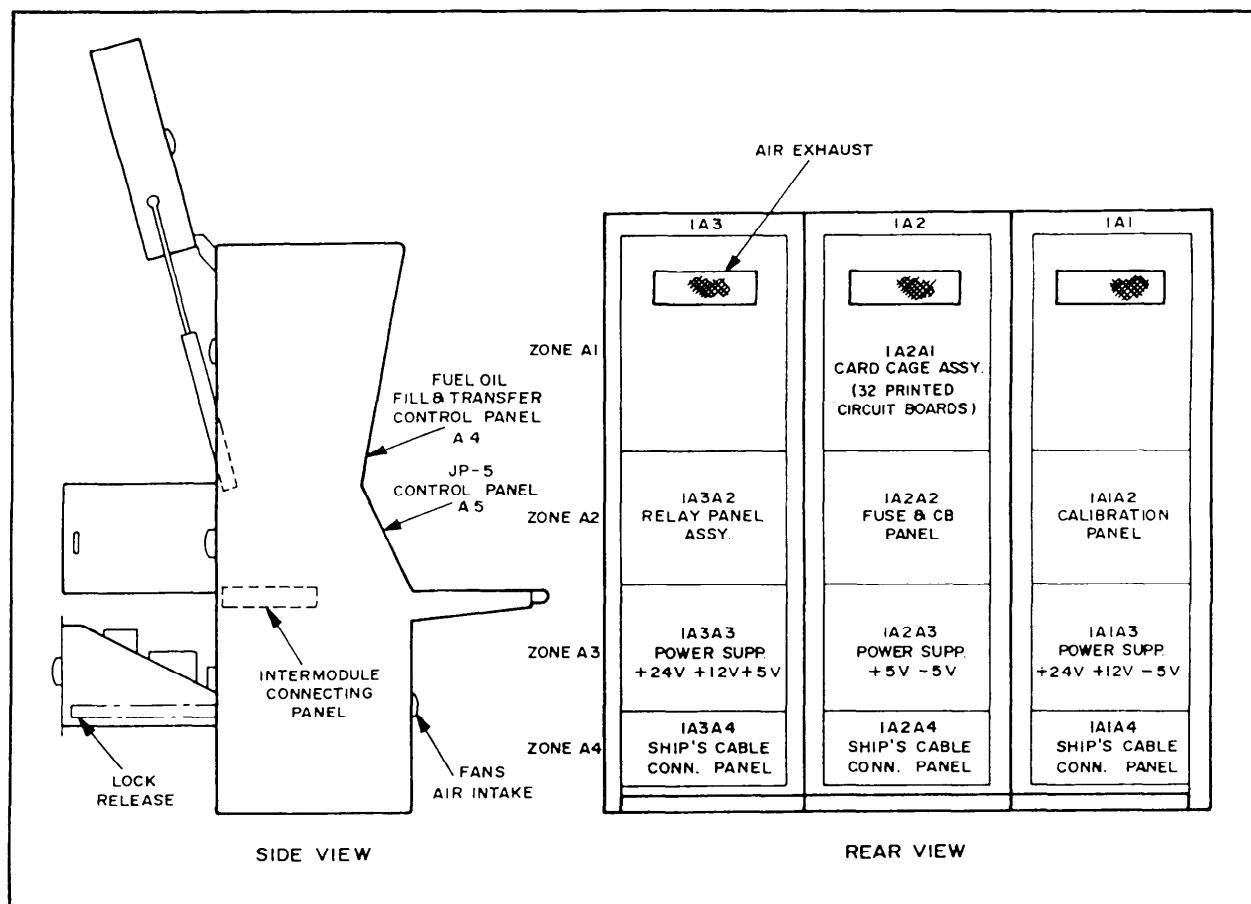


Figure 9-7.—Fuel system control console—component location.

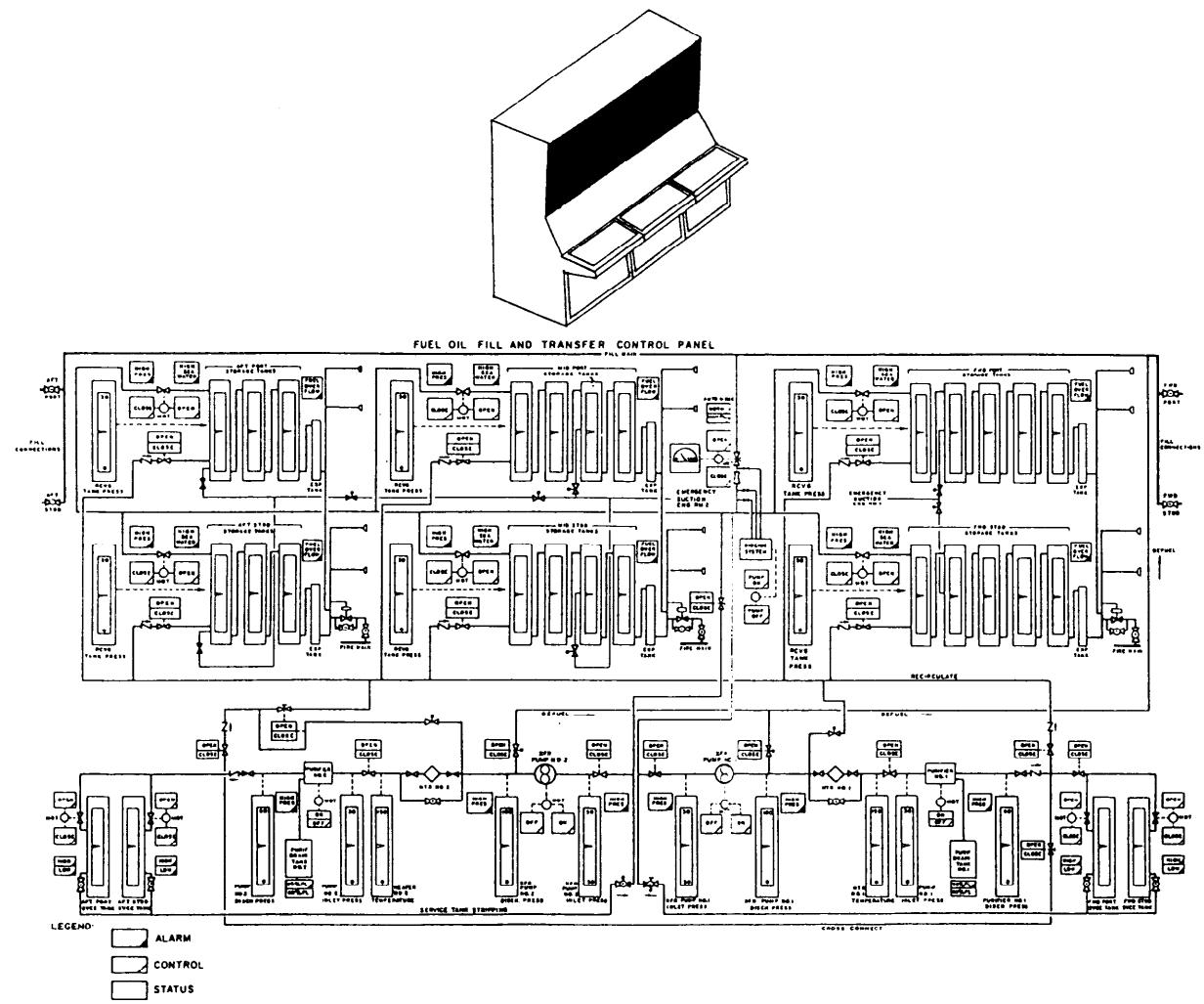


Figure 9-8.—Fuel oil fill and transfer panel.

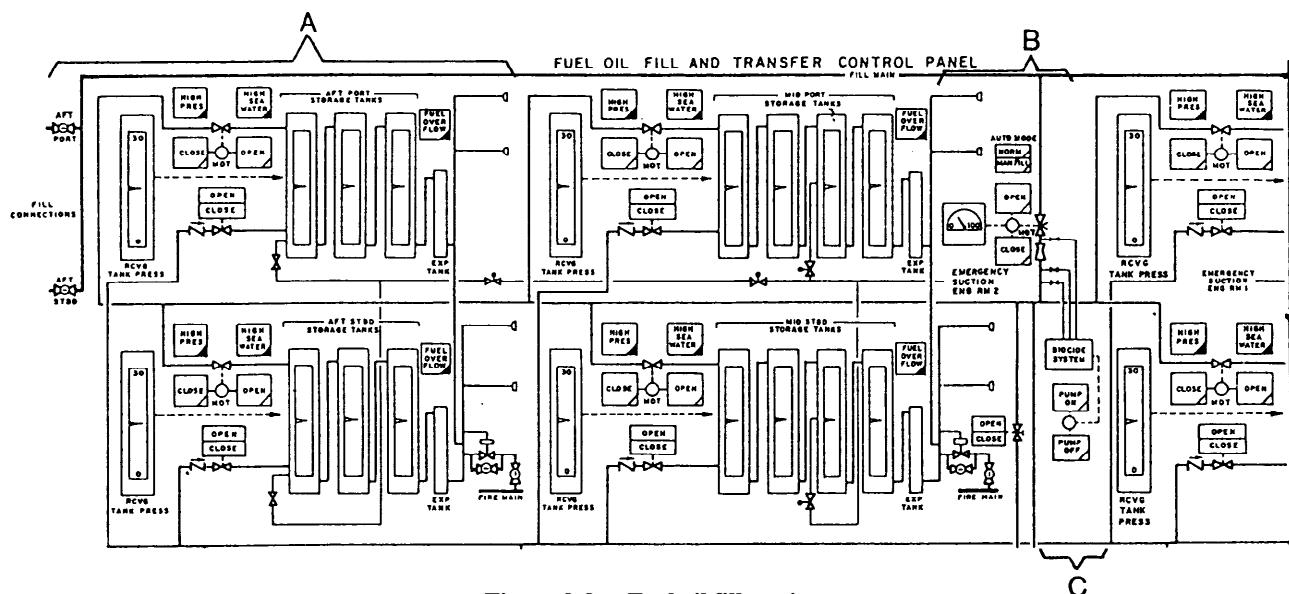


Figure 9-9.—Fuel oil fill section.

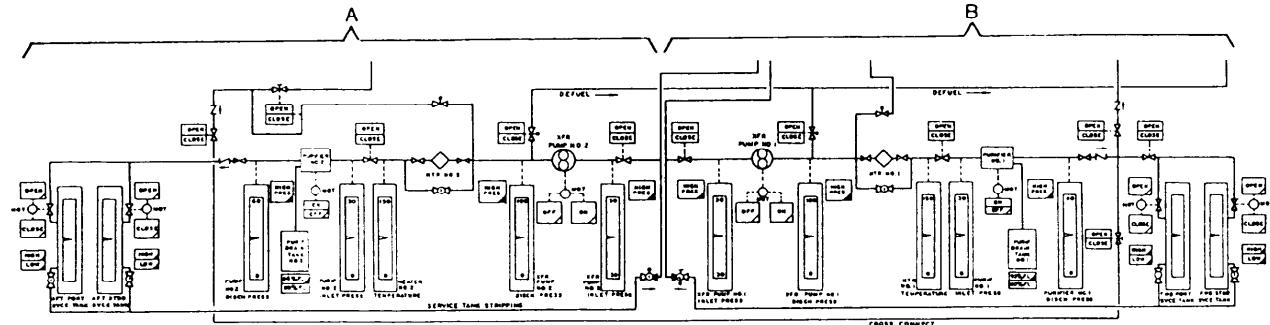


Figure 9-10.—Fuel oil transfer section.

and 9-10. Refer to figures 9-8, 9-9, and 9-10 as you read the description of each section.

### Fuel Oil Fill Section

The FO fill section is shown in detail in figure 9-9. The storage tanks are divided into six groups of tanks known as banks. Each tank group is identical except for the number of tanks in each bank. The AFT PORT and AFT STBD storage banks consist of three tanks. The MID PORT and MID STBD storage banks consist of four tanks. The FWD PORT and FWD STBD storage banks consist of five tanks. Individual meters provide tank level monitoring for each tank in the banks. Since all controls in each tank group are identical, only the AFT PORT storage tank group (A) will be discussed.

The first alarm indicator in this section (A), labeled HIGH PRES, illuminates amber to indicate that the pressure in the receiving tank is greater than 11 psig. The second alarm indicator, labeled HIGH SEA WATER, illuminates amber to indicate that the seawater level is 90 percent or greater in the receiving tank. This means only 10 percent of the receiving tank contains fuel, while the other tanks in the bank contain seawater. The third alarm indicator, labeled FUEL OVERFLOW, illuminates amber to indicate that the last tank in the bank is 90 percent full of fuel. The first meter in this section is labeled RCVG TANK PRESS. It displays the pressure of the receiving tank, which is the first tank in the bank. The first indicator control push button, labeled CLOSE, drives the motor-operated fill valve in the close direction. It illuminates white when the valve is fully closed. The second indicator control push button, labeled OPEN, drives the motor-operated fill valve in the open direction. It illuminates green when the valve is fully open. There are three vertical meters that perform the same function but for a different tank in the bank. These meters display the fuel level (in gallons) for the

appropriate storage tank. The first split-legends indicator is labeled OPEN and CLOSE. This indicator illuminates either open (green) or close (white) to reflect the position of the storage tank recirculation valve. The last item in this section, labeled EXP TANK, is a drawing representing an expansion/overflow tank. There are no meters or gauges for this tank on the FSCC.

Located between the MID PORT storage tanks section and the FWD PORT storage tanks section are the controls and indicators for the main fill valve of the fuel transfer system. (Refer now to section B of fig. 9-9.) The first split-legends push-button control under the heading AUTO MODE is labeled NORM and MAN FILL. In the NORM position, the storage bank fill valve for the bank being filled will automatically close upon receiving a FUEL OVERFLOW alarm. The main fill valve will start to close if a HIGH PRES alarm is received. In the MAN FILL position, the storage bank fill valve and the main fill valve must be controlled manually. The meter in this section is scaled from 0 to 100 percent to show the amount of opening of the main fill valve. The second push-button control, labeled OPEN, is used to manually open the main fill valve. It illuminates green when the valve is fully open. The third push-button control, labeled CLOSE, is used to close the main fill valve. It illuminates white to indicate the main fill valve is fully closed.

Located between the MID STBD storage tanks section and the FWD STBD storage tanks section are the controls and indicators for the biocide system. (Refer to section C of fig. 9-9.) We will not describe this system because it has been discontinued and removed from most ships. This system will not be indicated at all on the FSCC of newer classes of ships.

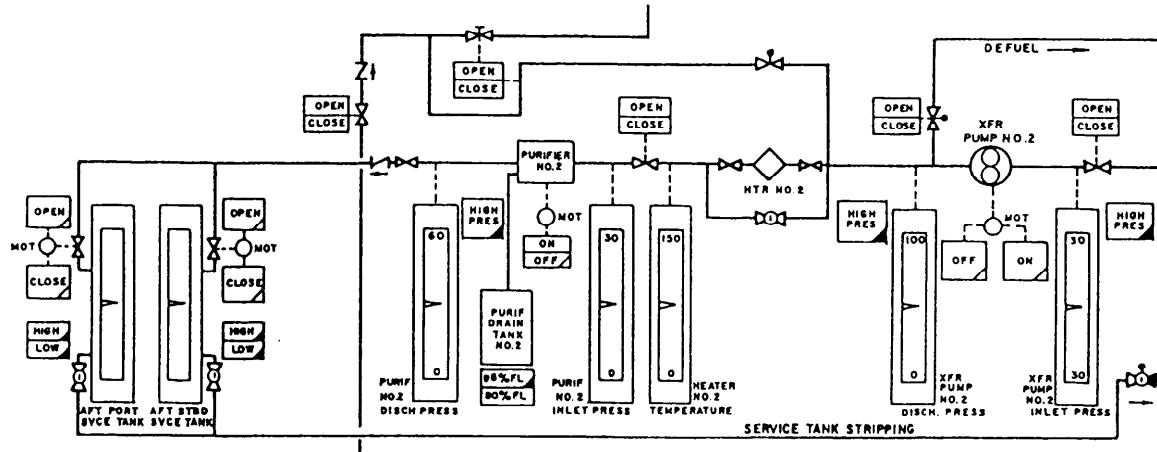
### Fuel Oil Transfer Section

The FO transfer section shown in figure 9-10 consists of two identical systems. The No. 1

system serves the FWD FO service system and the No. 2 system serves the AFT FO service system. The transfer system consists of a system of pipes from the storage tanks to the service tanks and the associated equipment necessary to move fuel between them. Each transfer system contains two service tanks, a FO purifier, a purifier drain tank, a FO heater, and a transfer pump. Since each system is identical, only the No. 2 fuel system will be discussed. Refer to section A of figure 9-10.

This section has five split-legends indicators labeled OPEN and CLOSE. They illuminate either OPEN or CLOSE to indicate the position of the manually operated cross-connect valves. There are four indicator control push buttons in this section. Two are labeled OPEN and two are labeled CLOSE. These push buttons operate the service tank fill valves. The OPEN push button illuminates green when the valve is fully open. The CLOSE push button illuminates white when the valve is fully closed. The three push-button alarm indicators, labeled HIGH PRES, illuminate amber to indicate that the purifier discharge pressure, the transfer pump discharge pressure, or the transfer pump inlet pressure has exceeded the preset limit. The first meter in this section is labeled AFT PORT SVCE TANK. This meter monitors the fuel level in the AFT PORT service tank. The second meter, labeled AFT STBD SVCE TANK, monitors the FO level in the AFT STBD service tank. The service tank meters are scaled to indicate fuel levels in gallons. The third meter, labeled PURIF NO. 2 DISCH PRESS, monitors the discharge pressure of the No. 2 FO purifier and is scaled in psig. The fourth meter, labeled PURIF NO. 2 INLET PRESS, monitors the inlet pressure of the No. 2 FO purifier and is scaled in psig. The fifth meter, labeled

HEATER NO. 2 TEMPERATURE, monitors the FO heater discharge temperature. It is scaled in degrees Fahrenheit. The sixth meter, labeled XFR PUMP NO. 2 DISCH PRESS, monitors the discharge pressure of the No. 2 FO transfer pump and is scaled in psig. The last meter, labeled XFR PUMP NO. 2 INLET PRESS, monitors the inlet pressure of the No. 2 FO transfer pump and is scaled in psig. There is one split-legends push button labeled ON and OFF. This ON/OFF push-button indicator controls the fuel purifier motor. This push button turns the purifier motor off if it is on, but it cannot be used by the operator to start the purifier motor from the FSCC. The ON portion of the push button is a status indicator that shows the purifier motor is running. This section has two indicator control push buttons the operator can use to operate the FO transfer pump motor. One push button is labeled OFF and the other is labeled ON. The OFF push button illuminates white when the motor is secured. The ON push button illuminates green when the motor is running. There are two split-legends alarm indicators labeled HIGH and LOW. The HIGH indicator illuminates amber when the service tank level reaches 90 percent. The LOW indicator illuminates amber when the service tank level drops to 10 percent. The last split-legends alarm indicator, labeled 80% FL and 95% FL, monitors the FO level in the purifier drain tank. The 80% indicator illuminates steadily when the drain tank is 80 percent full. The 95% alarm indicator illuminates amber when the level reaches 95 percent. The No. 1 FO transfer section (section B of fig. 9-10) is the same as the section we have just discussed, except this section contains the meters, indicators, and push-button controls for the No. 1 fuel transfer/service system.



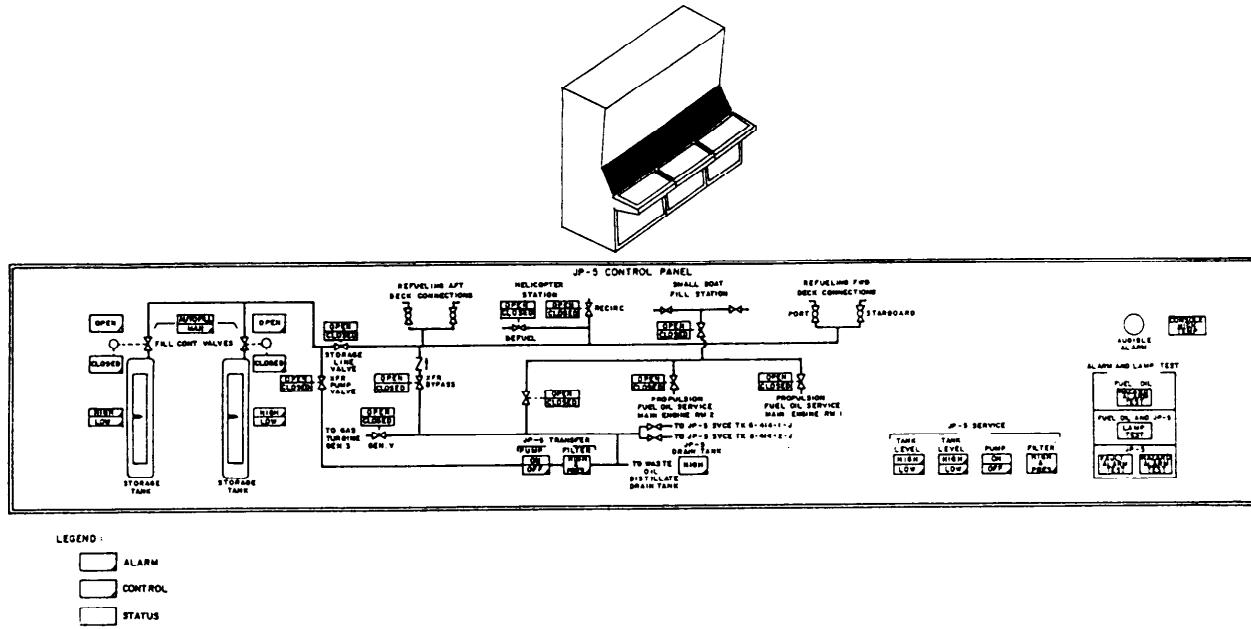


Figure 9-11.—JP-5 control panel (FSCC).

## JP-5 Control Panel

The JP-5 system is used to supply fuel to helicopters and small boats. However, JP-5 can be used as an emergency fuel for main engines and generators. Filling of the JP-5 storage tanks is controlled from the FSCC. The JP-5 transfer and service operations are controlled from the JP-5 local control panel. Refer to figure 9-11 as you read the following descriptions of this system. Our discussions of the sections of this system will follow a general left-to-right, top-to-bottom direction.

There are four push-button control indicators on the JP-5 control panel the operator uses to control the storage tank motor-operated valves. Two are labeled OPEN and two are labeled CLOSED. The OPEN push button illuminates green to indicate the valve is open. The CLOSED push button illuminates white to indicate the valve is closed. Located between the motor-operated valve control push buttons is a split-legends push button labeled AUTO FILL and MAN. In the AUTO FILL position, the JP-5 auto fill system functions to close the JP-5 storage tank valve during a fill operation if that particular storage tank generates a high level alarm. In the MAN position, the JP-5 storage tank valves are operated manually when the operator presses the appropriate OPEN or CLOSED push-button indicator. The JP-5 control

panel has 10 split-legends status indicators labeled OPEN and CLOSED. They illuminate either OPEN or CLOSED to indicate the position of the manually operated transfer valves. Associated with the two storage tanks are two split-legends indicators labeled HIGH and LOW. The HIGH indicator illuminates amber when the tank level reaches 90 percent capacity. The LOW indicator illuminates amber when the tank level drops to 10 percent capacity. There are two vertical meters in this section that continuously monitor the storage tank levels. Since the JP-5 storage tanks are not seawater compensated, the fuel level is measured directly from the bottom of the tank. The meters are scaled to indicate fuel level in gallons.

There are two push-button indicators, under the heading JP-5 TRANSFER located toward the bottom center of the JP-5 control panel. The split-legends push-button indicator labeled PUMP displays the JP-5 transfer pump ON or OFF status. Depressing this push button turns the pump off if it is running, but the pump cannot be started from the FSCC. The other indicator, under the heading JP-5 TRANSFER, is an alarm indicator labeled HIGH▲PRESS. It illuminates amber to indicate a high differential pressure across the JP-5 transfer pump filter. The alarm indicator, under the heading JP-5 DRAIN TANK, is labeled HIGH. It illuminates amber to indicate the drain tank level has exceeded the preset limit.

There are four alarm/status indicators grouped under the heading JP-5 SERVICE. The first indicator is a split-legends push-button indicator labeled HIGH and LOW. It illuminates HIGH when the PORT JP-5 service tank level reaches 90 percent. It illuminates LOW if the tank level drops to 10 percent. The second split-legends push-button indicator, labeled HIGH and LOW, performs the same monitoring function for the STBD service tank. The third split-legends control push button displays the service pump ON or OFF status. Depressing this push button turns the pump OFF if it is running, but the operator cannot start the pump from the FSCC. The fourth indicator, labeled HIGH ▲ PRESS, is an alarm indicator for the JP-5 service filter separator differential pressure. It illuminates amber if the differential pressure across the filter separator is 15 psid or greater.

Located on the right edge of the JP-5 control panel is an annunciator labeled AUDIBLE ALARM. It is a buzzer that provides the operator with an audible indication that an alarm has been generated. Located to the right of the AUDIBLE ALARM is a status indicator labeled CONSOLE HIGH TEMP. It illuminates amber to indicate the internal temperature of the FSCC has exceeded a preset temperature.

Located on the right of the JP-5 control panel of the FSCC are hazard, fault, and lamp test push buttons. Depressing the individual push buttons sends a test signal to the console electronics and actuates the alarms. The first push button is under the heading FUEL OIL. Depressing this push button, labeled HAZARD ALARM TEST, causes all the alarm indicators on the FO fill and transfer control panel to flash at a 4-Hz rate and produces an audible alarm. The operator must then depress the individual alarm indicators to clear the alarms. In fact, the operator must depress all the indicators before the audible alarm will clear. The HAZARD ALARM TEST indicates that the alarms are operating correctly within their prescribed setting. The second push button, under the heading FUEL OIL AND JP-5, is labeled LAMP TEST. Depressing this push button illuminates all lights on the console, allowing the operator to determine which light bulbs need replacement. Releasing the push button completes the test and extinguishes the lights. The last two push buttons are under the heading JP-5. The first push button, labeled FAULT ALARM TEST, is used by the operator to test the system's alarm circuitry. If a fault occurs, such as an open in the wiring, audible and visual alarm indicators are

activated at the 1-Hz rate. Depressing the FAULT ALARM TEST activates the audible and visual alarm indicators at 1-Hz. The operator clears the alarm in the same manner as for the hazard alarm. The second push button under the heading JP-5 is labeled HAZARD ALARM TEST. Depressing this push button allows the operator to perform a hazard alarm test of all alarm indicators on the JP-5 control panel.

Depressing the FO hazard alarm test push button during actual fueling operations in the NORM mode will cause the receiving tank cutout valves and the main fill valve to close. Acknowledging the alarm by depressing the alarm indicator will stop the main fill valve from closing at whatever point it has reached. The receiving tank valves will not stop closing but can be opened by depressing the OPEN push button after acknowledging the fuel overflow alarm.

Normally there is little maintenance necessary for the FSCC. On most ships, the FSCC must be tested and calibrated before refueling. To perform these test and calibration procedures, the operator must be familiar with the rear panel of the FSCC. The rear panels will be discussed in a left-to-right, top-to-bottom fashion. Refer to figure 9-12 during this discussion.

#### Card Cage

Section 1A2A1 houses the card cage. It contains the 32 printed circuit boards (PCBs)

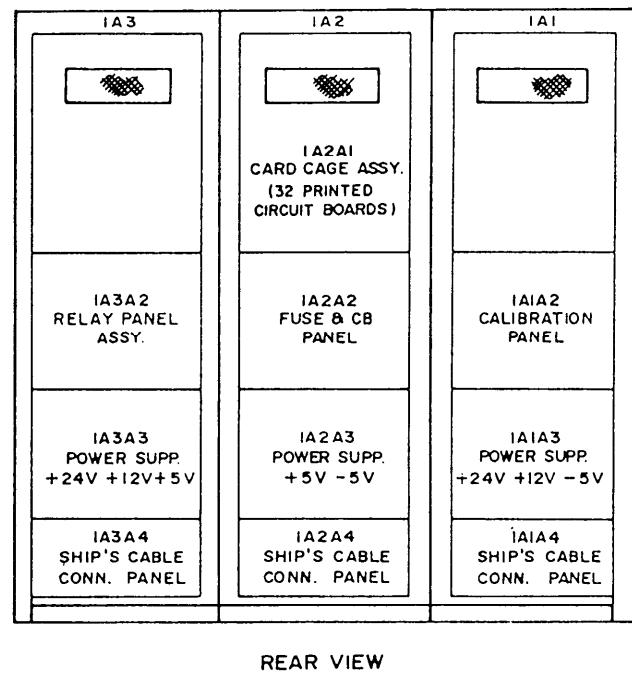


Figure 9-12.—Fuel system control console—rear view.

used in monitoring, alarm, and control functions. The card cage assembly will swing up for maintenance.

### **Relay Panel Assembly**

Section 1A3A2 of the FSCC contains the relay panel assembly. The nine 24-volt dc relays control FO and JP-5 valve closing. They are energized by the auto fill circuits. Associated with each relay is a suppression diode (CR1 through CR9) to prevent damage to the auto fill logic output circuits. The front side of this panel holds the spare fuses for the console.

### **Fuse and Circuit Breaker Panel**

Section 1A2A2 of the FSCC has the fuse and circuit breaker (CB) panel. CB1 is the main power CB for the FSCC. Fuses 1 through 10 protect the console from faults in the 120-volt ac remote control wiring. Three switches, S1, S2, and S3, turn power on and off to the three power supply drawers.

### **Calibration Panel**

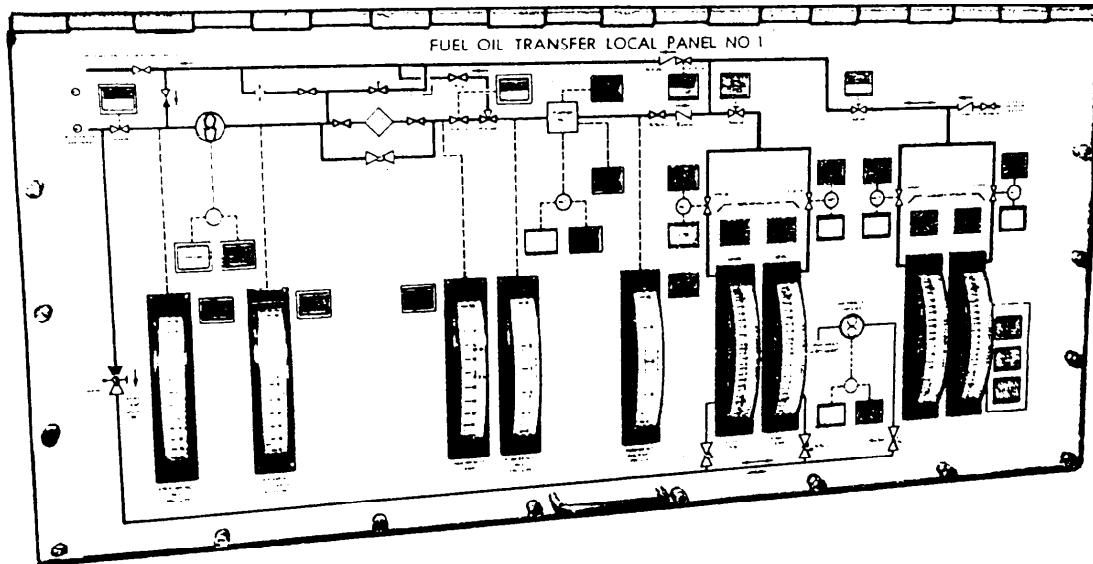
Section 1A1A2 of the FSCC houses the calibration panel. This panel contains the switches and potentiometers used in calibrating meter circuits and setting alarm points for those functions processed by the FSCC.

Storage tank level meter calibration is done by use of a three-position momentary contact switch, a full-scale adjust potentiometer, and the associated zero adjust potentiometer for each tank. If the switch is pushed to the FULL position, you can set the full adjust potentiometer to obtain a full-scale reading on the associated panel meter. When the switch is in the ZERO position, you can set the zero adjust potentiometer to obtain a zero panel meter reading.

You can also calibrate the FO receiving tank pressure meter circuits at this panel. A PUSH TO ADJUST FULL SCALE push button is associated with each receiving tank pressure circuit. When the push button is depressed, you can set the panel meter for full scale by adjusting the full-scale adjust screw on the panel meter assembly.

From the calibration panel, you can adjust the high seawater, fuel overflow, JP-5 storage tank level HI/LO, and FO receiving tank pressure high hazard alarm set points. When the push button for one of these alarms is depressed, the associated panel meter reads the alarm set point. By turning the corresponding adjust potentiometer, you can adjust the alarm set point to its desired value.

Also located on this panel are two mode switches. These affect the JP-5 storage tank circuits. When in the LOCAL ONLY position, only the FSCC panel meter indicates tank level. When in the LOCAL AND REMOTE position,



**Figure 9-13.—Fuel oil transfer local panel.**

both the FSCC and the JP-5 local control panel meters function.

### Power Supplies

The FSCC has eight dc power supplies located in the power supply drawers 1A3A3, 1A2A3, and 1A1A3 (+5 V, -5 V, +12 V, and +24 V). Two supplies are used for each voltage level. They normally operate in parallel, sharing the current load. The LEDs at the power supplies show voltage output. If one supply of a pair should fail, the LED for that supply extinguishes and the other power supply of the pair will automatically supply the load. Isolation diodes between the power supplies prevent the failed supply from absorbing current. Each power supply has an output voltage adjust potentiometer (R1) that serves to calibrate the supply within its specified tolerance.

The FSCC sends +24 volt dc power to all three local panels for illumination of indicators controlled by the FSCC. The FSCC also receives +24 volt dc power from the three local control

panels to operate indicators energized by the local panels.

### FUEL OIL TRANSFER LOCAL PANELS

Associated with the FSCC are two FO transfer local panels. (See fig. 9-13.) Panel No. 1, located in auxiliary machinery room (AMR) No. 1, monitors and controls the No. 1 FO transfer pump, heater, purifier, and associated valves. Panel No. 2, located in AMR No. 2, monitors and controls the No. 2 FO transfer equipment. Controls and indicators are similar to those on the FSCC but pertain only to the equipment associated with the particular local panel. Information is exchanged between each of the local panels and the FSCC.

The FO transfer local panels are bulkhead mounted. They have an upper and lower front panel and a metal enclosure that houses the power supplies and electronic circuits. The upper and lower front panels swing open for maintenance and card cage access. Figure 9-14 is an outline of the FO transfer local control panel.

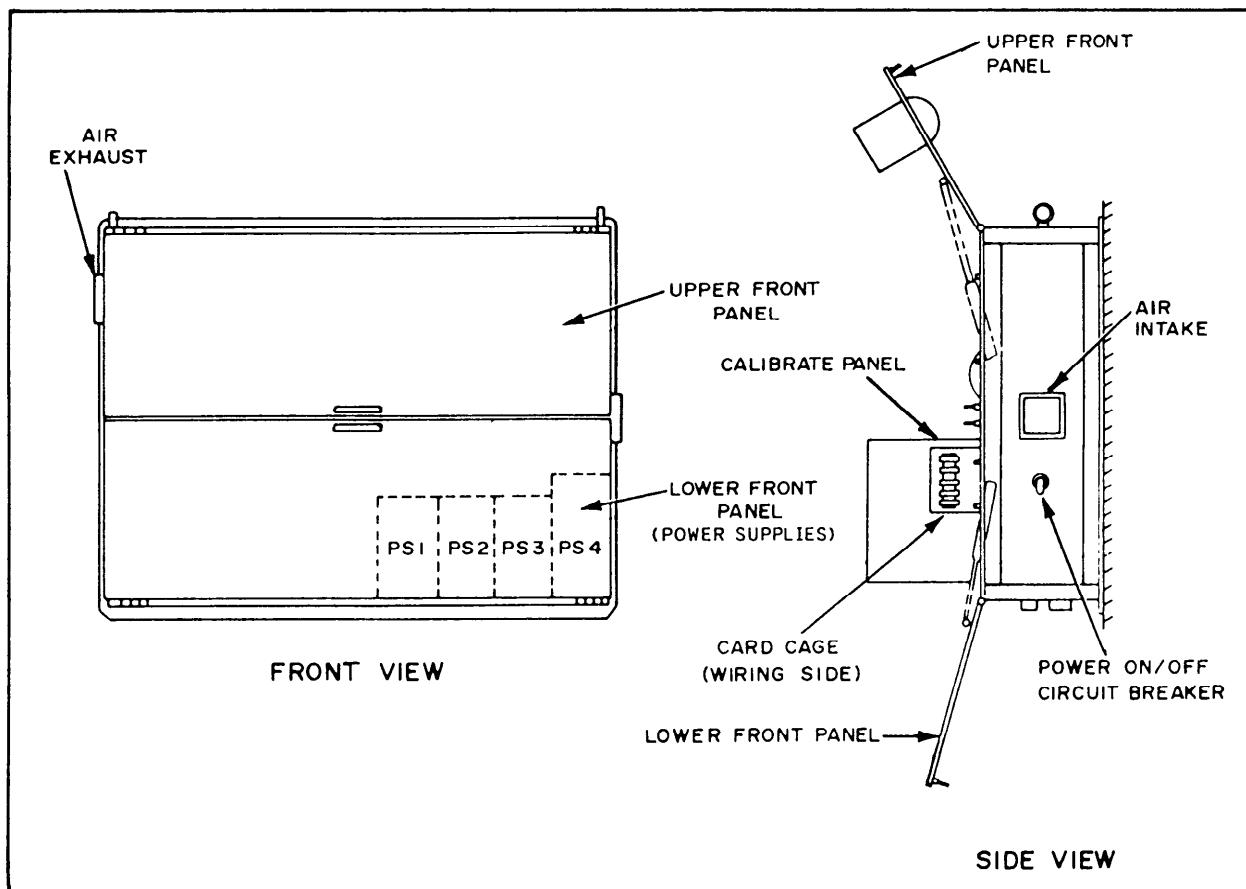


Figure 9-14.—Fuel oil and JP-5 local control panels—component location.

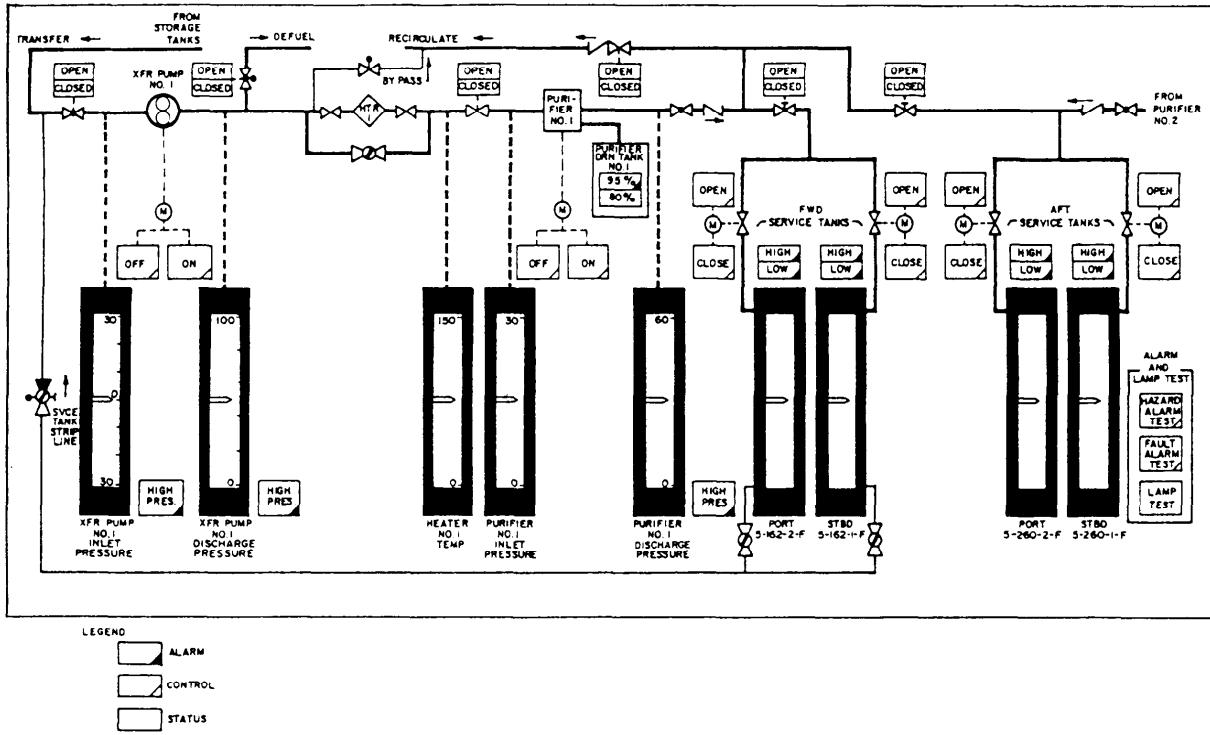


Figure 9-15.—Fuel oil transfer local panel No. 1.

The meters, indicators and controls on the local FO transfer panel are identical to those on the FSCC. Since the FO transfer local panels and the FSCC contain identical components, we will not discuss the FO transfer local panels. Figure 9-15, however, shows a detailed view of one of the local panels.

Normally there is little maintenance necessary for the FO transfer local panels besides changing light bulbs. However, there are circumstances that arise when the panels are required to be tested and calibrated. To perform these test and calibration procedures, the operator must be familiar with the internal components of the FO transfer local panels. We will discuss these components in the following paragraphs. Refer to figure 9-14 while you read this discussion.

### Power Supplies

Each FO local control panel has four power supplies, one for each dc voltage level used (+5 V, -5 V, +12 V, and +24 V). The local +5 volt, -5 volt, and +12 volt supplies are the same type as those in the FSCC. The 24-volt supply used in the local panels is functionally similar to the FSCC 24-volt supply; however, the maximum

power output is less. Each power supply voltage is adjustable. Each local panel sends 24-volts dc power to the FSCC. This is used to illuminate remote indicators controlled by the local panel.

### Card Cage

The card cage, mounted on a hinged panel with the calibrate panel, houses the 13 PCBs for each FO local control panel. These cards monitor and control the functions of the local panel.

### Power Distribution Panel

Each FO local control panel assembly houses a power distribution panel (not shown). This panel has the terminal boards for panel connections and the protective fuses for that particular panel.

Power to a local panel is controlled by one ac CB, CB1. This CB is located on the right side of the enclosure. (See fig. 9-14.)

### Calibrate Panel

Each FO local control panel has a calibrate panel. It serves the monitor and alarm circuits of the local panel in the same manner in which the

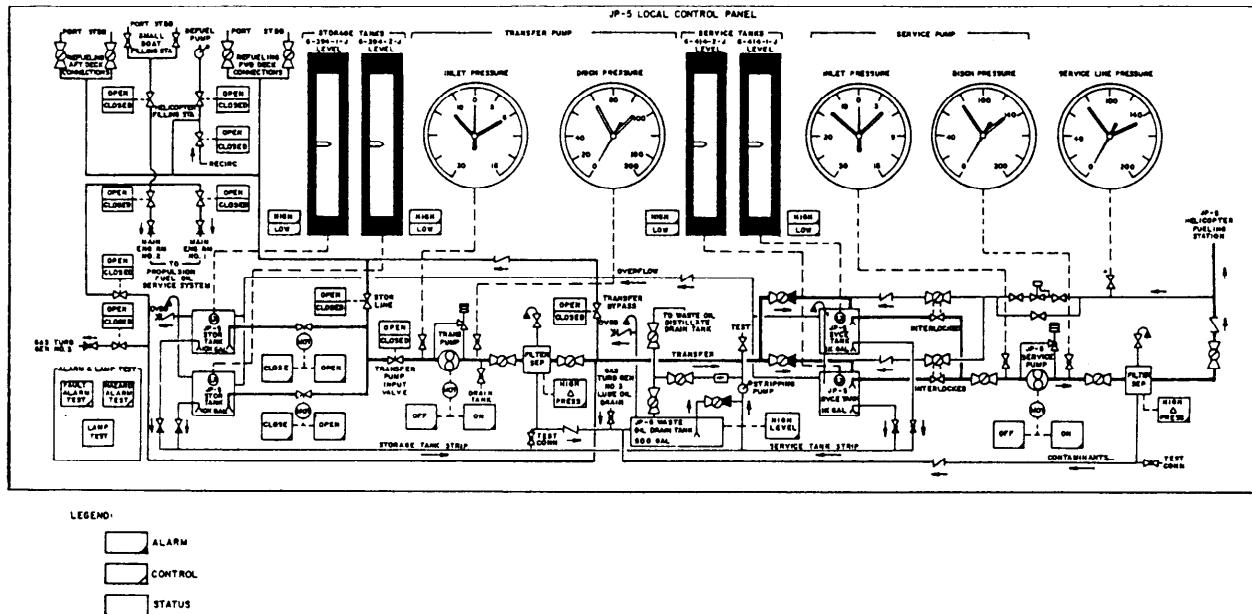


Figure 9-16.—JP-5 local control panel.

FSCC calibration panel serves the FSCC circuits. At this panel, you can calibrate the associated service tank level, transfer pump pressure, FO heater temperature, and purifier pressure meter circuits. You can also set the alarm points for service tank level (HI/LO), transfer pump pressure, and purifier discharge pressure at this panel. All seven meter circuits have mode switches for selection of LOCAL AND REMOTE or LOCAL ONLY displays.

### JP-5 LOCAL CONTROL PANEL

Primary control of the JP-5 fill system is accomplished from the FSCC in CCS. Transfer and service system control is accomplished from the JP-5 local control panel located in pump room No. 2. The JP-5 local control panel is similar in construction to the FO local control panel shown in figure 9-16. The monitoring and control functions of this panel are for the JP-5 fill, transfer, and service systems. This panel exchanges information with the FSCC only.

### Operator's Panel

The upper front panel of the JP-5 local control panel has the meters, gauges, indicators, and push buttons necessary to operate the JP-5 fill, transfer, and service systems. This panel is the primary control center for JP-5 transfer and

service operations because the FSCC has provisions only for limited monitoring and terminating of these operations.

All pressure monitoring at the JP-5 local control panel is done with pressure gauges. At the top of the enclosure are gauge cutout valves for each of the gauges. Because the alarms, indicators, and push buttons are identical to those on the FSCC JP-5 control panel, we will not discuss these components.

### Power Supplies

The JP-5 local control panel has four power supplies, one for each dc voltage level used (+5 V, -5 V, +12 V, and +24 V). The arrangement of these power supplies in the enclosure is similar to that in the FO local control panel. Twenty-four volts is sent to the FSCC for illumination of indicators controlled by the local panel. All four power supplies are energized by the CB1.

### Card Cage

The card cage, mounted on a hinged panel common with the calibrate panel, houses the 12 PCBs that control and monitor the functions of the local panel.

## Power Distribution Panel

The JP-5 local control panel has a power distribution panel. It is similar to those in the FO local control panels.

## Calibrate Panel

The calibrate panel of the JP-5 local control panel is similar in function to those in the FSCC and FO local control panels. The only circuits serviced by this panel are the JP-5 service tank level high and low alarm functions. No mode switches are on this panel. This is because the only JP-5 service tank level meters are at the JP-5 local control panel.

## OPERATION

This section is limited to general procedures for the FSCC and local panel power application, self-test, FO fill control, and turnoff. You can find detailed instructions for starting, operating, and securing this equipment in the *Fuel Control System Consoles* technical manual.

## Power Application

The FSCC is energized from the fuse and CB panel. The three power supply panel switches (S1, S2, and S3) should be in the ON position. Placing the main power CB (CB1) in the ON position then energizes the FSCC. All power supply indicator lights should be on. Since application of power to the console may alarm some circuits, all flashing push-button indicators should be depressed to reset the alarm circuitry.

To energize the JP-5 local control panel and the FO local control panels, place the ac power CBs in the ON position. To reset any alarms, depress any flashing push-button indicators.

## Self-Tests

The FSCC and the three local panels are equipped with alarm and lamp tests. Depressing the HAZARD ALARM TEST push button causes each hazard alarm circuit in the associated panel to activate (4-Hz flashing indicator and 4-Hz tone). You must acknowledge each hazard alarm. This test also starts associated remote hazard

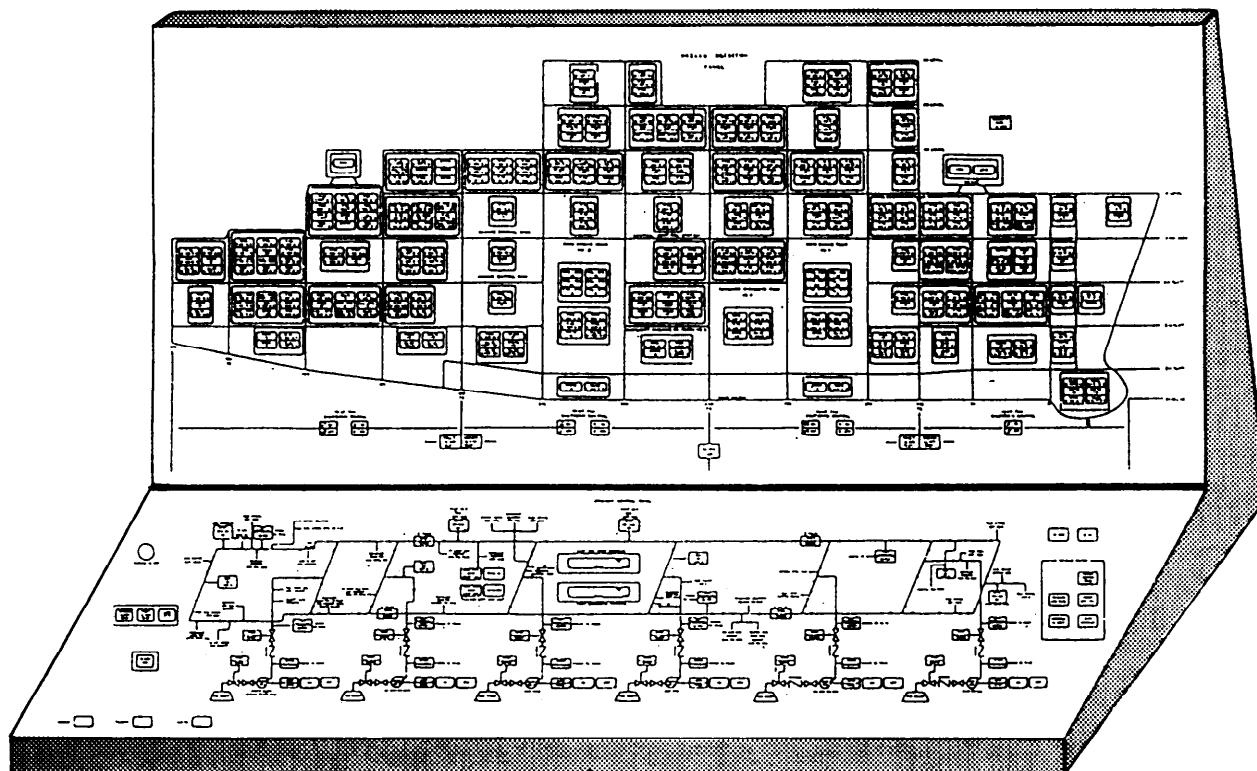


Figure 9-17.—Damage control console (DD-963 class).

alarms. Depressing the FAULT ALARM TEST push button causes each fault alarm circuit in the associated panel to start a fault alarm (1-Hz flashing indicator and 1-Hz tone). Releasing the push button will end this test. Depressing the LAMP TEST push button illuminates all indicator lights that are not checked by one of the alarm tests.

### Normal Securing

The FSCC is secured by placing the main power CB to the OFF position. The local panels are secured by placing the AC POWER switch to the OFF position.

### DAMAGE CONTROL CONSOLE FOR DD-963/993 AND CG-47 CLASS SHIPS

This section describes the major components and circuit functions of the damage control console (DCC) located in the CCS, adjacent to the FSCC. The DCC operates as an independent system from the FSCC and the ECSS. The only interface between the DCC and the ECSS is information received for GTM and GTG fire conditions. The FSCC and the DCC are both manufactured by the same vendor. They have many similar hardware items and circuit designs.

## DESIGN AND COMPONENTS

The DCC is composed of three cabinet assemblies bolted together to form the console. (Refer to fig. 9-17.) These three sections, accessible from the rear of the console, contain the card cages, power supplies, fuse and CB panel, and interconnection panels. The front side of the console houses the operator's panels, containing all the meters, indicators, and switches necessary for normal operation. In the following paragraphs, we will describe the design and components of the DCC in reference to the front and back sections of the console.

### Operator's Panels (Front of Console)

The front of the console is composed of two operator panels: the hazard detection panel (1A4) and the firemain control panel (1A5). The upper panel is the hazard detection panel; the lower panel is the firemain control panel. We will discuss both panels in a left-to-right, top-to-bottom fashion. The DCC operator panels on the CG-class ship are basically similar. We will point out any significant differences during the description of the panels.

**HAZARD DETECTION PANEL.**—The hazard detection panel has all the indicators for the fire, smoke, temperature, and bilge hazard alarm circuits. (Refer to fig. 9-18.) Also provided

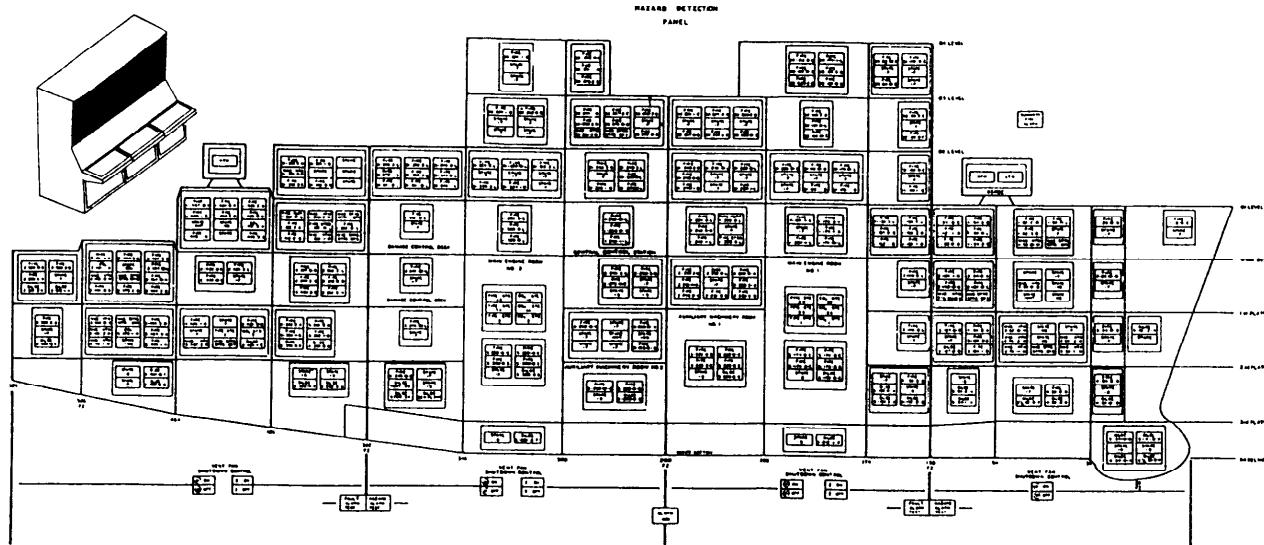


Figure 9-18.—DCC hazard detection panel (DD-963 class).

are push-button indicators the operator uses to conduct panel tests and to acknowledge alarms. The only control functions of this panel are vent fan shutdown and summary fire alarm manual initiation.

The hazard detection panel contains approximately 380 indicators for fire, smoke, temperature, and bilge alarms. Because the sensors for these indicators are located throughout the ship, we will limit our discussion to the most important indicators.

In the upper right-hand corner is a push-button control indicator labeled SUMMARY FIRE ALARM. This indicator illuminates amber to indicate a fire sensor is activated somewhere in the ship. The operator can depress this push button to start a summary fire alarm for a fire condition that is not detected by the hazard detection circuits. The second push-button control indicator is located under the heading VENT FAN SHUTDOWN CONTROL. The operator uses this push button to shut down the CIRCLE WILLIAM vent fans and to provide a status of the vent fans. There is no ON vent fan control provided by this push button. When ON is illuminated, this indicates the CIRCLE WILLIAM vent fans have been reset. There are four CIRCLE WILLIAM push buttons on the hazard detection panel (five on the CG). The third push-button control indicator, located under the heading VENT FAN SHUTDOWN CONTROL, is used to shut down the ZEBRA vent fans and to provide a status of the vent fans. Again, there is no ON vent fan control provided by this push button. There are three ZEBRA push buttons on this panel (five on the CG). When ON is illuminated, the ZEBRA vent fans have been reset. The fourth push-button control is labeled DOOR CLOSE (not applicable on the DD). This push button controls the fire boundary door closure for the designated fire zone. There are four DOOR CLOSE push buttons on the CG-class hazard detection panel.

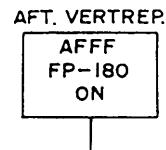


The fifth push-button control, labeled FAULT ALARM TEST (FAULT TEST on the CG), is located towards the bottom, left of center of the panel. Depressing this push-button indicator allows the operator to test the fault circuitry of the alarm cards for the left portion of the hazard

detection panel. The sixth push-button indicator, labeled HAZARD ALARM TEST (HAZARD TEST on the CG), is located next to the FAULT TEST push button. Depressing this push-button indicator allows the operator to test the hazard alarm cards for the left portion of the hazard detection panel. The seventh push button is labeled ALARM ACK. (The ALARM ACK push button is located next to the HAZARD TEST push button on the CG.) When depressed, this push button acknowledges the flashing alarm. If the alarm condition still exists, the alarm indicator will illuminate steadily. The alarm indicator will extinguish when the alarm condition no longer exists. The remaining push-button indicators on the right half of the hazard detection panel are mirror images of the push buttons just described.

**FIREMAIN CONTROL PANEL.**—The firemain control panel contains the indicators and controls that allow the operator to monitor the performance and status of the fire pumps, firemain risers, and firemain loops. (Refer to fig. 9-19.) This panel contains a mimic of the firemain system. Both automatic and manual starting of fire pumps is done from this panel. The 1000 gallons per minute (gpm) aqueous film forming foam (AFFF) hangar sprinkler system is controlled from this panel. Included are push-button indicators for the start of panel fault, hazard, and lamp tests. This panel has a console status section to display certain abnormal conditions in the console.

The first indicator, under the heading AFT VERTREP, is labeled AFFF FP-180 ON. It illuminates amber to indicate that the foam proportioner serving the aft vertical replenishment station is energized. There is no control function for the FP-180s on the DCC, only indications. There are three other indicators on the firemain control panel labeled AFFF FP-180 ON. They indicate the status of the other three AFFF stations.



The first split-leg indicator is labeled LOW PRESSURE and METER (not applicable on the CG). There are nine of these indicators on the firemain control panel to monitor firemain

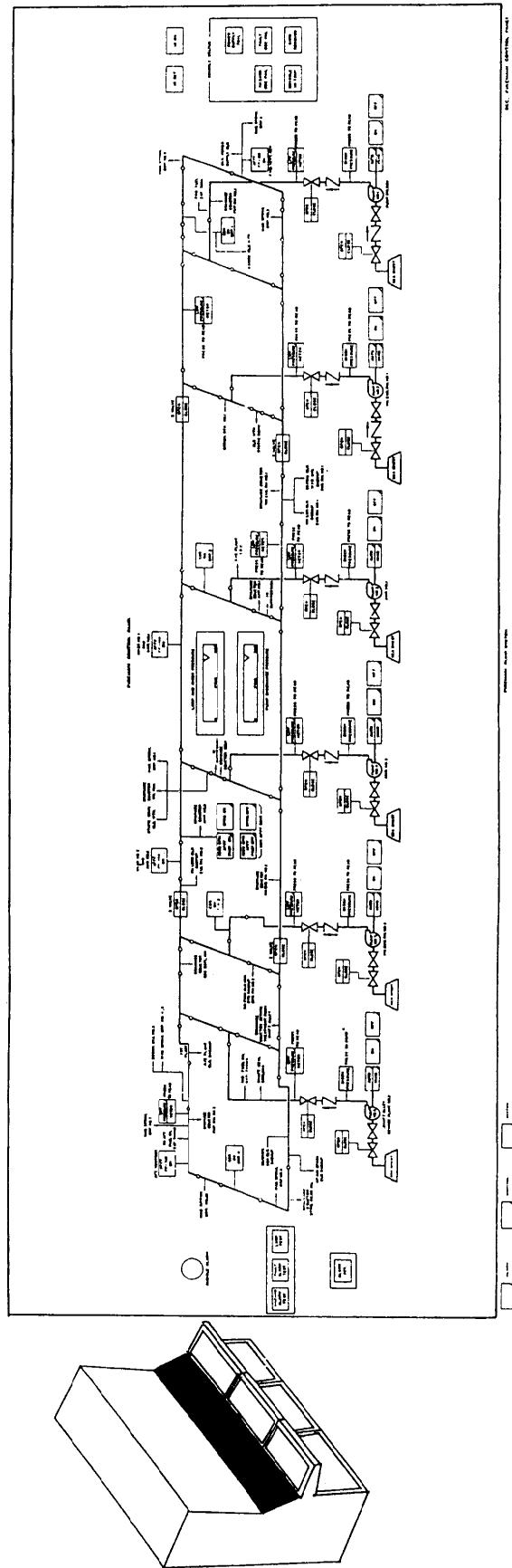
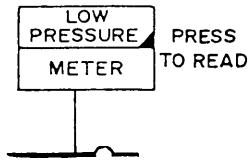
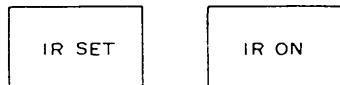


Figure 9-19.—DCC firemain control panel (DD-963 class).

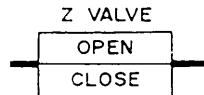
pressure at various points in the firemain loop. The LOW PRESSURE portion of the indicator illuminates red to indicate low pressure at that point in the firemain loop. When depressed, the METER portion of the indicator illuminates white and the LOOP AND RISER PRESSURE meter displays the firemain pressure at that point in the loop.



The two push-button indicators, labeled IR SET and IR ON, are located on the top right of the firemain control panel (not applicable on the CG). These push buttons are used in conjunction with the infrared suppression system. Use of this system has been discontinued; therefore, these push buttons are inoperative. These push-button indicators are not on the DCC of the newer ships.

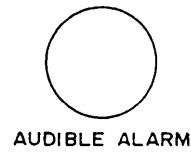


The split-legends indicator, under the heading Z VALVE, is labeled OPEN and CLOSE. There are four of these valves on the firemain control panel (three on the CG). They illuminate green to indicate the ZEBRA segregation valves are open. They illuminate white to indicate the valves are closed. There is no control of the ZEBRA segregation valves from the DCC, only indications.

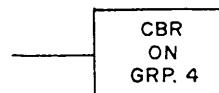


Located at the left edge of the panel is an annunciator labeled AUDIBLE ALARM. This is a buzzer that provides the operator an audible indication that an alarm or fault has occurred. The operator uses the alarm acknowledge push button on the hazard detection panel or

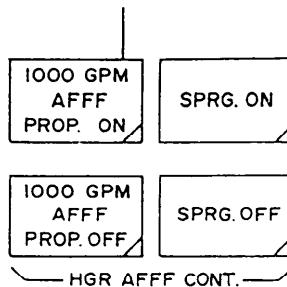
the firemain control panel to silence the buzzer.



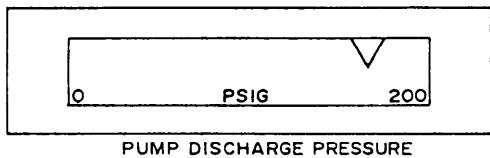
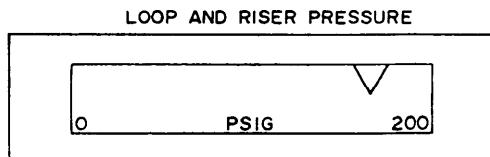
The next indicator is labeled CBR ON GRP 4. There are four of these indicators on the firemain control panel, each with a different group number. These indicators illuminate amber to indicate the respective chemical, biological, radiation (CBR) washdown group has been activated. There is no control for the CBR washdown system on the DCC, only indications.



The four push-button control indicators, over the heading HGR AFFF CONT, provide control and status of the 1000 gpm foam proportioner and the hangar sprinklers. The first control indicator in this section is labeled 1000 GPM AFFF PROP ON. When this push button is depressed, a control signal is sent to the proportioner for starting. The push button on the DCC illuminates amber to indicate the proportioner is on. The second push-button control indicator is labeled SPRG ON. When this push button is depressed, a open command signal is sent to the hangar AFFF sprinkler valve. The push-button indicator on the DCC then illuminates amber to indicate the hangar sprinkler system is on. The third push-button control indicator, labeled 1000 GPM AFFF PROP OFF, secures the AFFF foam proportioner and illuminates white to indicate the proportioner is off. The fourth push button in this section, labeled SPRG OFF, secures the hangar sprinkler system and illuminates white to indicate the sprinkler system is secured.

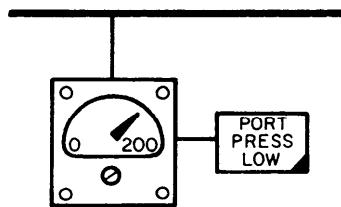


Located in the center of the firemain control panel are two horizontal meters. One is labeled LOOP AND RISER PRESSURE and the other is labeled PUMP DISCHARGE PRESSURE (not applicable on the CG). The LOOP AND RISER PRESSURE meter displays pressures from selected points in the firemain loop. This meter, scaled from 0 to 200 psig, is used in conjunction with the nine LOW PRESSURE/METER push-button indicators. The PUMP DISCHARGE PRESSURE meter, also scaled from 0 to 200 psig, displays the discharge pressure of any one of the six fire pumps and is used in conjunction with the six DISCH PRESSURE indicator push buttons.



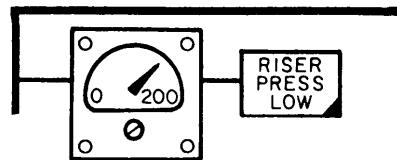
PUMP DISCHARGE PRESSURE

The next component is a 0 to 200 psig gauge and alarm indicator push button labeled PORT PRESS LOW (not applicable on the DD). This meter continuously monitors the port loop of the firemain system. The alarm indicator illuminates amber to indicate a low pressure on the port loop. There is an identical pressure gauge and alarm indicator labeled STBD PRESS LOW monitors the starboard loop.

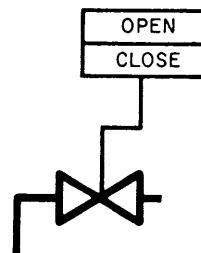


Located on each firemain riser is a gauge and alarm indicator labeled RISER PRESS LOW (not applicable on the DD). There are six identical gauges and alarm indicators, one for each fire pump riser. The riser pressure gauge, scaled from 0 to 200 psig, monitors the fire pump riser

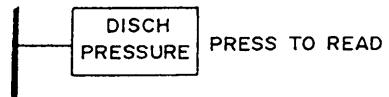
pressure. The alarm indicator illuminates amber to indicate a low pump riser pressure.



Located on the suction and discharge side of each fire pump is a split-legends push-button indicator labeled OPEN and CLOSE. There are 12 identical OPEN/CLOSE push-button indicators on the firemain control panel. The indicators illuminate green to indicate the respective fire pump discharge or suction valve is open. They illuminate white to indicate the respective fire pump discharge or suction valve is closed. There is no control for the fire pump discharge and suction valves on the DCC, only indications.

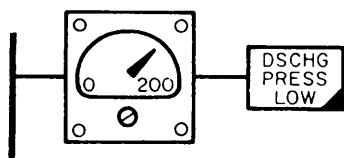


Located at the discharge of each fire pump is an indicator push button labeled DISCH PRESSURE (not applicable on the CG). There are six identical indicator push buttons, one for each fire pump discharge. When depressed, the PUMP DISCHARGE PRESSURE gauge indicates the fire pump discharge pressure for the selected pump. The DISCH PRESSURE indicator push button illuminates white.

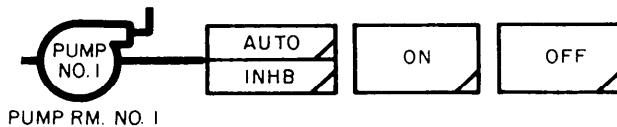


Located at the discharge of each fire pump, on the CG console, is a gauge and alarm indicator labeled DSCHG PRESS LOW (not applicable on the DD). There are six identical gauges and alarm indicators, one for each fire pump discharge. The discharge pressure gauge is scaled from 0 to 200

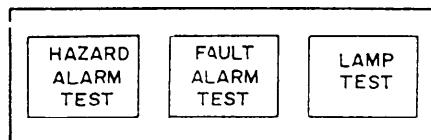
psig and monitors the fire pump discharge pressure. The alarm indicator illuminates amber to indicate a low pump discharge pressure.



Located to the right of each fire pump are three push buttons that control the starting and stopping of the fire pump. The first push-button indicator is a split-leg push button labeled AUTO and INHB. In the AUTO position, the designated fire pump is set for automatic starting upon loss of firemain pressure. In the INHB position, the designated fire pump is inhibited from automatically starting. The fire pump can be started manually. The second push-button control indicator is labeled ON. Each ON push button provides for manual starting of the associated fire pump from the DCC. It illuminates green to indicate the fire pump is running. The third push-button control indicator is labeled OFF. The OFF push button provides for manual stopping of the associated fire pump from the DCC and illuminates white to indicate the fire pump is secured.



The firemain control panel has a HAZARD ALARM TEST, a FAULT ALARM TEST, and a LAMP TEST push-button indicator on the left side. These indicators function in a manner similar to that of the hazard detection panel hazard, fault, and lamp tests. These push buttons test the circuits of the firemain control panel.

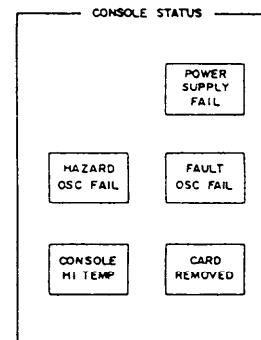


Located below the firemain control panel test push buttons is a push-button control indicator labeled ALARM ACK. When depressed, this

push button acknowledges flashing alarms on the firemain control panel. If the alarm condition still exists, the alarm indicator will illuminate steadily. The alarm indicator extinguishes when the alarm condition no longer exists.



The final section on the firemain control panel, right side, is labeled CONSOLE STATUS. This section contains five status indicators. The first indicator is labeled POWER SUPPLY FAIL. It illuminates red to indicate one of the dc power supply voltages has dropped below its limit. The second indicator, labeled HAZARD OSC FAIL, illuminates amber to indicate a failure of the hazard oscillator. The third indicator, labeled FAULT OSC FAIL, illuminates amber to indicate a failure of the fault oscillator. The fourth indicator is labeled CONSOLE HI TEMP. It illuminates red to indicate one of the three temperature switches has exceeded 168°F. The fifth indicator, labeled CARD REMOVED, illuminates amber to indicate a circuit card in the DCC is removed or improperly seated.



### Rear Panel (Back of Console)

The rear of the DCC consists of five sections. These sections are labeled card cages, relay panel assembly, fuse and circuit breaker panel, calibration panel, and power supply drawers. The following paragraphs describe the components of this panel. Refer to figure 9-20 during this discussion.

**CARD CAGES.**—Sections 1A3A1, 1A2A1, and 1A1A1 house the three card cage assemblies

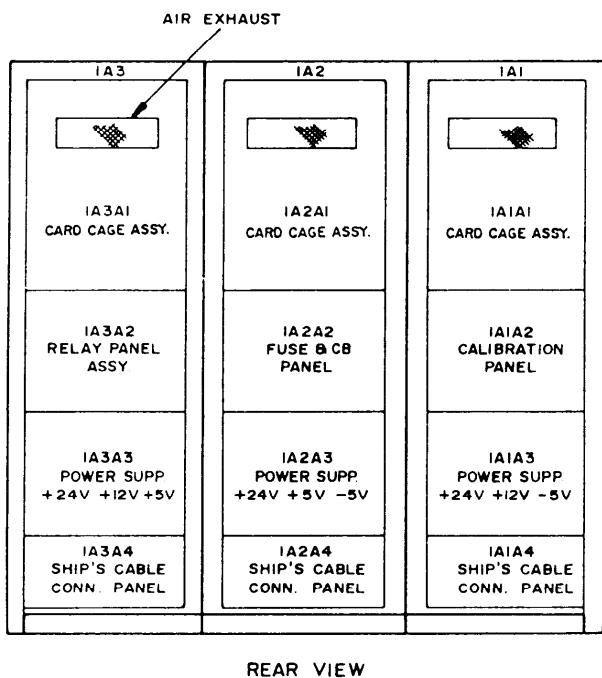


Figure 9-20.—Damage control console component location.

with the 155 PCBs used in monitoring, alarm, and control functions. One tab of each card is used to form a series circuit through all card receptacles in all three cages and the meter circuit card. Should this circuit be disturbed (card removed), the meter circuit board illuminates the CARD REMOVED indicator on the firemain panel.

**RELAY PANEL.**—Section 1A3A2 contains the relay panel. On the front of this panel are seven lighted push buttons. Push buttons S-2 through S-7 are used to test the automatic fire pump control circuits for pumps 1 through 6. A satisfactory test of a circuit is shown by illumination of the push button after it is depressed. Push button S-1, LAMP TEST, is used to test the lights on this group of push buttons.

On the rear of the panel are nine relays used for automatic starting of fire pumps, summary fire alarms, and to inhibit start-up of fire pumps during circuit tests. Associated with each relay is a suppression diode for circuit protection.

**FUSE AND CIRCUIT BREAKER PANEL.**—Section 1A2A2 of the DCC has the fuse and CB panel. This panel contains the fuses to protect the console's 120-volt ac fire pump and vent fan control circuits. This panel also has the 24-volt

dc fuses supplying the hazard detection and fire-main panels. The main power CB supplying 120 volts ac to the console and the three power supply drawer switches are also on this panel.

**CALIBRATION PANEL.**—Section 1A1A2 has the DCC calibration panel. This panel contains the push buttons and potentiometers necessary to set alarm points for low loop and low riser pressure circuits and to set full scale on both firemain panel pressure meters. It also has fuses for loop and riser pressure transducer circuits.

The LP alarm points for loop and riser circuits are set by depressing the PUSH TO SET ALARM POINT push button and LOW PRESSURE/METER push button at the same time for a particular point. The LOOP AND RISER PRESSURE meter reads the alarm set point. By adjusting the associated ADJUST potentiometer on the calibration panel, you can set the alarm point to the desired value. Releasing the two push buttons returns the circuit to the normal condition.

Depressing the PUSH TO SET FULL SCALE push button for either the loop and riser or pump discharge meters sends a full-scale signal to the meter. You can then make the adjustment to the meter by using the mechanical full-scale adjust on the meter body.

**POWER SUPPLIES.**—There are nine dc power supplies in the DCC located in the power supply drawers. There are two power supplies each for +5 volts, -5 volts, and +12 volts. Three power supplies are used for the +24 volts. Each power supply has an adjustment potentiometer for maintenance calibration. Because of the redundant power supplies, console operation is unaffected if one supply for a particular voltage level should fail. If one supply of that group should fail, the remaining supply or supplies automatically assume the load. Isolating diodes prevent the failed supply from absorbing current. The LED for the failed supply extinguishes, indicating that the supply has stopped supplying voltage. At the same time, the POWER SUPPLY FAIL light on the firemain panel illuminates. This shows that one of the nine power supplies is out of tolerance. The back panel of each power supply drawer contains the LEDs and ac fuses for each power supply and the drawer blower fuses.

## OPERATION

This section is limited to general procedures for DCC power application, turnoff, and self-tests.

Detailed instructions for starting, operating, and receiving this equipment are contained in the *Damage Control System Console* technical manual.

## Power Application

The DCC is energized from the fuse and CB panel. The three power supply panel switches (S1, S2, and S3) should be in the ON position. Placing the MAIN POWER CB (CB1) in the ON position energizes the DCC. All power supply indicator lights should be on. Since application of power to the console may cause some circuits to alarm, all flashing push-button indicators should be depressed to reset the alarm circuitry.

## Self-Tests

The hazard detection panel and the firemain panel are equipped with alarm and lamp tests. There are HAZARD ALARM and FAULT ALARM TEST push buttons for each half of the hazard detection panel and for the firemain panel. Exercise each group independently. Momentarily depressing a HAZARD ALARM TEST switch causes all hazard indicators for that group to flash. The audible alarm sounds at a 4-Hz rate. Holding the HAZARD ALARM TEST push button depressed and depressing the ALARM ACK for the panel will cause all flashing lights to illuminate steadily and silence the audible alarm. Then the operator may release the HAZARD ALARM TEST. Depressing ALARM ACK again will extinguish all indicators not actually in alarm and restore the circuits to normal operation.

Momentarily depressing a FAULT ALARM TEST switch will cause all hazard indicators for that group to flash at a 1-Hz rate. The audible alarm sounds at a 1-Hz rate. While holding FAULT ALARM TEST depressed, the operator can depress the ALARM ACK for the panel to cause the audible alarm to silence (indicators remain flashing). The operator may then release the FAULT ALARM TEST switch. Depressing ALARM ACK again will extinguish all indicators not actually in alarm and restore the circuits to normal operation.

After all fault and hazard tests have been performed, use the LAMP TEST to check all indicator lights that were not tested during the alarm tests. Perform these tests upon energizing the console and at regular intervals during operation.

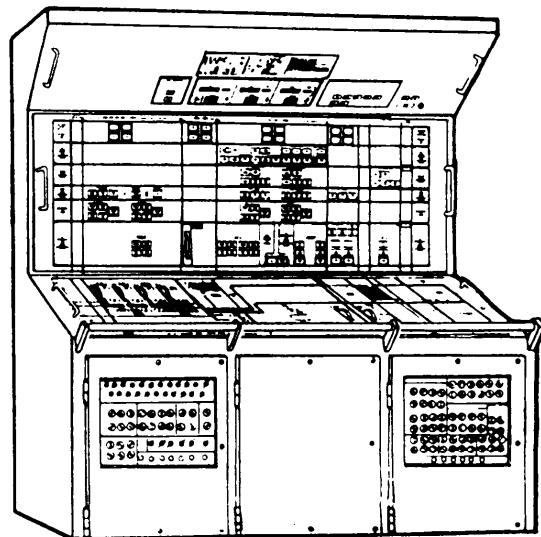


Figure 9-21.—Auxiliary control console.

## Normal Securing

The DCC is secured by placing the MAIN POWER CB in the OFF position.

## AUXILIARY CONTROL CONSOLE

This section describes the indicators and controls of the auxiliary control console (ACC). The ACC is located in the CCS, between the propulsion control console (PCC) and the EPCC. The ACC is used to operate and monitor the status of a majority of the auxiliary systems in the engineering plant of the FFG-class ship. (See fig. 9-21.) The following systems may be operated or controlled from the ACC.

- Machinery space ventilation
- Fuel filling, transfer, and purification system
- Chilled water circulating system
- Waste heat water circulating system
- Compressed air plants
- Main engines starting air system
- Air-conditioning and ship's stores refrigeration plants

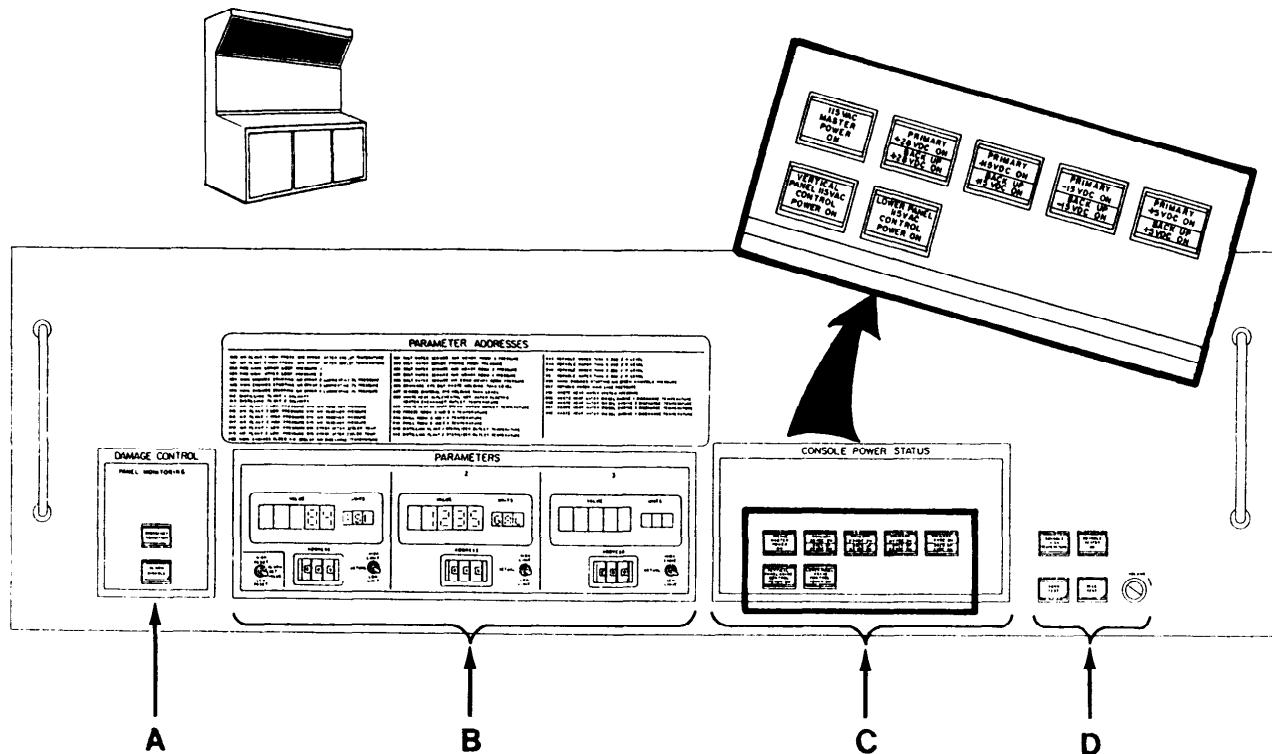


Figure 9-22.—ACC top panel.

- Potable water system, including fill valves
- Distilling plants
- Masker, prairie/fin stabilizer, and bleed air systems
- Sewage disposal system
- Saltwater service system
- Drainage system

### ACC TOP PANEL

The ACC top panel is shown in figure 9-22. This panel has three digital displays used to monitor any parameter having a DDI address. This panel also contains indicators that monitor the console power status and provide panel monitoring and alarm testing. Refer to figure 9-22 as we describe the following sections.

#### DAMAGE CONTROL Section

The first section on the top panel, under the heading **DAMAGE CONTROL**, is labeled **PANEL**

**MONITORING (A)**. This section monitors the damage control system. The first indicator push button, labeled **EMERGENCY CONDITION**, illuminates white to indicate an alarm condition exists on the DCC. The second indicator push button, labeled **ALARM DISABLE**, provides the ACC operator with the option either to enable or disable the **EMERGENCY CONDITION** fault alarm.

#### PARAMETERS Section

The second section is labeled **PARAMETERS (B)**. It contains three identical digital displays consisting of a DDI, a set of three thumbwheels, and a toggle switch. The number one digital display contains an additional toggle switch for checking the high or low reset value of the selected parameter. The first item in this section is the digital display windows labeled **VALUE**. The numerical value of the parameter selected by the thumbwheels is displayed in these windows. A second set of windows, labeled **UNITS**, display the unit of measurement of the selected parameter. The second item is a three-position toggle switch (digital display No. 1 only). The top

position is labeled HIGH RESET. In this position, the DDI displays the high reset value of the selected parameter. The middle position, labeled ALARM SET VALUE, displays the alarm set point of the selected parameter. The bottom position, labeled LOW RESET, displays the low reset value of the selected parameter. This toggle switch is not on digital displays No. 2 and No. 3. The third item is a set of three thumbwheels labeled ADDRESS. The thumbwheels are used to select the address of the parameter to be measured. The last toggle switch on the digital display is a three-position toggle switch. The top position is labeled HIGH LIMIT. In this position, the DDI displays the high limit of the selected parameter. The middle position, labeled ACTUAL, displays the actual value of the selected parameter. The bottom position, labeled LOW LIMIT, displays the low limit of the selected parameter.

### **CONSOLE POWER STATUS Section**

The third section of the top panel is labeled CONSOLE POWER STATUS (C). This section monitors the power supplies of the ACC. It contains seven push-button indicators. The first status indicator is labeled 115 VAC MASTER POWER ON. It illuminates white to indicate 115 volts ac is available to the ACC. The second indicator is a split-legends status indicator labeled PRIMARY +28 VDC ON and BACK UP +28 VDC ON. The upper portion of the indicator illuminates white to indicate the primary +28 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup +28 volt dc power converter is in operation. The third indicator is a split-legends status indicator labeled PRIMARY +15 VDC ON and BACK UP +15 VDC ON. The upper portion of the indicator illuminates white to indicate the primary +15 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup +15 volt dc power converter is in operation. The fourth indicator is a split-legends status indicator labeled PRIMARY -15 VDC ON and BACK UP -15 VDC ON. The upper portion of the indicator illuminates white to indicate the primary -15 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup -15 volt dc power converter is in operation. The fifth indicator is a split-legends status indicator labeled PRIMARY +5 VDC ON and BACK UP +5 VDC ON. The upper portion

of the indicator illuminates white to indicate the primary +5 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup +5 volt dc power converter is in operation. The sixth indicator is labeled VERTICAL PANEL 115 VAC CONTROL POWER ON. This indicator illuminates white to indicate 115-volt ac control power is available to the ACC vertical panel. The seventh indicator, labeled LOWER PANEL 115 VAC CONTROL POWER ON, illuminates white to indicate 115-volt ac control power is available to the ACC lower panel.

The fourth section of the top panel contains four push-button indicators and a potentiometer (D). The first push-button indicator, labeled CONSOLE HIGH TEMPERATURE, illuminates to indicate the console temperature has exceeded the preset limit. The second push-button indicator, labeled CONSOLE HEATER ON, illuminates to indicate the console heater is energized. Heater power is applied when the console power circuit is de-energized. The third push-button indicator, labeled HORN TEST, allows the operator to test the level 2 audible alarm. A level 2 alarm is indicated by a horn. The fourth push-button indicator, labeled BELL TEST, allows the operator to test the level 3 audible alarm. A level 3 alarm is indicated by a bell. The potentiometer, labeled VOLUME, allows the operator to adjust the volume of the audible alarm annunciator.

### **ACC VERTICAL PANEL**

The ACC vertical panel is shown on figure 9-23. This panel contains the controls and indicators for seven of the systems on the ACC. Study figure 9-23 as you read the following descriptions.

#### **Machinery Space Ventilation Fans (Emergency Use)**

Eight pairs of push-button switches are provided for emergency control of the machinery space supply and exhaust fans. Each pair has a FANS RUN and a FANS STOP push button. Status of the fans is indicated by the lights in the respective push buttons. Each machinery space fan control functions identically. For this reason, we will discuss only one pair of push-button controls.

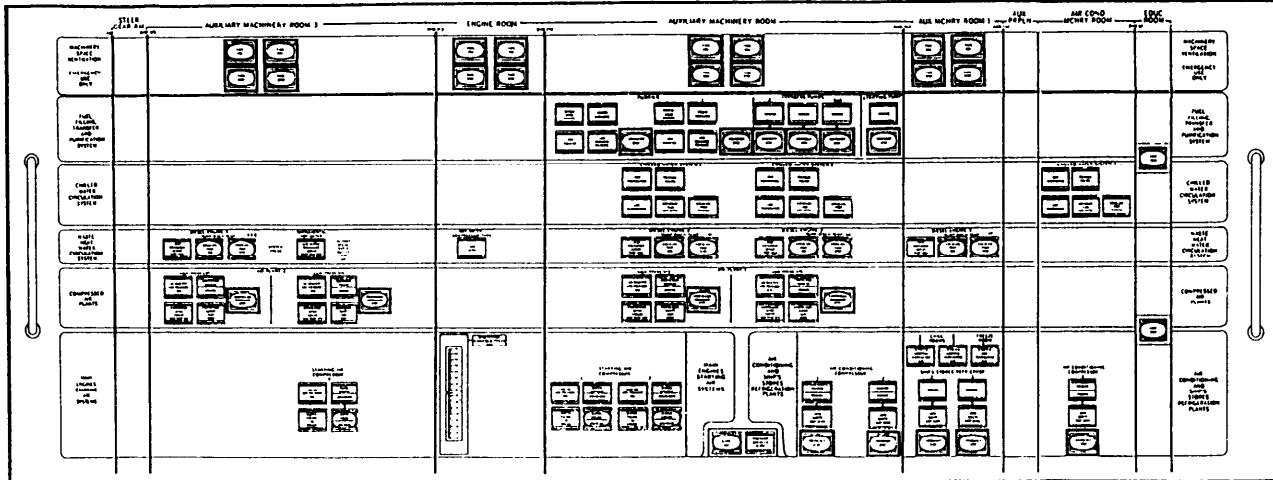
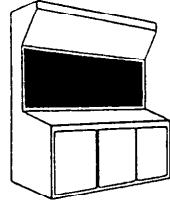
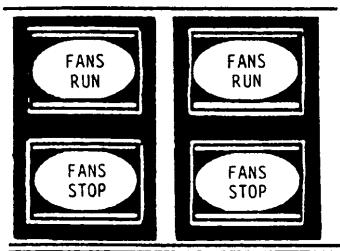


Figure 9-23.—ACC vertical panel.

The first push-button indicator switch is labeled FANS RUN. It is used to start one supply and one exhaust fan in the machinery space. The second push-button indicator switch, also labeled FANS RUN, is used to start the other supply and exhaust fan in that machinery space. The third push-button indicator switch, labeled FANS STOP, is used to stop the first set of supply and exhaust fans. The fourth ventilation push-button indicator switch, also labeled FANS STOP, is used to stop the second set of supply and exhaust fans.



The machinery space ventilation fans are located in the engine room and AMRs No. 1, No. 2, and No. 3. There are supply and exhaust fans in each room. Under normal conditions, the fans are started from the local controllers and left

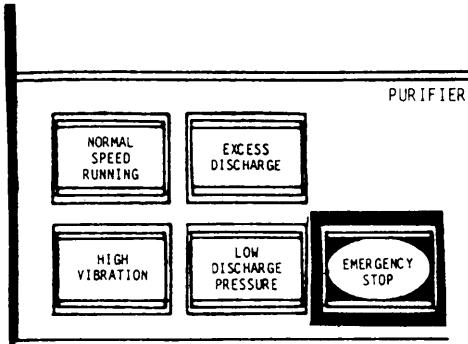
in the LOCAL/REMOTE mode. This allows for additional controller operations from both the local controller and the remote panel. If an emergency exists, the switches at the ACC are used. The local controller switch must be in the LOCAL/REMOTE position for the push buttons on the ACC to be operational.

### Fuel Filling, Transfer, and Purification System Section

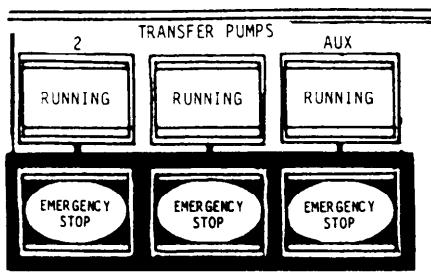
This section has controls and indicators for the purifier, transfer pump, and stripping pump in the fuel filling, transfer, and purification system. The controls have EMERGENCY STOP push buttons for each of the components. Indicators are provided to monitor the status of purifier speed, discharge, and vibration and the status of the transfer pump and the stripping pump. All the equipment monitored is located in AMR No. 2.

The ACC vertical panel contains five push-button controls and indicators for each fuel purifier. Since both purifier controls and indicators are identical, only one set will be discussed. The first indicator is labeled NORMAL SPEED RUNNING. This indicator illuminates green to indicate the fuel transfer purifier is

running at normal speed. The second indicator, labeled EXCESS DISCHARGE, illuminates red to indicate the flow through the breakover switch is excessive. This usually indicates a loss of purifier seal. The third indicator, labeled HIGH VIBRATION, illuminates red to indicate excessive vibration of the fuel purifier. The fourth indicator is labeled LOW DISCHARGE PRESSURE. It illuminates red to indicate the purifier discharge pressure has dropped to 20 psig. The push-button switch, labeled EMERGENCY STOP, is provided to allow the ACC operator to stop the fuel purifier in the event of an emergency.

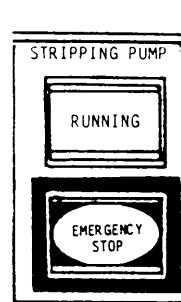


The TRANSFER PUMPS section of the ACC vertical panel contains controls and indicators for two fuel transfer pumps and one auxiliary transfer pump. The first three indicators, labeled RUNNING, illuminate green to indicate the No. 1, No. 2, or auxiliary fuel transfer pump is running. The next three push-button switches, labeled EMERGENCY STOP, allow the operator to stop the respective transfer pump in the event of an emergency.



The STRIPPING PUMP section contains the control and indicator for the fuel stripping pump. The RUNNING indicator illuminates green to indicate the stripping pump is running. The push-button switch, labeled EMERGENCY STOP,

allows the operator to stop the stripping pump in the event of an emergency.



The fuel filling, transfer, and purification system is used to distribute fuel from the deck filling connections to the fuel storage and overflow tanks. It also discharges fuel from the storage and overflow tanks via the deck connections. It is used to transfer fuel between storage tank groups to adjust trim and list. One of its primary jobs is to transfer fuel to the service tanks via the fuel transfer heaters and centrifugal purifiers. The system is designed for local start-up and unattended operation.

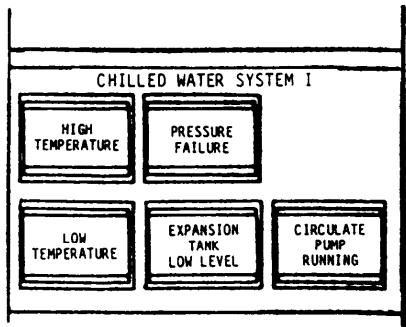
### Chilled Water Circulating System Section

This section contains the alarms and indicator lights that monitor the chilled water circulating system and indicate the status of the chilled water circulating pump. The alarms alert the operator to three occurrences: (1) a high or low chilled water temperature condition, (2) a circulating pump discharge pressure failure, or (3) a low level in the chilled water expansion tank.

The ACC vertical panel contains five push-button controls and indicators for each chilled water system. Since controls and indicators for the three chilled water systems are identical, only one set will be discussed.

The first indicator is labeled HIGH TEMPERATURE. It illuminates red to indicate the chiller outlet temperature has exceeded 45°F. The second indicator, labeled PRESSURE FAILURE, illuminates red to indicate the chilled water circulating pump discharge pressure has dropped below 30 psig. The third indicator, labeled LOW TEMPERATURE, illuminates red to indicate the chiller outlet temperature has dropped below 35°F. The fourth indicator, labeled EXPANSION TANK LOW LEVEL, illuminates red to indicate the expansion tank water level has dropped below 20 percent of the tank capacity. The last indicator in this section is labeled CIRCULATE PUMP

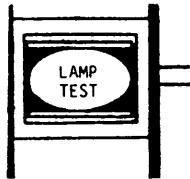
**RUNNING.** It illuminates green to indicate the circulation pump is running.



The chilled water circulating system distributes fresh cooling water throughout the ship for environmental control (air-conditioning), electronic equipment cooling, and bubbler drinking water cooling. The system can be divided into three independent loops. Each loop operates in conjunction with an air-conditioning plant. The circulating equipment for two loops is located in AMR No. 2. The equipment for the third loop is located in the air-conditioning machinery room. The system is designed for local alignment, local start-up, and unattended operation. This system is normally configured in a closed loop with one air-conditioning plant on line.

### Lamp Tests

Two backlit momentary-action LAMP TEST push buttons are provided on the right-hand side of the panel. These are used to test the lamps on the vertical panel.



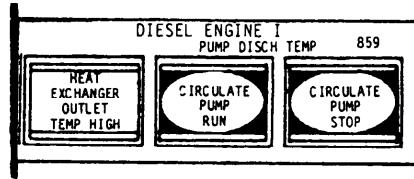
### Waste Heat Water Circulating Systems Section

This section contains the controls and alarms that indicate the status of the major components in the waste heat water circulating system. Push-button switches provide start and stop control

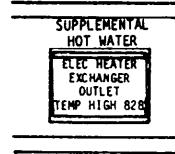
of the system circulating pumps. Alarms are provided to show three occurrences: (1) a high waste heat exchanger outlet temperature condition, (2) a high supplementary electric heater outlet temperature condition, or (3) a low water level in the system compression tank. You can obtain indication of the waste heat system pressure and the supplementary heaters outlet temperature on the demand display.

The first three push buttons are indicators and controls for the diesel engine waste heat system. There are four identical sets of push buttons, one set for each diesel engine. Since each set is identical, only one set will be discussed.

The first indicator is labeled HEAT EXCHANGER OUTLET TEMP HIGH. It illuminates red to indicate the heat exchanger outlet temperature has exceeded the preset limit. The second push-button indicator control, labeled CIRCULATE PUMP RUN, illuminates green to indicate the waste heat circulating pump is running. The third push-button indicator control, labeled CIRCULATE PUMP STOP, illuminates red to indicate the waste heat circulating pump is stopped.

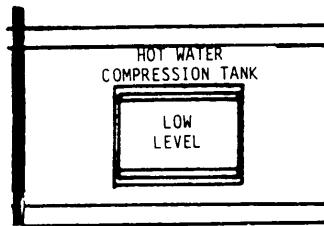


The next indicator is located under the heading SUPPLEMENTAL HOT WATER. The indicator is labeled ELEC HEATER EXCHANGER OUTLET TEMP HIGH. It illuminates red to indicate the supplementary electric heater outlet temperature has exceeded the preset limit.



The last push-button indicator in this section is located under the heading HOT WATER COMPRESSION TANK. This indicator, labeled LOW LEVEL, illuminates red to indicate the hot

water compression tank has dropped below the preset limit.



The waste heat exchanger transfers heat generated by the SSDG to the waste heat water circulating system. The waste heat water circulating system supplies heat to the fuel transfer heaters, the fuel service heaters, the LO purifier heater, the distilling plants, and the hot potable water accumulator tank heating coil. The system has four waste heat exchangers and four circulating pumps. The pumps start and stop automatically with the starting and stopping of their associated SSDG. The circulating equipment is located in the three AMRs and the engine room. The system is designed for automatic start-up and unattended operation.

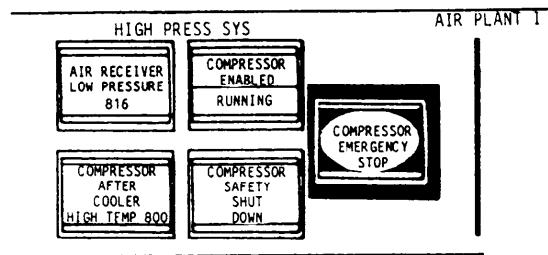
### Compressed Air Plants Section

The status of the HP air system and the LP air system is provided by alarms and visual indicators. Push buttons are provided to stop any of the four compressors in an emergency. The alarms alert the operator that the air receiver pressure is low, when the HP system after-cooler temperature is high, when the LP system dryer discharge temperature is high, and when an automatic compressor safety shutdown has occurred. A split-type indicator shows when power is being supplied to the compressor and when the compressor is running.

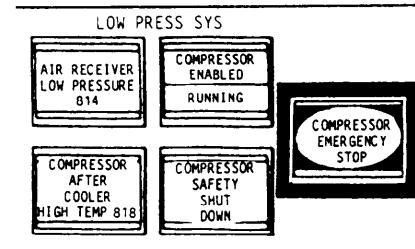
There are two air plants. Each one has an HP air system and an LP air system. One of the air plants is located in AMR No. 2 and the second is located in AMR No. 3. Each of the four compressed air systems is provided with indicators and a switch at the ACC. The systems are designed for local start-up and unattended operation. Since the two air plants are identical, only one plant will be discussed.

The HP air section of the ACC consists of five control indicator push buttons. The first indicator is labeled AIR RECEIVER LOW PRESSURE. It illuminates red to indicate the HP air receiver pressure is below the preset limit. The second split-legends indicator is labeled COMPRESSOR ENABLED and RUNNING. The top portion of

the indicator illuminates white to indicate power is being supplied to the compressor. The bottom portion of the indicator illuminates green to indicate the compressor is running. The third indicator, labeled COMPRESSOR AFTER COOLER HIGH TEMP, illuminates red to indicate the HP aftercooler temperature is above the preset limit. The fourth indicator, labeled COMPRESSOR SAFETY SHUTDOWN, illuminates red to indicate an automatic compressor shutdown has occurred. The push-button switch, labeled COMPRESSOR EMERGENCY STOP, allows the operator to stop the HP air compressor in the event of an emergency.



The LP air section of the ACC consists of five control indicator push buttons. The indicators and controls in this section are functionally identical to those discussed in the HP air section, except they are for the LP air compressor.

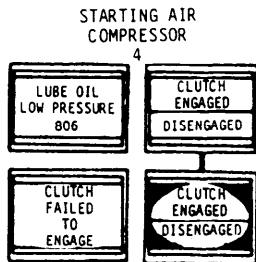


### Main Engines Starting Air System Section

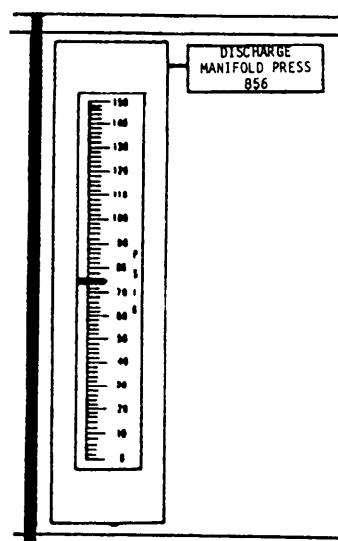
The starting air compressors in the main engine starting air system are designed for either local or remote start-up. This section provides controls to allow the operator at the ACC to engage or disengage the compressor clutch. For the controls to be operational, the local clutch controller selector switch must be in the REMOTE position. This section also provides indication of the clutch status and alarms for low compressor LO pressure and failure of the clutch to engage. A meter provides a continuous reading of the air discharge pressure.

The starting air compressor (SAC) section of the ACC contains the four control indicator push buttons for the three SACs. Since each SAC is identical, only one set of push buttons will be discussed.

The first indicator in this section is labeled LUBE OIL LOW PRESSURE. It illuminates red to indicate the LO pressure at the SAC is below the preset limit. The second split-legends indicator is labeled CLUTCH ENGAGED and DISENGAGED. The top portion of this indicator illuminates to indicate the SAC clutch is engaged. The bottom portion of the indicator illuminates to indicate the clutch is disengaged. The third indicator, labeled CLUTCH FAILED TO ENGAGE, illuminates red to indicate failure of the SAC clutch to engage. The last split-legends indicator control push button in this section is labeled CLUTCH ENGAGED and DISENGAGED. This push button allows the ACC operator to engage or disengage the SAC clutch.



The next item on the ACC vertical panel is a vertical reading pressure gauge labeled DISCHARGE MANIFOLD PRESS. This gauge provides a continuous reading of the discharge manifold air pressure.



The main engine starting air system provides compressed air to the gas turbine (GT) pneumatic starter. The starter rotates the GG for starting, motoring, or water washing. The starting air system uses compressed air supplied from one of three SACs. In an emergency, it can use compressed air from the bleed air system of an operating engine. Only one compressor is used for starting, motoring, or water washing. Two of the compressors are located in AMR No. 2; the third is located in AMR No. 3.

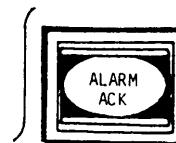
#### NOTE

The location of each SAC may be different on each flight of the FFG-class ship.

Each SAC is driven by an associated diesel generator set. The compressor is driven by the diesel engine via a step-up gearbox and hydraulic clutch. The clutch can be engaged whenever the electrical load on the respective SSDG is below 666 kW. During compressor operation, should the kW load on the SSDG exceed 666 kW, the clutch will disengage.

#### Alarm Acknowledge

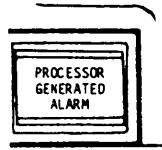
The ALARM ACK push button is located in the lower, center portion of the ACC vertical panel. When an out-of-tolerance condition occurs in a system being monitored at the ACC, the associated fault alarm actuates. The audible alarm is accompanied by a flashing visual light. The operator acknowledges the alarm by depressing the ALARM ACK push button. The audible portion of the alarm is silenced and the visual light stops flashing but remains illuminated. The light remains illuminated until the cause of the alarm has been cleared. This push button is used to acknowledge any alarm on the ACC.



#### Processor Generated Alarm

The processor is a special-purpose computer located in the EPCC. When an out-of-tolerance condition occurs on equipment being monitored at the ACC, the equipment sensor transmits a signal to the equipment fault alarm circuitry in

the console. The signal is also transmitted to the processor through the ACC. The processor compares the signal with the alarm set value to determine if an out-of-tolerance condition exists. If the condition does exist, the processor checks the equipment fault alarm circuitry to determine if the fault alarm has been actuated. If the processor detects an alarm condition not provided by the normal fault alarm circuitry, the PROCESSOR GENERATED ALARM indicator flashes and the parameter audible alarm sounds.

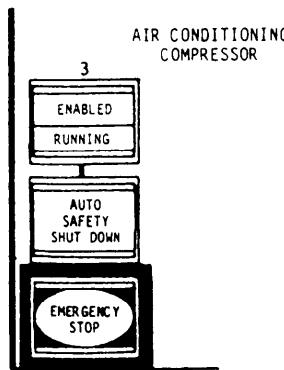


### Air-Conditioning Plants Section

The status of the three air-conditioning plants is provided at the ACC by visual indicators and alarms. Push buttons provide the capability for stopping the air-conditioning compressors in an emergency.

The ACC vertical panel provides controls and indicators for the three air-conditioning plants. Since these controls and indicators are identical for each plant, only one air-conditioning plant will be discussed.

The first split-legends push-button indicator is labeled ENABLED and RUNNING. The upper portion of the indicator illuminates white to indicate power is being supplied to the air-conditioning compressor. The lower portion of the indicator illuminates green to indicate the compressor is running. The second indicator, labeled AUTO SAFETY SHUTDOWN, illuminates red to indicate an automatic air-conditioning compressor shutdown has occurred. The push-button switch, labeled EMERGENCY STOP, allows the operator to stop the air-conditioning compressor in the event of an emergency.

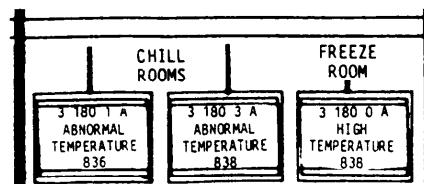


The air-conditioning plants provide chilled water for the chilled water circulating system. There are three air-conditioning plants. Each plant can service a separate loop in the chilled water system. Each plant has a rated capacity of 80 tons of refrigeration. The plants are designed for local start-up and unattended operation. One plant is located in the air-conditioning machinery room and two are located in AMR No. 2.

### Ship's Stores Refrigeration Plants Section

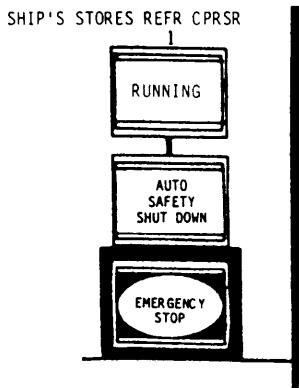
The status of the two ship's stores refrigeration plants is provided at the ACC by visual indications and alarms. Push buttons provide the operator with the capability of stopping the compressors in an emergency. An indicator provides the operating status of the compressor. Alarms are actuated when an automatic safety shutdown occurs, when the freeze room temperature is too high, or when an abnormal chill room temperature is detected (high or low).

The first two indicator push buttons monitor the two chill rooms of the refrigeration plant. The indicators, labeled ABNORMAL TEMPERATURE, illuminate red to indicate an abnormal temperature in the chill room exists. (This temperature can be abnormally high or low.) The third indicator is labeled HIGH TEMPERATURE. It illuminates red to indicate a high temperature in the freeze room.



The next three indicator push buttons are under the heading SHIP'S STORES REFR CPRSR. The first indicator, labeled RUNNING, illuminates green to indicate the refrigeration compressor is running. The next indicator, labeled AUTO SAFETY SHUTDOWN, illuminates red to indicate an automatic refrigeration plant compressor shutdown has occurred. The push-button switch, labeled EMERGENCY

**STOP**, allows the operator to stop the refrigeration compressor in the event of an emergency.



The ship's stores refrigeration plants allow for the preserving of perishable food stores. The plants serve one freeze room and two chill rooms. Each plant has a rated capacity of 1.1 tons of refrigeration. Both plants are located in AMR No. 1. They are designed for local start-up and unattended operation.

## ACC LOWER PANEL

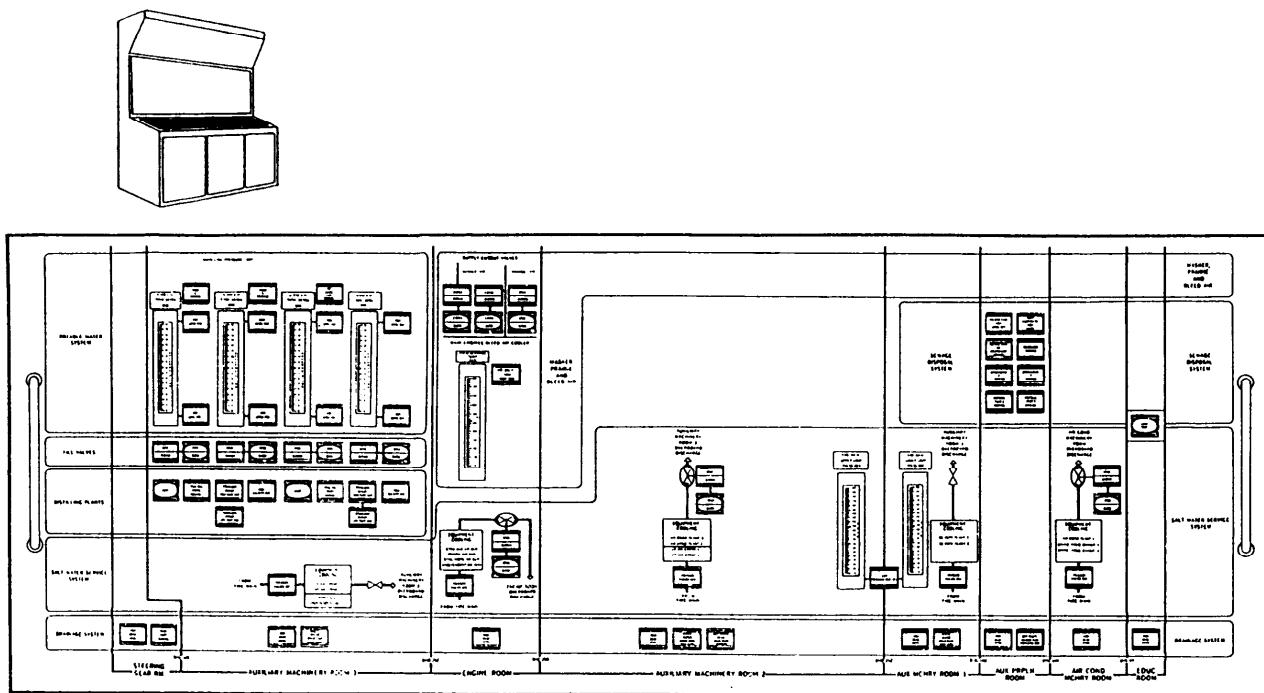
The ACC lower panel contains the switches and indicators that control and monitor the

potable water system; the masker, prairie, fin stabilizer, and bleed air systems; the sewage disposal system; the distilling plants; the saltwater service system; and the drainage system. This panel is shown on figure 9-24. Refer to figure 9-24 as you read the following descriptions.

## Potable Water System Section

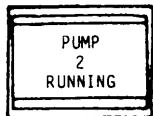
The indicators for the potable water system include tank level meters and indicators for the status of the four potable water tanks, the two potable water pumps, and the hot potable water pump. High- and low-level alarms are provided for each of the four tanks. The operator can use the demand displays to monitor the tank levels and the potable water system pressure. Push-button OPEN/CLOSE switches for the potable water tank fill valves allow the operator to coordinate the tank filling operation.

The first indicator in the potable water system section is labeled PUMP 2 RUNNING. It illuminates green to indicate that potable water pump No. 2 is running. The indicator



**Figure 9-24.**—ACC lower panel.

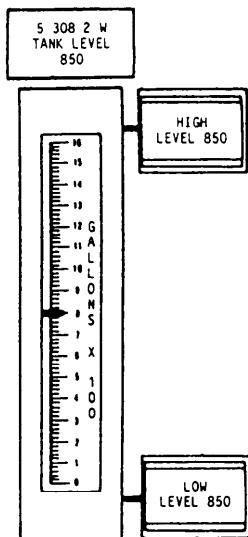
for potable water pump No. 1 is functionally identical.



The second indicator, labeled HOT WATER PUMP RUNNING, illuminates green to indicate the hot water pump is running.



The next component in this section is a vertical reading meter that continuously monitors the potable water tank level. There are four identical meters, one for each potable water tank. These meters are scaled in gallons. The third indicator push button, labeled HIGH LEVEL, illuminates red to indicate the level in the potable water tank is 90 percent of capacity. There is a high-level indicator for each potable water tank. The fourth indicator push button, labeled LOW LEVEL, illuminates red to indicate the level in the potable water tank is 10 percent of capacity. There is a low-level indicator for each potable water tank.

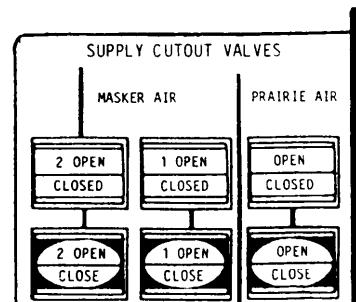


The potable water system stores and distributes brominated water required by the ship's crew and equipment. There are four potable water tanks. The system is served by two centrifugal pumps. Either pump can take suction from any of the four tanks. The pump discharges to either the filling and transfer main or to the service main. The system is designed for local start-up and unattended operation. All the system components being monitored or controlled are located in AMR No. 3.

## **Masker, Prairie/Fin Stabilizer, and Bleed Air Systems Section**

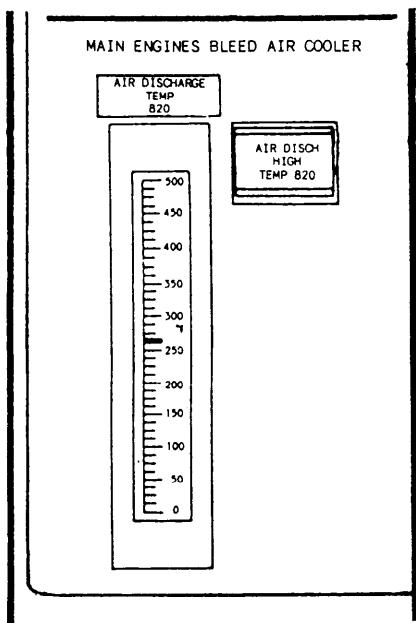
Push-button switches allow control of the two supply cutout valves in the masker air system and the supply cutout valve in the prairie/fin stabilizer air system. Split-type indicators provide the valve status. A meter allows the operator to continuously monitor the air discharge temperature from the bleed air cooler. An alarm is provided to alert the operator to an air high-temperature condition.

The first split-legend indicator push button is labeled 2 OPEN and CLOSED. The top portion of the indicator illuminates green to indicate the No. 2 masker supply cutout valve is open. The lower portion of the indicator illuminates red to indicate the masker supply cutout valve is closed. The second split-legend indicator push button, labeled 1 OPEN and CLOSED, functions identically to the No. 2 supply cutout valve control. The third split-legend indicator push button is labeled OPEN and CLOSED. This indicator illuminates to indicate the position of the prairie air supply cutout valve. The next three split-legend push-button switches allow control of the two masker air supply cutout valves and the prairie air supply cutout valve.



Located under the masker and prairie air supply valve controls is a vertical reading meter labeled AIR DISCHARGE TEMP. This meter

allows the operator to continuously monitor the bleed air cooler discharge temperature. The push-button indicator located next to the meter is labeled AIR DISCH HIGH TEMP. It illuminates red to indicate the bleed air cooler discharge temperature has reached 400°F.

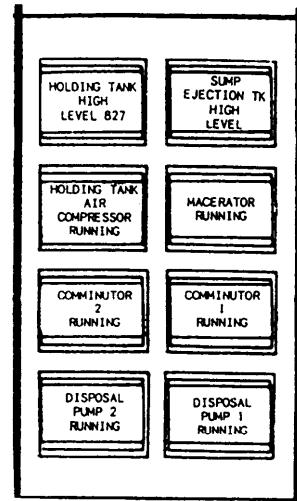


### Sewage Disposal System Section

The ACC has alarms and indicators to show the status of the collecting, holding, and transfer (CHT) tank level, the sump ejection tank level, the sewage holding tank air compressor, the macerator sewage pump, the comminutors, and the sewage ejection pumps. The level in the CHT tank can be obtained on the demand display.

The first indicator is labeled HOLDING TANK HIGH LEVEL. It illuminates red to indicate a high level in the sewage collecting holding tank. The second indicator, labeled SUMP EJECTION TK HIGH LEVEL, illuminates red to indicate a high level in the sump ejection tank. The third indicator is labeled HOLDING TANK AIR COMPRESSOR RUNNING. It illuminates green to indicate that the holding tank air compressor is running. The fourth indicator, labeled MACERATOR RUNNING, illuminates green to indicate that the macerator sewage pump is running. The fifth indicator, labeled COMMINUTOR 2 RUNNING, illuminates green to indicate that the No. 2

comminutor is running. The sixth indicator, labeled COMMINTOR 1 RUNNING, is functionally identical to the No. 2 comminutor indicator. The seventh indicator is labeled DISPOSAL PUMP 2 RUNNING. It illuminates green to indicate the No. 2 disposal pump is running. The eighth indicator, labeled DISPOSAL PUMP 1 RUNNING, is functionally identical to the No. 2 disposal pump indicator.

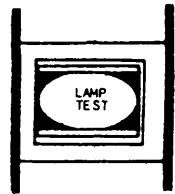


The sewage disposal system allows for the disposal of waste from the ship to satisfy the prevailing ecology requirements. The system has a CHT tank, two comminutors, and two ejection pumps located in the collecting, holding, and boiler room. It also has the sump ejection tank and macerator sewage pump located in the steering gear room. Soil and waste drains empty into the CHT tank, or directly overboard, depending on the location of the drain within the ship. The contents of the sump ejection tank are automatically pumped through the macerator sewage pump to the CHT tank when the ejection tank is filled to 70 percent of capacity. The CHT tank can be emptied by pumping it directly overboard when the ship is in unrestricted waters, to a barge when it is in restricted waters, or to shore facilities when the ship is secured to a dock. The system is designed for local start-up and unattended operation.

### Lamp Test

The backlit momentary-action LAMP TEST push button is provided on the right-hand

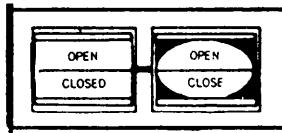
side of the panel. This push button is used to test the lamps on the lower panel.



### Fill Valves Section

This section consists of four sets of indicator and control push buttons for the fill valves of the potable water tanks. Since each set is identical, only one set of push buttons will be discussed.

The first split-legends indicator is labeled OPEN and CLOSED. The top portion of the indicator illuminates green to indicate the potable water tank fill valve is open. The lower portion illuminates red to indicate the potable water tank fill valve is closed. The second split-legends push-button switch allows control of the potable water tank motor-operated fill valve.

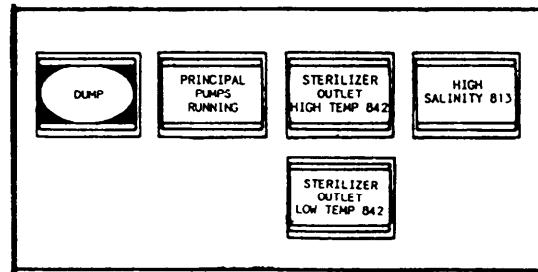


### Distilling Plants Section

Alarms, lighted indicators, and a push button are provided for monitoring and controlling the operation of the distilling plants. The alarms alert the operator to a high or low temperature of the distillate leaving the sterilizer and to a high distillate salinity condition. A lighted indicator provides the status of the three pumps associated with each distilling plant. A push button allows remote operation of the plant's 3-way solenoid trip valve. Each distilling plant section on the ACC contains four indicators and one control push button. The indicators and control for only one plant will be discussed.

The first control push button is labeled DUMP. It allows the operator to operate remotely the distilling plant's dump valve. The first indicator is labeled PRINCIPAL PUMPS RUNNING. This indicator illuminates green to indicate the three pumps associated with the distilling plant are running. The second indicator is labeled STERILIZER OUTLET HIGH TEMP. It illuminates red to indicate the sterilizer outlet temperature has reached 198°F. The third

indicator, labeled HIGH SALINITY, illuminates red to indicate the salinity of the distillate has reached 0.065 equivalent parts per million (epm). The fourth indicator, labeled STERILIZER OUTLET LOW TEMP, illuminates red to indicate the sterilizer outlet temperature has dropped to 160°F.

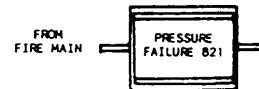


The function of each distilling plant is to supply fresh water for the ship's potable water system. It also supplies untreated distilled water to the GT water wash system, the electronic cooling water system, and the static frequency changers. There are two independent distilling plants, each producing 4000 gallons of distilled water per day. Both plants are located in AMR No. 3.

### Saltwater Service System Section

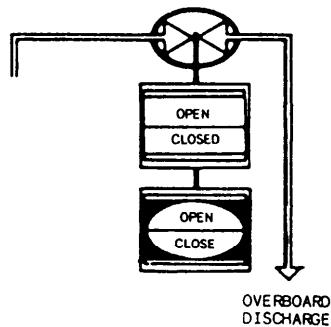
The status of the saltwater service system is provided by meters and an alarm for firemain pressure. Also, there are alarms for the seawater cooling system pressure in the three AMRs, the engine room, and the air-conditioning machinery room. Push-button switches and lighted indicators provide control and status of cooling water overboard discharge valves in the engine room, AMR No. 2, and the air-conditioning machinery room.

The first alarm indicator in this section is labeled PRESSURE FAILURE. It illuminates red to indicate the cooling water pressure from the firemain system has dropped to 110 psig. The saltwater section of the ACC contains five PRESSURE FAILURE alarm indicators, all of which function identically.

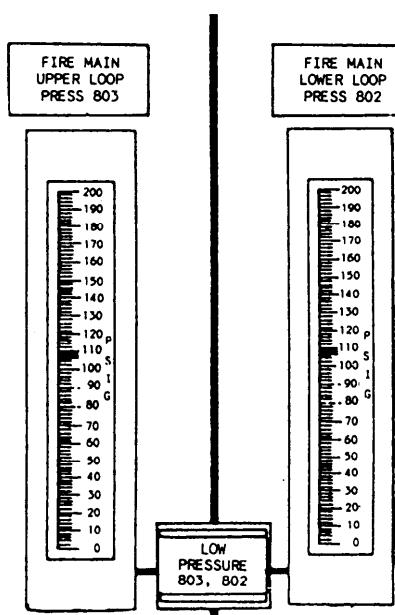


The first split-legends indicator in this section is labeled OPEN and CLOSED. The top portion of the indicator illuminates green to indicate the overboard discharge valve is open. The bottom

portion of the indicator illuminates red to indicate the overboard discharge valve is closed. The second split-legends control push button is labeled OPEN and CLOSE. This push button allows control of the motor-operated overboard discharge valve. There are three pairs of split-legends indicators and control push buttons in this section of the ACC.



The first vertical reading meter in this section is labeled FIRE MAIN UPPER LOOP PRESS. This meter, scaled in psig, provides continuous monitoring of the upper firemain loop pressure. A second vertical reading meter, labeled FIRE MAIN LOWER LOOP PRESS, provides continuous monitoring of the lower firemain loop pressure. Located between the two vertical reading meters is an alarm indicator labeled LOW PRESSURE. This indicator illuminates red to indicate that the firemain pressure in either loop has dropped to 110 psig.



## Drainage System Section

The drainage system indicators include alarms that indicate a high liquid level in the bilge of each of the eight rooms being monitored, a high level in the waste water drain tanks in the three AMRs, and a high level in the oily waste water holding tank. Indicators also show the status of the steering gear room drain pump and the bilge pump in AMR No. 2. The demand display may be used to monitor the level in the oily waste water holding tank.

The first alarm indicator is labeled HIGH BILGE LEVEL. It illuminates red to indicate the liquid level in the bilge has exceeded the preset limit. There are eight HIGH BILGE LEVEL alarm indicators in this section of the ACC.



The second indicator is labeled BILGE PUMP RUNNING. It illuminates green to indicate that the steering gear room bilge pump is running.



The alarm indicator is labeled WASTE WATER DRAIN TANK HIGH LEVEL. It illuminates red to indicate that the level in the waste water drain tank has exceeded the preset limit. There are three WASTE WATER DRAIN TANK HIGH LEVEL alarm indicators in this section of the ACC.



The fourth indicator is labeled OILY WASTE DRAIN BILGE PUMP RUNNING. It illuminates

green to indicate that the oily waste drain tank bilge pump is running.



The last alarm indicator in this section is labeled OILY WASTE HOLDING TANK HIGH LEVEL. It illuminates red to indicate the level of the oily waste holding tank has exceeded the preset limit.



## DAMAGE CONTROL CONSOLE FOR THE FFG-7 CLASS SHIPS

The DCC on the FFG-7 class ships has many of the same features as the DCC on the DD-963 and CG-47 class ships. (See fig. 9-25.) From this console, an operator can monitor and control many of the damage control systems installed on the FFG-7 class frigates. The DCC is located on the damage control side of CCS. These systems include the following components:

- AFFF sprinkling system valves
- Halon flooding system
- High water alarm
- Sprinkling systems
- High temperature alarms
- Supply fans
- Fire zone doors
- Exhaust fans
- Recirculating fans
- Ducting closures
- Firemain pumps and valves

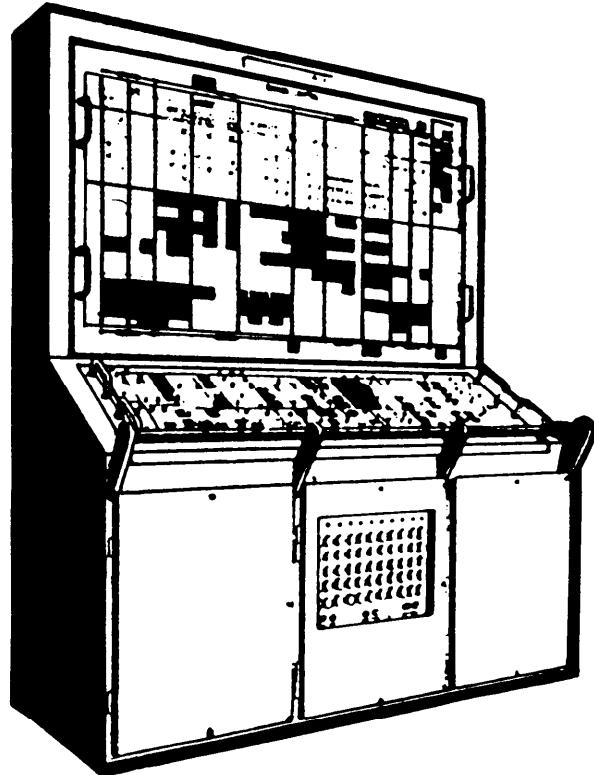


Figure 9-25.—Damage control console (FFG-7).

### DCC UPPER PANEL

The upper panel of the DCC, shown in figure 9-26, is used to monitor most of the systems of the DCC. This panel is divided into three major sections, with each section further divided into subsections. The upper panel also contains a power monitoring section. The three major sections are labeled as follows:

1. Misc. Fire Fighting
2. Alarm and Detection
3. Ventilation

The DCC upper panel displays the four fire zones on the FFG-class ship. During the discussion of the alarms, indicators, and controls of this panel, only FIRE ZONE 1 will be discussed. The other five fire zones are identical, with the exception of the indicator labels.

#### Power Monitoring Section

This section contains eight indicators to display the status of various console power requirements. The first two indicators are located

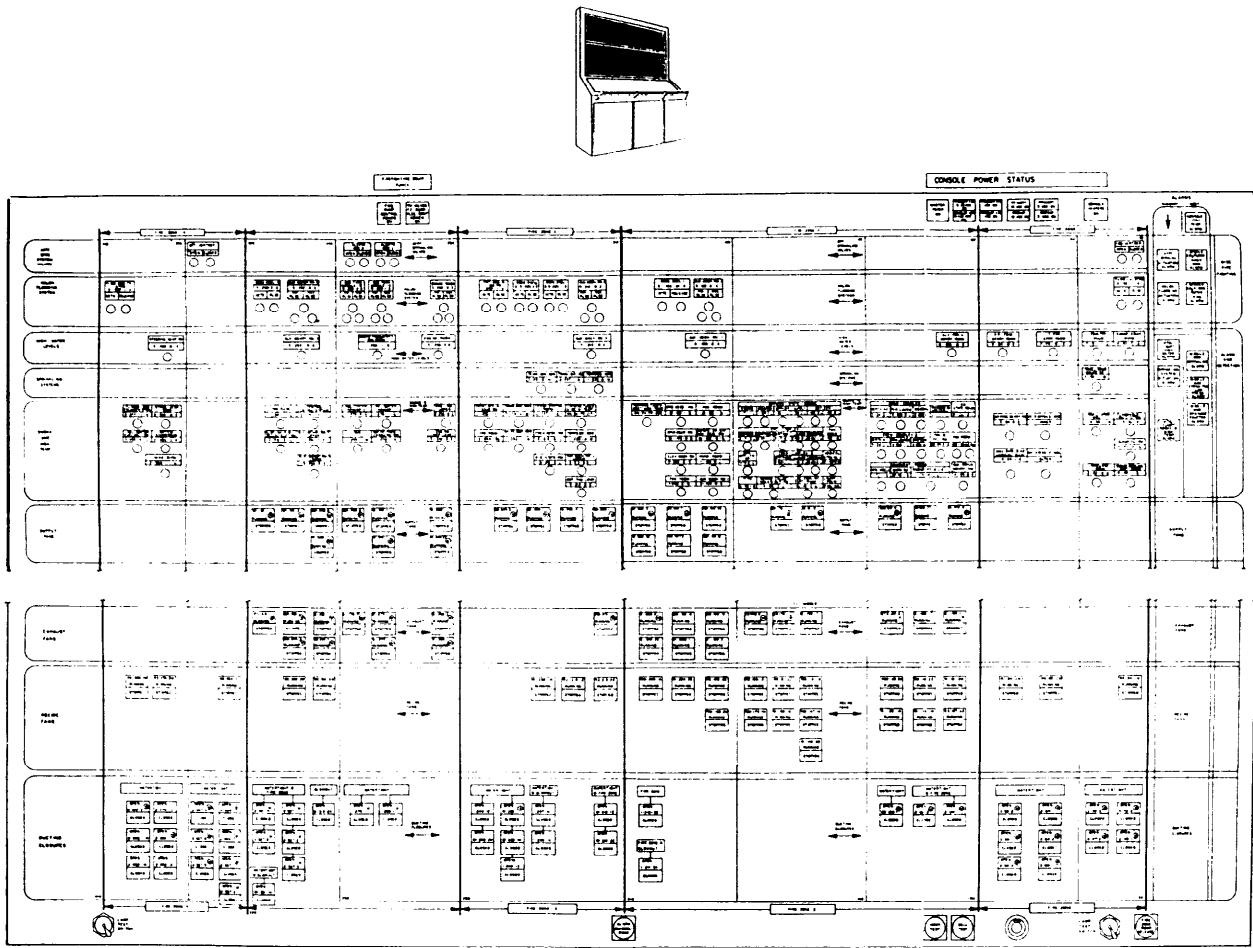
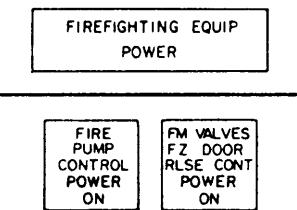


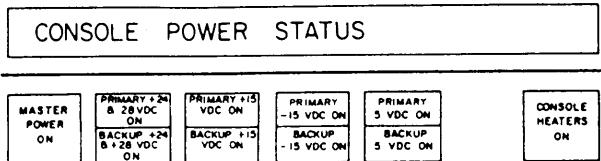
Figure 9-26.—DCC upper panel.

under the heading FIREFIGHTING EQUIP POWER. The first indicator is labeled FIRE PUMP CONTROL POWER ON. It illuminates white to indicate fire pump control power is energized. The second indicator is labeled FM VALVES FZ DOOR RLSE CONT POWER ON. It illuminates white to indicate the control power for the firemain motor-operated valves and the fire zone door release control is energized.



Located under the heading CONSOLE POWER STATUS are six status indicators. The first indicator, labeled MASTER POWER ON, illuminates white to indicate the main power to the DCC is energized. The second indicator is a split-legends status indicator labeled PRIMARY +24 & 28 VDC ON and BACKUP +24 & +28 VDC ON. The upper portion of the indicator illuminates white to indicate the primary 24/28-volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup 24/28-volt dc power converter is in operation. The third indicator is a split-legends status indicator labeled PRIMARY +15 VDC ON and BACKUP +15 VDC ON. The upper portion of the indicator illuminates white to indicate the primary +15 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup +15 volt dc power converter is in

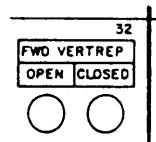
operation. The fourth indicator is a split-legend status indicator labeled PRIMARY - 15 VDC ON and BACKUP - 15 VDC ON. The upper portion of the indicator illuminates white to indicate the primary - 15 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup - 15 volt dc power converter is in operation. The fifth indicator is a split-legend status indicator labeled PRIMARY 5 VDC ON and BACKUP 5 VDC ON. The upper portion of the indicator illuminates white to indicate the primary +5 volt dc power converter is in operation. The lower portion of the indicator illuminates white to indicate the backup +5 volt dc power converter is in operation. The sixth push-button indicator, labeled CONSOLE HEATERS ON, illuminates white to indicate the console heaters are energized. Heater power is applied when the console power circuit is de-energized.



## Miscellaneous Fire Fighting Section

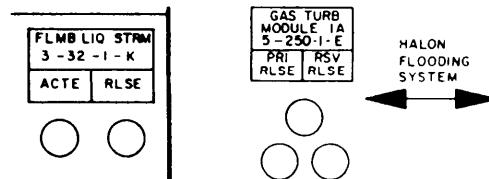
This section is the uppermost section of the top panel. It is divided into two subsections, one containing the AFFF sprinkling system valves and the other containing the Halon flooding system. The AFFF sprinkling system valves subsection shows the status of the four AFFF sprinkling valves. These valves control the sprinkling of AFFF at the two vertical replenishment (VERTREP) stations, forward (FWD) and aft (AFT), and the sprinkling systems in the two helicopter hangars. These valves are activated locally and their open or closed status is shown on the DCC.

Open and closed valve indication for sprinkler control valves at the forward and aft VERTREP and helicopter hangars is provided on the DCC by two indicating lights. The OPEN indicator light illuminates green to indicate the sprinkler control valve is open. The CLOSED indicator light illuminates white to indicate the valve is closed.



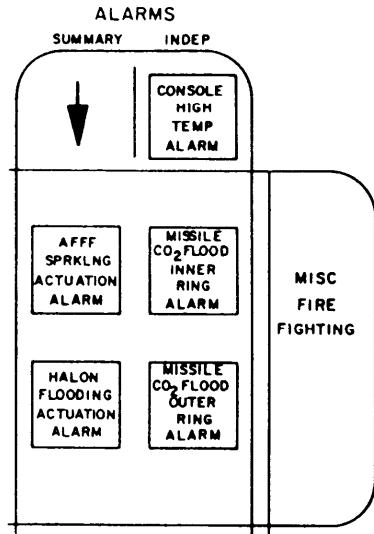
The second subsection contains the Halon flooding system. Halon is the extinguishing agent used to combat fires in high risk areas. The Halon system protects both GTM modules; all four SSDG enclosures; the engine room; all three AMRs; the recovery, assist, securing, and traversing (RAST) equipment room; the paint mixing room; and the flammable gas and liquid storerooms. The DCC has indicators, corresponding to the spaces, that display whenever Halon has been released to one of these spaces.

Halon release and actuation is displayed on the DCC with two types of indicator arrangements. The first type is for spaces that have only primary Halon protection. It contains two indicators labeled ACTE and RLSE. The associated ACTE indicator illuminates in response to a pressure switch contact closure that activates when the CO<sub>2</sub> actuation system is operated. The RLSE indicator illuminates to indicate Halon release in the associated space. The second indicator arrangement is for spaces that have primary and reserve Halon protection. This arrangement contains three indicators to display Halon actuation, primary Halon release, and reserve Halon release. The associated actuation indicator illuminates in response to a pressure switch contact closure that activates when the CO<sub>2</sub> actuation system is operated. The PRI RLSE indicator illuminates to indicate primary Halon release in the associated space. The RSV RLSE indicator illuminates to indicate reserve Halon release in the associated space.



Associated with the miscellaneous fire fighting section is a horizontal grouping of alarm indicators, labeled SUMMARY and INDEP. The first indicator is labeled CONSOLE HIGH TEMP ALARM. This alarm indicator illuminates red to indicate the console temperature has exceeded the preset limit. The second alarm indicator, labeled AFFF SPRKLNG ACTUATION ALARM, illuminates red when any one of the AFFF sprinkling system alarms occur. The third indicator, labeled MISSILE CO<sub>2</sub> FLOOD INNER RING ALARM, illuminates red to indicate CO<sub>2</sub> flooding for the inner ring of the missile launcher.

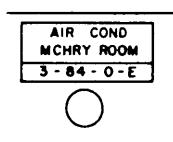
The fourth alarm indicator, labeled HALON FLOODING ACTUATION ALARM, illuminates red when any one of the Halon flooding systems alarms occurs. The fifth alarm indicator is labeled MISSILE CO<sub>2</sub> FLOOD OUTER RING ALARM. It illuminates red to indicate CO<sub>2</sub> flooding for the outer ring of the missile launcher.



## Alarm and Detection Section

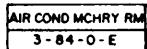
The alarm and detection section of the upper panel is located below the MISC FIRE FIGHTING section and contains three subsections. These subsections are high water levels, sprinkling systems, and high temperature.

The high water level indicators monitor water levels in spaces that have high potential for flooding. There are 11 of these alarms for spaces, such as the engine room, AMRs, and several other equipment rooms. The indicator light illuminates red to indicate the water level has exceeded the preset limit in its associated space.



Four alarm indicators are in the sprinkling systems subsection. These indicators display the status of sprinkling systems other than the AFFF

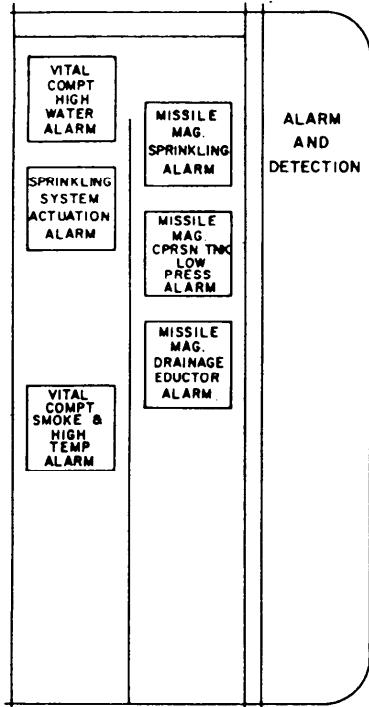
systems. These systems are located in three magazine spaces and in the trash disposal room. The sprinklers use salt water from the firemain system. The alarm indicator illuminates red to indicate the fire fighting sprinkler system is activated.



The last major subsection in this section is the high temperature section. There are 81 indicators activated by temperature sensors located throughout the ship. They alert the operator if a fire is detected in one of the ship's spaces. The indicator illuminates red to indicate the temperature of a compartment has exceeded the preset limit. The indicator also illuminates to indicate that there is an excess of smoke in a compartment.

Associated with the alarm and detection section is a horizontal grouping of summary and independent alarm indicators. The first alarm indicator in this section is labeled VITAL COMPT HIGH WATER ALARM. It illuminates red to indicate a high water level at one of the locations monitored. The second alarm indicator, labeled MISSILE MAG. SPRINKLING ALARM, illuminates red to indicate activation of the missile magazine sprinkling system. The third alarm indicator, labeled SPRINKLING SYSTEM ACTUATION ALARM, illuminates red to indicate one of the sprinkling systems is activated. The fourth alarm indicator is labeled MISSILE MAG. CPRSN TNK LOW PRESS ALARM. It illuminates red to indicate low pressure in the missile magazine compression tank. The fifth indicator, labeled MISSILE MAG. DRAINAGE EDUCTOR ALARM, illuminates red to indicate the missile magazine eductor is in operation. The sixth alarm indicator is labeled VITAL COMPT SMOKE & HIGH TEMP ALARM. It illuminates

red to indicate high temperature or excess smoke in one of the locations monitored.



## Ventilation Section

The largest section of the top panel is the ventilation section. This section contains four subsections, three of which monitor fan status and one that monitors duct closures. No control is available here, only monitoring capability.

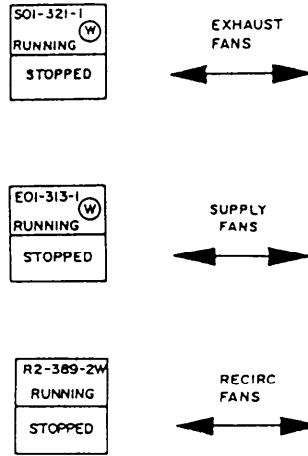
The top subsection is used to monitor the supply fans. Twenty-four split-legends indicators display either running or stopped status of the supply fans. The top portion of the indicator illuminates green to indicate the fan is RUNNING. The bottom portion of the indicator illuminates white to indicate the fan is STOPPED.

The exhaust fans section, located below the supply fan section, has 23 split-legends indicators. They monitor the on/off status of 23 exhaust ventilation systems. The top portion of the indicator illuminates green to indicate the fan is RUNNING. The bottom portion of the indicator illuminates white to indicate the fan is STOPPED.

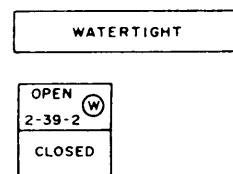
### NOTE

There are no supply or exhaust fan indicators in FIRE ZONE 1.

The recirculation fans section, located below the exhaust fan section, has 28 split-legends indicators. The 28 recirculation systems have their status displayed in this portion of the panel. The top portion of the indicator illuminates green to indicate the fan is RUNNING. The bottom portion of the indicator illuminates white to indicate the fan is STOPPED.



Below the recirculation system monitoring section are 46 indicators that monitor ducting closures. They display the open/closed status of a variety of watertight, blowout, and fire zone closures. The top portion of the indicator illuminates green to indicate the duct closure is OPEN. The bottom portion of the indicator illuminates white to indicate the duct closure is CLOSED.



Located on the lower left side of the upper panel is a switch labeled LAMP TEST SWITCH. This switch allows the operator to test the indicator lights on the upper panel. An identical switch is located on the lower right side of the panel and provides the same function.



Located at the lower center of the upper panel is a push-button switch labeled ALARM ACKNOWLEDGE. An alarm condition is displayed by a flashing indicator accompanied by an audible alarm. Depressing the ALARM ACKNOWLEDGE push button silences the audible alarm and causes the flashing indicator to illuminate steadily. The indicator extinguishes when the alarm condition clears.



The next two push-button switches provide for testing of the annunciator. The switches are labeled HORN TEST and BELL TEST. Depressing the HORN TEST push button sounds the horn, while depressing the BELL TEST push button sounds the bell. Associated with these push buttons is a volume control potentiometer that the operator can use to adjust the volume of the audible alarm.



The only control feature on the top panel is located on the lower right side. It is labeled FIRE ZONE DOOR RELEASE. When this push button is depressed, the console sends out a signal to close the fire boundary smoketight doors. This function prevents the spread of smoke throughout the ship during fires.



### DCC LOWER PANEL

The lower panel of the DCC, shown in figure 9-27, monitors and controls the ship's firemain system. This panel has a complete mimic of the major piping of the firemain. Some of the capabilities available from this panel include the following:

- Fire pump on/off control (five pumps)
- Control of major isolation valves (20 valves)
- AFFF proportioner activation indication
- Minor isolation valve indication

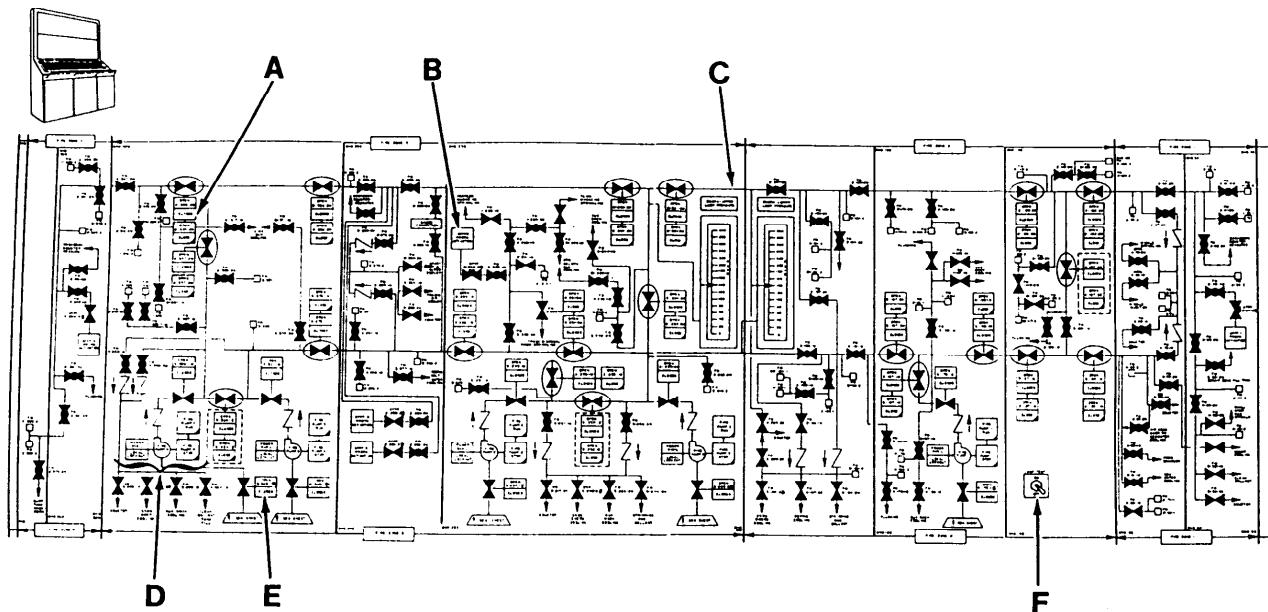


Figure 9-27.—DCC lower panel.

- Firemain pressure indication (two meters)
- Fire pump power status

During this discussion, refer to figure 9-27. The indicators and controls on the lower panel will be discussed from left to right and top to bottom.

The first indicator on this panel is a split-legends status indicator labeled OPEN and CLOSED (A). The top portion of the indicator illuminates green to indicate that the associated motor-operated valve is open. The bottom portion of the indicator illuminates white to indicate the valve is closed. Associated with each split-legends status indicator is a split-legends control push button labeled OPEN and CLOSE. It controls the motor-operated valve. For quick visual identification, the OPEN/CLOSE push buttons and valve position indicators for the three ZEBRA condition loop valves are each highlighted with dashed lined boxes. The second indicator is labeled AFFF PROPN ACTIVATION (B). It is an alarm indicator that illuminates to indicate the corresponding AFFF valve is activated. This alarm is energized in conjunction with the corresponding alarm on the miscellaneous fire fighting section of the upper panel. Located in the center of the DCC lower panel are two vertical reading meters labeled ZEBRA-UPPER LOOP PRESSURE and ZEBRA-LOWER LOOP PRESSURE (C). These meters reflect firemain pressure measured by transducers at the indicated locations. The meters are scaled from 0 to 300 psig.

The next section of the lower panel monitors and controls the fire pumps. It contains three push-button indicators. There are five identical sets of push buttons on this panel, one for each fire pump (D). The first control push-button indicator is labeled FIRE PUMP 4 RUN. It illuminates green to indicate the fire pump is running. There are five fire pump run control push buttons located on the lower panel. The split-legends indicator control push button is labeled POWER AVAIL and LOCAL LOCKOUT. The top portion of the indicator illuminates to reflect the status of power availability to the fire pump. The lower portion of the indicator illuminates to indicate the fire pump controller is in local control and remote operation of the pump is not available. The second control push-button indicator, labeled FIRE PUMP 4 STOP, illuminates red to indicate the fire pump is stopped. There are five fire pump stop control

push buttons located on the lower panel. At the inlet of each fire pump is a split-legends indicator labeled OPEN and CLOSED (E). This indicator displays the position of the fire pump suction valve. The top portion of the indicator illuminates green to indicate the valve is open. The bottom portion of the valve illuminates white to indicate the valve is closed. There are five indicators on the DCC lower panel. Located at the lower right of the panel is a toggle switch labeled LAMP TEST (F). It provides for testing the indicators on the lower panel.

Operation of the firemain system is fairly easy. You can start or stop pumps by depressing either the pump run or pump stop push button. These push buttons also serve as indicators of pump status. The motor-operated isolation valves have split-type indicators to display their status. A split-legends push button is also provided to allow operation of the valves.

During general quarters, condition ZEBRA, the firemain is segregated into two loops. In this mode, three motor-operated valves must be closed. This provides for an upper and a lower loop. The upper loop is fed by fire pumps 3 and 4. The lower loop is fed by pumps 1, 2, and 5. Since the firemain pressure may be different between the loops, two pressure meters are provided; one is for the upper loop and one for the lower loop.

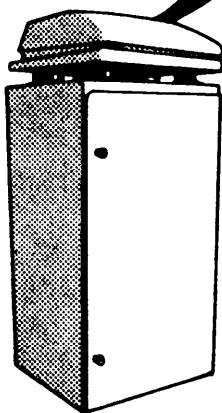
## BELL AND DATA LOGGERS

Two automatic loggers are located in the CCS to provide printed copies of plant conditions. These automatic loggers are the data logger and bell logger. Both of the printers are identical in design and operation. The difference is in the information the printer is commanded to print.

## DATA LOGGER

The data logger (fig. 9-28) provides a hard copy printout of selected monitor points. The printout is initiated automatically once every hour; however, an automatic/demand control permits the operator to demand a printout of data when it is needed. If a fault alarm occurs, the data logger prints out the parameter that caused the alarm. The data logger gives the time in seconds and identifies the monitored sensor.

TIME	PARAMETER	RANGE	VALUE
034532	SEAHAWK CLNG SUP PRESS	20-30 PSIG	21.4
034535	HYDRAULIC OIL TEMP	20-240 DEG	121.3
034538	GEAR LUBE OIL TEMP	20-200 DEG	83.5
034541	GEAR LUBE OIL STRN DP	0-20 PSIG	1.
034545	A LUBE SCAV FLT DEL F	0-60 PSIG	1.
034548	B LUBE SCAV FLY DEL F	0-60 PSIG	0.
034551	B GHS GEN SPEED VIER	0-10 MILS	0.1
034555	S GHS GEN POWER VIER	0-10 MILS	0.1
034558	B PHR TUR GHS GEN VIB	0-10 MILS	0.1
034601	B FWR TUR SPEED VIER	0-10 MILS	0.1
034603	B GT SCAV OIL TEMP A	0-400 DEG	84.2
034608	B GT SCAV OIL TEMP B	0-400 DEG	79.7
034611	B GT SCAV OIL TEMP C	0-400 DEG	80.7
034615	B GT SCAV OIL TEMP D	0-400 DEG	83.4
034618	B GT OIL COOL DIS TEMP	0-300 DEG	86.7
034621	B GT LO SCAV PRESS 0-150 PSIG	0.	0.
034625	B GT SCAV OIL TEMP GB	0-400 DEG	83.4
071	GT COMP DISC PRESS 0-100 PSIG	0.	0.
	GT COMP DISC PRESS 0-700 PSIG	0.	0.
	GEN SPEED VIER 0-10 MILS	0-10 MILS	0.
	GEN POWER VIER 0-10 MILS	0-10 MILS	0.
	GEN RPM 0-10 MILS	0-10 MILS	0.
	GEN DEG 0-10 MILS	0-10 MILS	0.



DATA LOGGER

Figure 9-28.—Data logger with sample printout.

## BELL LOGGER

The bell logger (fig. 9-29) provides an automatic printout each hour or when any of the following events occur:

- The propeller rpm or pitch is changed by more than 5 percent.
- A bell logger printout is demanded by the PCC operator.
- The EOT is changed.
- The controlling station has been changed (bridge or PCC).

The bell logger prints out the following information on a 72-column preprinted page:

- Time

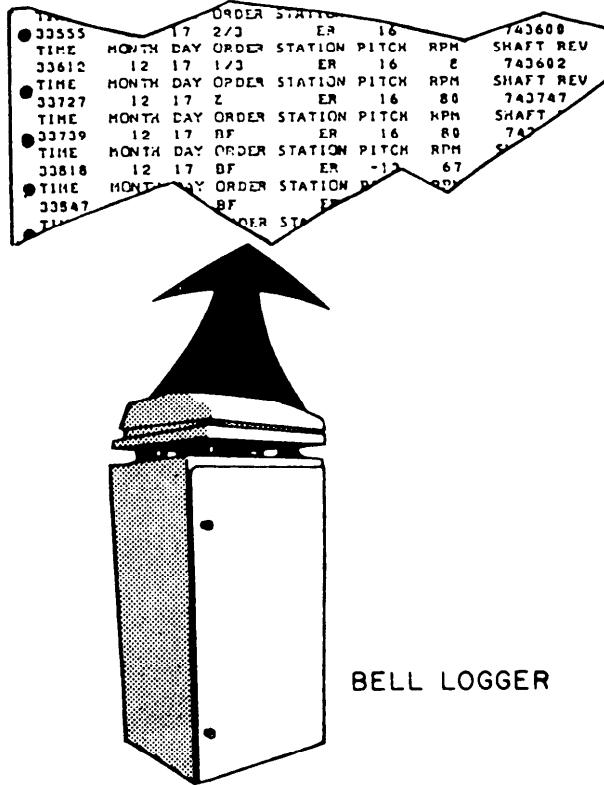


Figure 9-29.—Bell logger with sample printout.

- Month
- Day
- Order
- Station
- Pitch (angle of controllable pitch propeller)
- rpm
- Shaft revolutions

## DAMAGE CONTROL CONSOLE FOR DDG-51 CLASS SHIPS

The DCC on the DDG-51 class ship is a three-bay console with access to the components mounted in the enclosure through front and rear hinged access doors. The DCC is located in CCS.

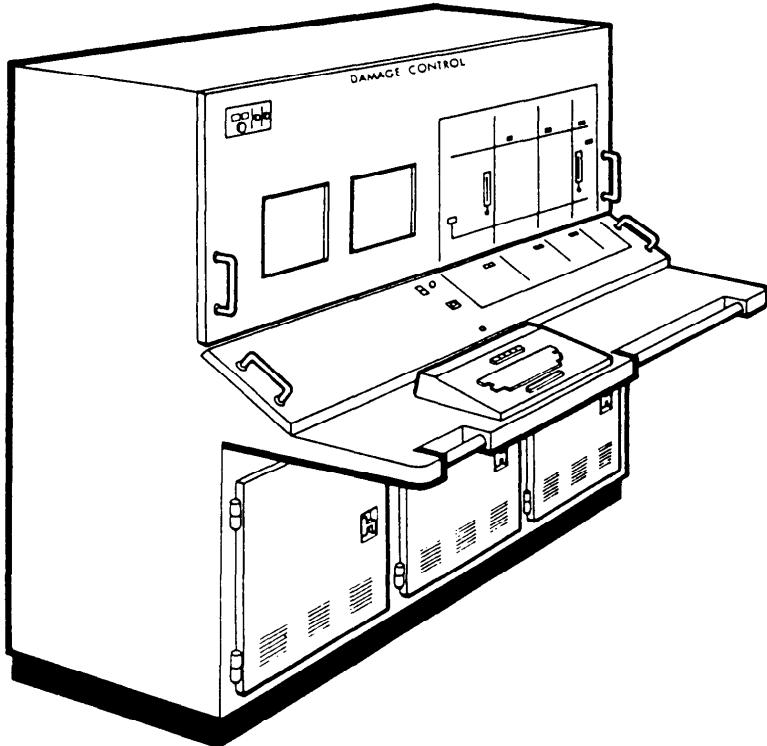


Figure 9-30.—Damage control console (DDG-51).

Figure 9-30 is an overall view of the console. The following paragraphs provide a physical description of the DCC.

The DCC is a single structural enclosure with three sections designated as A1, A2, and A3. The front console has vertical and sloping panels for mounting controls and displays and a work surface that supports a plasma display keyboard. Accessible from the rear of the A1 section are a power supply, a fuse panel, and a tone generator assembly with a speaker and a buzzer. The A2 section has another power supply and a power control panel that are accessible from the rear. Accessible from the rear of the A3 section is the panel distributor swing-frame that holds all of the standard electronic modules (SEMs). The front panels of the console are hinged at the top so the panels can be raised to reach the plasma display assemblies and the other panel-mounted components.

The DCC provides centralized control and monitoring of the damage control equipment on the DDG-51 class ship from the CCS. A backup console for the DCC is the repair station console (RSC), which is also a part of the machinery control system (MCS). The RSC is located in

repair station 2 and will automatically switch the primary damage control location between the DCC and the RSC when certain failures are identified in the DCC. The RSC will be discussed later in this chapter.

Damage control status signals are received from peripheral devices that monitor for fire, smoke, intrusion, firemain valve position, and firemain pump status. Command signals are sent from the DCC control panels to the firemain pumps, firemain valves, washdown counter-measure (WDCM) panel, and vertical launch sprinkler system.

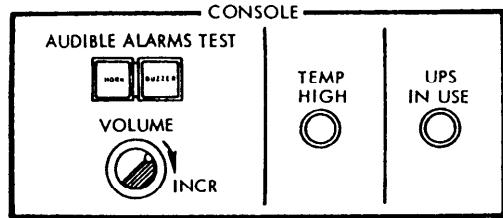
#### VERTICAL PANEL

The vertical panel of the DCC consists of a console test section, two plasma display units, and the firemain control panel.

#### Console Test Section

The first section of the DCC, labeled CONSOLE, is located at the upper left of the console. It contains two push-button indicators, a rotary potentiometer, and two indicator LEDs. The two push buttons, under the heading AUDIBLE ALARMS TEST, are labeled HORN

and BUZZER. When depressed, these push buttons sound the horn and buzzer. The rotary potentiometer, labeled VOLUME, adjusts the volume of the horn and- buzzer. The first LED is labeled TEMP HIGH. It illuminates yellow to indicate the temperature of the console has exceeded the preset limit. The second LED, labeled UPS IN USE, illuminates red to indicate the DCC is on UPS.



## Plasma Display Section

Located toward the center of the vertical panel are two plasma displays. All plasma display units

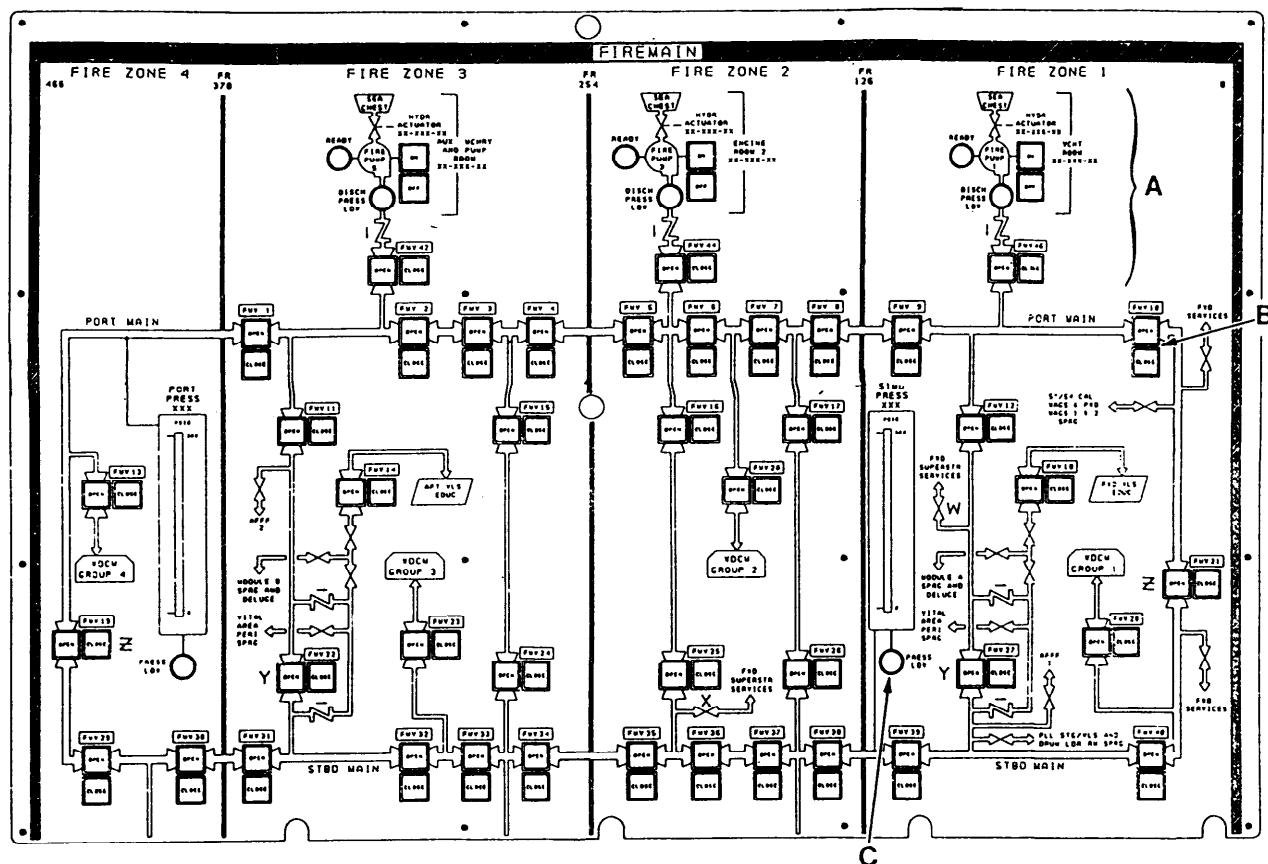
in the MCS are identical. A detailed description of the plasma display was presented in chapter 7 of this TRAMAN.

## **Firemain Panel**

The firemain panel (fig. 9-31) has a complete mimic of the major piping of the firemain. The panel is divided into the following four fire zones:

- FIRE ZONE 1 - Frame 0 to frame 126,
  - FIRE ZONE 2 - Frame 126 to frame 254,
  - FIRE ZONE 3 - Frame 254 to frame 370,  
and
  - FIRE ZONE 4 - Frame 370 to frame 466.

The firemain panel provides controls to operate fire pumps No. 1, No. 3, and No. 5, the firemain valves, and the washdown countermeasure valves. This panel also provides indicators to show



**Figure 9-31.**—Firemain panel.

the position of the firemain valves, the status of fire pumps No. 1, No. 3, and No. 5, and the pressure of the port and starboard firemain risers.

The DCC firemain panel displays the four fire zones. During the discussion of this panel, only FIRE ZONE 1 will be described. The other fire zones are similar. Their differences will be pointed out during the discussion.

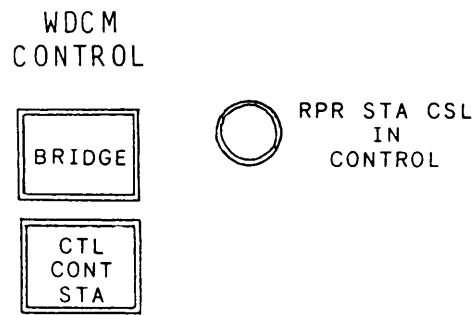
The first section of the FIREMAIN panel monitors and controls three fire pumps and their associated discharge valves. It contains four push-button indicators and two LEDs. There are three identical sets of these indicators and controls on this panel, one for each fire pump (A). The first LED indicator on the firemain panel is labeled READY. It illuminates green to indicate the fire pump is aligned for operation. A fire pump is ready for operation when its motor controller is in remote, and its discharge valve and its sea suction valve are fully open. The first control push button is labeled ON. When depressed, this push button starts the fire pump and illuminates green to show the fire pump is running. The second control push button is labeled OFF. When depressed, this push button stops the fire pump and illuminates white to show the fire pump is stopped. The second LED indicator, labeled DISCH PRESS LOW, illuminates yellow to indicate the fire pump discharge pressure is below the preset limit. The third control push button is labeled OPEN. When depressed, it opens the fire pump discharge valve and illuminates green to indicate the valve is open. The fourth control push button is labeled CLOSE. When depressed, it closes the fire pump discharge valve and illuminates red to indicate the valve is closed. Located below the fire pump controls are two control push buttons labeled OPEN and CLOSE (B). There are 40 identical sets of these push buttons on the firemain panel. These push buttons control the various firemain valves of the system and function the same as the fire pump discharge valves. Located at the center of FIRE ZONE 1 is a vertical reading meter labeled STBD PRESS (C). This meter continuously monitors the pressure of the starboard firemain loop. An identical meter, labeled PORT PRESS, is used to monitor the port firemain loop. The meter for the port loop is located at the center of FIRE ZONE 4. Associated with each vertical reading meter is an LED labeled PRESS LOW. It is located at the bottom of the firemain pressure meters. This LED illuminates yellow to indicate a low firemain pressure in the firemain loop.

## SLOPING PANEL

The sloping panel of the DCC contains the controls and indicators for WDCM control, the alarm acknowledge push button, the lamp test push button, and the fire pump panel.

### Washdown Countermeasure Control Section

This section is used to select which station has control of the WDCM valves. This section contains two control push buttons under the heading WDCM CONTROL. The first control push button is labeled BRIDGE. It transfers control of the WDCM group 1 through group 4 valves to the bridge control unit (BCU). It illuminates green to show the BCU has control of the valves. The second control push button, labeled CTL CONT STA, transfers control of the WDCM group 1 through group 4 valves to the DCC. It illuminates orange to show the DCC has control of the valves. The LED in this section is labeled RPR STA CSL IN CONTROL. It illuminates yellow to indicate the RSC has control of the firemain valves, the fire pumps, and the WDCM valves.



### Alarm Acknowledge

The alarm acknowledge push button is labeled ALARM ACK. Depressing the ALARM ACK push button silences the audible alarm and causes the flashing indicator to illuminate steadily. The indicator extinguishes when the alarm condition clears.



## Lamp Test

The next push button, located at the lower center of the sloping panel, is labeled LAMP TEST. Depressing this push button illuminates all the lights on the console. The operator uses this push button to determine which light bulbs need replacing. Releasing the LAMP TEST push button completes the test and extinguishes the lamps.



## Fire Pump Panel

The fire pump panel (fig. 9-32) is located directly below the firemain panel. It contains the controls and indicators for fire pumps No. 2, No. 4, and No. 6. This panel is also divided into four fire zones. The controls and indicators on this panel function identically to those discussed on the firemain panel.

## Plasma Display Keyboard

The final section of the DCC contains the plasma display keyboard. All plasma display keyboards in the MCS are identical. A detailed description of the plasma display keyboard was presented in chapter 7.

## REPAIR STATION CONSOLE

The RSC on the DDG-51 class ship is a two-bay console with access to the components

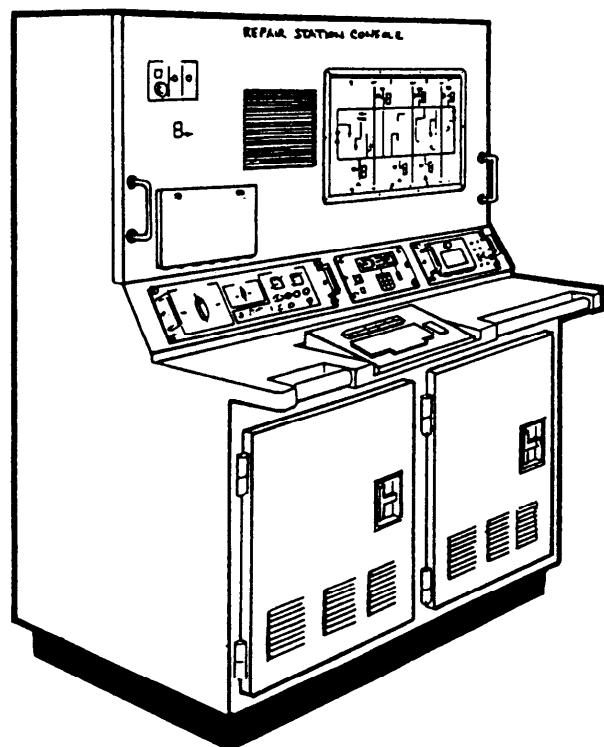


Figure 9-33.—Repair station console.

mounted in the enclosure through front and rear hinged access doors. Figure 9-33 is an overall view of the console. The following paragraphs provide a physical description of the RSC.

The RSC is a single structural enclosure with two sections designated as A1 and A2. The front console has vertical and sloping panels for mounting controls and displays and a work surface that supports a plasma

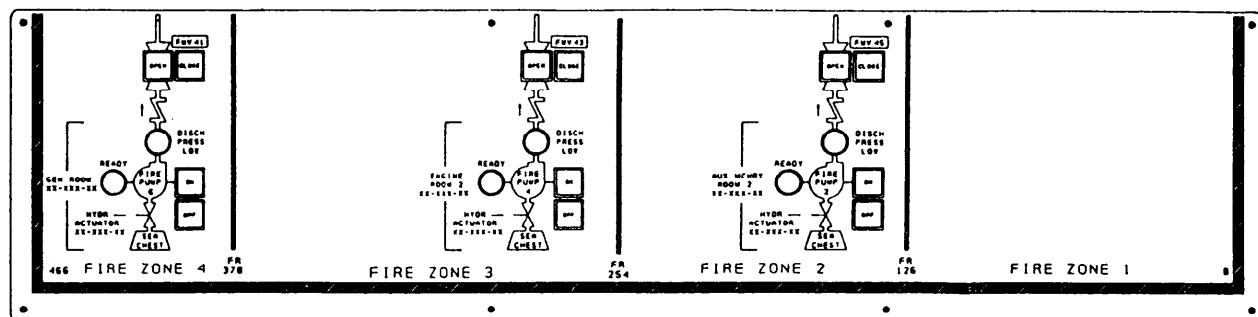


Figure 9-32.—Fire pump panel.

display keyboard. Accessible from the rear of the A1 section are a power supply for the plasma display and a tone generator assembly with a speaker and a buzzer. The front of the A1 section has the mounting for the plasma display, the AN/UYK-44 maintenance panel, two power supplies, a battery charger, and a power/fuse panel. The A2 section has two battery assemblies, a transformer, the AN/UYK-44 SEMs, and a bubble memory. The front panels of the console are hinged at the top so the panels can be raised to reach the plasma display assemblies and the other panel-mounted components.

The RSC provides centralized control of the damage control equipment and serves as the primary control station when the DCC is not available. The RSC is a backup console for the DCC and automatically switches the primary damage control location between the DCC and the RSC when certain failures are identified in the DCC. The RSC is located in repair station 2.

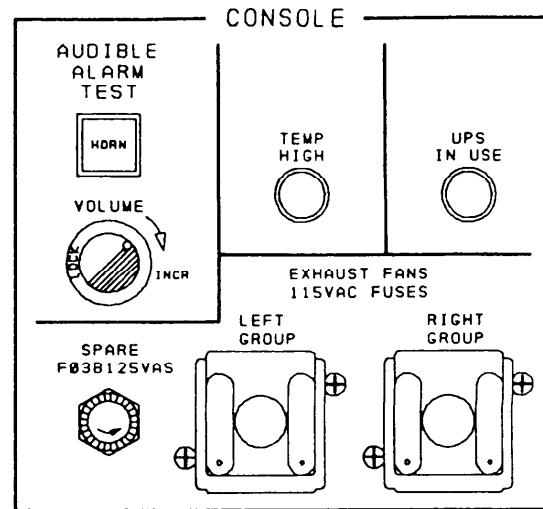
## VERTICAL PANEL

The vertical panel of the RSC consists of a console section, a control section, a plasma display unit, and the firemain panel.

### Console Section

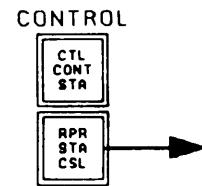
The first section of the RSC, labeled CONSOLE, is located at the upper left of the console. It contains a push-button indicator, a rotary potentiometer, two indicator LEDs, and three fuse holders. The push button, under the heading AUDIBLE ALARM TEST, is labeled HORN. When depressed, this push button sounds the horn. The rotary potentiometer, labeled VOLUME, adjusts the volume of the horn. The first LED is labeled TEMP HIGH. It illuminates yellow to indicate the temperature of the console has exceeded the preset limit. The second LED, labeled UPS IN USE, illuminates red to indicate the RSC is on UPS. The first fuse holder is labeled SPARE F03B125VAS. It houses a spare fuse for the console. The next two fuse holders are under the heading EXHAUST FANS 115VAC FUSES. They are labeled LEFT GROUP and

RIGHT GROUP. These fuses protect the exhaust fan circuits.



### Control Section

This section contains two control push buttons used to transfer damage control functions between the DCC and the RSC. The first push button is labeled CTL CONT STA. It illuminates to show the DCC has control of the firemain valves and fire pumps. The second push button, labeled RPR STA CSL, illuminates to show the RSC has control of the firemain valves and fire pumps.



### Plasma Display Section

Located toward the center of the vertical panel is a plasma display unit. All plasma display units in the MCS are identical. A detailed description of the plasma display was presented in chapter 7.

### Firemain Panel

The firemain panel has a complete mimic of the major piping of the firemain. (Refer to fig. 9-34.) This panel is similar to the firemain panel on the DCC. Only the fire pumps can be controlled and monitored from this panel.

## SLOPING PANEL

The sloping panel of the RSC contains the power control panel, the firemain valve panel, and the bubble memory system.

## Power Control Panel

The power control panel, shown in figure 9-35, distributes electrical power to various components of the RSC. The panel consists of 2 rotary snap

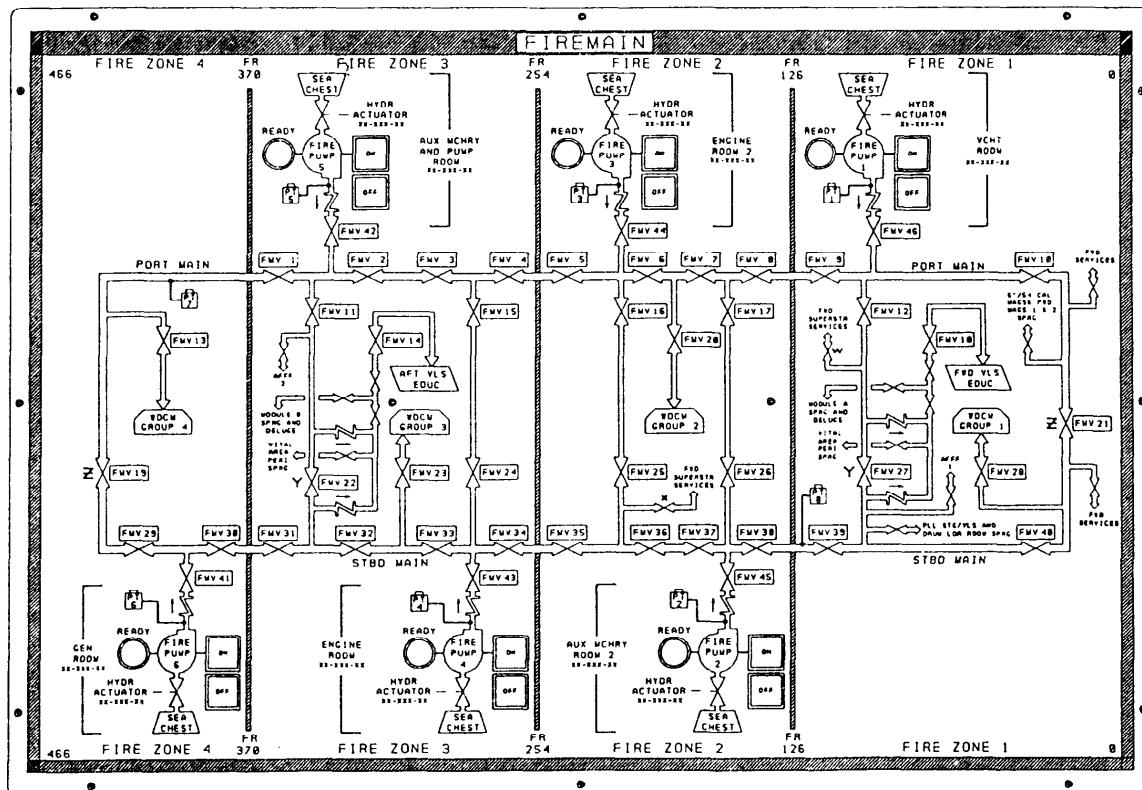


Figure 9-34.—Firemain panel.

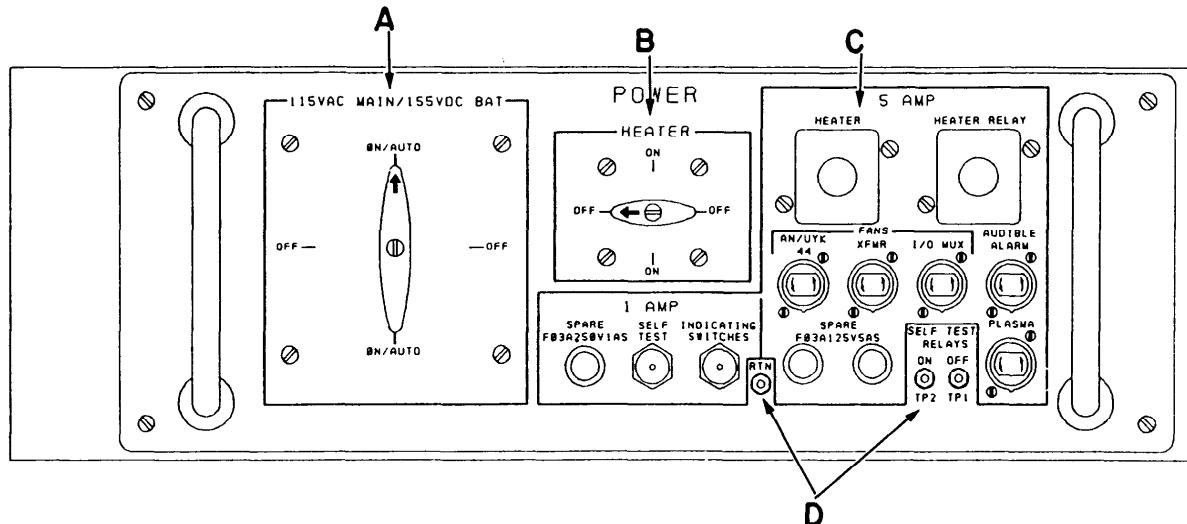


Figure 9-35.—Power control panel.

switches, 12 fuse holders, and 3 test points. The power control panel is located on left side of the sloping panel.

The first rotary snap switch is labeled 115VAC MAIN/155 VDC BAT (A). The positions of the switch are labeled OFF and ON/AUTO. In the OFF position, no power is applied to the RSC. In the ON/AUTO position, 115 volts ac is applied to the RSC. This switch position also enables the UPS circuitry. In the event normal power is lost, the 155-volts dc UPS is supplied to the RSC. The second rotary snap switch is labeled HEATER (B). The positions of the switch are labeled ON and OFF. This switch controls the power to the console heater.

The right-hand side of the POWER CONTROL PANEL is occupied by 12 fuse holders (C). The first two fuse holders, labeled HEATER and HEATER RELAY, are the dual-cartridge type. They hold the 5-amp fuses that serve to protect the heater and the heater relay circuits. The three fuse holders, located under the heading FANS, are single-cartridge, twist-type fuse holders. They hold the 5-amp fuses that protect the fans of the AN/UYK-44 computer, the transformer, and the input/output multiplexer. The fuse holder, labeled AUDIBLE ALARM, holds the 5-amp fuse that protects the audible alarm circuit. The three fuse holders, under the heading 1 AMP, contain a spare 1-amp fuse, a 1-amp fuse for the self-test circuit, and a 1-amp fuse for the indicating switch circuit. Next, there are two spare 5-amp fuse

holders. The last fuse holder on this panel is labeled PLASMA. It holds the 5-amp fuse that protects the plasma display circuits. Located below the fuse holder section are three test points (D). The first test point on the power control panel is labeled RTN. This is the return test point used with the self-test relay test points. The next two test points are located under the heading SELF TEST RELAYS. These test points provide for testing the self-test relays.

### Firemain Valve Panel

The firemain valve panel, shown in figure 9-36, contains a digital indicator, four push-button indicators, and a numerical keypad. The firemain valves can be opened or closed from the RSC using the controls on the firemain valve panel. The seven-digit valve number is addressed using the keypad, and the selected valve is displayed on the digital indicator. Once selected, the appropriate push button is used to open or close the valve.

The digital indicator (A) consists of three sections labeled LEVEL, FRAME, and ATHWART. This indicator displays the seven-digit valve number of the selected valve to be controlled.

**ALARM ACKNOWLEDGE.**—The alarm acknowledge push button (B) is labeled ALARM ACK. Depressing the ALARM ACK push button silences the audible alarm and causes the flashing

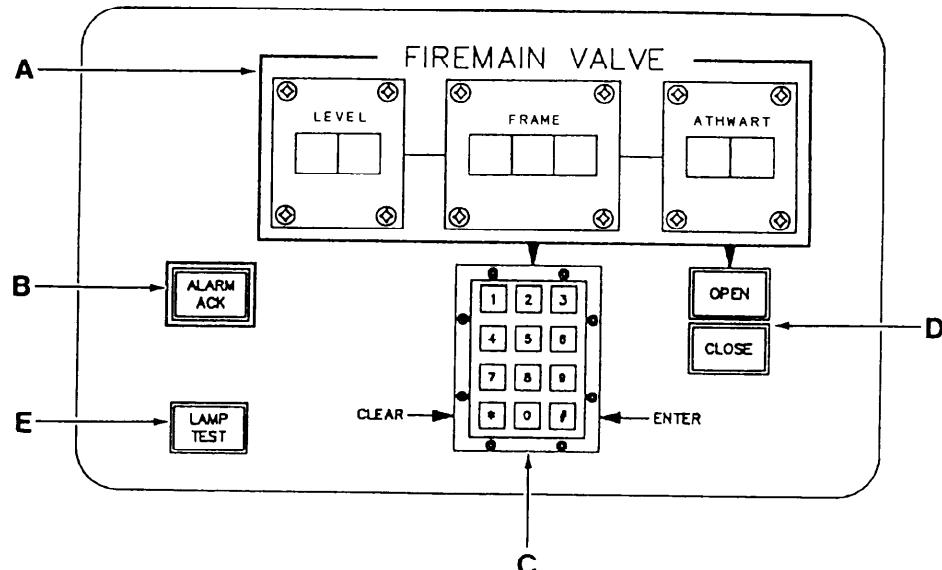


Figure 9-36.—Firemain valve panel.

indicator to illuminate steady. The indicator extinguishes when the alarm condition has cleared.

**NUMERICAL KEYPAD.**—The numerical keypad (C) is used to select the firemain valve to be controlled. As the keys are pressed, the corresponding digits are displayed on the digital indicator.

**VALVE CONTROLS.**—The valve control push buttons (D) are labeled OPEN and CLOSE. Once a valid valve number is entered into the digital display, an automatic display of the valve position results on the associated open and close push buttons. An invalid number will cause the level display on the digital indicator to flash and OPEN or CLOSE will not light. Depressing the OPEN or CLOSE push button causes the valve to cycle to the desired position. The appropriate OPEN/CLOSE push button illuminates to show the position of the valve.

**LAMP TEST.**—Depressing the LAMP TEST push button (E) illuminates all the lights on the RSC. This allows the operator to determine which bulbs need replacement. Releasing the LAMP TEST push button completes the test and extinguishes the lamps.

#### Bubble Memory Section

Located on the right side of the sloping panel is the bubble memory system. A detailed description of the bubble memory system was presented in chapter 7.

#### Plasma Display Keyboard

The final section of the DCC contains the plasma display keyboard. All plasma display keyboards in the MCS are identical. A detailed description of the plasma display keyboard was presented in chapter 7.

#### DATA MULTIPLEX SYSTEM

The ship's propulsion plant, electric plant, and damage control system are considered to be associated equipment of the MCS. The data

multiplex system (DMS), however, is functionally integrated with the MCS where all consoles depend upon the DMS for input data and for a communications link.

#### DMS SYSTEM

The DMS is a general-purpose, user-oriented, electronic information transfer system that provides data transfer for the major systems aboard the DDG-51 class ship. The DMS conveys data from shipboard subsystems such as navigation, damage control, and machinery control. Instead of using conventional multiple hard-wired signal cables unique to each major system, the DMS sends the signals over general-purpose multiplex cables. These cables are installed at locations in the ship that allow continued DMS operation even when the ship is damaged during combat conditions. The redundancy that is designed into the DMS system reduces the chance that data transfers will be lost because of a single-point failure. The DMS interfaces with the MCS consoles to provide console-to-console communications. The DMS also provides control and status of equipment in the machinery plant, including damage control equipment.

#### DMS INTERFACES

Six consoles in the MCS have AN/UYK-44 computers that interface with the DMS network. They are the SCU-1, SCU-2, PACC, EPCC, RSC, and EOOW/logging consoles. These interfaces are dual channel with a primary and alternate channel. Each channel has its own cable that connects between the console and the input-output unit (IOU) of the DMS.

There are two interfaces of MCS equipment that are not computer interfaces. The panels in the SCC and the WDCM panel connect to an input-output module in the DMS IOU. The communication protocol for this type of interface is different from that of the AN/UYK-44 computer.

The DMS provides the means of transferring information between consoles, for collecting data on the operating machinery monitored by the MCS, and for controlling equipment remotely

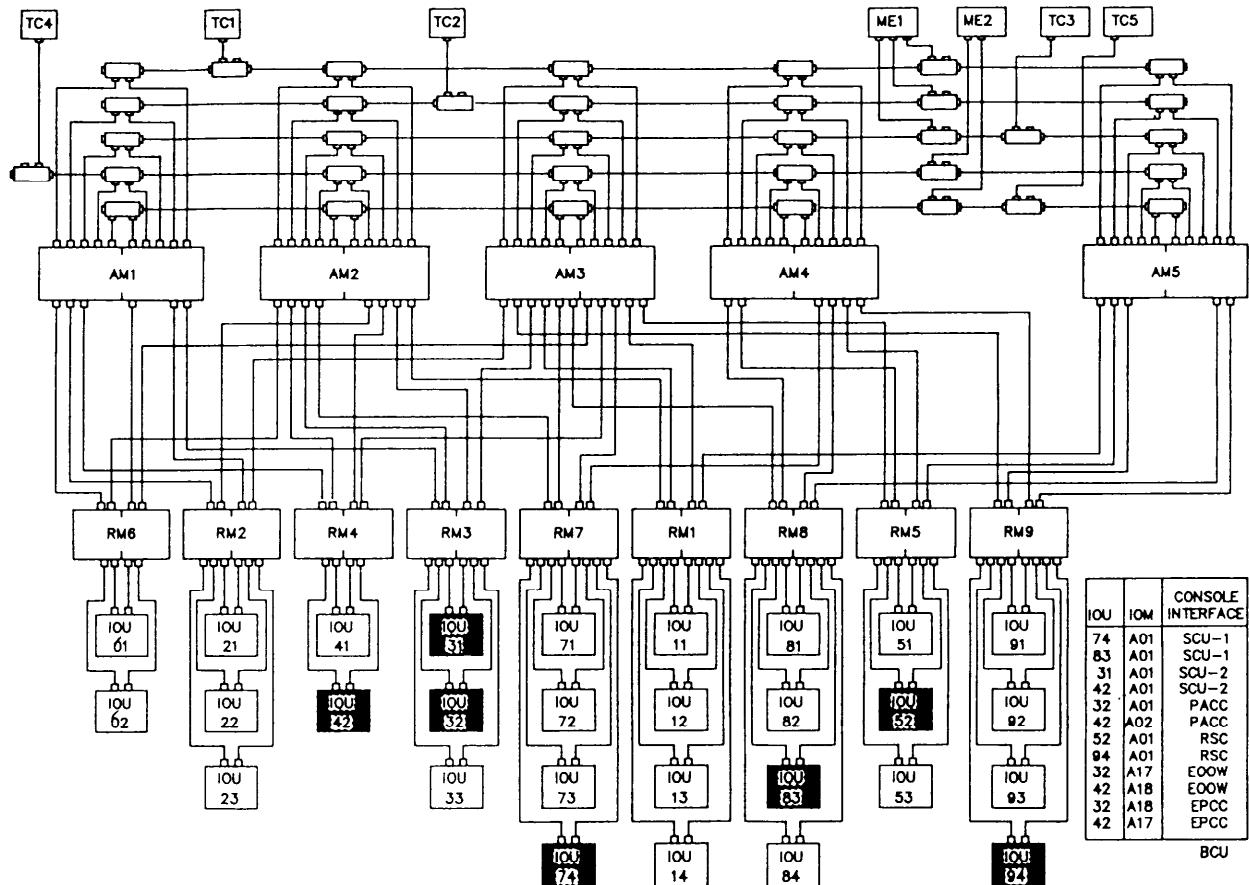


Figure 9-37.—DDG-51 DMS configuration.

from the consoles. (See fig. 9-37.) The DMS functionally connects the MCS equipment together by data message transfers. This reduces the number of cables that would otherwise be required to achieve the same compatibility.

### DMS CONFIGURATION

Figure 9-37 shows the DDG-51 class DMS configuration. The configuration shown has 29 IOUs, 9 remote multiplexers (RMs), 5 area multiplexers (AMs), 5 traffic controllers (TCs), and 1 maintenance group (MG) contained in two enclosures. The IOUs that interface with the MCS are shaded in figure 9-37.

The TCs operate independently of each other to provide orderly control of access to the primary busses. The AMs provide the interface for the groups of RMs so channel access offers from the TCs are matched with the service requests from the RMs. The AMs issue service offers to the RMs so they can start message transfer. The RMs

perform the primary control functions associated with starting message transfers when requested by the IOUs and responding to message transfer requests. The RMs also perform primary control functions associated with formatting messages for transmission and processing messages received from other RMs or AMs. The IOUs interface with user devices and the local RMs to provide user-to-user communication paths. The IOU converts the input user signals to the DMS signal format and converts the digital data from the DMS to signals that are compatible with interfacing user device.

### DMS TO MCS COMMUNICATIONS

Figure 9-38 is a block diagram of the devices on the DMS bus that communicate with the MCS equipment. There are three categories of communications used with MCS, each with its own protocol. They are computer-to-computer (smart-to-smart), computer-to-non-computer

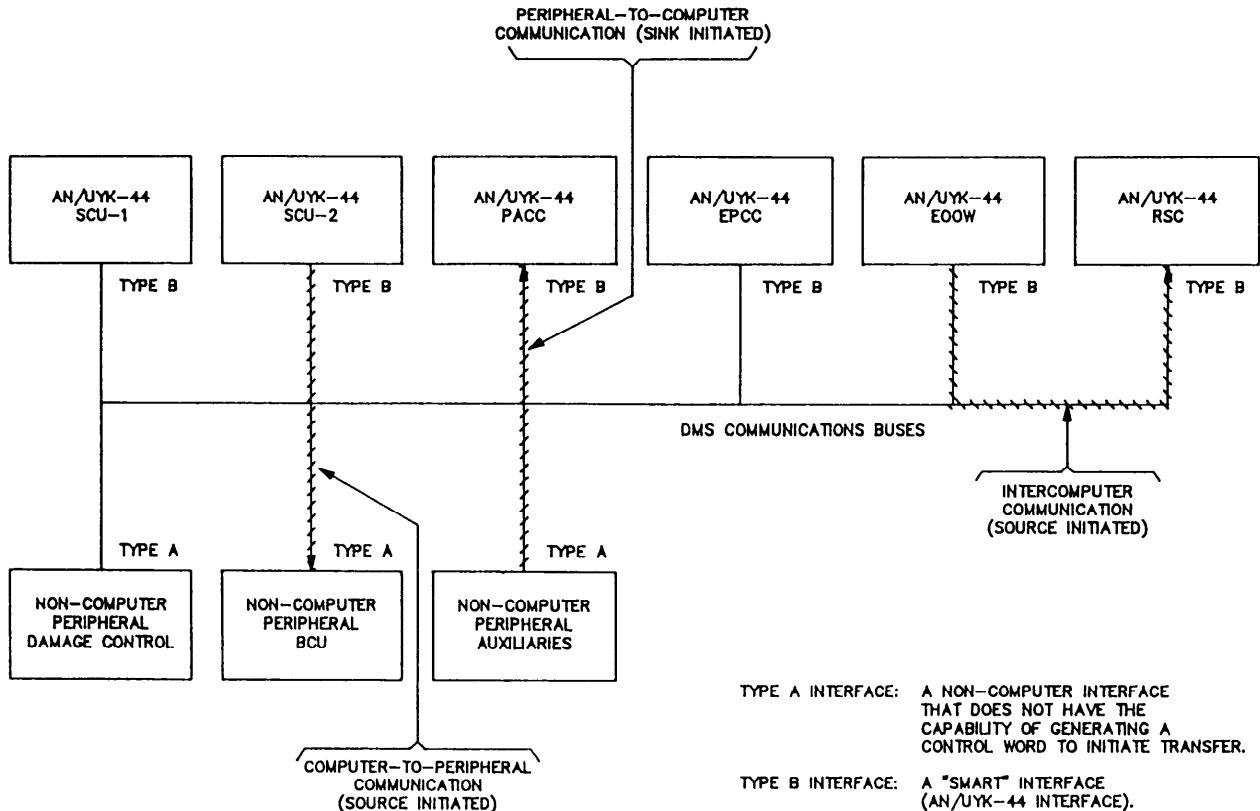


Figure 9-38.—DMS/MCS communication paths.

peripheral (smart-to-dumb), and non-computer peripheral-to-computer (dumb-to-smart).

### DMS COMMUNICATION TEST

The two communication channels that interface the DMS with the consoles are verified by sending test messages from one channel to the other and then reversing the transmitting channel and the receiving channel. All test messages must result in a positive acknowledgement. A negative acknowledgement, a time-out, or an error detected in the transmission results in a test failed message.

### SUMMARY

This chapter should have provided you with a basic understanding of the indicators and controls of the auxiliary equipment and consoles of gas turbine-powered ships. Most GSEs and GSMS assigned to a gas turbine-powered ship will stand watches at one time or another in the CCS. For this reason, you should be familiar with the capabilities of the CCS consoles and auxiliary

equipment. The GSEs are also responsible for maintenance of the consoles. Although these consoles are relatively trouble-free, you should become familiar with their internal operation.

While this chapter was written to familiarize you with the consoles in the CCS of DD-963, CG-47, FFG-7, and DDG-51 class ships, the information in this chapter is not sufficient for operational or troubleshooting purposes. This material provides you with enough knowledge to begin qualifying on CCS watches, in addition to your using the PQS applicable to the watch station you are learning.

The knowledge you have gained by reading this chapter should also provide you with enough information to help a qualified technician in the repair of this important equipment. Only technical manuals can give you the in-depth procedures as to how to troubleshoot and repair the CCS equipment. **Never try to work on this equipment without the proper manuals.** The *GSE 1 & C TRAMAN* also provides general information on troubleshooting techniques and repair procedures.

Like all other material in this manual, this chapter was written to provide you with

a basis upon which to start your qualifications at watch stations on your ship. Your knowledge of this material should help you to advance in rate and make you more valuable to the Navy.

In no way is this material meant to be a one-stop source for qualifying as a watch stander. You should use the EOSS, the PQS, ship information books, and the applicable technical manuals for this process.

## APPENDIX I

# GLOSSARY

**ADIABATIC**—To occur without loss or gain of heat by the substance concerned.

**AERODYNAMICS**—A branch of dynamics that deals with the motion of air and other gaseous fluids and the forces acting on bodies in motion relative to such fluids.

**ALARM ACKNOWLEDGE**—A push button that must be depressed to silence an alarm.

**ALLOY**—Any composition metal produced by the mixing of two or more metals or elements.

**ALTERNATING CURRENT (ac)**—An electrical current that constantly changes amplitude and polarity at regular intervals.

**AMBIENT TEMPERATURE**—The surrounding temperature, such as the air temperature that surrounds a conductor in a compartment or piece of equipment.

**AMBIENT PRESSURE**—The surrounding pressure, such as the air pressure that surrounds a conductor in a compartment or piece of equipment.

**AMPERE (amp)**—A unit of electrical current or rate of flow of electrons. One volt across 1 ohm of resistance causes a current flow of 1 ampere.

**ANALOG SIGNAL**—A measurable quantity that is continuously variable throughout a given range and that is representative of a physical quantity.

**ANALOG-TO-DIGITAL CONVERSION (A/D or ADC)**—A conversion that takes an analog in the form of electrical voltage or current and produces a digital output.

**ANNULAR**—In the form of or forming a ring.

**ANTI-ICING**—A system for preventing buildup of ice on the gas turbine intake systems.

**ATMOSPHERE**—A unit of measure equal to 14.696 psi or 29.92 inches of mercury (1 atmosphere = 14.696 psi).

**ATMOSPHERIC PRESSURE**—The pressure of air at sea level, about 14.7 psi.

**AUTOMATIC PARALLELING DEVICE (APD)**—The APD automatically parallels any two generators when an auto parallel command is initiated by the EPCC.

**AUXILIARY CONTROL CONSOLE (ACC)**—The console in CCS used to monitor the auxiliary systems on FFG-class ships.

**AXIAL FLOW**—Air flow parallel to the axis of the compressor rotor.

**BABBITT**—A white alloy of tin, lead, copper, and antimony that is used for lining bearings.

**BAFFLE**—A plate, wall, or screen used to deflect, check, or otherwise regulate the flow of a gas, liquid, sound waves, and so forth.

**BATTERY**—A device for converting chemical energy into electrical energy.

**BLEED AIR**—Air bled off the compressor stages of the GTEs. See BLEED AIR SYSTEM.

**BLEED AIR SYSTEM**—This system uses as its source compressed air extracted from the compressor stage of each GTE or GTG. It is used for anti-icing, prairie air, masker air, and LP gas turbine starting for both the GTEs and GTGs.

**BLOW-IN DOORS**—Doors located on the high hat assembly designed to open by solenoid-operated latch mechanisms if the inlet airflow becomes too restricted for normal engine operation.

**BORESCOPE**—A small periscope (instrument) used to visually inspect internal engine components.

**BRIDGE CONTROL UNIT (BCU)**—The console located on the bridge of the DDG-51 class ship that has equipment for operator control of ship's speed and direction.

**BUS TIE BREAKER (BTB)**—A device used to connect one main switchboard to another main switchboard.

**BUS**—An uninsulated power conductor (a bar or wire) usually found in a switchboard.

**CALIBRATION**—(1) The operation of making an adjustment or marking a scale so that the readings of an instrument conform to an accepted standard. (2) The checking of reading by comparison with an accepted standard

**CANTILEVER**—A horizontal structural member supported only by one end.

**CASUALTY**—An event or series of events in progress during which equipment damage and/or personnel injury has already occurred. The nature and speed of these events are such that proper and correct procedural steps will only serve to limit equipment damage and/or personnel injury.

**CENTRAL CONTROL STATION (CCS)**—The main operating station from which a majority of the engineering plant machinery can be controlled and monitored.

**CENTRAL INFORMATION SYSTEM EQUIPMENT (CISE)**—Located in CCS and is part of the PAMISE. It includes the general-purpose digital computer (ECU), S/CE No. 1, and supporting equipment.

**CENTRIFUGAL FORCE**—That force that tends to drive a thing or parts of a thing outward from a center of rotation.

**CIRCUIT BREAKER (CB)**—A device used to energize/de-energize an electrical circuit and for interrupting the circuit when the current becomes excessive.

**CLASSIFICATION**—A method of identifying and sorting various equipment and materials. For example: (1) check valve—swing check valve, stop check valve; (2) valve—solenoid valve, manual valve.

**CLUTCH/BRAKE ASSEMBLY**—a clutch/brake assembly for each GTE is mounted on the MRG housing to couple or decouple either or both engines to the drive train, to stop and hold the power turbine, and for shaft braking.

**COALESCE**—To grow together, unite, or fuse, as uniting small liquid particles into large droplets. This principle is used to remove water from fuel in the filter/separator.

**COHESION**—The force that causes molecules that are brought close together to stick together.

**COMBUSTION CYCLE**—The process that includes compression of air, burning of compressed air/fuel mixture, expansion of gases, and removal of gases.

**COMPRESSOR INLET TEMPERATURE (CIT or  $T_2$ )**—The temperature of the air entering the gas turbine compressor (GTE) as measured at the front frame; one of the parameters used for calculating engine power output (torque) and scheduling combustion fuel flow and VSV angle.

**COMPRESSOR DISCHARGE PRESSURE (CDP)**—Compressor discharge pressure is sensed by a pressure tap on the compressor discharge static pressure sensing line to the MFC and piped to a base-mounted transducer on the GTE.

**COMPRESSOR INLET TOTAL PRESSURE ( $P_{t_2}$ )**—The pressure sensed by a total pressure probe mounted in the GTE compressor front frame.

**COMPRESSOR**—The component of a GTE that compresses the air.

**CONCENTRIC**—Having a common axis or formed about the same axis.

**CONDUCTION**—The transfer of heat through matter by communication of kinetic energy from particle to particle rather than by a flow of heated material.

**CONTROLLABLE REVERSIBLE PITCH (CRP) PROPELLER**—A propeller whose blade pitch can be varied to control the amount of thrust in both the ahead and astern directions. (Known as controllable pitch propeller (CPP) on FFG-class ships.)

**CURRENT**—The movement of electrons past a reference point. The passage of electrons through a conductor. It is measured in amperes.

**DAMAGE CONTROL CONSOLE (DCC)**—This console is located in CCS and provides monitoring for hazardous conditions (fire, high bilge levels, and so forth). It also monitors the ship's firemain and can control the fire pumps.

**DATA MULTIPLEX SYSTEM (DMS)**—A general-purpose information transfer system that provides data transfer for most of the major systems aboard the DDG-51 class ship.

**DEAERATOR**—A device that removes air from oil (for example, the lube oil storage and conditioning assembly (LOSCA) tank which separates air from the scavenge oil).

**DEMAND DISPLAY INDICATOR (DDI)**—A numerical display that is used to read values of parameters within the engineering plant.

**DEMISTERS**—A moisture removal device (GTE intake system) that separates water from air.

**DENSITY**—The quantity of matter contained in a body.

**DIFFERENTIAL PRESSURE**—The difference between two pressures measured with respect to a common basis.

**DIFFUSER**—A device for reducing the velocity and increasing the static pressure of a medium passing through a system.

**DIGITAL-TO-ANALOG CONVERSION (D/A or DAC)**—A conversion that produces an analog output in the form of voltage or current from a digital input.

**DIRECT CURRENT**—An essentially constant value electric current that flows in one direction.

**DROOP MODE**—This mode is normally used only for paralleling with shore power. This mode provides a varying frequency for any varying load. Droop mode inhibits the load sharing circuitry.

**EDUCTOR**—A mixing tube (jet pump) that is used as a liquid pump to dewater bilges and tanks. A GTE exhaust nozzle creates an eductor effect to remove air from the enclosure.

**ELECTRIC PLANT CONTROL ELECTRONICS ENCLOSURE (EPCEE)**—The EPCEE is part of the EPCE. It contains power supplies that provide the various operating voltage required by the EPCC on the CG- and DD-class ships.

**ELECTRIC PLANT CONTROL CONSOLE (EPCC)**—This console contains the controls and indicators used to remotely operate and monitor the generators and the electrical distribution system.

**ELECTRIC PLANT CONTROL EQUIPMENT (EPCE)**—The EPCE provides centralized remote control of the GTGS and electrical distribution equipment. The EPCE includes the EPCC and EPCEE and is located in CCS.

**ELECTRONIC GOVERNOR (EC)**—A system that uses an electronic control unit with an electro-hydraulic governor actuator (EGA) to control and regulate engine speed.

**EMERGENCY**—An event or series of events in progress which will cause damage to equipment unless immediate, timely, and correct procedural steps are taken.

**ENGINEERING CONTROL AND SURVEILLANCE SYSTEM (ECSS)**—An automatic electronic control and monitoring system using analog and digital circuitry to control the propulsion and electric plant. The ECSS consists of the EPCE, PAMCE, PAMISE, PLOE, and SCE on the CG- and DD-class ships.

**ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)**—A two-part system of operating instructions bound in books for each watch station. It provides detailed operating procedures (EOP) and casualty control procedures (EOCC) for the propulsion plant.

**ENGINE ORDER TELEGRAPH (EOT)**—A non-voice communication system provided between the command station (pilot house), CCS, and the main engine room.

**EXECUTIVE CONTROL UNIT (ECU)**—A computer (part of PAMISE) that is the nucleus of the information center of the ECSS. The ECU gathers data information from the ship's propulsion, auxiliary, and electric plant equipment.

**EXPANSION**—The increase in volume of the gases in a turbine after combustion by which the gases continue to turn the rotor while expending part of its internal energy and losing in pressure and temperature.

**FEEDBACK**—A value derived from a controlled function and returned to the controlling function.

**FEEDWATER**—Distilled water made in evaporators for use in boilers. Feedwater is more pure than drinking (potable) water.

**FERROUS**—Refers to metals having iron as the base metal.

**FILTER**—(1) A device that removes insoluble contaminants from the fluid power system. (2) A device through which gas or liquid is passed; dirt, dust, and other impurities are removed by the separating action.

**FREE STANDING ELECTRONIC ENCLOSURE (FSEE)**—The FSEE provides the supporting electronic and engine control interface between the GTE and the control consoles. One FSEE is located in each MER.

**FREQUENCY**—The number of cycles (as in an alternating electrical current) completed per second.

**FRiction**—Resistance to the relative motion of one body sliding, rolling, or flowing over another with which it has contact.

**FUEL SYSTEM CONTROL CONSOLE (FSCC)**—Located in CCS and is the central station for monitoring and control of the fuel fill and transfer system.

**FUEL OIL SYSTEM**—This system provides a continuous supply of clean fuel to the GTEs.

**FULL POWER**—The condition in which both engines (GTEs) in one engine room are engaged and driving the reduction gear and propeller shaft.

**GAS GENERATOR (GG)**—The gas-producing section of any GTE. It usually has a compressor, a combustor, a high-pressure turbine, an accessory drive system, and controls and accessories.

**GAS TURBINE ENGINE (GTE)**—A GTE consists of a compressor, a combustor, a turbine, and an accessory drive system. Many variations of GTEs exist.

**GAS GENERATOR SPEED ( $N_{G_G}$ )**—The speed sensed by a magnetic pickup on the transfer gearbox of the GTE.

**GAS TURBINE GENERATOR SET (GTGS)**—The GTGS has a GTE, a reduction gearbox, and a generator.

**GENERATOR BREAKER (GB)**—The GB is used to connect a generator to its main switchboard.

**GOVERNOR CONTROL UNIT (GCU)**—A static GCU is supplied for each GTGS consisting of a static exciter/voltage regulator assembly, field rectifier assembly, motor-driven rheostat, and mode select rotary switch. It controls the output voltage of the generator.

**HEADER**—A piping manifold that connects several sublines to a major pipeline.

**HEAD TANK**—A tank located higher than other system components to provide a positive pressure to a system by gravity.

**HERTZ (Hz)**—A unit of frequency equal to one cycle per second.

**HIGH HAT ASSEMBLY**—A removable housing over the main engine air intake ducts that contains the moisture separation system (demisters), inlet louvers, and blow-in doors.

**HORSEPOWER (hp)**—A standard unit of power that equals 550 foot pounds of work per second.

**HUMIDITY**—The weight of water vapor in grains per cubic foot of air.

**HYDRAULIC**—Conveyed, operated, or moved by water or other liquid in motion.

**HYDRAULIC OIL POWER MODULE (HOPM)**—A component located near the MRG to deliver control oil and high pressure (HP) oil to an oil distribution box for distribution to the propeller hub and activation of the pitch control rod within the shaft.

**IMPELLER**—A blade or series of blades of a rotor that imparts motion.

**INERTIA**—Any change in motion being measured by the acceleration of the center of mass.

**INFORMATION CONTROL CONSOLE (ICC)**—Part of the ECU. ICC No. 1 is used to program and run the computer. ICC No. 2 is the tape reader and is used to input the program into the ECU.

**INLET GUIDE VANE (IGV)**—The variable vanes ahead of the first stage of compressor blades of a GTE. Their function is to guide the inlet air into the GTE compressor at the optimum angle.

**ISOCHRONOUS MODE**—This mode is normally used for generator operation. This mode provides a constant frequency for all load conditions. When two (or more) generators are operated in parallel, the isochronous mode also provides equal load sharing between units.

**JOULES**—Unit of energy. The work done when the point of application of 1 newton is displaced a distance of 1 meter in the direction of force.

**JP-5**—The primary type of fuel used for helicopters and small boats. The emergency source of fuel for the GTEs and GTGs.

**KILOWATT**—A unit of electrical power equal to 1000 watts. (A watt is a unit of power equal to the rate of work represented by a current of 1 ampere under a pressure of 1 volt.)

**KINETIC ENERGY**—Energy in motion.

**LABYRINTH/HONEYCOMB SEAL**—This seal combines a rotating element and a honeycomb stationary element to form an air seal. Used in GTEs to maintain close tolerances over a large temperature range.

**LABYRINTH/WINDBACK SEAL**—This seal combines a rotating element with a smooth surface stationary element to form an oil seal. The windback is a coarse thread on the rotating element of the oil seal which uses screw action (windback) to force any oil that might leak across the seal back into the sump.

**LIQUID FUEL VALVE (LFV)**—This valve meters the required amount of fuel for all engine operating conditions for the Allison 501-K17 GTE.

**LOAD SHEDDING**—Protects a generator from overloading by automatically dropping preselected loads when generator output reaches 100 percent.

**LOCAL OPERATING PANEL (LOP)**—The LOP is the local operating station for GTEs on the FFG-class ships. It is located in the MER and is used primarily for maintenance.

**LUBE OIL STORAGE AND CONDITIONING ASSEMBLY (LOSCA)**—The LOSCA is mounted remotely from the GTE and is a unit with a lube oil storage tank, a heat exchanger, a scavenge oil duplex filter, and a scavenge oil check valve (all mounted on a common base). Its function is to provide the GTE with an adequate supply of cool, clean lube oil.

**MACHINERY CONTROL SYSTEM (MCS)**—Provides centralized and remote monitoring and control of propulsion, electrical, auxiliary, and damage control systems of the DDG-51 class ship.

**MAIN REDUCTION GEAR (MRG)**—A locked train, double-reduction gear designed to reduce the rpm output of the GTE and drive the propeller shaft.

**MAIN FUEL CONTROL (MFC)**—A hydro-mechanical device on the propulsion GTE that controls  $N_{GG}$ , schedules acceleration fuel flow, deceleration fuel flow, and stator vane angle for stall-free, optimum performance over the operating range of the GTE.

**MASKER AIR SYSTEM**—This system disguises the sound signature of the ship and alters transmission of machinery noise to the water by emitting air from small holes in the emitter rings on the ship's hull.

**MASS**—The measure of the quantity of matter contained in a body.

**METALLURGY**—The science dealing with the structure and properties of metals and alloys, and the processes by which they are obtained from ore and adapted to the use of man.

**MICRON**—A unit of length equal to one millionth of a meter.

**MIL**—A unit of length equal to one thousandth of an inch.

**NAVY STANDARD DAY**—Parameters meeting the following requirements: sea level, barometric pressure of 29.92 inches of mercury, humidity of 0.00 inch of mercury, and a temperature of 59°F.

**NOZZLE**—A taper or restriction used to speed up or direct the flow of gas or liquid.

**OIL DISTRIBUTION (OD) BOX**—This box is located at the forward end of each MRG assembly. It directs HP oil from the HOPM to the propeller hub through the shaft bore. The OD box also establishes propeller pitch by using control oil from the HOPM to position the valve rod, which extends through the shaft to the hub.

**ORIFICE**—A circular opening in a flow passage that creates a flow restriction.

**PARAMETER**—A variable, such as temperature, pressure, flow rate, voltage, current, or frequency that may be indicated, monitored, checked, or sensed in any way during operation or testing.

**PERMANENT MAGNET ALTERNATOR (PMA)**—The PMA is mounted on the generator shaft extension of each GTGS and supplies speed sensing and power to the EG. The PMA also supplies initial generator excitation.

**PHOTOELECTRIC**—Electricity produced by the action of light.

**PITCH**—A term applied to the distance a propeller will advance during one revolution.

**PLENUM CHAMBER**—An enclosed space in which the pressure of the air is greater than the outside atmosphere.

**POTENSIOMETER**—A variable resistance unit having a rotating contact arm that can be set at any desired point along the resistance element.

**POWER TURBINE INLET TOTAL PRESSURE ( $P_{t5.4}$ )**—The pressure sensed by pressure probes located in the GTE turbine midframe and piped to a transducer on the bottom of the GTM.

**POWER TURBINE INLET GAS TEMPERATURE ( $T_{5.4}$ )**—The temperature sensed by thermocouples installed in the GTE midframe.

**POWER TURBINE SPEED ( $N_{p,t}$ )**—The speed sensed by magnetic pickups in the GTE turbine rear frame.

**POWER LEVEL ANGLE (PLA)**—A rotary actuator mounted on the side of the GTE fuel

pump and its output shaft lever. It is mechanically connected to the MFC power lever. The PLA actuator supplies the torque to position the MFC power lever at the commanded rate.

**POWER TURBINE (PT)**—The GTE turbine that converts the GG exhaust into energy and transmits the resulting rotational force via the attached output shaft.

**POWER TAKEOFF (PTO)**—The drive shaft between the GTGS GTE and the reduction gear. It transfers power from the GTE to the reduction gear to drive the generator.

**PRAIRIE AIR SYSTEM**—This system emits cooled bleed air from small holes along the leading edge of the propeller blades. The resulting air bubbles disturb the thrashing sound so identification of the type of ship through sonar detection becomes unreliable.

**PRESSURE**—Force per unit of area, usually expressed as psi.

**PRIME MOVER**—(1) The source of motion—as a GTE, (2) the source of mechanical power used to drive a pump, or compressor, (3) or rotor of a generator.

**PROPELLER**—A propulsive device consisting of a boss or hub carrying two or more radial blades. (Also called a screw.)

**PROPULSION AUXILIARY CONTROL CONSOLE (PACC)**—This console is located in CCS and is part of the PAMCE. It contains the electronic equipment capable of controlling and monitoring both propulsion plants and auxiliary equipment on a CG- or DD-class ship. (Also known as PACC on the DDG-51 class ship but not a part of PAMCE.)

**PROPULSION AND AUXILIARY MACHINERY CONTROL EQUIPMENT (PAMCE)**—This equipment is located in CCS, is part of the ECSS, and includes the PACC and PACEE. This equipment provides centralized control and monitoring of both main propulsion plants and auxiliary machinery on a CG- or DD-class ship.

**PROPULSION AND AUXILIARY MACHINERY INFORMATION SYSTEM EQUIPMENT (PAMISE)**—This equipment is located in CCS and is part of the ECSS. This equipment receives,

evaluates, and logs the engineering plant performance, status, and alarm state. The PAMISE contains the CISE and S/CE No. 1 on a CG- or DD-class ship.

**PROPULSION CONTROL CONSOLE (PCC)**—This is the main engine control console in CCS on an FFG-class ship. It is used for starting, stopping, and controlling the GTEs and propeller shaft.

**PROPULSION LOCAL CONTROL CONSOLE (PLCC)**—The PLCC is located in each engine room and is part of the PLOE. It has controls and indicators necessary for operator's control of one main propulsion plant and its supporting auxiliaries on a CG- or DD-class ship.

**PROPULSION LOCAL OPERATING EQUIPMENT (PLOE)**—The PLOE is located in each engine room and is part of the ECSS. It includes the PLCC and PLCEE. The PLOE provides for local control and monitoring of the main propulsion GTE and the associated auxiliary equipment on a CG- or DD-class ship.

**PUMP**—( 1) A device that converts mechanical energy into fluid energy. (2) A device that raises, transfers, or compresses fluids or gases.

**RADIALLY**—Developing uniformly around a central axis.

**REPAIR STATION CONSOLE (RSC)**—Provides centralized control of the damage control equipment on DDG-51 class ships. The RSC serves as the primary control station when the DCC is not available.

**RESISTANCE TEMPERATURE DETECTOR (RTD)**—A temperature sensor that works on the principle that as temperature increases, the conductive material exposed to this temperature increases electrical resistance.

**RESISTOR**—A device possessing the property of electrical resistance.

**RHEOSTAT**—A variable resistor having one fixed and one moveable terminal.

**ROTOR**—A rotating wheel or group of wheels in a turbine.

**SALIENT POLE GENERATOR**—A generator whose field poles are bolted to the rotor, as opposed to a generator whose field poles are formed by imbedding field windings in the slots of a solid rotor.

**SCAVENGE PUMP**—A pump used to remove oil from a sump and return it to the oil supply tank.

**SENSOR**—The part of an instrument that first takes energy from the measured medium to produce a condition representing the value of the measured variable.

**SHAFT CONTROL UNIT (SCU)**—The SCU is located in each engine room. It has controls and indicators necessary for operator control of one main propulsion plant and its supporting auxiliaries on a DDG-51 class ship.

**SHIP CONTROL CONSOLE (SCC)**—This console is located on the bridge of CG- and DD-class ships. It has equipment for operator control of ship's speed and direction.

**SHIP'S SERVICE DIESEL GENERATOR (SSDG)**—The SSDG is the main source of electrical power for a ship. It uses a diesel engine as the prime mover for the generator.

**SHIP'S SERVICE GAS TURBINE GENERATOR (SSGTG)**—The SSGTG is the main source of electrical power for a ship. It uses a GTE as the prime mover for the generator.

**SIGNAL CONDITIONING ENCLOSURE (S/CE)**—Part of the PAMISE and provides the major input interface between the propulsion plant machinery and the ECSS control consoles. The S/CE accepts inputs from the plant machinery and outputs normalized signals to the ECSS control consoles. Also has alarm detection and alarm output circuitry. One S/CE is located in each engine room and one is a part of the CISE (located in CCS).

**SOLENOID**—A coil of wire in the form of a long cylinder that resembles a bar magnet. When current flows in the wire, a movable core is drawn into the coil.

**SPLIT PLANT**—The condition in which only one engine in an engine room is driving the reduction gear/propulsion shaft.

**STALL**—An inherent characteristic of all gas turbine compressors to varying degrees and under certain operating conditions. It occurs whenever the relationship between air pressure, velocity, and compressor rotational speed is altered so that the effective angle of attack of the compressor blades becomes excessive, causing the blades to stall.

**STATOR**—The body of stationary blades or nozzles of a turbine.

**SUMMARY ALARM**—An indicator at a console that indicates to an operator that one of several abnormal conditions has occurred on a certain piece of equipment.

**SYNCHRO SELF-SHIFTING (SSS) CLUTCH**—The SSS clutch is a fully automatic, free-wheel device that transmits power through gear-toothed elements.

**TACHOMETER**—An instrument used to measure the speed of rotation of a device.

**TEMPERATURE**—The quantitative measure of the relative hotness or coldness of an object.

**THERMAL ENERGY**—The potential and kinetic energy of particles of a body which can be evolved as heat.

**THERMOCOUPLE**—(1) a bimetallic device capable of producing an emf roughly proportional to temperature differences on its hot and cold junction ends. (2) A junction of two dissimilar metals that produces a voltage when the junction is heated.

**THERMODYNAMICS**—A branch of dynamics that deals with the applied forces caused by the application of heat.

**THRUST BEARING**—Bearing that limits the axial (longitudinal) movement of the shaft.

**THRUST**—The forward directed reaction force produced by a high-speed jet of air discharged rearward from a nozzle or orifice.

**TOLERANCE**—The allowable deviation from a specification or standard.

**TORQUE**—A force or combination of forces that produces or tends to produce a twisting or rotary motion.

**TRANSDUCER**—(1) A device that converts a mechanical input signal into an electrical output signal. (2) Generally, a device that converts energy from one form into another, always retaining the characteristic amplitude variations of the energy converted.

**TRANSFORMER**—A device composed of two or more coils, linked by magnetic lines of force, used to step up or step down an ac voltage.

**TURBINE OVERTEMPERATURE PROTECTION SYSTEM (TOPS)**—A system used on a CG- or DD-class ship to protect a surviving generator from overload if another generator fails.

**TURBINE INLET TEMPERATURE (TIT)**—The GTGS turbine inlet temperature on the Allison 501-K17. (Known as  $T_{5.4}$  for an LM2500 GTE.)

**ULTRAVIOLET (UV) SENSOR**—A device that senses the presence of fire in the GTE and GTG enclosure and generates an electrical signal that is sent to the ECSS.

**UNINTERRUPTIBLE POWER SUPPLY (UPS) SYSTEM**—Critical ship control systems have a UPS as an emergency power source. The UPS is used to maintain operations during any interruption of the normal power source.

**VACUUM**—Pressure less than atmospheric pressure.

**VARIABLE STATOR VANE (VSV)**—A compressor stator vane that is mechanically varied to provide optimum, stall-free compressor performance over a wide operating range.

**VELOCITY**—The rate of motion in a particular direction. The velocity of fluid flow is usually measured in feet per second.

**VENTURI**—A device that depends for operation upon the fact that as the velocity of flow of air increases in the throat the pressure decreases.

**VISCOSITY**—The internal resistance of a fluid which tends to prevent it from flowing.

**VOLT**—A unit of electrical potential.

**VOLTAGE**—An electric potential difference, expressed in volts.

**VOLUME**—The amount of space that matter occupies.

**VORTEX**—That which resembles a whirlwind or whirlpool.

**WASTE HEAT BOILER (WHB)**—Each waste heat boiler is associated with a GTGS and uses the hot exhaust gases to convert feedwater to steam for various ship's services on CG-, DD- or CG- and DD- class ships.

**WATT**—A unit of electric power equal to the rate of work represented by a current of 1 ampere under a pressure of 1 volt.



## APPENDIX II

# ABBREVIATIONS AND ACRONYMS

This appendix is a listing of the abbreviations and acronyms used in this text. Although this is an extensive listing, it is not an all-inclusive list of abbreviations and acronyms used by the Gas Turbine Systems Technicians. The *GSE3/GSM3*, NAVEDTRA 10563, volume 1, also has an appendix II with abbreviations and acronyms used in the text. However, this list will help form a basis for your qualification under the PQS system and allow for rapid access to terms used by Gas Turbine Systems Technicians.

### A

- A/C—air conditioning  
ACC—auxiliary control console  
ADC—analog-to-digital converter  
AFFF—aqueous film forming foam  
AGB—accessory gearbox  
AM—area multiplexers  
AMR—auxiliary machinery room  
APD—automatic paralleling device  
ASROC—antisubmarine rocket  
ASW—antisubmarine warfare

### B

- BCU—bridge control unit  
BLISS—boundary layer infrared suppression system  
BTB—bus tie breaker

### C

- CB—circuit breaker  
CBR—chemical, biological, radiation

CCS—central control station

CDP—compressor discharge pressure

CHT—collecting, holding and transfer

CISE—central information system equipment

CIT—compressor inlet temperature

CO<sub>2</sub>—carbon dioxide

CODAG—combined diesel and gas

CODOG—combined diesel or gas

COGOG—combined gas or gas

COSAG—combined steam and gas

CPU—central processing unit

CRP—controllable reversible pitch

CT—current transformer

### D

DAC—digital-to-analog converter

DCC—damage control console

DDI—demand display indicator

DFM—diesel fuel, marine

DMS—data multiplex system

DVM—digital voltmeter

## **E**

ECSS—Engineering Control and Surveillance System

ECU—electronic control unit

EG—electrohydraulic (electric) governor

EHGA—electrohydraulic governor actuator

EMI—electromagnetic interference

EOOW—engineering officer of the watch

EOSS—Engineering Operational Sequencing System

EOT—engine order telegraph

EPCC—electric plant control console

EPCE—electric plant control equipment

EPCEE—electric plant control electronics enclosure

EPM—equivalent parts per million

## **F**

FO—fuel oil

FOD—foreign object damage

FSCC—fuel system control console

FSEE—free standing electronic enclosure

ft<sup>3</sup>/min—cubic feet per minute

## **G**

GB—generator circuit breaker

GCU—governor control unit

GG—gas generator

GMLS—guided missile launching system

GMT—greenwich mean time

gpm—gallons per minute

GSE—Gas Turbine Systems Technician (Electrical)

GSM—Gas Turbine Systems Technician (Mechanical)

GSs—Gas Turbine Systems Technicians

GT—gas turbine

GTE—gas turbine engine

GTG—gas turbine generator

GTGSs—gas turbine generator sets

GTM—gas turbine module

## **H**

HF—high-frequency

HP—high-pressure

hp—horsepower

HSS—high-signal select

HVAC—heating, ventilation, and air conditioning

## **I**

ICC—information center console

IGV—inlet guide vane

in.H<sub>2</sub>O—inches of water

IOU—input-output units

IR—infrared

## **K**

KOH—potassium hydroxide

	<b>L</b>	
lb/min—pounds per minute		NOAP—Navy Oil Analysis Program
lb/set—pounds per second		$N_{p,t}$ —power turbine speed
LCAC—landing craft, air cushion		NRTC—nonresident training course
LED—light-emitting diode		
LFV—liquid fuel valve		
LO—lube oil		
LOCOP—local operating control panel		
LOP—local operating panel		
LOSCA—lube oil storage and conditioning assembly		
LOSIP—local operating station instrument panel		
LP—low-pressure		PACC—propulsion and auxiliary control console
LSS—low-signal select		
lube—lubricating		PAMCE—propulsion and auxiliary machinery control equipment
LVDT—linear variable-displacement transformer		
	<b>M</b>	
MCS—machinery control system		PAMISE—propulsion and auxiliary machinery information system equipment
MER—main engine room		PCB—printed circuit board
MFC—main fuel control		PCC—propulsion control console
MG—maintenance group		PCS—propulsion control system
MPU—magnetic pickup unit		PG—patrol combatant
MRC—maintenance requirement card		
MRG—main reduction gear		
	<b>N</b>	
$N_1$ —speed voltage		PKP—potable potassium bicarbonate
$N_{gg}$ —gas generator speed		PLA—power lever angle
		PLCC—propulsion local control console
		PLOE—propulsion local operating equipment
		PMA—permanent-magnet alternator
		PMS—Planned Maintenance System
		PQS—Personnel Qualification Standard
		$P_{s,3}$ —compressor discharge static pressure
		PSEA—power supply enclosure assembly
		psia—pounds per square inch absolute

psid—pounds per square inch differential

psig—pounds per square inch gauge

PT—power turbine

$P_{t2}$ —compressor inlet total pressure

$P_{t5.4}$ —power turbine inlet total pressure

PTO—power take-off

PWB—printed wiring board

## R

RC—resistive capacitive

RFI—radio-frequency interference

RM—remote multiplexers

rpm—rotations per minute

RSC—repair station console

RTD—resistance temperature detector

RTE—resistance temperature element

## S

SKE—signal conditioning enclosure

SAC—starting air compressor

SCCP—self-cleaning centrifugal purifier

scfm—standard cubic feet per minute

SCS—supervisory control status

SEM—standard electronic module

SHP—shaft horsepower

SPM—speed phase matching

srpm—shaft rpm

SS—ship's service

SSAS—ship's service air system

SSDG—ship's service diesel generator

SSGTGS—ship's service gas turbine generator set

SWBD—switchboard

## T

$T_2$ —compressor inlet temperature

$T_{5.4}$ —power turbine inlet gas temperature

TC—traffic controllers

TGB—transfer gearbox

TIT—turbine inlet temperature

TOPS—turbine overtemperature (overload) protection system

TRAMAN—training manual

## U

UPS—uninterruptible power supply

UV—ultraviolet

## V

VERTREP—vertical replenishment

VSV—variable stator vane

## W

WDCM—washdown countermeasure

WHB—waste heat boiler

## X

xdcr—transducer

# INDEX

## A

Abbreviations and acronyms, AII-1 to AII-4  
ACC, auxiliary control console, 9-28 to 9-42  
    lower panel, 9-37 to 9-42  
    distilling plants section, 9-40  
    drainage system section, 9-41 to 9-42  
    fill valves section, 9-40  
    lamp test, 9-39  
    masker, prairie/fin stabilizer, and  
        bleed air systems section, 9-38  
    potable water system section, 9-37  
    saltwater service system section, 9-40  
    sewage disposal system section, 9-39  
top panel, 9-29 to 9-30  
    CONSOLE POWER STATUS section, 9-30  
    DAMAGE CONTROL section, 9-29  
    PARAMETERS section, 9-29  
vertical panel, 9-30 to 9-37  
    air-conditioning plants section, 9-36  
    alarm acknowledge, 9-35  
    chilled water circulating system section, 9-32  
    compressed air plants section, 9-34  
    fuel filling, transfer, and purification  
        system section, 9-31  
    lamp tests, 9-33  
    machinery space ventilation fans, 9-30  
    main engines starting air system  
        section, 9-34  
    processor generated alarm, 9-35  
    ship's stores refrigeration plants section, 9-36 to 9-37  
    waste heat water circulating systems  
        section, 9-33  
Accessory drive system, 1-28  
Adiabatic compression, 1-9  
Aegis pumps section, 5-25  
Air cond plants section, 8-51  
Air cond section, 5-24  
Air control section, 5-25 to 5-26  
Air intake system, 2-9 to 2-14

Air start system, 3-29  
Air systems, 1-27  
Alarm ACK section, 5-32  
Alarm test panel, 5-46 to 5-47  
Alternating current generator and voltage  
    regulator, 3-39 to 3-46  
Anti-icing air system, 4-18 to 4-20  
Anti-icing system, 2-14  
Aqueous film forming foam system, 4-27  
Auto parallel section, 8-15 to 8-16  
Auxiliary cooling system, 4-26  
Auxiliary equipment and consoles, 9-1 to 9-60  
    auxiliary control console, 9-28 to 9-42  
    lower panel, 9-37 to 9-42  
    top panel, 9-29 to 9-30  
    vertical panel, 9-30 to 9-37  
bell and data loggers, 9-48 to 9-49  
    bell logger, 9-49  
    data logger, 9-48  
damage control console for DD-963/993  
    and CG-47 class ships, 9-21 to 9-28  
        design and components, 9-21 to 9-26  
        operation, 9-27 to 9-28  
damage control console for DDG-51 class  
    ships, 9-49 to 9-53  
    sloping panel, 9-52 to 9-53  
    vertical panel, 9-50 to 9-52  
    damage control console for the FFG-7  
        class ships, 9-42 to 9-48  
    lower panel, 9-47 to 9-48  
    upper panel, 9-42 to 9-47  
data multiplex system, 9-57 to 9-59  
    communication test, 9-59  
    configuration, 9-58  
DMS to MCS communications, 9-58  
interfaces, 9-57  
system, 9-57

Auxiliary equipment and consoles—Continued  
  fuel system control equipment, 9-9 to 9-21  
    control console, 9-9 to 9-17  
    fuel oil transfer local panels, 9-17 to 9-19  
    JP-5 local control panel, 9-19 to 9-20  
      operation, 9-20 to 9-21  
  propulsion and auxiliary machinery information system equipment, 9-1 to 9-9  
    bell and data loggers, 9-7 to 9-9  
    central information system equipment, 9-2 to 9-5  
    signal conditioning equipment, 9-5 to 9-7  
  repair station console, 9-53 to 9-57  
    sloping panel, 9-55 to 9-57  
    vertical panel, 9-54  
  summary, 9-59 to 9-60  
Axial-flow compressors, 1-11 to 1-16

## B

Ballast system, 4-23 to 4-24  
Bell and data loggers, 9-48 to 9-49  
  bell logger, 9-49  
  data logger, 9-48  
Bellmouth and bulletnose, 2-19  
Bleed air control panel, 5-34 to 5-35  
Bleed air start system, 4-17 to 4-18  
Bleed air system, 2-46, 3-20 to 3-21, 4-17 to 4-21  
Blow-in and blow-out panels, 3-4 to 3-5  
Blow-in doors, 2-13 to 2-14  
Bus tie & SWBD section, 8-8  
Bus tie & SWBD voltage select section, 8-13

## C

CG, and DD anti-icing system, 4-18 to 4-19  
CG, and DD cooling system, 2-17 to 2-18  
CG, and DD inlet duct systems, 2-10 to 2-13  
CG, and DD low-pressure air system, 4-21 to 4-22  
CG, and DD masker air system, 4-20 to 4-21  
CG, and DD seawater sysems, 4-25  
CG, and DD steam distribution system, 4-26  
CG exhaust duct system, 2-15 to 2-16  
Centrifugal compressor, 1-10 to 1-11  
Chilled water section, 5-25

Circuit breaker switches/indicators, 8-8 to 8-10  
CO<sub>2</sub> system, 3-10 to 3-11  
Combat dry air section, 5-25  
Combustion chamber design, classification by, 1-16 to 1-19  
  annular chamber, 1-16 to 1-18  
  can chamber, 1-16  
  can-annular chamber, 1-18 to 1-19  
Compressor cleanliness, effect of, 1-10  
Compressor type, classification by, 1-10 to 1-16  
Compressed air systems, 4-21 to 4-23  
Compressor inlet temperature/compressor discharge pressure sensor, 3-26  
Compressor inlet temperature sensor, 2-38  
Console power status/console/vital power feeder circuit breaker status panel (A-3), 8-31 to 8-33  
Control console, electric plant (CG-class ships), 8-17 to 8-26  
Control console, electric plant (DD-class ships), 8-1 to 8-17  
Control console, electric plant (DDG-51-class ship), 8-44 to 8-53  
Control console, electric plant (FFG-class ships), 8-27 to 8-44  
CRP section, 5-3 to 5-4

## D

Damage control console for DD-963/993 and CG-47 class ships, 9-21 to 9-28  
  design and components, 9-21 to 9-26  
  operator's panels (front of console), 9-21 to 9-26  
  rear panel (back of console), 9-26  
  operation, 9-27 to 9-28  
    normal securing, 9-28  
    power application, 9-28  
    self tests, 9-28  
Data multiplex system, 9-57 to 9-59  
  DMS communication test, 9-59  
DMS configuration, 9-58  
DMS interfaces, 9-57  
  DMS system, 9-57  
DMS to MCS communications, 9-58  
DCC, damage control console for DDG-51 class ships, 9-49 to 9-53  
  sloping panel, 9-52 to 9-53  
    alarm acknowledge, 9-52  
    fire pump panel, 9-53  
    lamp test, 9-53  
    plasma display keyboard, 9-53

DCC, damage control console for DDG-51 class ships—Continued  
 vertical panel, 9-50 to 9-52  
 console test section, 9-50  
 fireman panel, 9-51  
 plasma display section, 9-51 to 9-52

DCC, damage control console for the FFG-7 class ships, 9-42 to 9-48  
 lower panel, 9-47 to 9-48  
 upper panel, 9-42 to 9-47  
 alarm and detection section, 9-45  
 miscellaneous fire fighting section, 9-44  
 power monitoring section, 9-42 to 9-44  
 ventilation system, 9-46 to 9-47

DD exhaust duct systems, 2-15

DDG-51, machinery control system, 7-1, 7-2

Demands panel, 6-7

Demister panels, 2-13

Distilling section, 5-24

Distribution panel (A-2), 8-51 to 8-53

Drainage and ballast systems, 4-23 to 4-24

Droop mode, 3-32

## E

Eductors, 2-15

Electrical plant operation, 8-1 to 8-53  
 electric plant control console (CG-class ships), 8-17 to 8-26  
 400-Hz alarm/status panel, 8-19 to 8-21  
 400-Hz alarm/status indicator section, 8-20 to 8-21  
 400-Hz ground detect section, 8-21  
 meter section, 8-21

400-Hz MIMIC panel, 8-25 to 8-26  
 converter control section, 8-25 to 8-26  
 mimic section, 8-25

alarm/status panel, 8-17 to 8-19  
 alarm acknowledge, 8-19  
 alarm/status indicator section, 8-17 to 8-19  
 demand display section, 8-19  
 emergency power section, 8-19  
 generator and gas turbine lube oil meters section, 8-19  
 synchronizing indication section, 8-19

Electrical plant operation—Continued  
 electric plant control console (CG-class ships)—Continued  
 generator status panel, 8-19  
 MIMIC panel, 8-21  
 system control panel, 8-21 to 8-24

electric plant control console (DD-class ships), 8-1 to 8-17  
 alarm /status panel, 8-1 to 8-6  
 alarm acknowledge, 8-6  
 alarm/status section, 8-1 to 8-4  
 emergency power section, 8-4  
 gas turbine generators demand display section, 8-5 to 8-6  
 load shedding switch/indicator, 8-5  
 main switchboard ground detect section, 8-5  
 switchboard section, 8-4  
 synchronizing lights section, 8-5

generator status panel, 8-6 to 8-8  
 bus tie & SWBD section, 8-8  
 generators section, 8-6  
 shore power section, 8-7 to 8-8

load centers, 8-16

MIMIC panel, 8-8 to 8-11  
 circuit breaker switches/indicators, 8-8 to 8-10  
 gas turbine start mode selector, 8-10  
 generators sections, 8-10  
 miscellaneous indicators, 8-10 to 8-11

system configuration, 8-16 to 8-17  
 emergency configurations, 8-17  
 nonstandard plant configurations, 8-16 to 8-17  
 standard parallel-plant configurations, 8-16  
 standard split-plant configurations, 8-16

system control panel, 8-11 to 8-16  
 auto parallel section, 8-15 to 8-16  
 bus tie & SWBD voltage select section, 8-13  
 generators section, 8-11 to 8-13  
 logic self test section, 8-15  
 MALF section, 8-14 to 8-15  
 power section, 8-14  
 synchro control section, 8-13 to 8-14  
 system section, 8-14  
 test section, 8-15

turbine overload protection system, 8-16

- Electrical plant operation—Continued
- electric plant control console (DDG-51-class ship), 8-44 to 8-53
    - distribution panel (A-2), 8-51 to 8-53
      - air cond plants section, 8-51
      - alarm acknowledge section, 8-51
      - gas turbine section, 8-52
      - lamp test section, 8-51
      - load shedding section, 8-52
      - shore power section, 8-51 to 8-52
      - start air section, 8-52
      - switchboard section, 8-51
      - synchronization section, 8-52 to 8-53
    - output monitor panel (A-1), 8-47 to 8-50
      - console section, 8-47
      - plasma display section, 8-48
      - power generation and distribution section, 8-48 to 8-49
      - summary alarms section, 8-47
      - synchronization section, 8-49 to 8-50
      - system output section, 8-49
  - electric plant control console (FFG-class ships), 8-27 to 8-44
    - console power status/console/vital power feeder circuit breaker status panel (A-3), 8-31 to 8-33
      - console power status section, 8-32 to 8-33
      - console section, 8-33
      - vital power feeder circuit breaker status section, 8-33
    - engine fuel systems panel (AI), 8-27 to 8-28
    - shore power/generators panel (A-9), 8-43
      - generators section, 8-44
      - shore power section, 8-43 to 8-44
    - SSDG output and distribution panel (A-5), 8-33 to 8-37
      - alarm acknowledge and processor generated alarm section, 8-37
      - governor control section, 8-36
      - meter section, 8-36
      - voltage regulator control section, 8-36
    - SSDG output and distribution panel (A-8), 8-40 to 8-43
      - circuit breaker control and switchboard control sections, 8-42 to 8-43
      - engine starting and stopping section, 8-41 to 8-42
- Electrical plant operation—Continued
- electric plant control console (FFG-class ships)—Continued
  - SSDG panel (A-4), 8-33
  - SSDG panel (A-7), 8-37 to 8-40
    - exhaust temperature section, 8-40
  - jacket cooling water system section, 8-40
  - seawater system section, 8-40
  - supervisory control status/synchronization/paralleling/parameters panel (A-2), 8-28 to 8-31
    - paralleling section, 8-30 to 8-31
    - parameters section, 8-31
    - supervisory control status section, 8-28 to 8-29
    - synchronization section, 8-30
  - system output monitor/ground status test/generator 4 panel (A-6), 8-37
    - audible test switches and rheostat section, 8-37
    - generator 4 section, 8-37
    - ground status test section, 8-37
    - system output monitor section, 8-37
- Engine fuel system, 3-21 to 3-25
- Engine instrumentation, 2-47 to 2-48
- Engine No. 1 demands panel, 5-32 to 5-34
- Engine No. 1 panel, 5-17
- Engine No. 2 demands panel, 5-26 to 5-30
- Engine room No. 2 panel, 5-2 to 5-9
- Engine order telegraph (EOT) panel, 5-30
- Engine order telegraph section, 5-32
- Engine panel, 6-9 to 6-15
- Engine performance, factors affecting, 1-9 to 1-10
- Engine start panels, 6-4 to 6-7
- Engine systems, 2-33 to 2-47
- Engineering auxiliary and support systems, 4-1 to 4-27
- bleed air system, 4-17 to 4-21
    - anti-icing air system, 4-18 to 4-20
      - CG, and DD anti-icing system, 4-18 to 4-19
      - FFG anti-icing system, 4-19 to 4-20
    - bleed air start system, 4-17 to 4-18
    - masker air system, 4-20 to 4-21
      - CG, and DD masker air system, 4-20 to 4-21
      - FFG masker air system, 4-21
      - prairie air system, 4-21

Engineering auxiliary and support systems—  
Continued

- compressed air systems, 4-21 to 4-23
- CG, and DD high-pressure air system, 4-22
- CG, and DD low-pressure air system, 4-21 to 4-22
- FFG high-pressure air system, 4-22 to 4-23
- FFG low-pressure air system, 4-22
- drainage and ballast systems, 4-23 to 4-24
  - ballast system, 4-23 to 4-24
  - main drainage system, 4-23
  - secondary drainage system, 4-23
- fire-extinguishing systems, 4-27
  - aqueous film forming foam system, 4-27
  - fixed flooding CO<sub>2</sub> system, 4-27
  - Halon 1301 fire-extinguishing system, 4-27
- firemain system, 4-24
- fuel systems, 4-11 to 4-17
  - JP-5 system, 4-16 to 4-17
  - naval distillate system, 4-11 to 4-16
    - fuel oil fill and transfer system, 4-11 to 5-15
    - fuel and service system, 4-15 to 4-16
- lube oil fill, transfer, and purification system, 4-4 to 4-7
  - lube oil purifiers, 4-5 to 4-7
  - purification of lube oil, 4-5 to 4-6
    - sampling of lube oil, 4-6 to 4-7
  - storage and settling tanks, 4-4 to 4-5
- lube oil system fundamentals, 4-1 to 4-4
  - friction and lubrication, 4-1 to 4-2
  - lubricating oils, 4-2 to 4-4
    - classification of lube oils, 4-2 to 4-3
    - properties of lube oil, 4-3 to 4-4
- main lube oil system, 4-7 to 4-11
  - system components, 4-7 to 4-10
    - header, 4-10
    - lube oil cooler, 4-9
    - lube oil filter, 4-10
    - lube oil pumps, 4-8 to 4-9
    - lube oil sump, 4-7
    - temperature regulating valve, 4-9
    - unloading valve, 4-9
  - system lube oil flow, 4-7
  - system monitoring, 4-10 to 4-11

Engineering auxiliary and support systems—  
Continued

- seawater service system, 4-24 to 4-26
- CG, and DD seawater systems 4-25
- FFG seawater systems, 4-25 to 4-26
  - auxiliary cooling system, 4-26
  - main propulsion reducing gear cooling system, 4-25
  - SSDG cooling system, 4-25 to 4-26
- steam and waste heat systems, 4-26
  - CG, and DD steam distribution system, 4-26
  - FFG waste heat distribution system, 4-26

EOOW/LU, Engineering Officer of the Watch/Logging Unit, 7-1 to 7-8

- keyboard control section, 7-7 to 7-8
  - arrow/home keys, 7-8
  - function keys, 7-8
  - standard keys, 7-8
- panel assembly A1, 7-3 to 7-6
  - AN/USH-26 section, 7-4 to 7-6
  - bubble memory section, 7-4
  - fuse assembly section, 7-3
- panel assembly A2, 7-6 to 7-7
  - console section, 7-6
  - plasma display section, 7-6
  - printer section, 7-6 to 7-7

EOT panel, 5-44

Exhaust systems, 2-14 to 2-16

## F

- FFG anti-icing system, 4-19 to 4-20
- FFG cooling system, 2-18
- FFG exhaust duct system, 2-16
- FFG high-pressure air system, 4-22 to 4-23
- FFG inlet duct system, 2-13 to 2-14
- FFG low-pressure air system, 4-22
- FFG seawater systems, 4-25 to 4-26
- FFG waste heat distribution system, 4-26
- Filter, high pressure, 3-25
- Filter, low-pressure, 3-24 to 3-25
- Fire detection and extinguishing systems, 2-7 to 2-9, 3-7
  - CG-, and DD-class ships, 2-8 to 2-9
  - FFG-class ship, 2-9
  - fire detection and extinguishing systems, 3-7

Fire-extinguishing systems, 4-27  
Firemain system, 4-24  
Fixed flooding CO<sub>2</sub> system, 4-27  
400-Hz alarm/status panel, 8-19 to 8-21  
400-Hz MIMIC panel, 8-25 to 8-26  
Free standing electronic enclosure, 2-48 to 2-58  
Fresh water section, 5-22  
FSEE circuitry tests, 2-56 to 2-57  
Fuel and speed-governing system, 2-34 to 2-46  
Full manifold drain valve, 3-26  
Fuel manifold system, 2-37  
Fuel nozzles, 2-37 to 2-38  
Fuel oil fill and transfer system, 4-11 to 4-15  
Fuel oil service system panel, 6-15 to 6-16  
Fuel oil section, 5-4 to 5-6  
Fuel oil system, 1-28  
Fuel pump, 3-24  
Fuel pump and filter, 2-34 to 2-36  
Fuel shutdown valves, 2-37  
Fuel shutoff valve, 3-26  
Fuel system control equipment, 9-9 to 9-21  
    control console, 9-9 to 9-17  
        calibration panel, 9-16  
        card cage, 9-15  
        fuel oil fill and transfer control panel, 9-10 to 9-12  
        fuel oil fill section, 9-12  
        fuel oil transfer section, 9-12, 9-13  
        fuse and circuit breaker panel, 9-16  
        JP-5 control panel, 9-14 to 9-14  
        power supplies, 9-17  
        relay panel assembly, 9-16  
    fuel oil transfer local panels, 9-17 to 9-19  
    calibrate panel, 9-18 to 9-19  
        card cage, 9-18  
        power distribution panel, 9-18  
        power supplies, 9-18  
JP-5 local control panel, 9-19 to 9-20  
    calibrate panel, 9-20  
    card cage, 9-19  
    operator's panel, 9-19  
    power distribution panel, 9-20  
    power supplies, 9-19  
operation, 9-20 to 9-21  
    normal securing, 9-21  
    power application, 9-20  
    self-tests, 9-20  
Fuel systems, 4-11 to 4-17  
Fuse and status panels, 6-3 to 6-4

## G

Gas generator assembly, 2-18 to 2-30  
Gas turbine engine assembly, 2-18 to 2-33  
Gas turbine engine fundamentals, 1-1 to 1-35  
    gas turbine engine auxiliary systems, 1-26 to 1-31  
        accessory drive system, 1-28  
    air systems, 1-27  
        primary airflow, 1-27  
        secondary airflow, 1-27 to 1-28  
    fuel oil system, 1-28  
    lubrication system, 1-28 to 1-31  
        lubrication system subsystems, 1-29 to 1-30  
        oil seals, 1-30 to 1-31  
    spark igniter system, 1-32 to 1-33  
    starting systems, 1-31 to 1-32  
Gas turbine generators demand display section, 8-5 to 8-6  
Gas turbine generator set module components and systems, 3-4 to 3-11  
Gas turbine start mode selector, 8-10  
Gear lube oil panel, 6-16 to 6-18  
Generator and gas turbine lube oil meters section, 8-19  
Generator assembly, 3-39 to 3-41  
Generator lube oil system, 3-40  
Generator space heater, 3-40  
Generator status panel, 8-6 to 8-8  
Generator temperature monitoring, 3-41  
Glossary, AI-1 to AI-9  
Governor control unit, 3-36  
GTE assembly, 3-11 to 3-18  
GTE starting and stopping, 6-26 to 6-27  
GTGS fire stop and CO<sub>2</sub> system, 3-10 to 3-11  
GTGS LOCOP model 104, 3-46 to 3-49  
GTGS LOCOP model 139, 3-49 to 3-52  
GTM 2A manual start section, 5-15 to 5-16  
GRM 2A section, 5-12  
GTM 1B manual start section, 5-17  
GTM 1 B section, 5-15  
GTM 2B start/GTM 2B stop section, 5-29  
GTM 2 B section, 5-6 to 5-8  
    gas turbine engine theory, 1-4 to 1-10  
        adiabatic compression, 1-9  
        basic GTE operation theory, 1-5 to 1-7  
        convergent-divergent process, 1-7 to 1-8  
        factors affecting engine performance, 1-9 to 1-10  
            effect of ambient temperature, 1-9 to 1-10  
            effect of compressor cleanliness, 1-10  
        open, semiclosed, and closed cycles, 1-5  
        theoretical cycles, 1-4 to 1-5

## GTM 2 B section—Continued

history and background, 1-1 to 1-4  
advantages and disadvantages, 1-3 to 1-4  
future trends, 1-4  
twentieth-century development, 1-2 to 1-3  
    American development, 1-2  
    marine gas turbine engine, 1-2 to 1-3  
types of gas turbine engines, 1-10 to 1-26  
classification by combustion chamber design, 1-16 to 1-19  
    annular chamber, 1-16 to 1-18  
    can chamber, 1-16  
    can-annular chamber, 1-18 to 1-19  
classification by compressor type, 1-10 to 1-16  
    axial-flow compressors, 1-11 to 1-16  
    centrifugal compressor, 1-10 to 1-11  
classification by type of shafting, 1-19 to 1-20  
main bearings, 1-26  
turbine assemblies, 1-20 to 1-26  
    gas generator turbine, 1-20 to 1-24  
    power turbines, 1-25 to 1-26

## H

Halon 1301 fire-extinguishing system, 4-27  
High hat assembly, 2-11 to 2-12  
High-speed flexible coupling shaft, 2-32 to 2-33

## I

Ignition exciter, 3-19  
Ignition system, 2-44 to 2-46  
Infrared suppression, 2-15  
Intake, cooling, and exhaust systems, 3-7 to 3-9  
Intake monitoring and control, 2-14  
IR SUPPR section, 5-17  
Isochronous mode, 3-32

## J

Jacket cooling water system section, 8-40  
JP-5 system, 4-16 to 4-17

## L

Lamp test section, 8-51  
LM2500 gas turbine engine, 2-1 to 2-58  
    air intake system, 2-9 to 2-14  
    CG, and DD inlet duct systems, 2-10 to 2-13  
        ducting, 2-12 to 2-13  
        high hat assembly, 2-11 to 2-12  
        overall flow description, 2-11  
FFG inlet duct system, 2-13 to 2-14  
    anti-icing system, 2-14  
    blow-in doors, 2-13 to 2-14  
    demister panels, 2-13  
    intake monitoring and control, 2-14  
base/enclosure assembly, 2-2 to 2-9  
base assembly, 2-4 to 2-5  
enclosure, 2-5 to 2-7  
    heater, 2-6 to 2-7  
    lighting, 2-5 to 2-6  
fire detection and extinguishing systems, 2-7 to 2-9  
    CG-, and DD-class ships, 2-8 to 2-9  
        FFG-class ship, 2-9  
engine instrumentation, 2-47 to 2-48  
engine systems, 2-33 to 2-47  
    fuel and speed-governing system, 2-34 to 2-40  
        compressor inlet temperature sensor, 2-38  
    fuel manifold system, 2-37  
    fuel nozzles, 2-37 to 2-38  
    fuel pump and filter, 2-34 to 2-36  
    fuel shutdown valves, 2-37  
    main fuel control, 2-36  
    power lever angle rotary actuator, 2-39 to 2-40  
    pressurizing valve, 2-36 to 2-37  
    purge valve, 2-37  
    variable stator vane actuators, 2-39  
    variable stator vanes, 2-38 to 2-39  
ignition system, 2-44 to 2-46  
    balance piston air, 2-47  
bleed air system, 2-46  
    eighth-stage air, 2-46  
    ignition exciters, 2-45  
    ignition leads, 2-46  
    ninth-stage air, 2-46 to 2-47  
    sixteenth-stage air, 2-47  
    spark igniters, 2-45  
    thirteenth-stage air, 2-47

LM2500 gas turbine engine—Continued  
 engine systems—Continued  
     water wash system, 2-46  
     start air system, 2-33 to 2-34  
         starter, 2-34  
         starter air valve, 2-34  
     synthetic lube oil system, 2-40 to 2-44  
         lube oil flow, 2-44  
         lube oil system components, 2-41  
             to 2-43  
     exhaust systems, 2-14 to 2-16  
 CG exhaust duct system, 2-15 to 2-16  
     DD exhaust duct systems, 2-15  
         eductors, 2-15  
         infrared suppression, 2-15  
         silencers, 2-15  
     FFG exhaust duct system, 2-16  
 free standing electronic enclosure, 2-48 to 2-58  
 FSEE circuitry tests, 2-56 to 2-57  
 overspeed switch control, 2-50  
 PLA actuator electronics, 2-53 to 2-56  
     PLA actuator drive, 2-54  
     PLA actuator theory of operation,  
         2-55 to 2-56  
     protective functions, 2-54 to 2-55  
     servomotor, 2-53  
     slider potentiometer, 2-53  
     tachometer, 2-53 to 2-54  
 power supply, 2-51 to 2-53  
     CG, and DD FSEE power  
         distribution, 2-51 to 2-53  
     FFG FSEE power distribution,  
         2-51  
 signal conditioning electronics, 2-49  
     to 2-50  
 start/stop sequences, 2-57  
 torque computer, 2-50  
 gas turbine engine assembly, 2-18 to 2-33  
     gas generator assembly, 2-18 to 2-30  
         accessory drive section, 2-29 to 2-30  
         bellmouth and bulletnose, 2-19  
         combustor section, 2-24  
         compressor section, 2-19 to 2-24  
         high-pressure turbine section,  
             2-25 to 2-29  
     high-speed flexible coupling shaft,  
         2-32 to 2-33  
     power turbine/low-pressure section,  
         2-30 to 2-32  
             rotor, 2-31  
             stator, 2-31 to 2-32  
 module cooling systems, 2-17 to 2-18  
     CG, and DD cooling system,  
         2-17 to 2-18  
     FFG cooling system, 2-18

Load centers, 8-16  
 Load shedding switch/indicator, 8-5  
 Local operating control panel, 3-46 to 3-52  
 Local operating panel, 6-27 to 6-36  
 Local operating station instrument panel, 6-29  
     enclosure section, 6-29  
     fuel system section, 6-29  
     gas generator section, 6-29  
     lube oil section, 6-29  
     power turbine section, 6-29  
     throttle section, 6-29  
 Logic self test section, 8-15  
 LOP bottom panel, 6-36  
 LOP fuse panel, 6-36  
 LOP status panel, 6-35  
 LOP top panel, 6-29 to 6-35  
     enclosure section, 6-32 to 6-33  
     engine lube oil section, 6-34  
     fuel section, 6-33  
     gas generator section, 6-33  
     power turbine and output section, 6-34 to  
         6-35  
     seawater cooling supply pressure and  
         reduction gear lube oil remote bearing  
         pressure meters, 6-34  
     start/stop section, 6-33  
     vibration section, 6-34  
 Lube oil cooler, 4-9  
 Lube oil fill, transfer, and purification  
     system, 4-4 to 4-7  
 Lube oil filter, 4-10  
 Lube oil fundamentals, 4-1 to 4-4  
 Lube oil pump, 4-7  
 Lube oil, purification of, 4-5 to 4-6  
 Lube oil, sampling of, 4-6 to 4-7  
 Lube oil section, 5-9  
 Lube oil system, 3-26 to 3-29  
 Lube oil system, main, 4-7 to 4-11  
 Lubrication system, 1-28 to 1-31

## M

Machinery control system for DDG-class  
 ships, 7-1 to 7-23  
     DDG-51, machinery control system, 7-1,  
         7-2  
     EOOW/LU, 7-1 to 7-8  
         keyboard control section, 7-7 to 7-8  
         panel assembly A1, 7-3 to 7-6  
         panel assembly A2, 7-6 to 7-7

Machinery control system for DDG-class ships—Continued  
PACC, 7-8 to 7-17  
    plasma display keyboard panel (A3), 7-17  
    propulsion monitor panel (Al), 7-9 to 7-13  
    thrust/auxiliary panel (A2), 7-14 to 7-17  
    shaft control unit, 7-18 to 7-23  
        horizontal keyboard panel, 7-23  
        propulsion monitor panel (Al), 7-18  
        thrust auxiliary panel (A2), 7-19, 7-23  
Main bearings, 1-26  
Main fuel control, 2-36  
Main seawater cooling panel, 6-8 to 6-9  
MALF section, 8-14 to 8-15  
Malfunction section, 5-28  
Marine gas turbine engine, 1-2 to 1-3  
Masker air system, 4-20 to 4-21  
MIMIC panel, 5-9 to 5-17  
Module cooling systems, 2-17 to 2-18

## N

Naval distillate system, 4-11 to 4-16

## P

PACC and PLCC for DD- and CG-class ships, 5-1 to 5-48  
    propulsion and auxiliary control console, 5-1 to 5-47  
        bleed air control panel, 5-34 to 5-35  
            groups and auxiliary demands section, 5-35  
        port and starboard engine room sections, 5-34  
    engine No. 1 demands panel, 5-32 to 5-34  
    engine No. 1 panel, 5-17  
    engine No. 2 demands panel, 5-26 to 5-30  
        2B emergency controls section, 5-28  
        GTM 2B start/GTM 2B stop section, 5-19 to 5-30  
        malfunction section, 5-28  
        port shaft propulsion demands section, 5-26 to 5-28  
        test section, 5-28 to 5-29

PACC and PLCC for DD- and CG-class ships—Continued  
    propulsion and auxiliary control console—Continued  
        engine order telegraph (EOT) panel, 5-30  
        engine order telegraph section, 5-32  
            alarm ACK section, 5-32  
            throttle transfer section, 5-32  
    engine room No. 2 panel, 5-2 to 5-9  
        CRP section, 5-3 to 5-4  
        fuel oil section, 5-4 to 5-6  
        GTM 2 B section, 5-6 to 5-8  
        lube oil section, 5-9  
        RDCN gear LUBO section, 5-2  
    integrated throttle control panel, 5-35 to 5-37  
    MIMIC panel, 5-9 to 5-17  
        GTM 2A manual start section, 5-15 to 5-16  
        GTM 2A section, 5-12  
        GTM 1B manual start section, 5-17  
        GRM 1B section, 5-15  
        lower center section, 5-16  
        main center section, 5-12 to 5-15  
        PLA and VIBRATION meters and MRG mimic section, 5-15  
PACC auxiliary/bleed air panel, 5-17 to 5-26  
    aegis pumps section, 5-25  
    air cond section, 5-24  
    air control section, 5-25 to 5-26  
    chilled water section, 5-25  
    combat dry air section, 5-25  
    distilling section, 5-24  
    fresh water section, 5-22  
    HP air section, 5-22 to 5-23  
    IR SUPPR section, 5-17  
    REFRD section, 5-23  
    seawater section, 5-21 to 5-22  
    sewage and sewage/waste sections, 5-23  
    SS air section, 5-24 to 5-25  
    steam header press section, 5-21  
    waste HT BLR section, 5-17 to 5-21  
port manual throttle section, 5-30 to 5-32

PACC and PLCC for DD- and CG-class ships—Continued

propulsion local control console, 5-37 to 5-47

alarm test panel, 5-46 to 5-47

GTM A section, 5-46

malfunction section, 5-47

power section, 5-46

test section, 5-46

EOT panel, 5-44

alarm acknowledge section, 5-44

engine order telegraph section, 5-44 to 5-45

GTM A panel, 5-41 to 5-42

CRP section, 5-42

GTM A section, 5-42

lube oil section, 5-42

GTM A/B panel, 5-40 to 5-41

GTM B panel, 5-38

emergency controls section, 5-39

fuel oil section, 5-38 to 5-39

GTM B section, 5-39

PLA and pitch control levers, 5-47

self test panel, 5-42 to 5-44

GTM B section, 5-43 to 5-44

start/stop self test section, 5-43

PACC, propulsion and auxiliary control console, 7-8 to 7-17

plasma display keyboard panel (A3), 7-17

propulsion monitor panel (A1), 7-9 to 7-13

console section, 7-9 to 7-10

plasma display section, 7-11

propulsion section, 7-11 to 7-13

thrust/auxiliary panel (A2), 7-14 to 7-17

console section, 7-16

control location section, 7-17

independent aux section, 7-14

programmed control lever section, 7-17

propulsion auxiliaries section, 7-14 to 7-16

thrust setting section, 7-16

PAMISE, propulsion and auxiliary machinery information system equipment, 9-1 to 9-9

bell and data loggers, 9-7 to 9-9

central information system equipment, 9-2 to 9-5

ECU test panel, 9-5

executive control unit, 9-2

monitor and control panel, 9-2 to 9-5

signal conditioning equipment, 9-5 to 9-7

CALIBRATION section, 9-6

MALFUNCTION section, 9-7

PCC and LOP for FFG-class ships, 6-1 to 6-37

local operating panel, 6-27 to 6-36

local operating station instrument panel, 6-29

enclosure section, 6-29

fuel system section, 6-29

gas generator section, 6-29

lube oil section, 6-29

power turbine section, 6-29

throttle section, 6-29

LOP bottom panel, 6-36

LOP fuse panel, 6-36

LOP status panel, 6-35

LOP top panel, 6-29 to 6-35

enclosure section, 6-32 to 6-33

engine lube oil section, 6-34

fuel section, 6-33

gas generator section, 6-33

power turbine and output sec-

tion, 6-34 to 6-35

seawater cooling supply pressure and reduction gear lube oil

remote bearing pressure meters,

6-34

start/stop section, 6-33

vibration section, 6-34

propulsion control sole, 6-2 to 6-27

GTE starting and stopping, 6-26 to 6-27

PCC control modes, 6-25 to 6-27

programmed control mode, 6-25

to 6-26

remote manual mode, 6-26

PCC controls and indicators, 6-2 to 6-25

demands panel, 6-7

engine panel, 6-9 to 6-15

engine start panels, 6-4 to 6-7

fuse and status panels, 6-3 to 6-4

fuel oil service system panel, 6-15

to 6-16

gear lube oil panel, 6-16 to 6-18

main seawater cooling panel, 6-8

to 6-9

operational adjustments panel, 6-24

to 6-25

propulsion control panel, 6-19

PLA actuator electronics, 2-53 to 2-56

Plasma display section, 8-48

Potentiometer, motor-operated, 3-32

Power lever angle rotary actuator, 2-39 to 2-40

Power supply, 2-51 to 2-53

Power take-off assembly, 3-30 to 3-31

Power turbines, 1-25 to 1-26  
Power turbine/low-pressure section, 2-30 to 2-32  
Prairie air system, 4-21  
Pressure relief valve, 3-25  
Pressurizing valve, 2-36 to 2-37  
Purge valve, 2-37

## Q

Oil seals, 1-30 to 1-31  
Oils, classification of lube, 4-2 to 4-3  
Oils, lubricating, 4-2 to 4-4  
Operational adjustments panel, 6-24 to 6-25  
Overspeed switch control, 2-50

## R

RDCN gear LUBO section, 5-2  
Reduction gear and lube oil system, GTGS, 3-30  
References, AIII-1 to AIII-4  
REFRO section, 5-23  
Repair station console, 9-53 to 9-57  
    sloping panel, 9-55 to 9-57  
    bubble memory section, 9-57  
    fireman valve panel, 9-56  
    plasma display keyboard, 9-57  
    power control panel, 9-55  
    vertical panel, 9-54  
        console section, 9-54  
        control sectikon, 9-54  
        firemain panel, 9-54  
        plasma display, 9-54

## S

SCU, shaft control unit, 7-18 to 7-23  
    horizontal keyboard panel, 7-23  
    propulsion monitor panel (A1), 7-18  
    thrust auxiliary panel (A2), 7-19, 7-23  
Seawater section, 5-21 to 5-22  
Seawater service system, 4-24 to 4-26  
Seawater system section, 8-40  
Self test panel, 5-42 to 5-44  
Servomotor, 2-53  
Sewage and sewage/waste sections, 5-23  
Shafting, classification by type of, 1-19 to 1-20

Ship's service gas turbine generator sets, 3-1 to 3-52  
    alternating current generator and voltage regulator, 3-39 to 3-46  
    generator assembly, 3-39 to 3-41  
    generator lube oil system, 3-40  
    generator space heater, 3-40  
    generator temperature monitoring, 3-41  
    voltage regulation, 3-41 to 3-46  
        model 104 voltage regulation, 3-41 to 3-43  
        model 139 voltage regulation, 3-44 to 3-46  
    engine instrumentation 3-31 to 3-46  
        speed pickup, 3-31  
        thermocouple, 3-31  
        vibration transducer, 3-31  
    engine systems, 3-18 to 3-29  
        air start system, 3-29  
            air starter motor, 3-29  
            high-pressure air start system, 3-29  
            low-pressure air start system, 3-29  
        bleed air system, 3-20 to 3-21  
            fifth- and tenth-stage bleed air, 3-21  
            fourteenth-stage bleed air, 3-20 to 3-21  
        engine fuel system, 3-21 to 3-26  
            compressor inlet  
            temperature/compressor discharge pressure sensor, 3-26  
            electrohydraulic governor actuator, 3-25 to 3-26  
            fuel manifold drain valve, 3-26  
            fuel pump, 3-24  
            fuel shutoff valve, 3-26  
            high-pressure filter, 3-25  
            low-pressure filter, 3-24 to 3-25  
            model 104 fuel system flow path, 3-21 to 3-24  
            model 139 fuel system flow path, 3-24  
            model 104 liquid fuel valve, 3-25  
            model 139 liquid fule valve, 3-25  
            models 104 and 139 flow divider  
                fuel manifold, and fuel nozzles, 3-26  
            pressure relief valve, 3-25  
            start limit control valve, 3-26

Ship's service gas turbine generator sets—Continued

- engine systems—Continued
  - ignition system, 3-19
    - ignition exciter, 3-19
    - spark igniters, 3-19
  - lube oil system, 3-26 to 3-29
    - external scavenge pump, 3-28
    - main pressure and scavenge oil pump, 3-28
    - oil filter, 3-28
    - turbine scavenge pump, 3-28
    - vent system, 3-28
  - gas turbine generator set module components and systems, 3-4 to 3-11
    - base, 3-4
    - enclosure, 3-4 to 3-6
      - blow-in and blow-out panels, 3-4 to 3-5
    - module cooling air flow and temperature monitoring, 3-5 to 3-6
    - fire detection and extinguishing systems, 3-7
    - GTGS fire stop and CO<sub>2</sub> system, 3-10 to 3-11
      - CO<sub>2</sub> system, 3-10 to 3-11
      - model 104 fire stop logic, 3-10
      - model 139 fire stop logic, 3-10
    - intake, cooling, and exhaust systems, 3-7 to 3-9
      - exhaust duct system, 3-9
      - intake duct, 3-8
      - module cooling system, 3-8 to 3-9
    - seawater service system, 3-11
      - water wash system, 3-6 to 3-7
    - general description of the generator set, 3-1 to 3-4
  - GTE assembly, 3-11 to 3-18
    - accessory drive section, 3-18
    - air intake, 3-12 to 3-15
    - combustion section, 3-16
    - compressor section, 3-15
    - turbine section, 3-17 to 3-18
  - GTGS reduction gear and lube oil system, 3-30
  - local operating control panel, 3-46 to 3-52
    - model 104 LOCOP, 3-46 to 3-49
      - turbine start/stop sequencing, 3-48
      - turbine temperature and speed control box, 3-48 to 3-49
    - model 139 GTGS LOCOP, 3-49 to 3-52

Ship's service gas turbine generator sets—Continued

- power take-off assembly, 3-30 to 3-31
- housing, 3-31
- power take-off shaft and adapter, 3-30 to 3-31
- speed governing system, 3-31 to 3-39
  - model 104 governor system, 3-32 to 3-35
    - electrohydraulic governor actuator, 3-34 to 3-35
    - electronic control unit, 3-32 to 3-34
    - motor-operated potentiometer, 3-32
  - model 139 governor system, 3-35 to 3-39
    - electronic fuel control unit, 3-36 to 3-39
    - governor control unit, 3-36
- operating modes, 3-32
  - droop mode, 3-32
  - isochronous mode, 3-32
- Shore power/generators panel (A-9), 8-43
- Shore power section, 8-7 to 8-8
- Signal conditioning electronics, 2-49 to 2-50
- Silencers, 2-15
- Slider potentiometer, 2-53
- Spark igniter system, 1-32 to 1-33
- SS air section, 5-24 to 5-25
- SSDG cooling system, 4-25 to 4-26
- SSDG output and distribution panel (A-5), 8-33 to 8-37
- SSDG output and distribution panel (A-8), 8-40 to 8-43
- SSDG panel (A-4), 8-33
- SSDG panel (A-7), 8-37 to 8-40
- Start air system, 2-33 to 2-34
- Starting systems, 1-31 to 1-32
- Steam and waste heat systems, 4-26
- Steam header press section, 5-21
- Storage and settling tanks, 4-4 to 4-5
- Supervisory-control status/synchronization/paralleling/parameters panel (A-2), 8-29 to 8-31
- Switchboard ground detect section, main, 8-5
- Switchboard section, 8-51
- Synchro control section, 8-13 to 8-14
- Synthetic lube oil system, 2-40 to 2-44
- System output monitor/ground status test/generator 4 panel (A-6), 8-37

**T**

- Tachometer, 2-53 to 2-54  
Temperature regulating valve, 4-9  
Test section, 5-28 to 5-29  
Thermocouple, 3-31  
Throttle transfer section, 5-32  
Torque computer, 2-50  
Turbine assemblies, 1-20 to 1-26  
Turbine overload protection system,  
  8-16

**U**

- Unloading valve, 4-9

**V**

- Variable stator vanes, 2-38 to 2-39  
Vibration transducer, 3-31  
Voltage regulation, 3-41 to 3-46

**W**

- Waste HT BLR section, 5-17 to 5-21  
Water wash system, 2-46, 3-6 to 3-7

