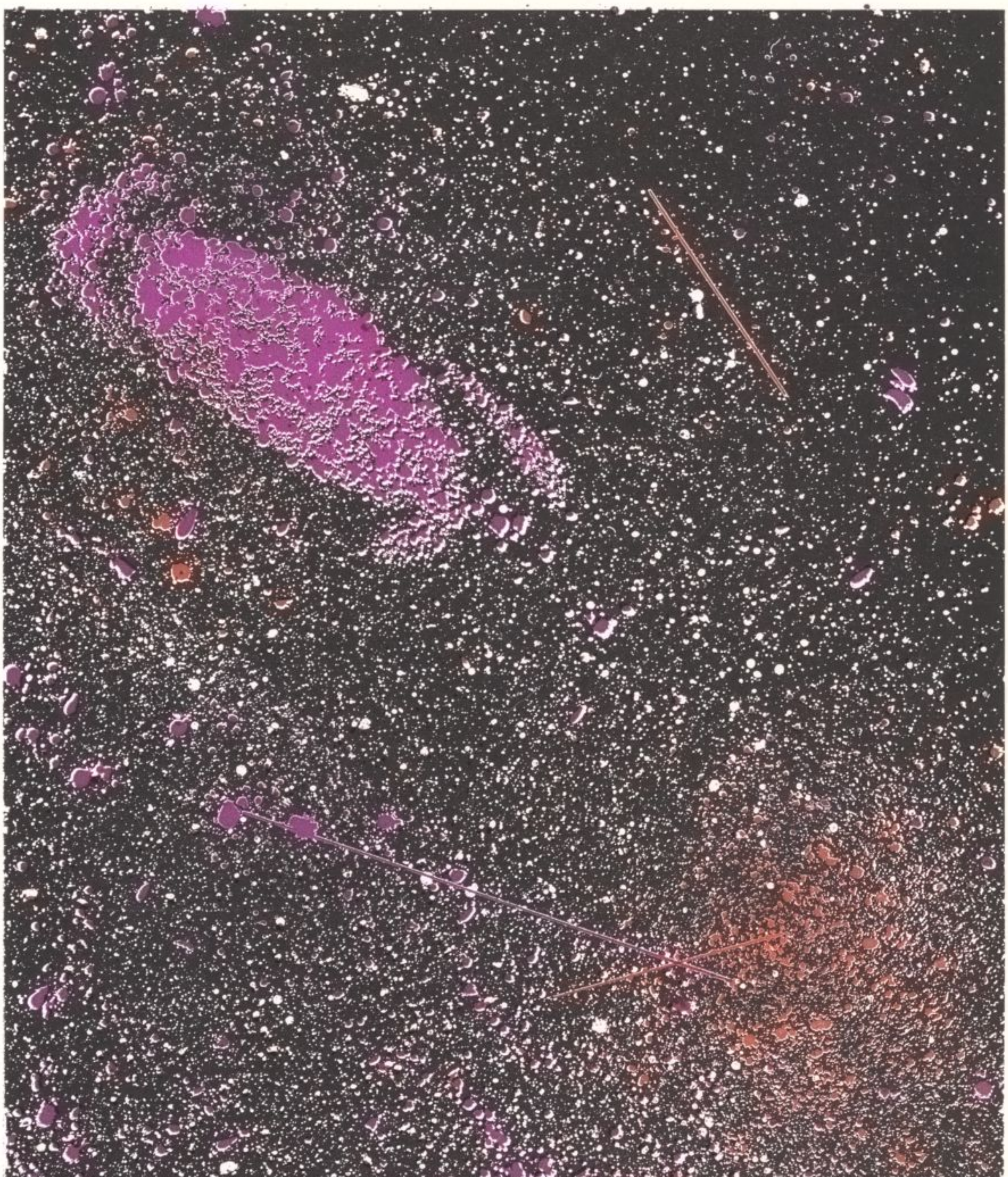
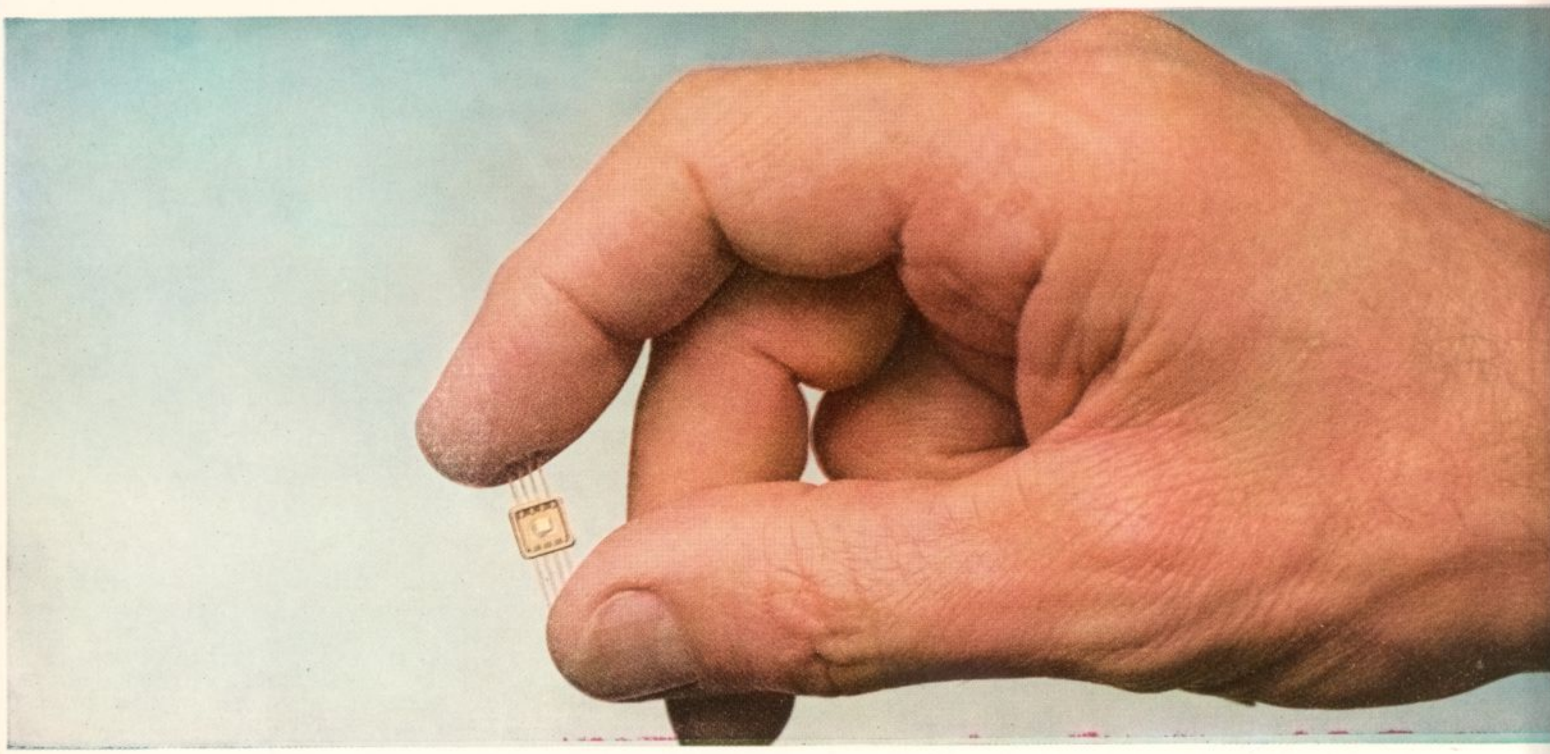
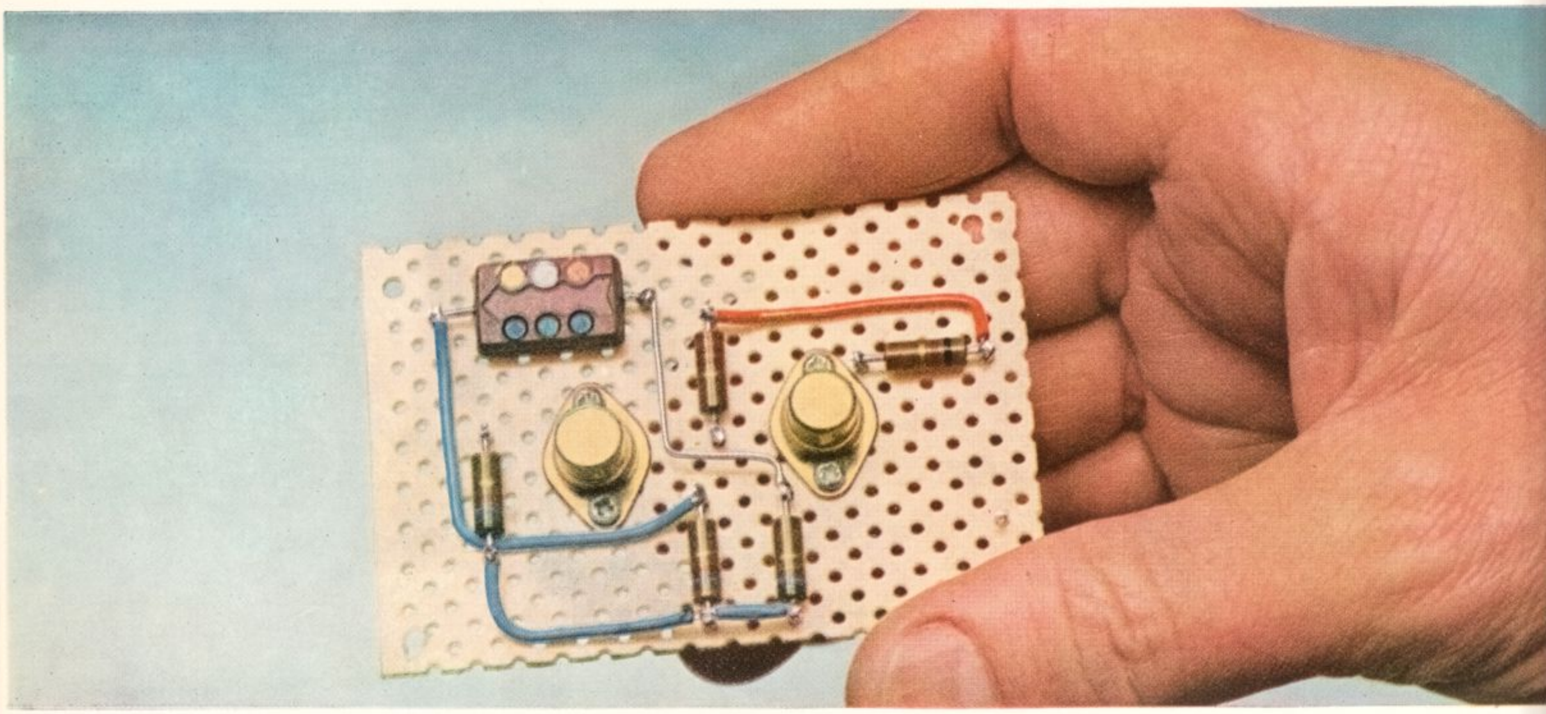
Purdue Engineer

February 1964 35c





This tiny device is an ultra-reliable Westinghouse TV amplifier



It can replace all these wires and electronic parts

"With fewer parts and connections," Westinghouse scientists decided, "we'd have a much more reliable amplifier."

So they developed a new kind, using techniques called "molecular electronics." The device is a functional electronic block, one quarter-inch square. (That's the capsule. Actually, the electronics are on a bit of specially-treated silicon the size of a chip diamond.)

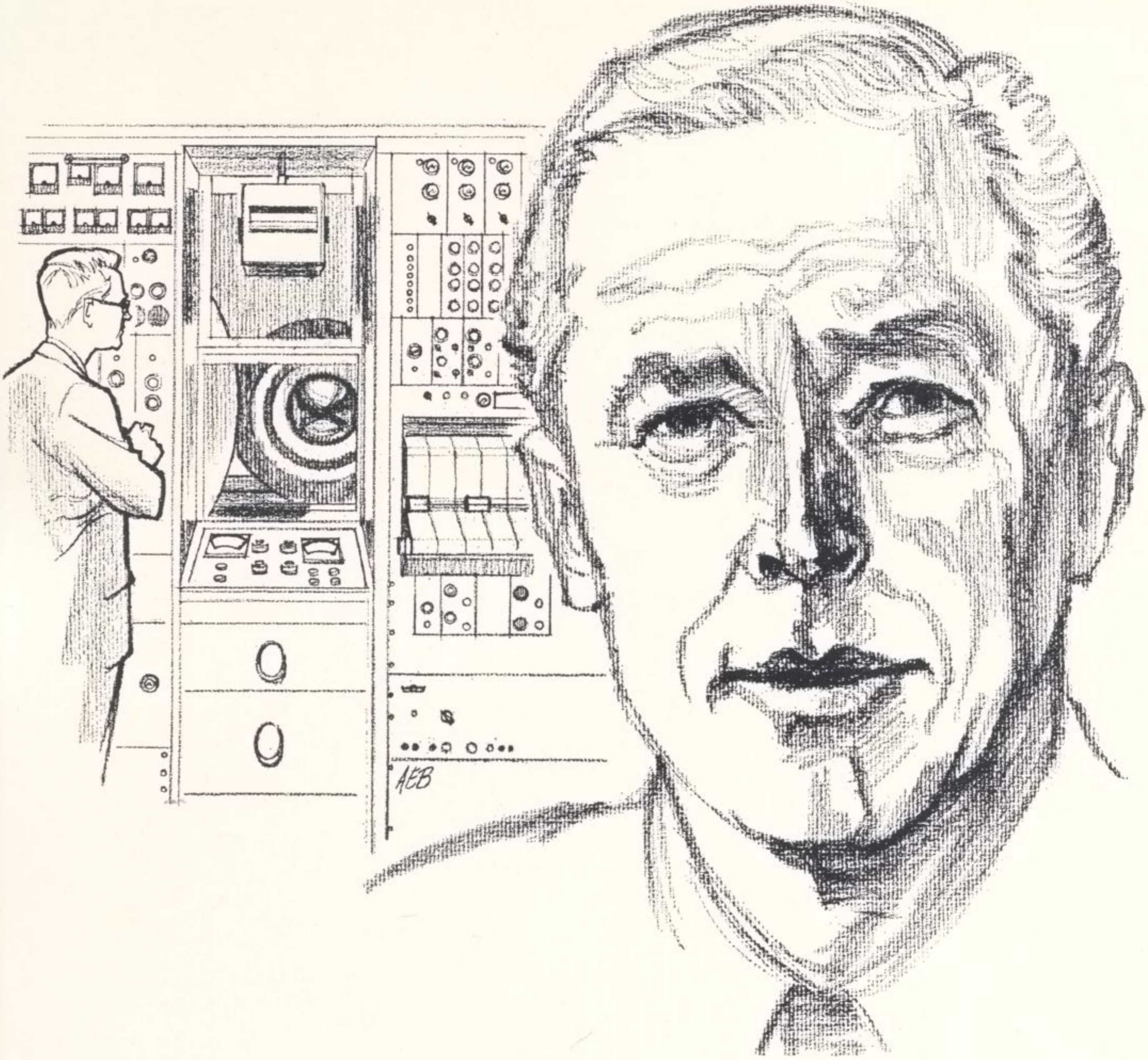
Other Westinghouse functional electronic blocks are just as small. They're used in experimental products like a pocket-size TV camera and a radio receiver that's half an inch square and an inch long.

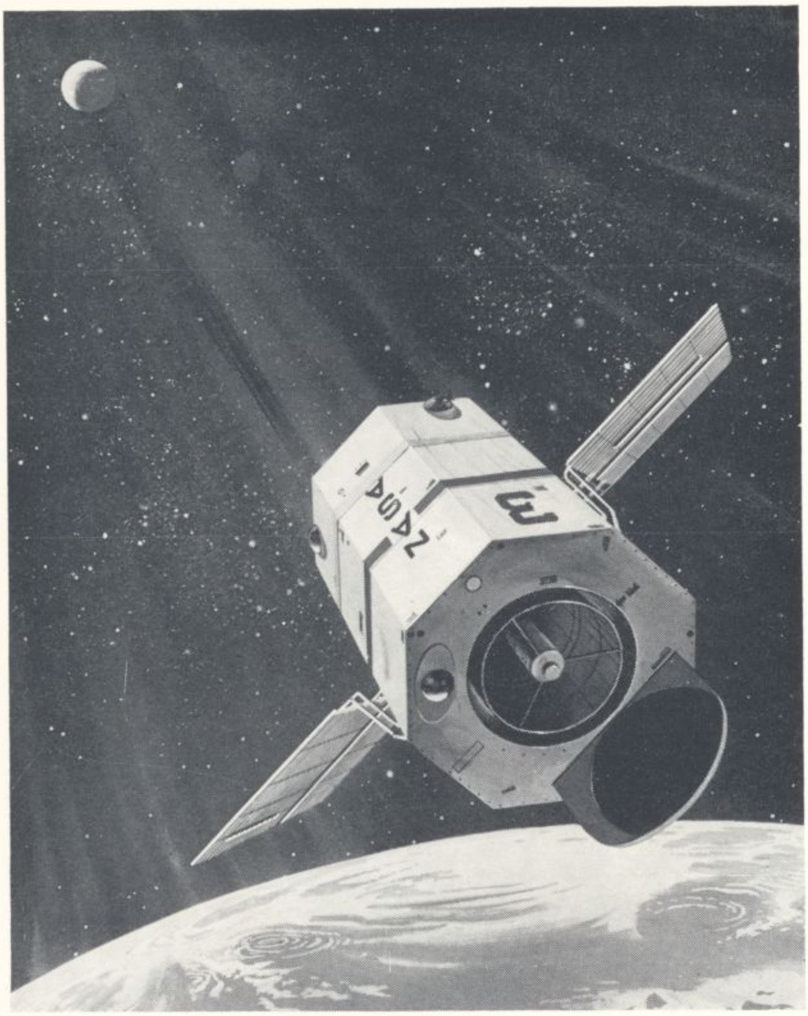
Today, Westinghouse makes these ultra-reliable little devices mostly for military applications.

One day, you'll find them in electronic products everywhere.

You can be sure . . . if it's Westinghouse.

For information on a career at Westinghouse, an equal opportunity employer, write to L. H. Noggle, Westinghouse Educational Department, Pittsburgh 21, Pa.


AEB



This artist's conception illustrates NASA's Orbiting Astrophysical Observatory (OAO) in orbit about the earth with its instruments trained on a distant object. The satellite is now undergoing extensive system design, performance, durability, and environmental testing at General Electric's Valley Forge Space Center. The extensive and constantly expanding facilities of this space center enable the conditions of space to be simulated to within a fraction of actual conditions.

MEMBER OF ENGINEERING COLLEGE MAGAZINES ASSOCIATED

National Advertising Representative:
Littell-Murray-Barnhill, Inc.
369 Lexington Ave.
New York 17, N. Y.

ECMA Chairman:
J. Gale Chumley
Louisiana Polytechnic Institute
Ruston, Louisiana

Printer:
Lafayette Printing Co.
Lafayette, Indiana

Engraver:
Clear Cut Engraving Co.
Lafayette, Indiana

FEBRUARY 1964

VOLUME 60 NUMBER 5

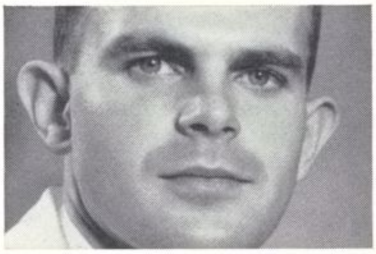
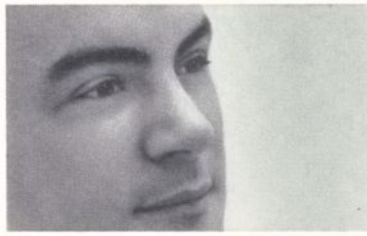
Purdue Engineer

Departments

Cover:

Drawn by James F. Nicolaus

Published monthly from October through May by engineering students at Purdue University, Lafayette, Indiana. Second class postage paid at Lafayette, Indiana, under the Act of March 3, 1879. Subscription rate $2.00 per year (eight issues) if mailed in United States; foreign $3.00 per year; single copies, 35 cents each. Advertising rates available upon request. Business and editorial offices located in Room 14, Memorial Center, West Lafayette, Indiana.



THIS MONTH

At Purdue, Editorial, Books, 50 Years Ago, and Contributors

THE ever increasing academic requirements placed on college students have forced most organized college extra-curricular activities and social groups to curtail many of their time-consuming functions. Students have less and less time for non-academic pursuits. Evidence of this can be seen in diminishing participation in campus activities and reduced pledge programs in social fraternities. Engineering students, already burdened with a very heavy academic load, are especially feeling the pinch on their scarce free time.

The organizations that should be leading the trend toward taking less of the students' time are our academic honorary fraternities. Surely, the members in these groups are the ones who fully appreciate the importance of time and its efficient use. It is my proposition, however, that not only have our engineering honoraries at Purdue failed to lead this trend, they are falling far behind in taking steps to adjust themselves to the changing situation. Indeed, in many cases, they are moving in the opposite direction.

Extra time is taken needlessly, I feel, by many honoraries. As an example, one can cite the Eta Kappa Nu and Tau Beta Pi essays. Even required attendance at the meetings of some honoraries is certainly not necessary. Approaching ridiculousness is the requirement that pledges learn the names of their "pledge brothers" in the large Tau Beta Pi classes.

This, of course, raises the question of the exact purpose of scholastic honoraries. Does the organization provide not only recognition, but also a place for seminars, an atmosphere for "brotherhood," and an educational experience? I think not. These areas are all adequately covered by institutions at the University which deal specifically with them and the repetition is wasteful. The purpose of an academic honorary should be primarily to recognize scholastic achievement and extra non-essential activities should not be undertaken.

The problem, I feel, arises as a result of two factors. The first is the influence of tradition in the pledge programs. Tradition which will not adapt to the situation has no place in the programs of these groups. The idea that, "I did it as a pledge, so he should too," is absurd. Secondly, too many officers of scholastic honoraries have placed their allegiance to that group above that of any other affiliation they may have and expect others to do the same. I do not object to the man who makes a scholastic honorary his major activity, indeed we need these people to run the organization, but I ask that they not try to force this attitude on every member.

The time for re-evaluation is the present. Only the members of these organizations can make sure that future pledge classes and actives will not waste valuable time participating in valueless functions.

—*R. D. Hostetler*

At Purdue

IN A WAY, the problem almost seems paradoxical.

In underground atomic testing—now of greatly increased importance—there is need to transmit a lot of information in a short time. The objective of a test, of course, is to develop as much new data as possible. But the data has to be gotten out—carried several thousand feet away from the explosion site—in the brief interval before much of the instrumentation volatilized by the blast.

Coaxial cable meets the need under ordinary circumstances—over a relatively narrow frequency band. A TV channel, for example, has a band width of only six megacycles—no problem there.

But data transmission in underground atomic testing is another matter.

To send a mass of information in a short time, pulse type signals—short and sharp—must be used. But pulse signals require a very wide frequency band for undistorted transmission—1,000 megacycles instead of TV's six.

The solution to the problem lies in the direction of using thinner wire and thinner shield. That's because of a phenomenon called the "skin effect," which amounts to this:

In a coaxial line, as frequency increases, current tends to bunch toward the outer surfaces or skins of the conductors. Thus, for transmitting high frequency current, a thin hollow wire can serve as well as a thick solid one. Moreover, as the frequency gets lower, the current is more equally distributed—and if the wire is thin and hollow, the low frequency current will be forced to the surface, too. The result: a near-equalization of low and high frequency behavior, a near-constant behavior of all frequencies over a wide band.

But very thin conductors present mechanical difficulties—problems of easy breakage both in manufacture and use.

In their effort to surmount these difficulties, Evans and his co-workers have departed from an assumption prevalent in the past: that all of the structure of a cable, except for the shell and wire, must consist of some type of perfect insulator.

Their novel approach: part of the remainder of the structure can be metal—a metal that can be used to back up the conducting metal firmly.

They have determined that it is possible to have a shell close to film thickness—about 0.003 inch—if it is backed by another metal that could be 100 times as thick.

And that the inner conductor, instead of being solid wire, could be very thin, hollow wire with a firm reinforcing core of another metal.

They have determined that the other metal that would thus turn a coaxial cable into a two-shelled—inner and outer skin—carrier could be a magnetic one such as iron, steel, or an alloy of steel. And they have calculated that while it would conduct some current, the amount would be so much less than that carried by the copper, silver or aluminum conductors that the electrical effect would be negligible.

The design, proposed as a possible solution to the problem of transmitting greater amounts of atomic explosion

data so each test could become more meaningful, may be applicable as well for other broad band data transmission, including computer-to-computer "talk."

The year-long research of the Evans group has been under the sponsorship of an Atomic Energy Commission subcontractor.

Now continuing their work, Evans and his chief associate—Lawrence Whicker—believe they may be close to establishing a general criterion for design to achieve better transmission of any desired frequency band, a criterion which would allow an engineer, given the band, to quickly choose the right backing and cable construction.

—*Backgrounder from Purdue*

IS IT REALLY true that students and faculty differ greatly in values and attitudes? What personality factors influence student grades? And do informational tests actually measure only information?

These are among questions being explored by Prof. A. N. Emery of the School of Chemical Engineering in a study aimed at applying psychological and social principles and measurements to engineering education. The study is beginning to produce provocative insights—and challenges.

Starting with what, on the surface, seemed like a clear enough "fact of life"—that students and professors differ substantially in values (witness frequent student gripes about assignments, exams, teachers, teaching methods)—Emery came across the unexpected as soon as he probed to see how deep the differences went. He drew up a test, gave it to a group of students and to a group of faculty members as well. Each was asked to rate 26 different concepts ranging from "mother" and "sin" to examinations (closed book, open, and take-home) and problems (exact, trial and error, fuzzy).

The rating was done on a semantic differential scale developed by Prof. Charles Osgood of the University of Illinois—a bipolar scale with opposite values at the ends ("good" and "bad" for example) and a series of values in between.

Right down the line, remarkably little difference could be found between student and faculty opinions. "Science," "research," "engineering," "mother," and the "U.S.A.," were the most highly rated concepts, and by students and faculty alike.

It was no surprise to have faculty members rate cheating on examinations more highly negative than sin; but so did students. For "fuzzy"—and therefore, more challenging—problems to be preferred over exact types by faculty might have been expected; but they were also distinctly preferred by students.

Samples in the study thus far have been small, and broad generalizations are not in order. But a few conclusions, Emery feels, now seem valid:

- Students think highly of their chosen profession and also of the activities involved in it—and if occasional resistance in class suggests that this is not the case, such resistance comes from personality clashes between students and staff rather than lack of interest in the goal of education;
- If it sometimes appears that students are seeking only to perform the least amount of labor in order to acquire a degree that will admit them to high-paying jobs, the results belie this; they appreciate the value of some of the harder tasks:
- Students have many values remarkably like those of faculty. Why? "Staff members transmit their values, at least in technical and educational realms, whether they want to or not. The fact that this happens reflects a more interesting situation—that students feel sufficient agreement with faculty aims to be influenced. There is not a condition of sullen resentment, but rather a high degree of cooperation between the two groups."

In another phase of his research, Professor Emery is trying to see whether a psychological tool, factor analysis, can be used to make "educated estimates" of aspects of personality which influence student grades.

In factor analysis, correlation coefficients are calculated between student grades on various tests and factors which may have influenced the grades. An attempt is then made to find a small set of factors which correlate closely with grades.

In all analyses, imagination has turned up as a positive in determining whether a student gets good grades. Other positive factors have not shown up with regularity but several—skill with mathematical abstractions and attention to detail, for example—have cropped up occasionally.

Interestingly enough, nothing yet has appeared that could be called a general intelligence factor. And the only factor with negative correlation is group allegiance—a tendency to go along with what the group thinks and does.

Hopefully, there could be another dividend from such studies: clarification of any criteria currently being used, unknowingly, to judge students.

"The fact is," says Professor Emery, "that quizzes and exams are not purely informational tests. They elicit responses that may be determined as much by personality factors as factual knowledge. We ought to find out about this so that, hopefully, we can design better tests—using criteria that make more sense."

—*Backgrounder from Purdue*

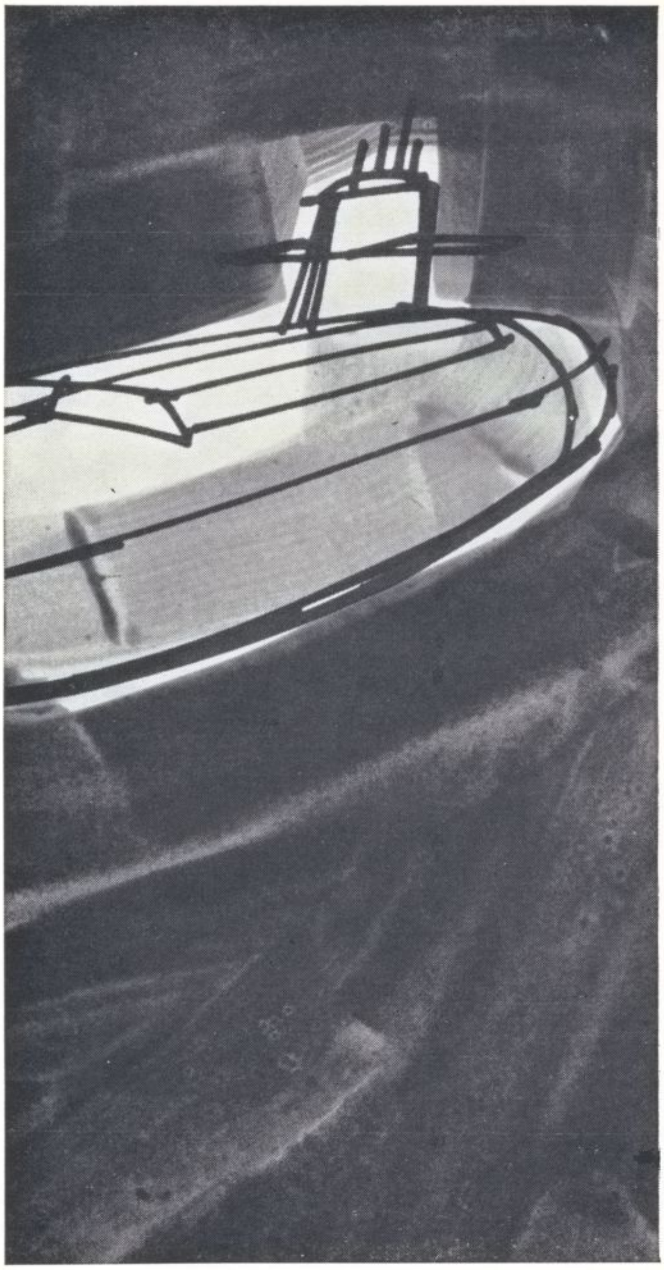
Fifty Years Ago

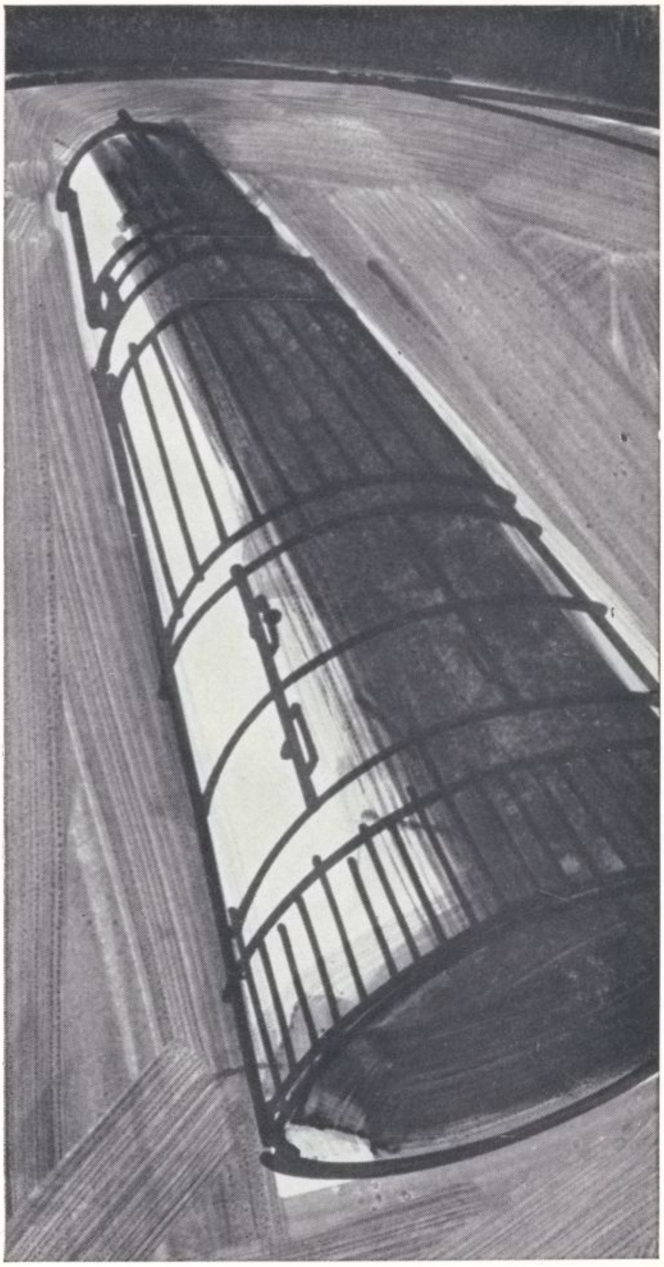
IN 1914, the factors affecting the maintenance of Indiana highways were as crucial to the economy of the state as they are today. For this reason Assistant Professor George E. Martin of the Purdue Civil Engineering School presented a bulletin on the maintenance of highways primarily for those concerned with future construction or repair of highways, fifty years ago.

Highlights of that bulletin are presented here to illustrate the problems of 1914.

The tendency of the traveling public to always drive in the same track greatly decreases the life of the roads and increases the cost of maintenance. It is well understood that many of the roads in this state are no narrow that it is almost necessary to drive in one track. However these roads are being widened as rapidly as possible. Even on the wider roads there is often one track down the center and the remainder of the improved surface lies idle. Almost any pavement, except brick or concrete, will be cut into ruts and rapidly destroyed by the action of wheels and horses concentrated on a few feet of the available road surface.

The automobile has greatly increased the amount of road maintenance necessary. However the advent of the motor driven vehicle has been the direct cause of greatly increased interest in road problems. It is a means of transportation which is here to stay and which must be taken care of in the future.





Several counties have built too many miles of road for funds available. The result has been some very defective construction and a greatly increased amount of maintenance because of this.

In many counties sufficient money is not appropriated to keep the roads in good shape. The amount of money per mile of road per year necessary for maintenance will vary with local conditions. Amount and kind of traffic, quality and proximity of surfacing material, grade and drainage of the road are the main factors in this determination. The average amount appropriated in Indiana is $68.50 per mile at the present time. Money received from the automobile tax will slightly increase this amount. This is lower than the actual cost in those states where accurate accounts of this matter are kept. Where the levy is too low it is not possible to do efficient work, *because the money is spread out too thin.* The operations carried on are often necessarily of a *temporary* nature and because of this much of the work *must be repeated each year.* If the levy could be increased for a time until the roads were gotten in good shape, it might then be reduced to a lower figure and the roads efficiently maintained. An appropriation for repairs would give the same result.

The maintenance of any type of road requires constant attention. It is not always the amount of work that has been done, but rather the time when it was done, and the way in which it has been carried out, that determines whether the road is well maintained or not. The public must be educated to the fact that *there is no perfect road surface. All of them,* no matter how built, or of what material, *require maintenance.* This work must begin, in most cases, as soon as the road is built and be carried out thoroughly. Proper and regular attention to the roads at the right time will do much to improve the condition of the highways in Indiana.

—*Al Hribar*

Books

ENERGY DOES MATTER, by Werner Emmerich, Milton Gottlieb, Carl Helstrom, and William Stewart, Walker and Company, Publishers, March 1964, 256 pages, $5.95.

The second volume in the Westinghouse Search Books series deals with matter and energy and the relationship between them in accordance with established principles of physics and mathematics. The subject matter for ENERGY DOES MATTER is an appropriate choice for the second book in the series as all branches of science deal with energy in one form or another. Hence, an understanding of energy is fundamental to an understanding of science.

Dr. Emmerich introduces the book in this provocative manner: "If we were to convert the mass of a copper penny entirely into energy, we could drive the ocean liner Queen Mary clear around the world at top speed. This is a prediction of the theory of relativity . . . Nobody has succeeded in performing this particular trick with a penny, and we don't even know if it is feasible. But it is one example in which the nature of energy is revealed to us through one of the most famous equations in science—$E = Mc^2$."

Such an introduction raises the question, "What is energy all about?" Dr. Gottlieb, the physicist, tells what he thinks it is all about in his discussion of mechanics, heat, light, sound, magnetism, and electricity. He gives a rational explanation of natural phenomena such as: conservation of energy, laws of thermodynamics, Carnot cycle, Coulomb's law, Ohm's law, Faraday's law, electromagnetic spectrum, quantum theory, black body radiation, energy conversion, and thereafter, quickly brings the subject into proper perspective. Through his description of energy, the reader learns how the scientist encounters energy in the laboratory and how it is encountered on the earth and in the universe. His review of the rudimentary ideas is deliberate; this gives him the basis for presenting more abstract concepts, more advanced ideas. He leaves little doubt that energy controlled is beneficial and benevolent; whereas, energy uncontrolled is terrifying to contemplate.

Such matters are not the concern of the mathematician beyond the fact that they make it possible for him to relate his abstract discussion of the mathematics of energy to a concrete base. And, Dr. Helstrom—the mathematician—does just this as he brings within the grasp of the uninitiated layman such complicated themes as the special theory of relativity and quantum mechanics, which ". . . have brought about a revolution in the world of physics which has affected its very foundation."

The person who puts theory to work —the engineer—writes the concluding chapters in this book. Dr. Stewart, who looks at economics as well as engineering, tells how theory is applied to develop more efficient machines for converting energy into useful forms. He analyzes the full spectrum of energy sources, to find out which can serve man most economically through the years. He describes known reserves or supplies of energy, outlines current projects for converting this energy into a useful form, and then speculates a bit about exotic methods of energy conversion. He also speculates about the ultimate supply of energy needed to maintain life as we know it. And, like the true scientist he is, he ends on a realistic, but hopeful, note; a note of challenge—science and technology will, and must, anticipate energy demands and figure practical ways to supply them.

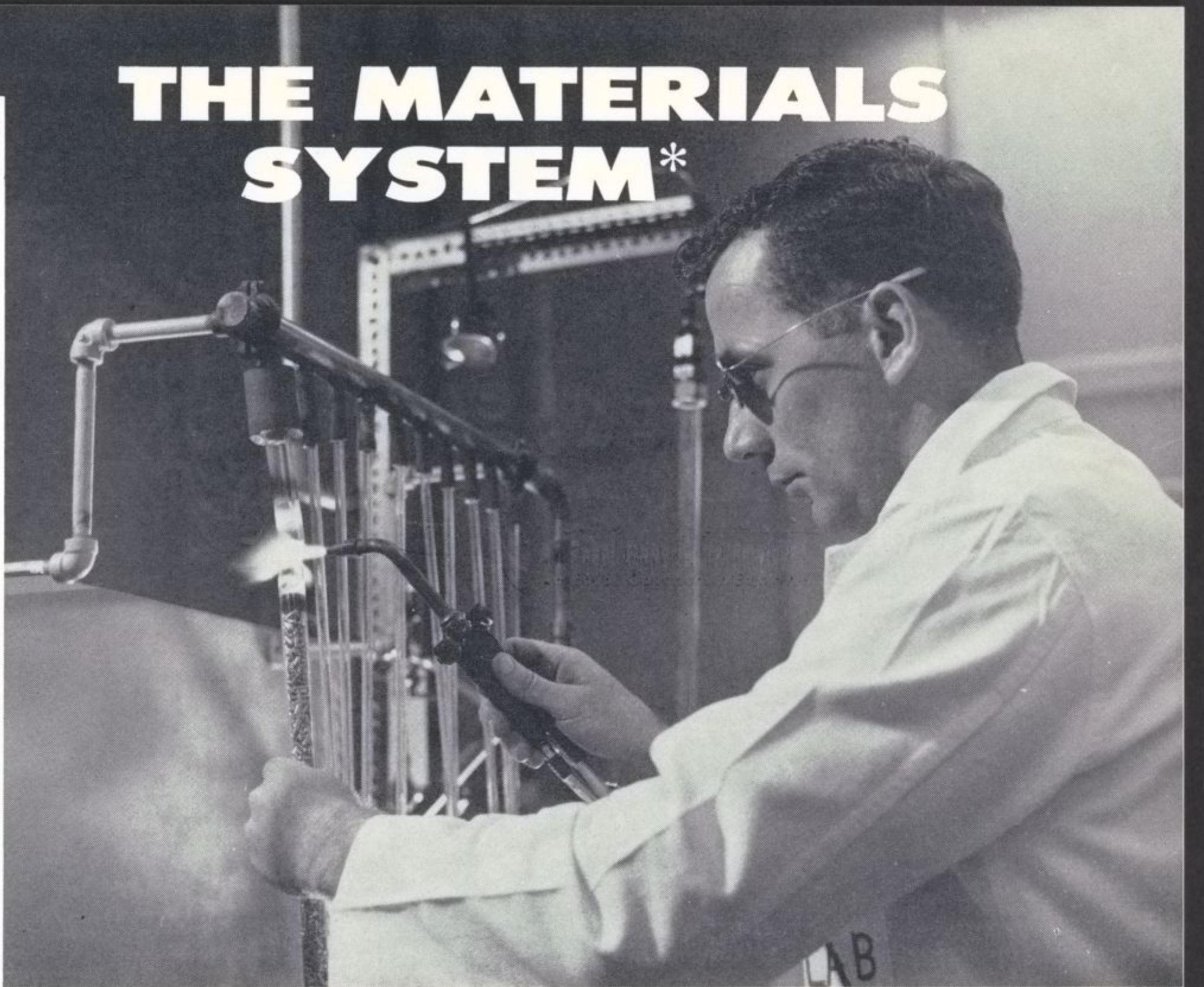
Contributors

AL HRIBAR ("Problems in Fusion") radiates with enthusiasm as evident by this, his fifth article contribution to the *Engineer* ("Surveyor," Feb. 1963, "MA-9," March 1963, "Comfort Engineering," Oct. 1963, and "Boeing's New 727," Jan. 1964). Al also serves on the *Engineer* staff as Copy Editor. A member of Theta Tau fraternity, he is also a member of Pi Tau Sigma and Tau Beta Pi honoraries.

Ken Bower ("Origin of the Universe") makes his second contribution to the *Engineer* this month ("Spirit of Relativity," Nov. 1963). Although basically a down to earth person, an interest in astronomy led Ken to write this article. He is a member of Eta Kappa Nu, Phi Eta Sigma and lives at H-3.

Jack Lienesch ("Tube Testing with Eddy Currents") hard worker and managing editor of the *Engineer*, has been a frequent contributor ("New Concepts in Steam Generation," Oct. 1963 and "Rendezvous with the Morning Star," Dec. 1962). Jack is an ME-7 in the pre-grad option, a member of Tau Beta Pi and Pi Tau Sigma and Phi Kappa Tau social fraternity. ■

AIRWAYS CONTROL
ALLOYING
AUTOMATION
AVIONIC SWITCHING
BONDED METALS
CAPACITORS
CERAMICS
CIRCUITRY
CLAD METALS
COMMUNICATIONS
COMPONENTS
COMPUTER ELEMENTS & PROGRAMMING
CONTROLLED RECTIFIERS
CONTROLS
CRYOGENICS
CRYSTAL GROWTH
CYBERNETICS
DATA HANDLING
DEVICE DEVELOPMENT
DIELECTRICS
DIFFUSION
DIODES
ELASTIC WAVE PROPAGATION
ELECTROCHEMISTRY
ELECTROLUMINESCENCE
ELECTROMECHANICAL PACKAGING
ELECTROMECHANICS
ELECTRO-OPTICS
ELECTROTHERMICS
ELECTRON PHYSICS
ENERGY CONVERSION
ENVIRONMENTAL & QUALIFICATION TESTING
FERROMAGNETICS
GEODETIC SURVEYS
GEOMAGNETICS
GEOPHYSICAL EXPLORATION
GEOSCIENCES
GLASS TECHNOLOGY
GRAVIMETRY
INDUSTRIAL ENGINEERING
INFRARED PHENOMENA
INSTRUMENTATION
INTEGRATED CIRCUITS
INTERCOMMUNICATIONS
LASER PHENOMENA
MAGNETIC DETECTION
MECHANIZATION
METALLURGY
METER MOVEMENTS
MICROWAVES
MISSILE & ANTIMISSILE ELECTRONICS
NAVIGATION ELECTRONICS
NUCLEAR FUEL ELEMENTS
OCEANOGRAPHY
OPERATIONS RESEARCH & ANALYSIS
OPTICS
PHOTOVOLTAIC DEVICES
PHYSICAL CHEMISTRY
PHYSICS
PIEZOELECTRICS
PLASMA THEORY
PLATING
QUALITY CONTROL
QUANTUM ELECTRONICS
RADAR
RARE EARTHS
RECONNAISSANCE
RECTIFIERS
REFRACTORY MATERIALS
RELIABILITY
RESEARCH & DEVELOPMENT
RESISTORS
SEISMOLOGY
SEMICONDUCTORS
SOLAR CELLS
SOLID STATE DEVICES
SOLID STATE DIFFUSION
SONAR
SOUND PROPAGATION
SPACE ELECTRONICS
SUPERCONDUCTIVITY
SURVEILLANCE SYSTEMS
TELEMETRY
THERMOELECTRICITY
THERMOSTATIC DEVICES
TRANSDUCERS
TRANSISTORS
UNDERSEA WARFARE



COMPOSITE MATERIALS Emphasize Broad Spectrum of TI Professional Opportunities

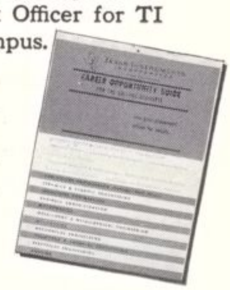
Texas Instruments employs metallurgists, metallurgical and mechanical engineers, ceramists, and other professionals for process engineering, product development and technical marketing in the area of THE MATERIALS SYSTEM* — metal, alloy, cermet, or ceramic. TI capabilities with solid materials extend from growing semiconductor crystals and alloying metals through processing of finished composite metal forms, parts and sub-assemblies.

Texas Instruments is a multidivisional company requiring professionals at all degree levels. The Materials & Controls division is recognized internationally for its ability to produce NEW materials *with a combination of characters not available in existing materials.*

Creation of composite materials provides fascinating and important careers in at least four of TI's 89 professional fields listed at left.

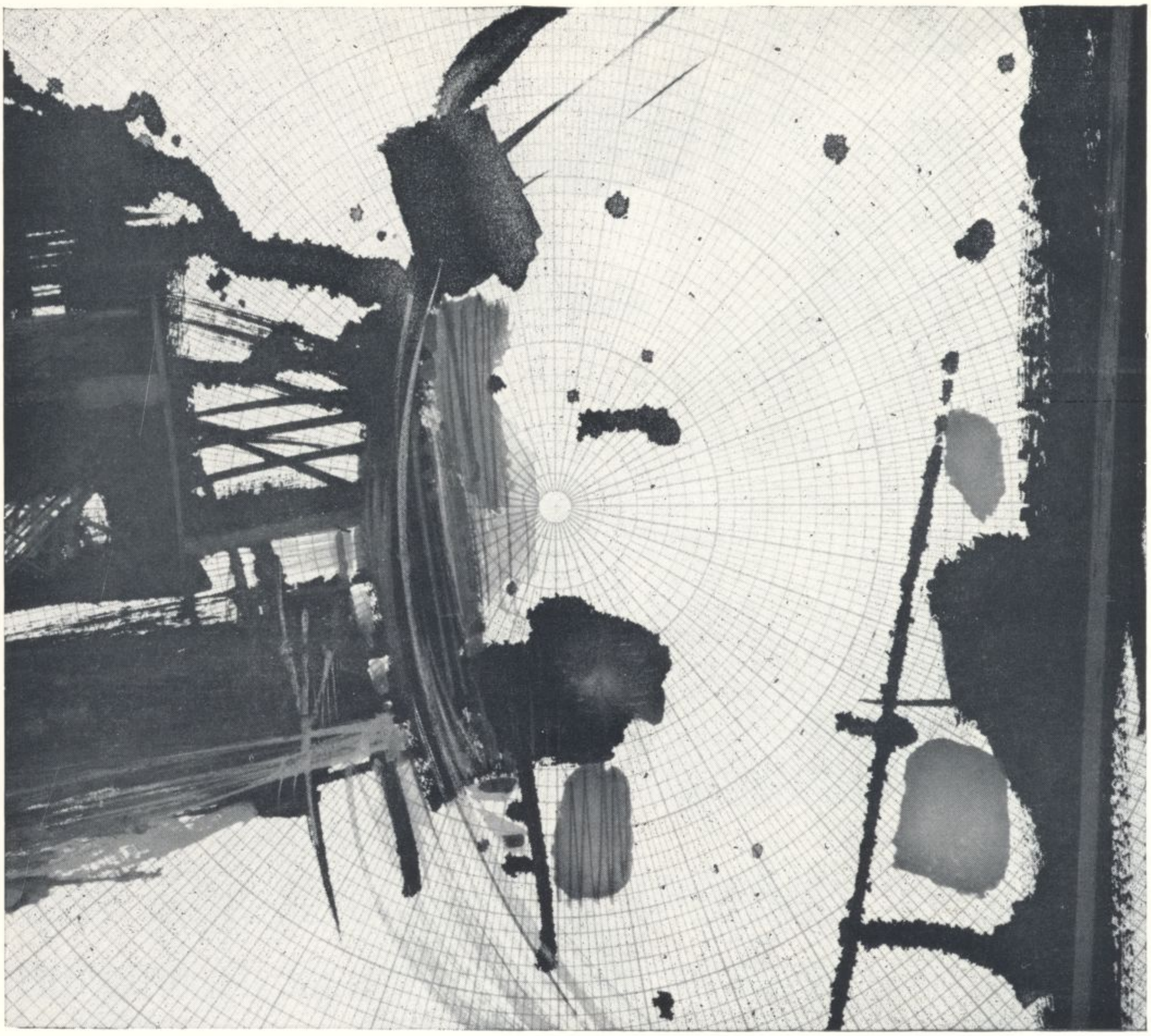
INVESTIGATE TI OPPORTUNITIES by submitting your resume, or sending for "Career Opportunity Guide for the College Graduate," to Mr. T. H. Dudley, Dept. C-30. Ask your College Placement Officer for TI interview dates on your campus.

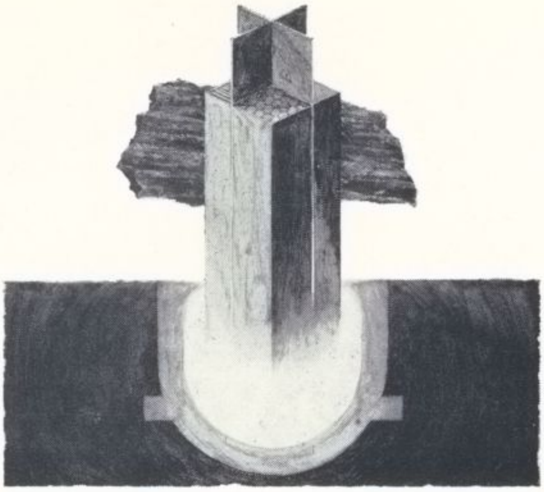
*The integration of two or more materials resulting in a new material with a set of useful properties not otherwise available.

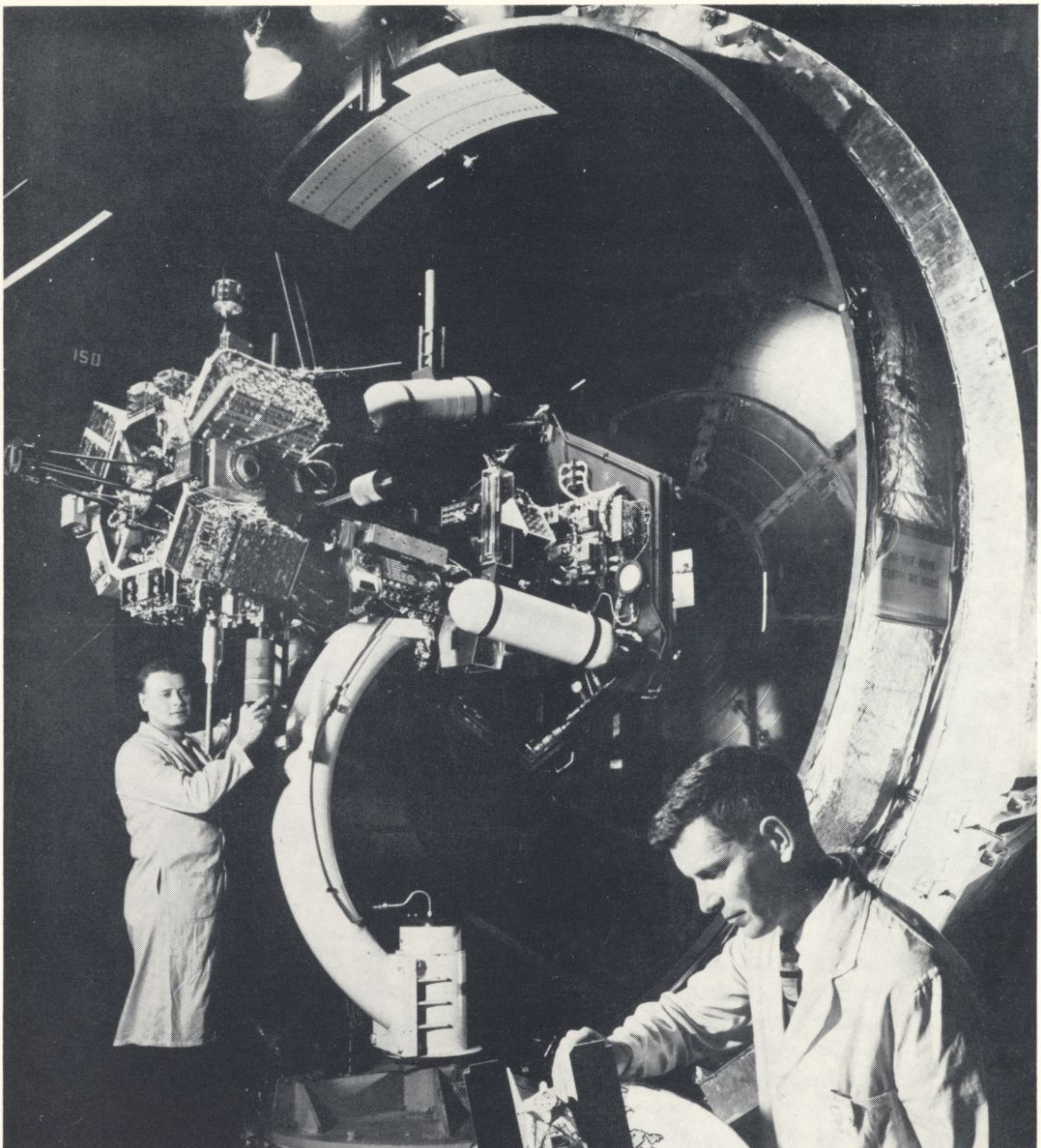


TEXAS INSTRUMENTS
INCORPORATED
P. O. BOX 5474 • DALLAS 22, TEXAS

An Equal Opportunity Employer







SPACE SIMULATION

By David Werstler, METE '65

WHEN WE THINK of the great space efforts of our country, our thoughts are about the dramatic launchings from Cape Kennedy and the Vandenburg Base in California, of manned satellites and Polaris missiles. Rarely do we consider the great amount of work that is done on the ground to develop and test the vehicles before they are finally ready for the launching pad. Besides government laboratories, there are several industrially-operated complexes of space research and development, where, in their honeycomb of laboratories, engineers and scientists are trying to solve some of the most complex technological problems faced by man. The largest of these is the General Electric Valley Forge Space Technology Center.

The General Electric facility is just a few blocks from the Valley Forge campground of the Revolutionary War. It is an 800,000 square foot facility whose principal purpose is "the terrestial testing of spacecraft parts and systems before exposure to the hostile outer-space environment the vehicles will encounter in actual flight." The actual space vehicles are tested here for periods up to a year or more under almost real space conditons. The testing is not all done at one time, but rather there are several labs which test a certain desired function for perhaps three or four consecutive months. The following paragraphs are a description of several of these facilities and their capabilities.

The Space Simulation Chamber resembles a cylinder with a dome-shaped top and bottom. Located in a building, 100 feet square and 88 feet tall, the chamber measures 32 feet in diameter, 54 feet in height, and weighs 80 tons. The building houses only that portion of the auxiliary equipment which must be protected. Storage tanks, cooling tower, and several pieces of pumping equipment are located adjacent to the facility.

In the foreground, a scientist working on the problems of space vehicle reliability, watches a small model of the Nimbus weather satellite. It illustrates the flight of the full scale model which peers into a metal half shell approximating the earth's horizon.

Constructed of stainless steel, the chamber's panels can resist pressure up to one ton on every square foot of surface. The thickness of the steel is a minimum of ¾ inches with no stiffening members required.

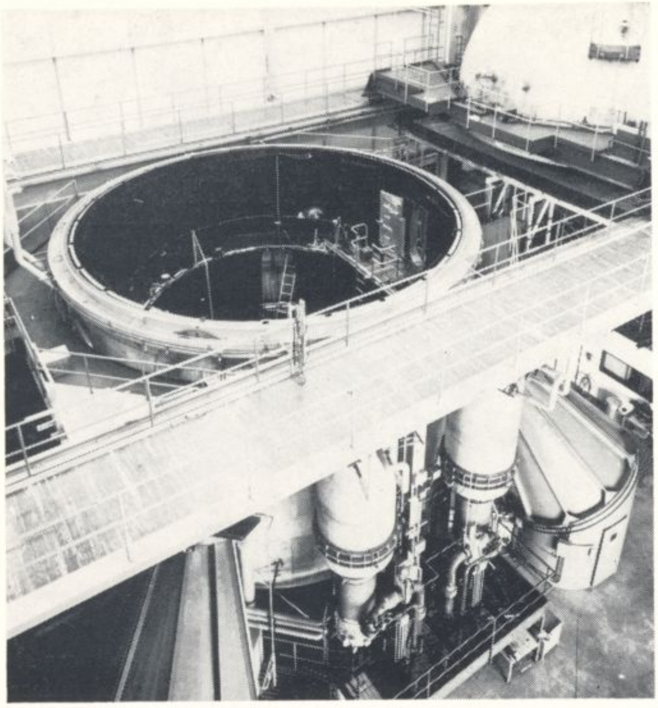
The dome-shaped lid is provided with a trolley and mechanical jacking system allowing it to be raised from the chamber and moved aside. When open, the vessel accommodates a vehicle access area of twenty feet in diameter. The dome also contains the parabolic reflectors used in solar simulation and three penetrations are provided to incorporate television cameras for visual monitoring of the vehicles during test.

To achieve extremely low pressures, a method known as cryogenic pumping is employed. Essentially, this method freezes the gas thereby removing it from the environment in its original state and depositing it as a solid on the cooling panel. The cryogenic pumping uses two separate systems of cooling panels through which liquid nitrogen and dense, gaseous helium are circulated. Nitrogen panels cover the majority of the chamber's interior maintaining this area at minus 300 degrees Fahrenheit.

Another environmental condition unique to outer space is referred to as "cold black space." This term describes the ability of space to absorb limitless quantities of energy; forms such as heat and light are of major consideration in the simulator's design.

When a spacecraft is subjected to extremely low pressures, as experienced in outer space, heat and gaseous molecules are radiated from the vehicle. In space, these particles travel through infinite distances and are harmless to surrounding objects. In a simulated environment, as the space chamber, this "outgassing" phenomenon poses a problem. In the vessel's enclosed area, the molecules are reflected back to the vehicle under test raising the pressure above the desired level.

To combat this problem, a scientist discovered that if angular fins were placed along the inner edge of the chamber, saw-tooth fashion, the molecules would be trapped between the plates allowing the moving particles to harmlessly "bounce" within the panels until their energy had been dissipated. This method, dealing with the outgassing phenomenon, is called the the Santeler Array. It feigns the limitless depths of space providing an even greater simulation effect.



The Space Simulation Chamber, pictured above, is able to reproduce solar conditions by means of parabolic reflectors located in the dome-shaped lid. The minimum pressure reaches 100° K.

The temperature of space may be as low as 3 degrees Kelvin, above absolute zero, and any vehicle entering such an environment is subjected to the low temperature extreme—the cold space. To simulate cold, black space, the interior surfaces of the Simulator must be maintained at an extremely low temperature. The temperature of the walls approaches that of outer space and permits absorption of heat and light energy at a high rate. To produce the desired effect the chamber's inner sides are treated to produce an extremely dense, flat, black finish.

The principal feature of the facility is its Solar Simulation System. The amount, character and direction of the solar energy must closely match that of actual conditions. Four enclosures on the ground floor of the Simulator's building provide housing for the water and air cooled power arrays.

Four banks, each containing thirty-seven 5,000-watt xenon-arc lamps provide the light energy. Each lamp is individually mounted and has its own power supply facilitating calibration and focusing. The intensity of the total array is adjustable permitting various solar energy level effects. The light energy is directed through a quartz lens, about 15 inches in diameter and 3 inches thick, onto one mirror divided into four parabolic reflectors which collimate the light producing light rays appearing to originate from a single source. This type of solar simulation has been referred to as "cold black sun."

Still in the planning stages, is an access port designed to permit entry of several technicians during operation of the simulator. The opening, on the chamber's side, will be equipped with an airlock in which there are two compartments. The astronaut enters the first compartment and waits until the atmosphere is reduced to an intermediate level. This level is well below atmospheric but far from the vacuum level in the chamber. The technician then moves into the second compartment immediately adjacent to the chamber; here the pressure is further reduced to equal the chamber's level before entering the actual vessel.

The ability to simulate a combination of solar, pressure, and temperature conditions makes the Space Environment Simulation Laboratory unmatched in existing or known planned space simulators. The facility allows entire space vehicles to be subjected to several realistic space conditions before actual flights are performed.

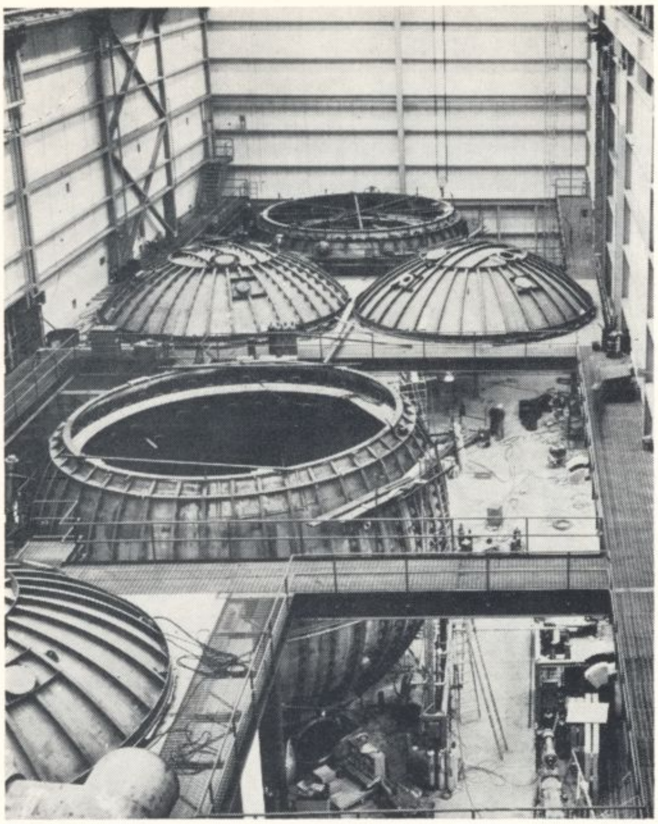
THE SPACE ENVIRONMENTAL TEST FACILITY is designed to duplicate, as closely as possible, almost all of the actual environmental conditions to which spacecraft will be exposed.

Complete systems tests can be run in the space simulator just as though the vehicle were in orbit. Ground equipment can be checked out from interpretation of telemetric signals transmitted to and from the test specimen. Maneuvers made by the attitude control system of the vehicle upon receipt of telemetric commands from an external "ground station" can be observed either by closed circuit TV or through a test specimen replica which is mounted externally and "slaved" to the attitude of the actual test vehicle. Movements of the test vehicle are recorded by hermetically-sealed motion picture on Fastex cameras which are placed within the chamber.

The environmental chambers, a basic part of the Space Environmental Test Facility, are designed to subject the subsystems and complete vehicle systems to extremely high vacuum and solar thermal simulation environments during the development, acceptance, and certification/qualification stages of the spacecraft cycle. The more extensive and sophisticated research developmental test programs will be generally conducted in the adjacent Space Environmental Simulation Laboratory. The SETF chambers also provide a capability for running basic engineering tests where solar simulation is not a requirement. In such an engineering test, of which a thermal balance test is an example, a complete vehicle is put into a simulated space flight and instrumentation is attached to record the actual conditions experienced by the various components and sub-systems operating as an integrated test system. The environmental data obtained supplements and confirms the theoretical data and assumptions used by the research scientists in the design of subsequent spacecraft assemblies. The data may also be compared with information obtained in experiments with solar simulation.

Should the test readout instrumentation indicate a need for the change of a component or sub-system during the test, the vehicle may be "returned from orbit" and the required modification implemented. The result of this modification can then be subjected to the same simulated space environment and checked to verify the validity of the change.

The SETF is a separate building designed and constructed specifically to meet the demands of utility and flexibility required for the environmental testing of full-scale spacecraft systems. Within this building are housed three environmental chambers measuring 39′ in diameter in addition to a 12′ x 26′ horizontally-oriented chamber. The building is 240′ long, 100′ wide and 82′ high and houses the chambers and that portion of the auxiliary chamber support equipment which must be protected from the elements. Liquid nitrogen storage tanks, process cooling water tanks, gaseous helium storage and primary transformers are located adjacent to the facility. Within the building adequate space is available for test setups along with required supporting control room and office areas.



Illustrated above is the Space Environmental Test Facility. It was designed to meet the demands of utility and flexibility required for the environmental testing of space craft systems.

The areas used for test setup are enclosed and air conditioned. For some tests it may be desirable to bring the vehicle into the setup area and complete the installation and checkout of test instrumentation before attaching the vehicle to the 30′ chamber cover. At the completion of the checkout phase the cover, with attached vehicle and instrumentation, will be lifted from the setup area by a 20-ton crane and placed on the chamber. A final checkout of the vehicle and test instrumentation is made prior to pumpdown and cooling of the chamber.

Before the vehicle has left the chamber, its complete mission will have been simulated. All the commands and responses inherent in the vehicle's specific mission profile will be delivered and recorded.

The vehicle is not immediately placed in the chamber, but rather is checked and rechecked through "dry runs" to ensure proper operation of all systems. In addition, all instrumentation leads and equipment are thoroughly checked to see that they are functioning normally before the vehicle is placed in the chamber.

The chambers are constructed of ⅜″ stainless steel plates stiffened on the outside by heavy carbon steel ribs. Within the chamber the test spacecraft is completely surrounded by liquid nitrogen-cooled aluminum cryopanels operating at temperatures of approximately –320°F. Supplementary panels are cooled by the use of gaseous helium and will normally operate at –425°F. A large number of access ports are provided on each chamber to provide feed-throughs for electrical power, thermocouple leads, viewing ports and other services needed for special tests. Normal access to the 39′ chambers is provided through a manned access door located at the "equator" of the chamber. This opening allows access to the chamber without removing the large cover. The structural design of the chamber provides for the addition of a manned access lock at a future date. Such a lock will be invaluable in the use of the chamber for training technicians in performing various operations in a vacuum environment.

Various mechanical and diffusion pumping systems are employed in sequence dependent upon their ranges of effective operation. When the limit of mechanical pumping has been attained, the diffusion pumps are automatically made operable to reduce the vacuum to the 10^{-6} or 10^{-7} Torr range. Activation of the cryogenic systems at this point produces further cryo-pumping of the gases which have not been handled by the diffusion pumps. The pumping equipment for these chambers is designed for six months' continuous operation. This same criteria holds true for the cryogenic and the infrared heating systems.

THE long-life requirements of space vehicles require meticulous care and inspection in their manufacture and assembly functions. Particular emphasis must, therefore, be placed on environmental control. Completed in February, 1962, the immediate reason for building the Clean Room was to meet the need to maintain dust-free conditions during the assembly of solar cell devices, pneumatic systems, sun sensors, electro-mechanical devices, and critical electronic assemblies. For example, a specification on the cleanliness of pneumatic systems equipment calls for the elimination of particles larger than twelve microns and 98% free of particles over five microns. The room actually excludes 99.7% of all air particles over .3 microns in size.

Occupying eleven thousand square feet on the main floor of the Space Technology Center, the facility encompasses corridors and a bonded storage area. Other components include locker rooms, a lunch area, air showers, a wash room, offices, a development room, and an inspection center.

Unique features of the controlled area include a reliability development room for personnel training and development of methods for attaining maximum cleanliness levels prior to actual adaptation to the work routine.

The entire facility is designed to provide for both pressure and temperature gradations. Sensitive controls regulate temperature at 72°F±1° and humidty at 40%±5% throughout the clean room. The desired temperature level is maintained by means of re-heat coils in the cooled air supplied to the individual areas.

All furnishings and equipment, including tables, chairs, cabinets, and benches, are designed to eliminate any possibility of flaking, chipping or, in other ways, producing dust particles and contaminants. Nothing is made of wood. All materials are constructed of either glass, chrome-plated steel, stainless steel, or sheet metal with a baked-on acrylic finish. Each piece of equipment used to test and assemble spacecraft components is contoured to minimize dust-collecting surfaces.

Wall panels are covered with "psychologically soothing" colors. Beige, blue, yellow, and green have been found to be efficient and all have non-flaking, non-chipping surfaces. Glass room dividers give a feeling of spaciousness and depth and can be re-arranged to form new room sizes. It is not necessary for maintenance men to enter for repairs; the unique construction enables all work of this nature to be accomplished from the outside.

Control begins before the employee enters the facility. Outer garments are stored before entering the corridor to the area's entrance. At this point, the operator uses one of two mechanical shoe cleaners followed by walking over a tacky rubber mat before entering the outer locker room. Once inside, he again treads across a sticky mat before depositing all articles as cigarettes, paper, books, and food in storage lockers. The operator then steps into the air shower that separates the storage area for personal effects from the inner locker room. He remains there for about 18 seconds, holding his arms aloft and rotating his body 360 degrees. After the air blast, clean room garments consisting of hood, coverall, boots, and sometimes, gloves, are put on followed by a second air shower and a thorough hand and face washing—he is now ready to pass into the work areas.

During lunch or break periods, a special room is provided just outside the working area. Clean room garments are left in the locker areas and following eating or smoking, the operator is subjected to the same cleansing cycle before re-entering the manufacturing area.

For communication, an inter-com and voice diaphragms of airtight, stretched plastic screening, permit conversation from within the area to those on the outside.

SPACE VEHICLES require intricate guidance and control equipment to establish and maintain the motion and position requirements set by their missions. Control systems installed in these craft must rotate the craft to its proper position, reduce the rate of deviation to a predetermined minimum, and maintain this position despite external forces which might disturb the spacecraft.

The more complicated the intended mission of a vehicle moving in space, the more critical the design of its control system becomes. Failure of such a system in flight cannot be tolerated; the delay and expense of a second launch is too great. Therefore, an expedient and practical method to evaluate the performance of a spacecraft, prior to launching, is most necessary. To meet this requirement, General Electric's Spacecraft Department has developed motion simulators to determine that the system performance matches the requirements.

Several motion simulators with varying degrees of complexity have been designed, developed, fabricated, and used by MSD's Spacecraft Department.

Each simulator meets the needs of a different testing program; therefore, each differs somewhat in design. The simulated vehicle must be capable of a high degree of freedom for rotational motion about all three axes, but frictional forces opposing this motion must be negligible. A gas lubricated bearing, which provides this frictionless condition, is the key element in any simulator.

A spherical gas bearing is attached to the spacecraft or simulated vehicle at the center of gravity. In a typical three-axis simulator, the system has 360-degree rotation about the local vertical axis, and ± 90-degree freedom about the other two axes. During dynamic testing, the spherical bearing is supported by pressurized gas flowing into a seat mounted on a support stand. The simulator is equipped with support devices, data acquisition equipment, and stellar reference bodies which are needed to stimulate spacecraft sensors.

In MSD's 39-foot cryogenic vacuum chamber, the motion simulator used to test the entire Nimbus vehicle (NASA's weather satellite) utilizes a six-inch diameter gas bearing. A recessed bearing seat is fed by a single variable orifice. The seat and ball are of stainless steel and are lapped together to a sphericity of better than 50-millionths inch. Carbon dioxide at 120 psi "floats" the spacecraft. A collector shroud prevents gas escapement, thus maintaining the vacuum environment. Tests at 10^{-5} Torr and 100°K wall temperature proved the operability of the gas bearing system under test load conditions. In the 39-foot chamber test facility, a simulated earth rotates about the spacecraft and the spacecraft controls orient the vehicle relative to this earth and to collimated light system that simulates the sun.

A similar motion simulator is used in another facility, in which only the attitude control system of Nimbus is tested. A heated earth and cooled chamber walls, representing the coldness of space relative to the earth, create a temperature differential which activates the infrared sensors in the control system.

A third motion simulator is provided to test the stabilization and control system of the OAO (Orbiting Astronomical Observatory) satellite, one that controls itself by referencing the sun and stars. In the OAO test facility, the control system orients itself to three adjustable simulated star sources and light from a simulated sun. A position and rate readout system, accurate to one arc second, is provided to measure the control system performance.

In addition to the motion simulators already discussed, a separate development facility is being used to study, evaluate, and improve the performance of basic elements such as gas bearing, structure, and components.

Evaluation and development of spacecraft control systems are made on the Orientation Evaluation Facilities. The test stands provide for virtually frictionless freedom of rotation of functional models by mounting them on an air bearing. The facilities allow for ± 90 degrees of freedom of rotation about two axes, and unrestricted rotation about a third axis. Sun and star stimulations of the proper relative radiation intensity provide targets for the attitude control system posi-

A technician is measuring the dimensions of a test device in the clean room. The measurements are made through the glass wall in order to prevent contamination from the air and the surroundings.

tions sensors. In addition, the low-altitude facility has a heated earth simulator and is housed in a water cooled room to provide the required temperature difference between earth and sky. The earth rotates about the system at orbital rate to simulate vehicle motion around the earth. Various kinds of techniques for static and dynamic balancing are also used to compensate for center-of-gravity shifts. External vehicle disturbances are simulated through the use of a cold, pressurized gas supply to an auxiliary reaction system that impacts torques to the system. All power is provided with on-board batteries with all other connection completed through a telemetry and command system.

There are three major sections of the facility. The first is the Astronomical Orientation Facility, which simulates the sun and stars with ± one second accuracy and one second readability. The Low-altitude Orientation Facility and the High-altitude Orientation Facility both test the ability of a satellite to orient itself with the sun and the earth with ± one degree accuracy and one degree readability.

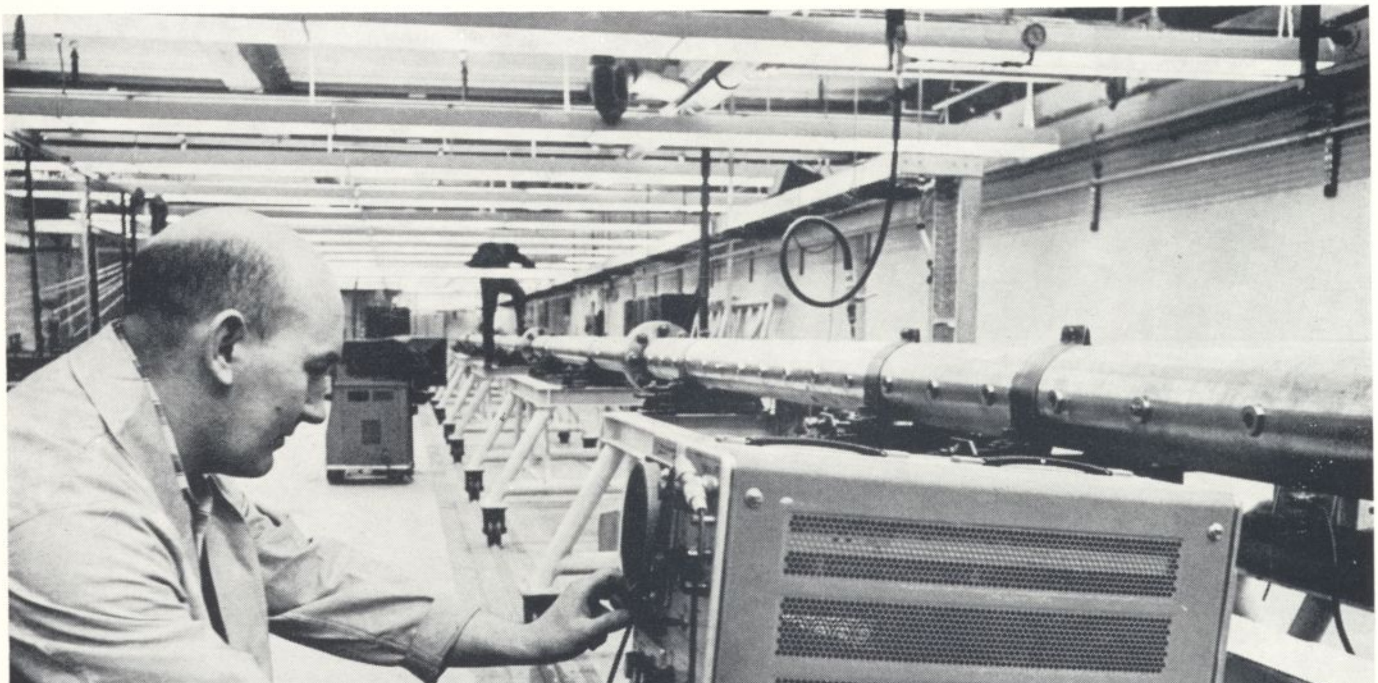
Basic and applied research is conducted at the center in the Space Sciences Laboratory. The general areas of work being done there are complementary to the actual testing of vehicles and include study of environmental phenomena, low-temperature plasma physics, structures and materials, celestial mechanics, shock wave phenomena, and physical biology.

There are several shock tunnels in the lab, the largest being of 6-inch diameter. It has a 22-foot driver tube, where the initial explosion of gases takes place, and a 112-foot tube which leads to the 30-inch diameter test section. Model size is up to ten inches. It is actually a blow-down wind tunnel using a shock tube to provide a working gas of high stagnation enthalpy and pressure. Data-recording devices measure surface phenomena, surface heat transfer rates, axial forces, free-flight static ability, and visual flow fields. Other tunnels include a high-performance tunnel capable of Mach 40 and several 2-inch tunnels.

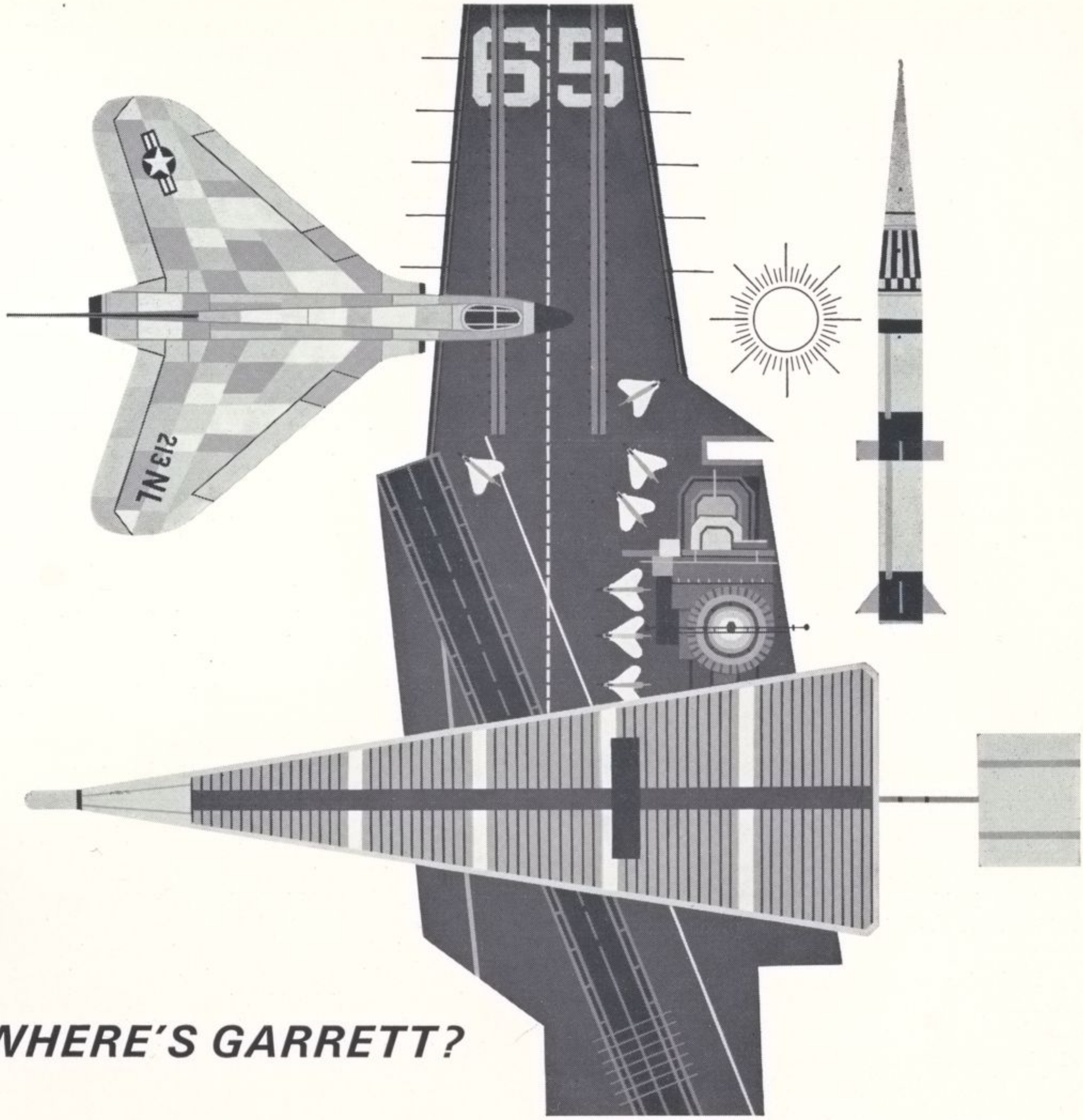
For the study of stagnation-point ablation of materials, there is a supersonic wind tunnel, a hypersonic wind tunnel, and a small air arc. In the tunnels, the air is super-heated by air arcs, to heat ranges of 20 to 100 BTU/ft^2 second, and high altitude conditions of above 200,000 feet can be maintained.

Studies of plasma accelerators that can be used for propulsion and attitude control are being conducted in a 20-foot-long vacuum chamber which can be evacuated to 10^{-8}mm Hg. Thrust, velocity of plasma, effects on engine components, and electrical discharge characteristics are all observed during testing. The accelerators produce thrust when an ionized gas is highly accelerated by powerful magnetic fields. The electrical discharge that ionizes the fuel comes from a capacitor bank that has been charged by a power supply capable of producing 20,000 volts and 150,000 watts.

This is only part of the story of the many facilities being used today to build the space vehicles of the future. In labs, classrooms, and shops around the country, the technology needed to put man into space is being constantly improved. ■



This shock tunnel, one of several in the lab, has a 22-foot driver tube, where the initial explosion of gases take place, and a 112-foot tube which leads to the 30-inch diameter test section. High altitude conditions of above 200,000 feet can be maintained.


655
213 NL

PROBLEMS IN FUSION

By Al Hribar, ME '65

THE overall goal of the nation's research in controlled thermonuclear reaction is to develop a means of harnessing useful power from the energy released in nuclear fusion reactions. In thermonuclear reactions, fusionable material such as heavy hydrogen (deuterium) or tritium, must be heated to very high temperatures in order to cause fusion of the nuclei of these atoms. The hydrogen bomb achieves this type of reaction on an enormous uncontrolled scale. For actual power production, much more control must be exercised over the fusion reaction. To harness fusion reactions to produce power, three goals must be reached.

- A fusionable material must be heated to the ignition temperature. (This is the threshold temperature for a self-sustaining reaction.) At this point, fusion energy is being released within the fusion fuel at a rate sufficient to offset the loss of energy from the fuel by radiation. For fusion fuels consisting of heavy hydrogens, this ignition temperature is of the order of 100 million degrees.
- After ignition temperatures have been achieved, a machine must be designed that will produce an excess of power.
- Production of power from a fusion reactor must be economically competitive with electricity produced by other methods.

I will assume the reader has a familiarity with the fusion reaction. If not, or if the reader wishes to refresh his memory, any elementary chemistry text will furnish the necessary information. On this basis, this article will examine and explain the key research problems which must be overcome in order to attain the necessary ignition temperature for fusion. Generally, these problems, in the order of presentation, are the temperature problem, the heating problem, the confinement problem and the energy losses.

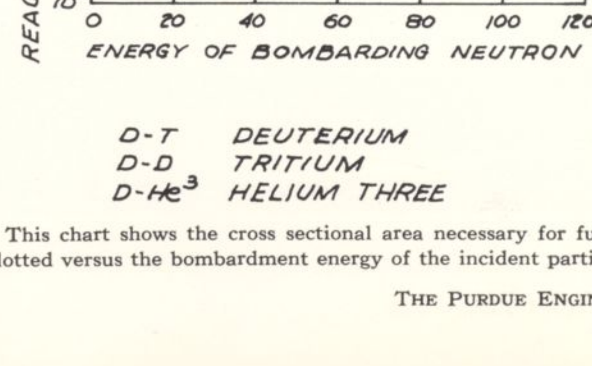
The high temperatures sought in controlled thermonuclear research represent the average velocities or energies which deuterons must maintain for appreciable periods, with essentially random movements in a confined space, in order for a considerable number of them to fuse.

In order to overcome the coulomb barrier (force of repulsion between nuclei) and accomplish fusion, two deuterons must be made to collide with high relative velocity. The probability of fusion occurring at a given relative energy is measured by the cross section which is the effective interaction area per target nucleus. Figure 1 shows experimentally determined cross sections as functions of bombardment energy. Cross sections are usually given in "barns"; 1 barn equalling $10^{-24}cm^2$. These curves were obtained by directing a beam of deuterons at a target containing deuterium, tritium, or helium 3, respectively. The most probable result of two deuterons colliding is that instead of fusing, they will bounce apart without reacting. An important consequence of this relatively high probability of scattering is that deuterons must, on an average, be forced to collide many times, in order to assure that considerable numbers will fuse. At each scattering collision there will be, in general, some exchange of kinetic energy. But if considerable numbers of deuterons in a confined volume are given similar energies, the multiple collisions will not, on an average, change the energies of the deuterons. Thus, after long pre-fusion paths, and many scattering collisions, the deuterons will still have sufficient relative energy for a fusion reaction to occur.

To accomplish these repeated collisions, the energetic deuterons must be allowed to move essentially at random within a confined volume, just as molecules of air in a room have random motion. And to accomplish fusion, the temperature (the relative energies) of the deuterons must be very high.

The heating of matter to very high temperatures results in ionization of the matter. The resulting mixture of ions and electrons is called a plasma. Deuterium heated to a temperature sufficient to provide a substantial reaction rate becomes a plasma consisting of deuterons and electrons in equal numbers. The overall charge neutrality provided by equal densities of positive ions and negative electrons is not essential for the ions and electrons to be at the same temperature. Through energy-exchanging collisions, the two temperatures will tend to be the same, but it is only the ion temperature which influences the fusion reaction rate, since it is the ions which must maintain sufficient velocities to fuse.

The term "temperature should be strictly applied only to systems which are in thermal equilibrium, hence systems in which average quantities such as the energy and density of a large number of particles do not change appreciably in the time required for the particles to interact with one another through collisions. Fusion reactions can occur in a plasma of fusionable material which is not in thermal equilibrium. Nevertheless, attempts are directed principally toward heating deuterium in systems under conditions such that one can



This chart shows the cross sectional area necessary for fusion plotted versus the bombardment energy of the incident particles.

validly refer to the temperature in the system. A very close approach to thermodynamic equilibrium cannot be achieved in man-made fusion systems, but for ease of calculation it is generally assumed that the systems are in equilibrium. Consequently it is assumed that the ions and electrons have the characteristic Maxwellian velocity distributions; a distribution in which a few particles have extremely high velocities relative to the rest, some have very low velocities, and the remainder are in an intermediate range. Strictly speaking the term "thermonuclear reactions" should be reserved for those fusion reactions which occur in hypothetical systems where the reacting nuclei are in thermodynamic equilibrium, characterized by a unique temperature, or at least close to such conditions.

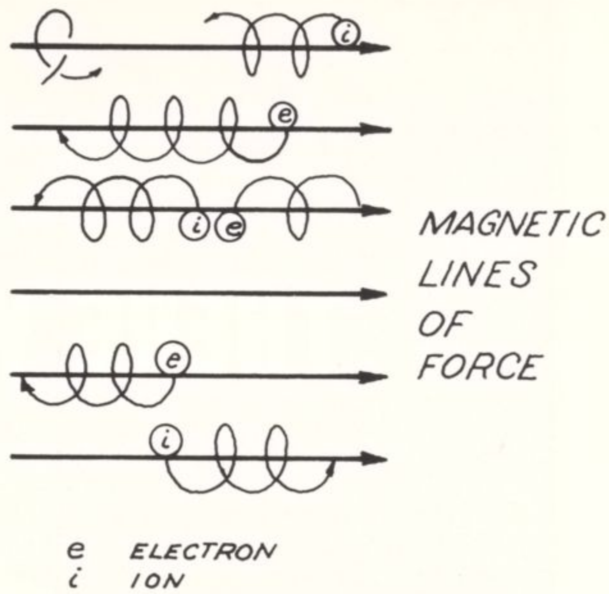
How to heat a low temperature plasma to the extremely high temperatures required for fusion is a major problem. A number of methods involve applying electric fields to the plasma. The fields accelerate charged particles and impart energy to them.

Passage of a current through a plasma results in ohmic or resistive heating. This is the type of heating that occurs when current flows through the filament of a light bulb. For inductive processes in which the current is not changing too rapidly, energy from the electric field is delivered preferentially to the electrons, which in turn share energy with the ions. However, the resistivity of a plasma decreases as its temperature is increased. At temperatures of the order of a million degrees, it is no longer practical to try to heat ions by using hot electrons. Resistive heating (I^2R) loses its utility because of the decrease in the plasma resistance (R) and practical limits to the amount of current (I) that can be supplied.

CONTAINING the hot plasma is fully as difficult as attaining the necessary temperatures.

The plasma exerts an outward pressure proportional to the total number of particles per unit volume and to the temperature. Therefore, it tends to expand. The expansion of the hot plasma must be opposed at least long enough to allow a significant fraction of the fusionable fuel to burn. It is necessary to work at fairly low plasma densities in order to keep the plasma pressure down to manageable levels. Plasma with a density of about one ten thousandth of normal atmospheric density will, at the extreme temperatures required, exert a pressure of the order of 100 atmospheres. The temperature required for ignition is independent of plasma density, but low density does result in a very long mean free path for nuclei—the average distance the ions will travel between collisions. Therefore, the mean fusion reaction time also is very long (of the order of seconds) and the average energetic deuteron will travel thousands of miles before it reacts. Actually, the mean distance that a deuteron must travel before it fused under these conditions is almost equal to the orbit of an artificial satellite about the earth.

Confinement of a very hot dilute plasma is thus a major problem. Material walls cannot be used for direct confinement because hot particles form the central region would strike the walls, give up a good amount of energy, and return to the central region as cool particles. For any container of any reasonable size, this would result in an intolerable drain of the energy of the system. Also, contact between the plasma and the container walls results in the introduction of impurities into the reaction area, and these further increase the energy lost.



This illustration shows schematically how ions (i) and electrons (e) move along (fictitious) lines of force in magnetic field.

The plasmas of the stars and the sun are confined by gravitational forces, but these forces are far too weak for the smaller systems which earthbound experimenters must work with. It is generally agreed that magnetic fields provide the best means of confining a hot plasma. All experimental devices in the United States and all other countries (so far as is known) make use of some form of "magnetic container" to confine the plasma and keep it centered relative to a reaction vessel. Material walls still must be used to separate the low-density plasma in the vessel from the outside world, but the magnetic field keeps the plasma away from the walls.

An electrically charged particle moving in a magnetic field experiences a force perpendicular both to the direction of the field and to the direction in which the particle is moving. As a result of this force, an ion or an electron, moving in a plane perpendicular to a uniform magnetic field, will follow a circular path around a magnetic line of force. By means of magnetic fields attainable in a laboratory, a deuteron moving fast enough to undergo fusion can readily be made to follow a path whose radius is of the order of inches.

Motion in a direction parallel to the magnetic field's lines of force is unaffected by the field, so that in general a charged particle follows a helical, or spiral, path along a line of force in a strong uniform field. (See figure 2) The particle is "tied" to the magnetic line of force. Lines of force are fictitious models useful in showing the "shape" and intensity of a magnetic field.

The particle pressure and density will tend to be low in regions of an equilibrium system where the magnetic field is high, and vice versa. The confining magnetic fields may be produced by current-carrying coils outside the system or by currents passing through the plasma. Under ideal conditions, a magnetic field of 50,000 gauss, existing outside the plasma and thereby containing it, could withstand a particle pressure of about 1000 atmospheres.

Achievement of a net power balance, the energy level represented by the ignition temperatures, is a problem involving competition between the rate of nuclear energy produc-


THERE WILL BE AN EAGLE

ON THE MOON...

Our world-recognized trademark—"the P&WA eagle"—has been identified with progress in flight propulsion for almost four decades, spanning the evolution of power from yesterday's reciprocating engines to today's rockets. Tomorrow will find that same Pratt & Whitney Aircraft eagle carrying men and equipment to the moon and to even more distant reaches of outer space.

Engineering achievement of this magnitude is directly traceable to our conviction that basic and applied research is essential to healthy progress. Today's engineers at Pratt & Whitney Aircraft accept no limiting criteria. They are moving ahead in many directions to advance our programs in *energy conversion for every environment.*

Our progress on current programs is *exciting,* for it anticipates the challenges of tomorrow. We are working, for example, in such areas as advanced gas turbines . . . rocket engines . . . fuel cells . . . nuclear power—all opening up new avenues of exploration in every field of aerospace, marine and industrial power application.

The breadth of Pratt & Whitney Aircraft programs requires virtually *every technical talent* . . . requires ambitious young engineers and scientists who can contribute to our advances of the state of the art. Your degree? It can be a B.S., M.S. or Ph.D. in: **MECHANICAL • AERONAUTICAL • ELECTRICAL • CHEMICAL and NUCLEAR ENGINEERING • PHYSICS • CHEMISTRY • METALLURGY • CERAMICS • MATHEMATICS • ENGINEERING SCIENCE or APPLIED MECHANICS.**

Career boundaries with us can be further extended through a corporation-financed Graduate Education Program. For further information regarding opportunities at Pratt & Whitney Aircraft, consult your college placement officer—or—write to Mr. William L. Stoner, Engineering Department, Pratt & Whitney Aircraft, East Hartford 8, Connecticut.

Pratt & Whitney Aircraft

CONNECTICUT OPERATIONS EAST HARTFORD, CONNECTICUT
FLORIDA OPERATIONS WEST PALM BEACH, FLORIDA

DIVISION OF UNITED AIRCRAFT CORP.

An Equal Opportunity Employer

SPECIALISTS IN POWER . . . POWER FOR PROPULSION—POWER FOR AUXILIARY SYSTEMS. CURRENT UTILIZATIONS INCLUDE AIRCRAFT, MISSILES, SPACE VEHICLES, MARINE AND INDUSTRIAL APPLICATIONS.

tion by fusion within the reacting plasma, and the rate of energy loss by various means through the outer surface of the plasma. Radiation is a primary and unavoidable cause of energy loss. Fortunately, the hot plasma in a thermonuclear device does not radiate like a black body; if this were the case, the energy loss, and the pressure exerted by the radiation would become impossibly large. The saving condition is that the plasma column in fusion reactors will not be dense enough or physically large enough to radiate like a black body, and the radiation will escape immediately from the surface of the plasma column.

Energy may be lost though primarily through radiation, particle interaction or leakage and collective movements of particles through instabilities of various kinds. Each of these areas for energy loss will be discussed.

A "braking radiation" (called Bremsstrahlung) is emitted continually as a result of coulomb interactions in the plasma. This loss consisting essentially of soft x-rays, exceeds the nuclear energy production at low temperatures, but it increases with rising temperatures less rapidly than does the production of fusion energy. At sufficiently high temperatures, the rate of energy release in the form of kinetic energy of the charged reaction products will exceed the Bremsstrahlung loss.

The temperatures at which fusion power release equals the radiation loss is the ignition temperature for the system. (Neutrons are not considered in calculating ignition temperatures because they are electrically neutral and thus escape immediately from the system.) The ignition temperature is independent of density since both fusion and radiation processes both depend on two-particle reactions. The fusion reaction can be thought of as self-sustaining above this point without additional external contributions of energy to maintain the temperature.

At the ignition temperatures and temperatures for deuteron fusion, the thermonuclear flame of reaction would be almost invisible. It would produce enormous quantities of soft x-rays, but these would not penetrate even a thin window. It would also produce enormous quantities of protons and helium nuclei which would remain in the system, and of neutrons which would escape.

The radiation losses are greatly increased by the presence in the plasma of impurities of high atomic number. Another radiation loss caused by impurities is excitation radiation, which can be very troublesome at low temperatures. Partially ionized impurities readily absorb energy from electrons in the plasma and promptly radiate it away in a continuous or cyclic fashion. This effect disappears if the impurities are completely ionized, i.e. at high temperatures.

Energy is lost from the system when energetic charged particles escape from the magnetic fields that confine them. Charged particles moving freely along lines of force may leak out of the reaction zone if the lines intersect the walls of the reaction chamber. Another loss of energy is diffusion, or migration of particles across the magnetic field, which results from repeated collisions between particles. A particle "tied" to a line of force may transfer to another line of force when it suffers a collision, and move progressively toward the reaction chamber wall. From the standpoint of this type of diffusion alone, no "magnetic vessel" can be made completely leakproof.

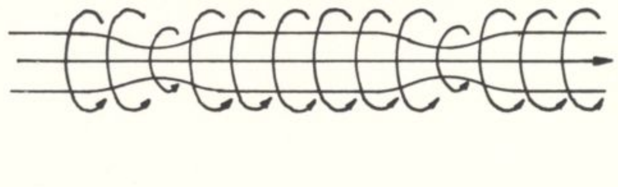
The process of charge-exchange leads to another kind of loss. Fast ions become neutralized by picking up electrons through collisions with slow neutral atoms or molecules which have wandered into the system. Since magnetic fields bind only charged particles, the fast neutral atoms thus produced, quickly escape from the plasma, leaving slow ions behind. This effectively cools the system. The cross section for charge-exchange between a deuteron and a deuterium molecule has a broad peak at about 15 kev where its value is 15 x 10^{-16}cm^2, or 1.4 billion barns. This is to be compared to the cross section for the fusion reaction, which is of the order of only 1 barn. The deuteron deuterium cross section falls very steeply as deuteron energy increases beyond 15 kev.

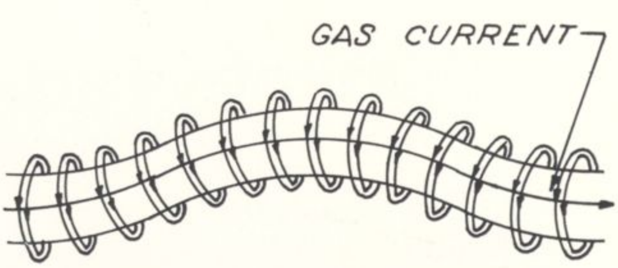
One of the most complex problems in the field of plasma physics is the analysis of such cooperative phenomena taking place in a completely ionized gas. These phenomena include a wide range of macroscopic effects arising from the forced motion of very large numbers of electrons and ions interacting with electromagnetic fields. Thus, the behavior of a plasma must be studied not only from a single-particle standpoint, but also from a group, or fluid dynamics standpoint. One concerns the statistical behavior of large numbers of particles acting independently; the other concerns gross behavior of a large number of particles which are acting collectively as a result of long range interactions between them.

Two major class of instabilities plague systems in which hot plasma is confined by magnetic fields. (See figure 3) Hydromagnetic instabilities are associated with an inbalance between the magnetic energy of the field which compresses the plasma and the compressional energy of the plasma. Under the influence of some random disturbance, either force can drive the system away from equilibrium. The kink instabilities which afflict the pinch discharge are of this type.

The other class of instabilities is of an electrostatic nature. Such unstable motions are driven by electrical energy associated with the electric fields in the plasma. Electric fields can lead, for example, to bunching of fast electrons and other secondary effects which gather particles.

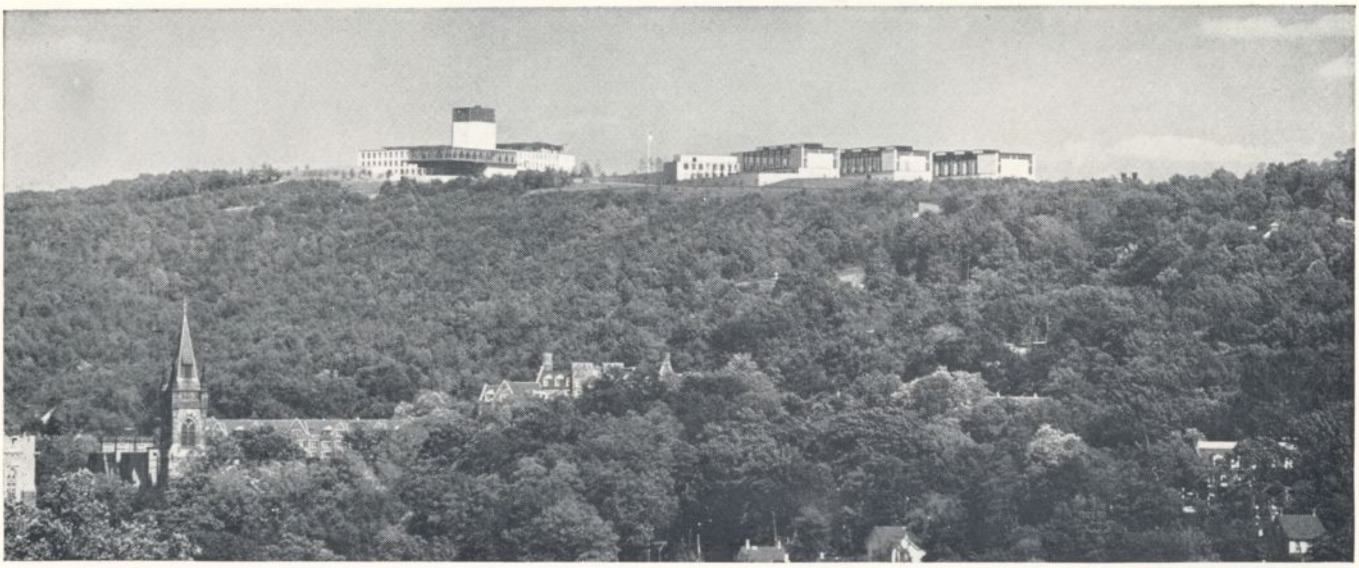
A plasma can become unstable in a variety of ways. Probably some modes of unstable motion have not been discovered, much less understood. The question of stability is a crucial one in the fusion research field and there are many problems which have not been satisfactorily solved. ■



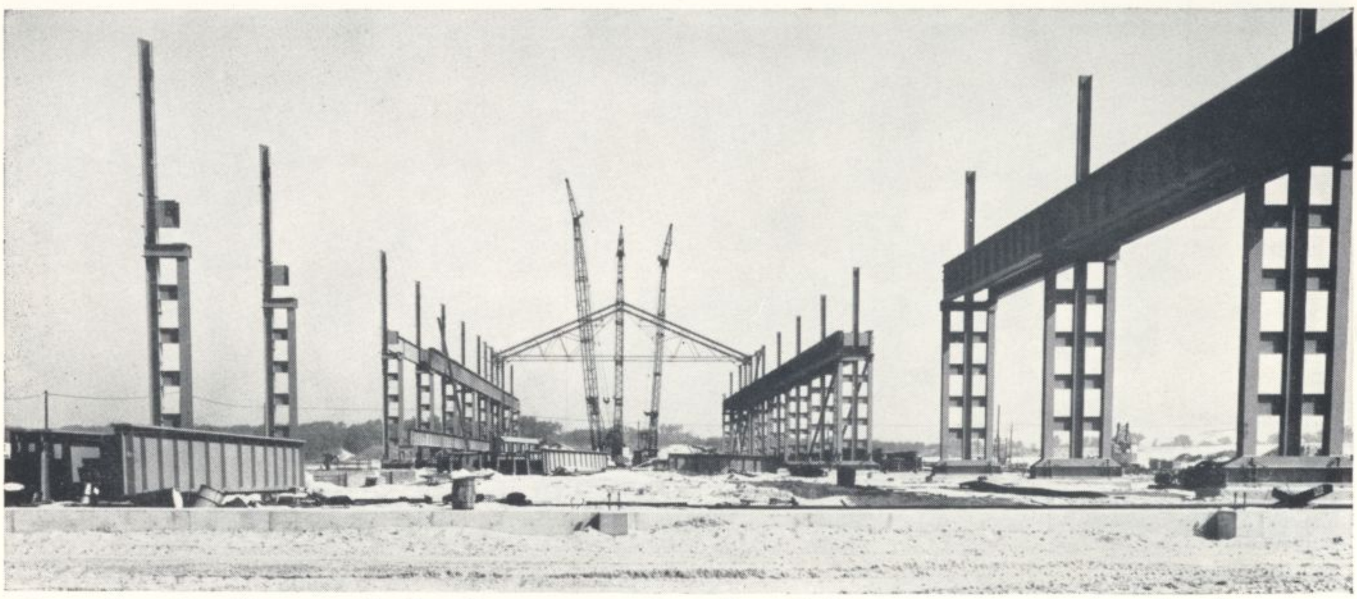


There are two types of hydromagnetic instabilities observed in pinch discharges. The upper illustration is that of the so called "sausage" instability and the lower is called the kink instability.

What's new at Bethlehem Steel?



On a Pennsylvania mountaintop, new research laboratories . . .



On the Indiana lakefront, we're building a new steel plant

Looking for real opportunity? On the crest of South Mountain, in Bethlehem, Pa., we have recently completed the industry's newest research laboratories, a $40-million investment aimed at making Bethlehem the leader in steel technology. And, at Burns Harbor, Indiana, we're building a new plant at an initial investment of $250 million. It will incorporate the latest advances known to metalworking science.

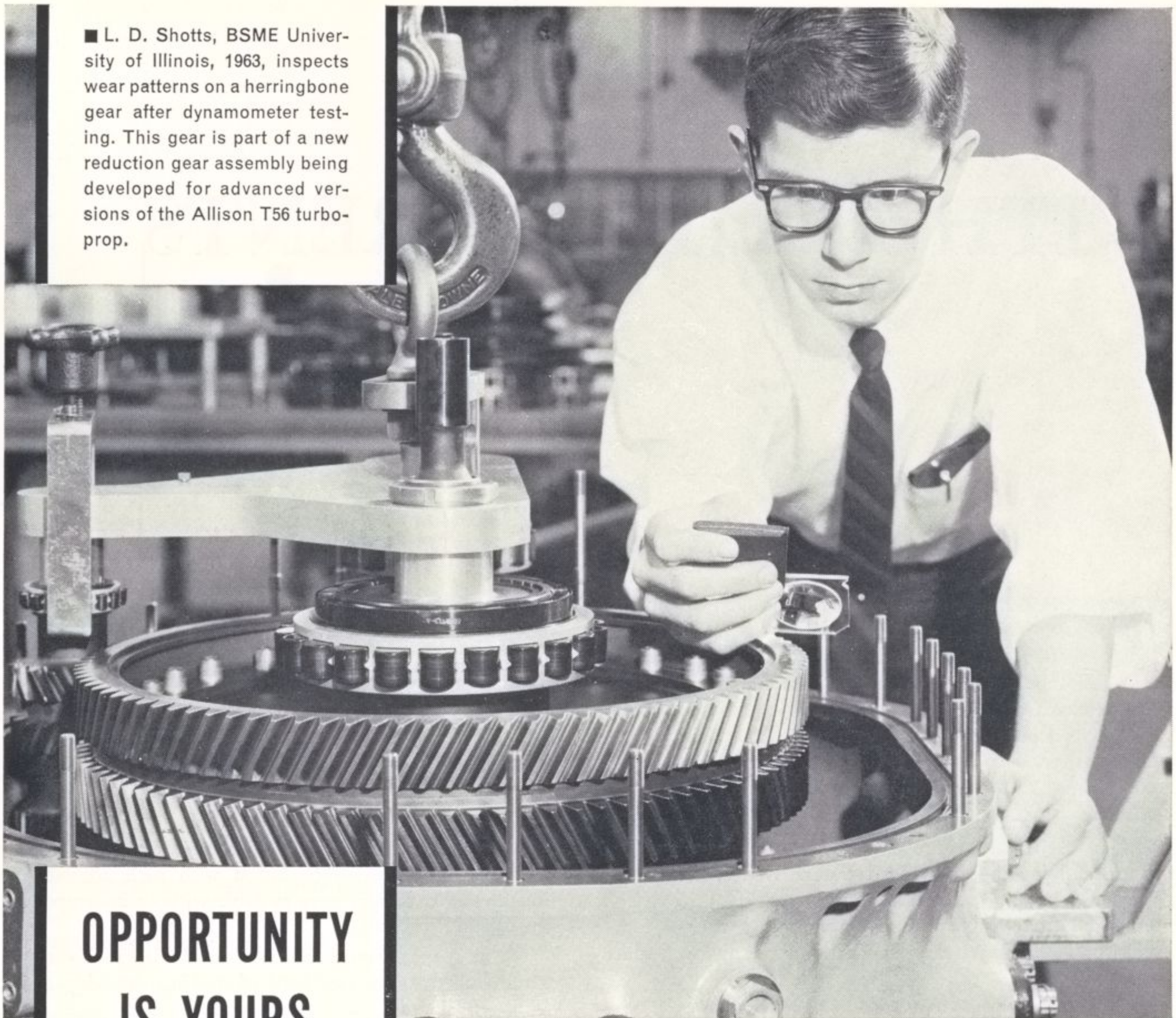
At Bethlehem Steel we have our sights set on continuous growth and modernization; constant development of new and improved products. This means career opportunities for alert and aggressive college graduates . . . in steel plant operations, sales, research, mining, shipbuilding, fabricated steel construction, and many other activities.

You can get a copy of our booklet, "Careers with Bethlehem Steel and the Loop Course," at your Placement Office, or by sending a postcard to our Personnel Division, Bethlehem, Pa.

BETHLEHEM STEEL

BETHLEHEM STEEL

An equal opportunity employer



■ L. D. Shotts, BSME University of Illinois, 1963, inspects wear patterns on a herringbone gear after dynamometer testing. This gear is part of a new reduction gear assembly being developed for advanced versions of the Allison T56 turboprop.

OPPORTUNITY IS YOURS AT ALLISON

■ For L. D. Shotts, the move from the University of Illinois was a natural. L. D. had learned of the work Allison is doing in advanced turbine engine development. Particularly, he was impressed with Allison's assignment to develop the T78 regenerative turboprop engine.

The T78—selected by the Navy for anti-submarine aircraft—utilizes turbine exhaust heat to raise the temperature of compressor discharge air, resulting in increased fuel economy for extended long-range and on station aircraft capability.

Air-cooled turbine blades, another Allison achievement, mark a significant advance in turbine engine state of the art. And, the workhorse of turboprops, the Allison T56, continues to set new standards as our engineers find additional means of improving performance and reliability.

In addition to leadership in the turboprop area, Allison also is making great strides in the development of nuclear energy conversion projects, including a compact, mobile nuclear reactor and an energy depot concept which will permit manufacturing of fuel "on the spot" for military field units.

Well-qualified, young engineers will find unlimited opportunities in the long-range, diversified energy conversion programs at Allison. Talk to our representative when he visits your campus. Let him tell you what it's like in the creative environment at Allison where Energy Conversion Is Our Business.

An equal opportunity employer

Allison

THE ENERGY CONVERSION DIVISION OF GENERAL MOTORS, INDIANAPOLIS, INDIANA

GM GENERAL MOTORS

TUBE TESTING WITH EDDY CURRENTS

By Jack Lienesch, ME '65

ONE OF THE biggest headaches in power plant maintenance is the prevention of tube leaks in the steam generator and associated heat exchangers. In a large plant, these tubes may be thousands in number and may add up to hundreds of miles in length—finding out that a leak has developed is no problem; spotting its exact location is another matter.

Boiler manufacturers in the past have utilized a hydrostatic test to determine the location of a leak. This amounts to little more than filling a tube bundle with water under high pressure and looking for spilled water. Even such a basic method as this, however, has proved ineffectual in determining all the possible failures in a tightly packed tube bundle, or in finding a tiny leak without destroying a tube completely.

Researchers at General Electric's Hanford Laboratories in Richmond, Washington, felt this inadequacy very strongly. Hanford has ten nuclear-powered steam generators whose heat exchanger units are cylindrical pressure vessels, each of which contains about twenty-one miles of stainless steel tubing. There was a definite need for rapid and accurate methods of determining the location of faulty tubes. As a result of this demand, Hugo A. Libby, a G.E. engineer at Hanford, began experimenting with a new eddy current technique for tube inspection. He has recently applied to the Atomic Energy Commission for a patent for the device.

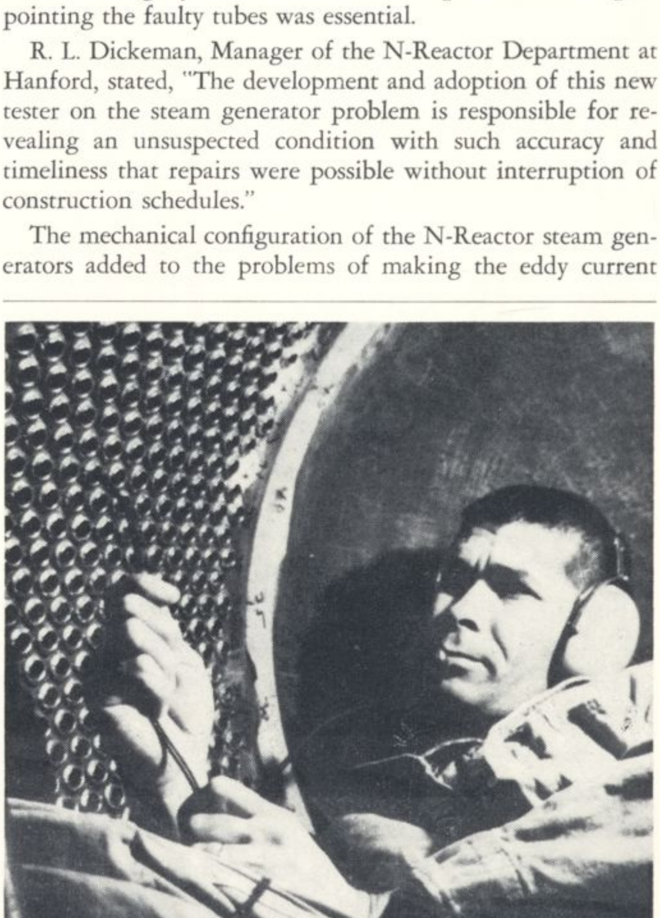
Mr. Libby's new method consists of a small, sensitive probe which is dragged through each tube and relays the tube's weaknesses by means of a change in its magnetic field. The new method effectively isolates harmful defect signals from normal background signals. Tubes which have been destructively examined, have, without exception, revealed defects in the exact location indicated by the eddy current tests.

General Electric anticipates that the new technique will find wide application in nondestructive testing of nearly all types of metal tubing, whether circular or of some other configuration. Accurate tests have been run on tubing as small as one eighth inch in diameter. Tubing, which contained thermocouple wires imbedded in ceramic, has also been successfully tested with the new instrument.

The new techniques were primarily developed to inspect the tubing of the new N-Reactor steam generators (heat exchangers). Leaks had been detected in the tubing of two generators during hydrostatic tests and a rapid method of pinpointing the faulty tubes was essential.

R. L. Dickeman, Manager of the N-Reactor Department at Hanford, stated, "The development and adoption of this new tester on the steam generator problem is responsible for revealing an unsuspected condition with such accuracy and timeliness that repairs were possible without interruption of construction schedules."

The mechanical configuration of the N-Reactor steam generators added to the problems of making the eddy current



Insertion of the eddy current probe in the heat exchanger tubes in the steam generators required a man to work in a pipe only three feet in diameter. Probe was blown down the tube and withdrawn.

Far superior to previous hydrostatic methods of determining tube failure locations, Hanford's new eddy current probe technique can easily differentiate between corroded areas of varying depth in the tube wall, readily distinguishing those that penetrate less than 50% into the tube wall, from those going beyond 50%

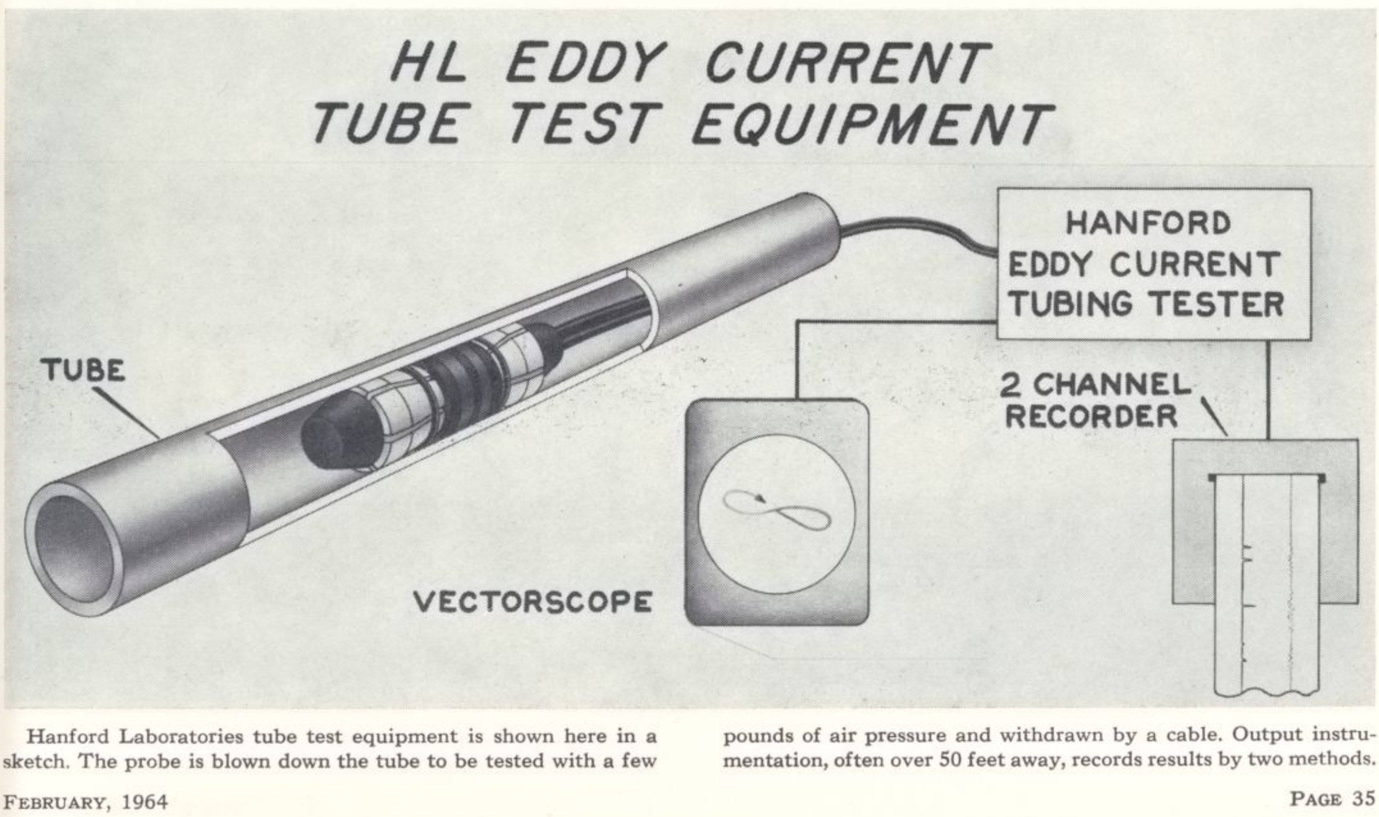
tests. The generators are cylindrical pressure vessels, 57 feet in length by 10 feet in diameter with shells of 3 inch carbon steel, mounted horizontally. Each generator contains two bundles of U-shaped tubing, with each bundle consisting of nearly 1000 five-eighths O.D. stainless steel tubes.

The eddy current tests are run through each tube end (4000 per generator). A probe assembly is blown into the tube with a few pounds of air pressure and then withdrawn at a uniform rate by cable.

SPECIAL techniques were employed to analyze the test data. Signals from harmful defects were effectively isolated and distinguished from the normal background or test signals. It was these techniques which really made the tests effective.

The test signal is electrically broken in quadrature components, each being fed onto a strip chart recorder that the vector signal from any point in the tube can be reconstructed in both amplitude and phase. The signals are also fed into an oscilloscope in such fashion that an operator can readily distinguish harmful defect signals from acceptable defect signals.

The tests have been particularly successful in locating regions containing intergranular corrosion in the N-Reactor steam generator tube walls. The new tests can differentiate between corroded areas of varying depth in the tube wall, readily distinguishing those that penetrate less than fifty percent into the tube wall from those that go beyond fifty percent.



Hanford Laboratories tube test equipment is shown here in a sketch. The probe is blown down the tube to be tested with a few pounds of air pressure and withdrawn by a cable. Output instrumentation, often over 50 feet away, records results by two methods.

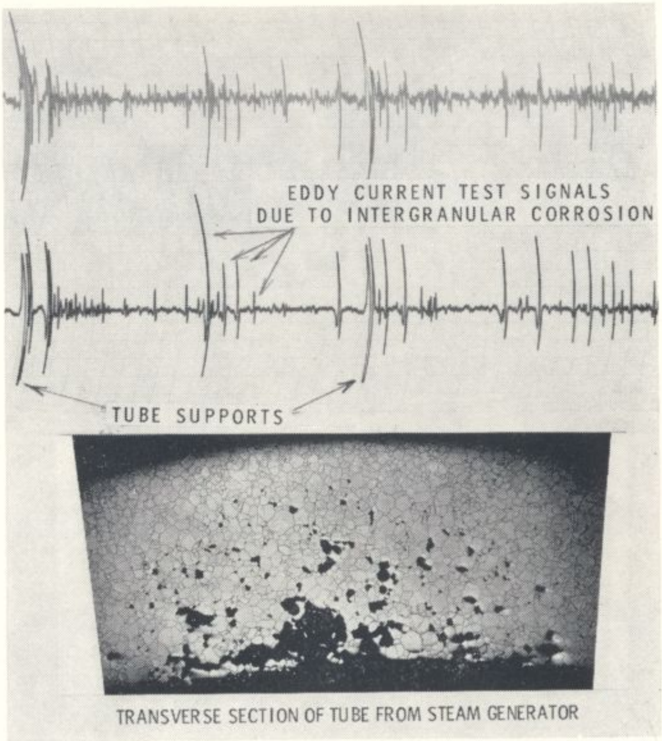
The new tests can determine whether a given defect originated on the tube's outside or inside surface. They also permit the operator to distinguish clearly between holes or corroded areas and minor, non-harmful defects such as small tube dimensional variations, surface scratches, and minor isolated kinks, bumps or depressions.

The probes, developed by Hanford Laboratories scientists, consist of two coils of 130 turns each of No. 38 copper wire connected in a series opposing circuit. The coils are wound on a cylindrical coil form with approximately one-sixteenth inch separation between them. The test frequency is 200 kc.

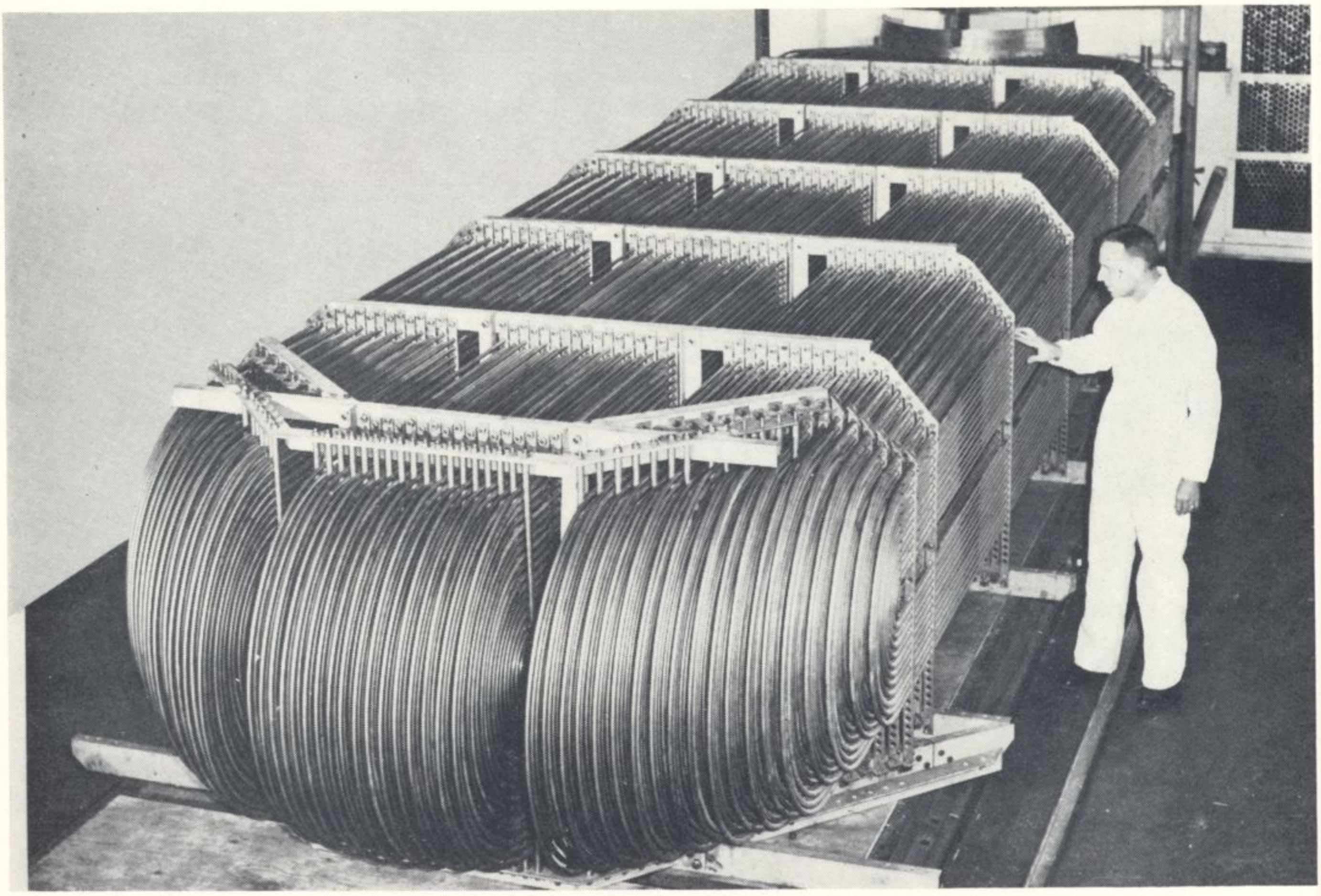
The oscilloscope is connected to present the phase angle between the in-phase and quadrature components of the voltage vector. As defects are encountered in the tubing a figure eight is drawn on the face of the scope and the angle or tilt of the figure eight is a principle element in the identification of the condition in the tubing.

The strip chart recorder provides a permanent trace of the two voltage vectors, in such a manner that the phase angle can be reconstructed from the chart alone. Reconstruction of the phase angle from the chart provides the identification of the condition encountered in the tubing with the eddy current probe.

Much conjecture as the possible future uses of the eddy current technique has been offered. Already, tubing manufacturers have started using the probes as an accurate recorder of test section conditions. Perhaps, in the near future, steam power plants will stock electronic probe equipment as a matter of policy. ■



A reproduction of the eddy current test record showing the type of intergranular corrosion identified in the heat exchanger tubing. The grain boundaries have been dissolved away by the corrosion.



Installation of tube bundles in a pressure vessel for one of the ten Hanford N-Reactor steam generators. The pressure vessels are 57 feet in length, 10 feet in diameter, with shells of 3 inch carbon steel. Each boiler contains two bundles of U-shaped tubing.

ORIGIN OF THE UNIVERSE

By Ken Bower, EE '64

"WHY did you want to climb the mountain?" was asked of the conqueror of the Matterhorn. The answer given was a profound simplicity, "Because it was there!"

Man has always had an inborn curiosity concerning the world around him. He habitually absorbs himself with unknown quantities. This innate curiosity, interwoven with the fiber of reason which is unique to man, is the very attribute which places him above the rest of the animal kingdom.

There is always a great deal of satisfaction associated with earning another's respect. The most obvious way of winning their respect was to defeat them in some form of competition.

As the population from mankind began to grow, he found it quite advantageous to separate himself into small groups, wherein he could find security from the seasons and from predatory beasts.

With the competition severely reduced by such close living, the competitive spirit was transcended, to appear in the form of rivalries between the groups. This competition manifested itself in as many ways as man's mind could conceive. Some groups engaged their neighbors in annual games, with the winning tribe claiming to be the better tribe. Some groups made war on their neighbors. Some ate their neighbors.

While the merits of the various techniques which man invented with which to antagonize his neighbors is a matter of some discussion, it is obvious that the formed a part of the vehicle which transported this spirit of competition to our present time. One can easily perceive many remnants of these competitive techniques in evidence in our world. The tribes are just larger.

It is of great significance that the individual curiosity of man was preserved over so long a period of time, when group ventures were stressed. Whatever was the mechanism of the forces of this retention, fact remains that men of deep vision have explored relentlessly the environs of man since the foundation of his existence.

Through the very fact that man was governed by the sun, which defined his days, and by the weather, which he imagined to be a weapon the gods used to discipline him, man was led to have an anxious interest in the heavens. Perhaps the methodic changes of the moon's phases, the curious wandering stars, the splendor of a meteor shower, or the peaceful, tantalizing aurora spurred his interest anew when it began to wane. Perhaps the fixed background, with its inherent air of permanence, held his interest. To see almost nightly a vast display of tiny twinkling lights, without having any knowledge of its origin or function, was the possible cause for man's endeavors for knowledge.

The history of astronomy is sufficiently well known as to be adequate without enchantment in this context. It consists of the works of many men, over many centuries. With Brahe, Kepler, and Newton, the fund of knowledge was classified, fortified, and modified, and astronomy became a science.

Like all schools of knowledge, astronomy was plunged into the Industrial Revolution, to fight for its continued life with sciences of obvious and immediate application to man's terrestial existence. No person of reasonably coherent thoughts could argue against the economic wisdom of studies of chemistry, of physics, and of mathematics; but why should rational educators and businessmen devote money in substantial sums to the study of distant galaxies—to gain knowledge of what happened to some region of the universe a billion light-years from earth, a billion years ago? Because it was' there? Are institutions so rich that they can afford to squander money, which might go for obviously useful research, on telescopes and cameras?

All scientific progress has been accompanied and augmented by the formulation of theories to explain some given phenomenon; theories which are continually revised as new data are obtained. The theory stands or collapses according as it predicts correctly or erroneously some physical interaction of objects. As a theory withstands the tests to which it is subjected, it slowly becomes accepted as a physical law.

If it fails to predict or agree with some observed physical reality, as in the case of the partially reconciled theories of light, it serves as a useful basis and stepping-stone to more exact theories. In all instances, however, the formation of new theories resulted from the realization that the now outmoded theories had inherent inaccuracies! The observed data were not compatible with the theory. The "scientific method" —an elusive animal at best—is that name assigned to the attempts of man to reduce a fantastic accumulation of knowledge to a set of "simple" rules, which are, in turn, compatible with, and capable of predicting, the data observed.

In the twilight of civilization, the challenge of competition manifested itself in many ways. Some groups engaged in games with their neighbors . . . some groups made war on their neighbors . . . some groups ate their neighbors.

Something seems not quite right here . . .
by seemingly reasonable logic, we have arrived at the perfectly
absurd conclusion that it never gets dark at night.

What better place from which to extract the data exists than the entire universe? Where can one find bodies so dense as to weigh thousands of tons per cubic inch? Or matter so scarce that a region the size of a basketball would be lucky to contain a molecule of gas for a fleeting moment? Where can one find temperatures from near absolute zero to millions of degrees? Where could one find continual nuclear holocausts so large that if they were concentric with our sun, they would engulf the entire orbit of the earth within their surfaces?

Is there any comparison of the value of data collected here, on earth, which is essentially nowhere, to that taken there, which is everywhere else?

Of course there is! Where would astronomy be if a gentleman long ago had not decided to make a lens? No plant life has ever been studied by long-range telescope (with the possible exception of primitive plant life on Mars); no electric generator was ever built because the moon changes its phase.

A truly intelligent, economically sound assault on the unknown by scientific methods can best be attained by a marriage of all of the various types of knowledge available. Because of the recent advancements in communications and transportation, and because of the very size of the laboratory the universe is, we may rightly expect that observations of the universe will play an increasingly important role in our lives just because it is there.

IN 1826, a German astronomer, Heinrich Olbers (1758-1840), published a rather interesting paper, in which he attempted to determine the amount of light reaching earth from stellar sources. Due to the tremendous observed number of stars, Olbers assumed that there was some average brightness, and average diameter, which could be assigned to typical stars, which would yield the correct result in his calculations. His further assumption of a uniform distribution of stars was also quite reasonable, in accordance with all observations. To ease the problems of calculations further, he assumed that the universe was in a static state—that is, that the distant stars were not in motion, and that no dust or foggy material were present, which would diminish the light from the stars.

The calculations now proceed with ease. A star of constant diameter will subtend increasingly small solid angles as it becomes increasingly more distant from an observer. This angle varies as the inverse of the square of the distance between the observer and the star. The inverse square of light provides the final bit of impetus to the calculations.

Let there be a region of space, in the form of a hollow sphere, concetric with the earth. If ΔR represents the radial thickness of the shell, and R the inner radius, then the volume of the shell is roughly $4\pi R^2 \Delta R$. If N is the number of stars per unit volume, and L represents the typical light emitted per star, the total light emitted from the shell is $4\pi R^2 (\Delta R) NL$.

By the time the light from any one of the stars reaches earth, it spreads out over a sphere of radius R, and its brightness at earth is $\frac{1}{4}\pi R^2$ of its brightness at one unit of distance. Hence, the total light received from the shell must be $NL(\Delta R)$. Taking the limit, now (mathematicians need not watch), as $\Delta R \rightarrow 0$, we arrive at the differential light the earth receives from the shell: NLdR.

One must be cautious in the next step. Note that some stars are excluded from being sources in that they are hidden behind nearer stars. It is thus obvious that the N in the formula must be replaced by some "effective N," which becomes systematically smaller as R increases. This effect prevents the sum of light from reaching infinity, as R varies from zero upwards, but the resulting calculation still yields a surprisingly large amount of light. Earth, predicts the calculation, is continually being bombarded with light from all quarters—light of such intensity that the sun's disc might appear to be just a little dull in comparison. Light accompanied by amounts of heat which would raise the temperature of the earth—in fact, of the whole of the universe—to over 10,000°F. Since this light comes from all directions, there would be no such entity as "night" in existence.

The astute reader will readily agree that something is not quite right with this result. By seemingly reasonable logic, we have arrived at the prefectly absurd conclusion that it never gets dark at night.

Olbers concluded that the assumption which was wrong was that there was no dust which would intercept the stars' light. Hence, concluded Olbers, there must be gas and dust in the "outer space." This conclusion was correct, but it did not resolve his paradox, as he thought it did.

For if, as Olbers concluded, there were this dust, it too would absorb radiation, heat up, and become a source of light itself.

Perhaps a different distribution of stars might cause the paradox to be soluble. In 1922, C. V. L. Charlier suggested that, just as stars were grouped into galaxies, and galaxies into clusters of galaxies, so might clusters of galaxies form super clusters, and so proceed indefinitely. While this would indeed resolve the paradox, it also lacks the element of simplicity we desire. Just where one should truncate the series involves many problems. A little reflection on the types of configurations possible which would resolve the paradox should quickly discourage the most ardent person.

If the assumption of average intensity were correct, then we could construct a model where the intensity of stars decreases as they become more distant from earth. This would resolve the paradox, but would also define the region about earth as the center of the universe. This is a trap of the type into which man has fallen since he first considered the heavens. Let us not also fall; moreover, to avoid this situation, let us agree that any theory which predicts that there is a center of the universe near earth will be our last choice of possible solutions to a problem.

". . . we have concluded that it is dark at night because the universe is expanding!"

What if the universe were not static? Could that resolve our paradox? Suppose that the universe were expanding, for instance. Compared with those from a static star, the number of, and energy of photons from a receding star are less. Thus, it will be in perfect harmony with observation, and with the calculation modified to account for it. However, this motion of recession must be of a very special kind if an observer or another galaxy is to see the same effect as we do. The motion which satisfies this requirement defines a system where the speed of recession of a galaxy is directly proportional to its distance from the observer. This motion will not define a center of the universe at all, since this effect will remain true everywhere.

We may say, then, that we have concluded that it is dark at night because the universe is expanding! The rate of the actual expansion will determine the amount of light received —the faster the recession, the darker the night.

By observing the amount of light received on a moonless, cloudless night, then, we may calculate the proportionality constant, H, in the formla

$HS = d$

H proportionality constant
S speed of recession of star
d distance to star

This value turns out to be H = 10 billion years. It is a noble number, and deserves a name. Let us call it Hubble's constant. The fact that Hubble's constant has the dimensions of time is deemed by many to be of great significance in the history of the universe. This is discussed again later.

Olbers first published his paradox in 1826. His unfortunate failure to follow a line of reasoning similar to that above ranks as one of the classical missed opportunities in the history of science.

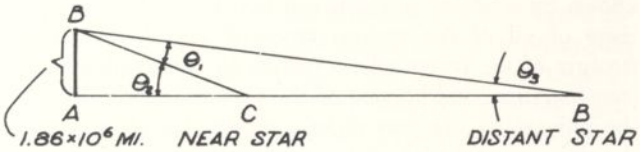
For it was nearly one hundred years later, in 1924, that Edwin P. Hubble confirmed the actual expansion, and made the first (inaccurate) calculations of the constant which was to bear his name.

The measurement techniques used by Hubble and his predecessors are quite ingenious in themselves. The Doppler effect—the lengthening of the wavelengths of light from receding objects—was known by 1842. In 1848, Fizeau suggested that measurements of the wavelengths of the spectral lines received from receding stars would yield to fairly accurate measurements. Comparison of the wavelengths of a particular line received from a star with the same line, as expected from a static source, allowed for a calculation of the radial motion of the star. In 1868, Sir. William Huggins first measured the radial speed of Tirius. The shift of frequency accounted for only one-ten thousandth of the total frequency, but Huggins managed to arrive at the value of 29 miles per second recession.

IN 1912, the first measurement of the radial motion of another galaxy was performed by V. M. Slipher. His measurements, when corrected for the rotation of our "Milky Way," yielded the result that the Andromeda Galaxy was approaching us at about thirty miles per second.

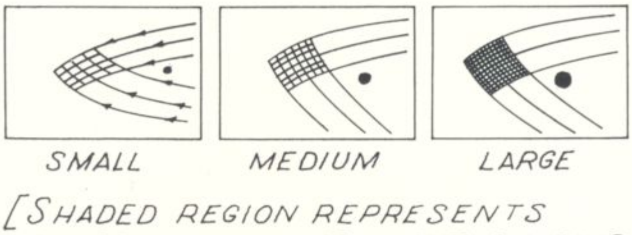
However, when motions were determined for other galaxies, Slipher noted that most of them were receding at a very high velocity. Astronomers were quite surprised by this fact, for Olber's paradox had been all but forgotten.

With the Doppler effect applicable to the measurement of the speeds of the very distant galaxies, astronomers set about to find just what these distances were.



· DIAGRAM FOR PARALLAX ·

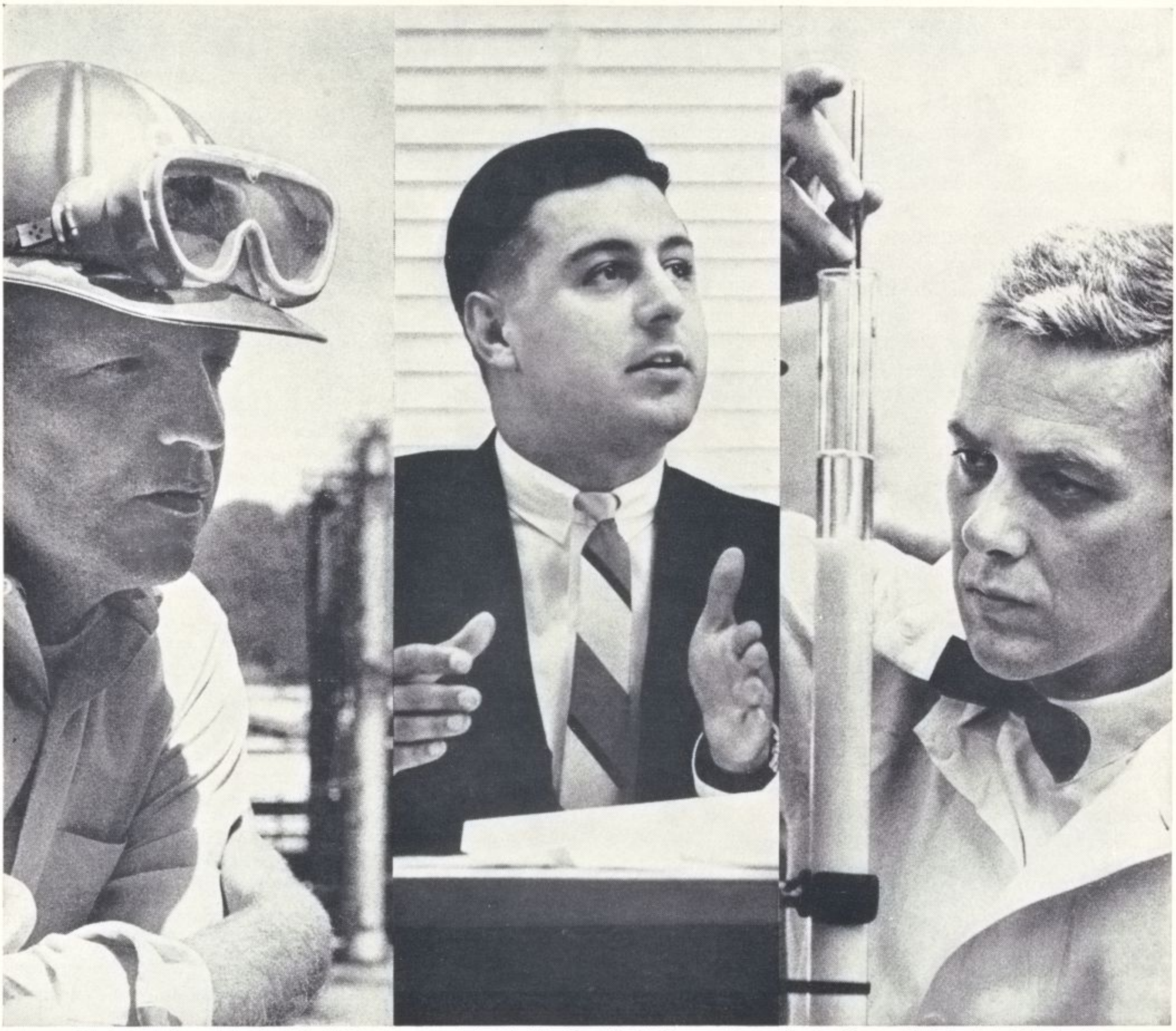
· THE FINITE, UNBOUND WORLD OF A BUG ·



[SHADED REGION REPRESENTS CONCENTRATED GAS, LIGHT SHADING FOR SMALL GALAXY, MEDIUM FOR MEDIUM, HEAVY FOR LARGE.]

· BIRTH OF A GALAXY ·

At top, the diagram for the parallax method for measuring the distance between stars; center, for the bug, a two dimensional world seems one dimensional; at bottom, each dot is a speeding galaxy which attracts intergalactic dust to form a new galaxy.



Production Superintendent Carl W. Yost, B.S. Chemical Engineering, U. of Alabama, is now supervising Glycols and Polyols Production, Organics Division.

Assistant to Vice President Thomas E. Watson, B.A., Earlham College, is currently helping to run Brass Sales, Metals Division.

Senior Research Scientist Malcolm H. Von Saltza, Ph.D., U. of Wisconsin, is currently working at the Squibb Institute for Medical Research, Squibb Division.

The most accessible way to measure the distances to the stars was the method of parallax. The simplest method to explain the calculations involved is to work through a problem.

Suppose that, at the instant the earth is furthest from the sun, we note a certain region of the sky, and notice a star so bright that we are forced to assume that it is comparatively near. From previous observations we are certain that this star is obscuring a very dim, distant star. The two stars would line up with earth. Six months later, earth passes closest to the sun, we note that the stars are no longer in a line, and we quickly measure the angle between them. Suppose that this angle is 1.74″ of angle. Six months later still, when we might have expected the stars to be in line, we note that they are still separated. Suppose this angle is 0.36″ of angle.

Referring to the diagram, we know the distance AB to be 186,000,000 miles. Also, if C is stationary, we have

$$\theta_1 + \theta_3 = \theta_2$$

Since star D is assumed to be very distant, let $\theta_3 \approx 0$, and

$$\theta_1 \approx \theta_2$$

Now we are in a position to complete the computations. Since there is a permanent displacement noted over the year, it follows naturally that half of the displacement, 1.18″, occurred in half the year. Thus,

$$\theta_1 = 1.74'' - 0.18'' = 1.56''$$

Now, $1.56'' = 0.0000075$ radians, and

$(AB) \approx \theta(AC)$, so we get

$$\frac{AB}{\theta} \approx AC$$

or $AC = 24.8 \times 10^{12}$ miles/6.3×10^{12} miles/Light yr.

$= 3.94$ Light years.

Since the nearest star—Alpha Centauri, is about 4.3 light years away, the angles given above are larger than would be expected in actual distance measurements. Since the radial motion per year of the star was also measured, the tangential motion of the star is easily calculated.

Certain problems are inherent to the parallax measurement. First, the most accurate measurement of the distance to a star would require a full year of observation. Secondly, the angular displacements are commonly much smaller than the values used in our example. Modern techniques enable measurements of angle to about 0.01 second of angle. This corresponds to the angle subtended by the head of a pin at a distance of ten miles. But even this amazing precision becomes insufficient beyond several hundred light years.

Astronomers had noted, luckily, that certain stars would vary in brightness in regular fashion, an effect which was easily observable on earth. Purely for academic reasons, the period and brightness extremes of many of these stars were measured and catalogued. The first such star, discovered in 1874 by a certain John Goodricke, in the constellation Cepheus. The general name "Cepheid variable" was quickly applied to stars falling into this class.

Since the distances to these stars were, in general, known, the extremes of the absolute brightness of the star could be calculated. In 1912, Mill Henrietta Leavitt found that there was a definite relation between the period of a Cepheid variable, and its absolute brightness. Merely by measuring the period of oscillation of the brightness of a star, and measuring its average brightness, one can calculate the distance which would account for the observed light.

When these variable stars were used in computing the distances to the near galaxies, they were found to be very far removed from our galaxy, hence, were assumed to be of coordinate rank with ours. Hubble's measurements and calculations indicated that the external galaxies were roughly 10,000 light-years.

However, in 1952, Walter Baade, an American astronomer, discovered that there were two types of Cepheid variables in existence. The measurements within the Milky Way were with Type II Cepheids, while those on the external galaxies by Type II Cepheids.

When the resulting corrections were made, the distances to, and the diameters of the external galaxies had to be multiplied by a factor of ten, which suddenly demoted our galaxy to a very average position.

By 1929, Hubble had begun to note a regularity in the motions of the galaxies. He had found that the rate of recession of the galaxies within six million light years of the Milky Way was directly proportional to their distance.

By 1931, he extended the range of validity of his law to 1.5 billion light years; by 1936, the validity was confirmed to 2.4 billion light years. Finally, in 1957, the law was declared valid up to seven billion light years, or about 44,000,000,000,000,000,000,000 miles. At that distance, the galaxies are receding at about four-tenths of the speed of light.

Obviously, at a distance of about two and one half times the distances now measurable, the galaxies would be receding at the speed of light, if they continue to follow Hubble's law. Since this possibility can be precluded, we can only render opinions as to what happens at such great distances.

We may conclude that Hubble's law fails to hold at these distances for instance. But then, another galaxy "A" outside the range of the law will not obey Hubble's law relative to its near galaxy neighbors. Also, observers within that galaxy could distinguish a direction to the expansion, since the galaxies more distant from the earth would recede more slowly, relative to observers within "A," than would the galaxies nearer earth. At some other point in the universe, the situation would also occur, and the direction of the expansion, in conjunction with that direction originally determined, would define our region as some favored region—the center of the universe. Let us disregard this possibility for sanity's sake.

SUPPOSE, instead, that Hubble's law holds to the end of creation. Since matter cannot travel at the speed of light relative to other matter, the universe must be bounded, lying totally within a sphere 18 billion light-years in diameter, centered in the earth. Since this sphere contains all of matter, it must contain the center of all of the matter. If his center were earth, we would disregard it. If it were any place else, reasonable observers there would probably disregard it.

This presents rather an interesting dilemma—if Hubble's law holds at extreme distances, there must be some center of the universe, which we agreed not to allow. If Hubble's law fails to hold, then there exists also a center of the universe.

We are thus in the rather awkward position of having two seemingly opposite views of the conditions existing at the extremes of the universe both suggesting the geocentric model of the universe, something we have faithfully disregarded.

To avoid the embarrassing situation of admitting a miscalculation, let us reach into the hat of warped solutions, and announce boldly that the universe is finite, but unbounded.

It this is true, then the statement, "It is dark at night" is sufficient to imply, "The universe is finite, but unbounded."

This choice of statements is rather convenient, for if the universe is finite, there is no need for the speeds of recession to approach the speed of light. If it is unbounded, Hubble's law is not necessarily non-linear anywhere. Hence, we have a solution which will solve our dilemma—provided the solution itself is plausible.

Consider the illustration of the circle. On the circle is a spot, representing a bug, which can go either backwards or forwards along the circumference. Quite unaware that the "line" he is on folds back on itself, he might well consider it to be infinite. It is obvious that the line is not infinite, but it is unbounded in the sense that the bug can go either forwards or backwards as far as he pleases. Here, a two-dimensional entity is mistakenly assumed to be one-dimensional.

A similar situation occurs when a bug on a sphere assumes it to be a flat, infinite plane. Here again is a finite entity which yields an air of infinitude to its inhabitants, in that they may proceed in any planar direction indefinitely. A similar misconception was held by man about the earth until a fellow named Columbus took a cruise in the Caribbean.

By simple analogy, there could exist some four-dimensional region which is inhabited by strange creatures who believe it to be three-dimensional. If the region were sufficiently large, the curvature of the "three-space" would not be noticeable, and the creatures would consider it to be infinite, though, in reality, it was finite and unbounded.

Many theories are floating about concerning the origin of the universe, which would tend to explain the state it is in. One theory stands out among the multitude—the steady-state theory—which predicts more things correctly than any other theory.

In this theory, "creation" was not a one-shot, long ago occurrence. "Creation" is still occurring!

The major points are something on this order:

1. There have always been galaxies.
2. Spontaneously, and from "nowhere," and in even distribution over the expanse of the universe, hydrogen molecules are continually being created.
3. The universe is now in steady state.

The creation of this hydrogen gas is proceeding at a rate such that a volume the size of the earth would probably experience the formation of "new" gas equal in weight to a heavy particle of dust every million years or so. This is sufficiently small to be immeasureable. The height of understatement!

Suppose that we have a situation with a galaxy moving through the intergalactic gas at a considerable speed. Gas molecules will be attracted to the galaxy, but by the time the molecules reach their destination, the galaxy will have moved on.

BEHIND the galaxy, there will occur a region of space with a high concentration of this gas. There occurs a point at which this concentrated gas will collapse under its own gravitation, thereby forming a galaxy. This galaxy may be captured by its mother galaxy, forming a small cluster, or may strike off on its own. We then expect to see both clusters of galaxies, and single, "field" galaxies. When the clusters get extremely large, galaxies may escape, and become field galaxies. Thus, there will be a steady-state concentration of field galaxies and clusters.

By referring to the figures above, we see that the size of the parent galaxy will affect the concentration of the gas in its wake. The concentration is a measure of the compression therein, which in turn determines the temperature of the gas, which in turn determines the state of motion of the gas itself, which must finally be controlled by the gravitational forces. We thus see that the mass of the parent is sufficient to determine the mass of the child. Moreover, light parents will give birth to light children heavier than they, and heavy parents will beget heavy children lighter than they. Thus, in the steady state, the galaxies will tend to one standard size—10^{43} or 10^{44} grams—which is precisely the range noted.

Since the universe is expanding, but must, by postulate, be in a steady state, the gas used in forming the galaxies must be replaced. By referring to Hubble's constant, we can calculate the rate of creation necessary to maintain steady-state density.

One thing we didn't explain is the motion that the original galaxy we considered must have had relative to the gas. When galaxies escape from clusters to become field galaxies, they must have a considerable speed.

The major proponents of the steady-state theory—Hermann Bondi, Thomas Gold, Fred Hoyle, and D. W. Sciama, among others—have justified theoretically the existence of Cepheid variables of both types; of the heavy elments; of the formation of Red Giants; of White Dwarfs; and of many other natural, observed phenomena, by using their steady-state, continuous creation theory. It is from their works that much of the elaboration in this paper was taken.

Certainly, as more information is derived from the universe, these theories will be rejected or evolved to fit the data. Until such time as man can call himself master of the universe, which probably will never happen, he must be content to make attempts at explaining it, by theory, in hopes that he will better be able to cope with it.

At this point, I am reminded of a story by Isaac Asimov, about a computer which was built to digest all of the data available in the universe. The computer's task was to determine if the entropy of the universe could ever be increased.

After several years of work, feeding data to the computer, the scientists pushed the button to ask for the answer, but the computer typed:

"SUFFICIENT DATA NOT YET AVAILABLE."

At each subsequent attempt, the computer gave this same answer. Millions of years wore by. By this time the computer was a solar powered, self-repairing, growing monster that covered the earth like a huge octopus. Yet the answer remained:

"SUFFICIENT DATA NOT YET AVAILABLE."

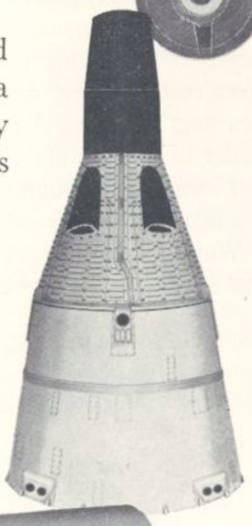
As the eons rolled along, bright stars like our sun began to burn out, yet the computer kept growing, absorbing other planets and even reaching out into the galaxy. Yet when asked about the possibility of bringing back the lost warmth of the dead suns, the answer remained:

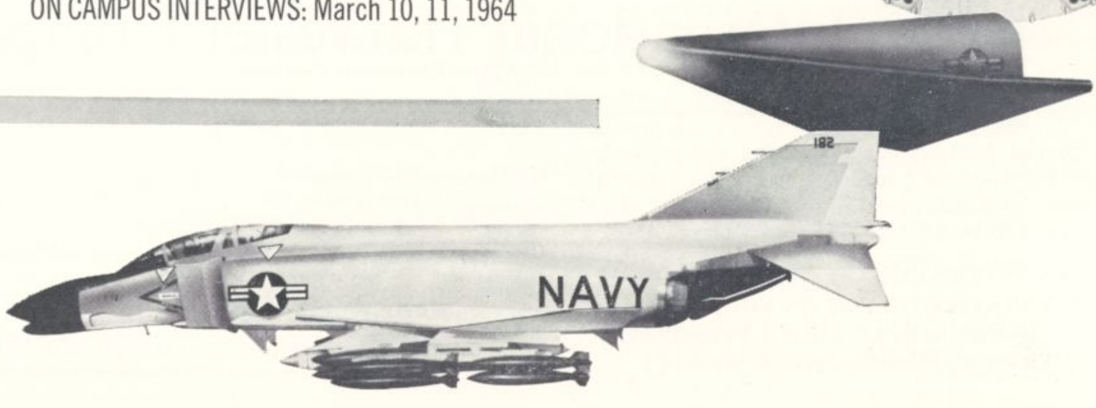
"SUFFICIENT DATA NOT YET AVAILABLE."

At last, the computer had engulfed the entire universe, except for a few tons here and there. There was a pause in its intricate circuitry, and then its output flooded the universe;

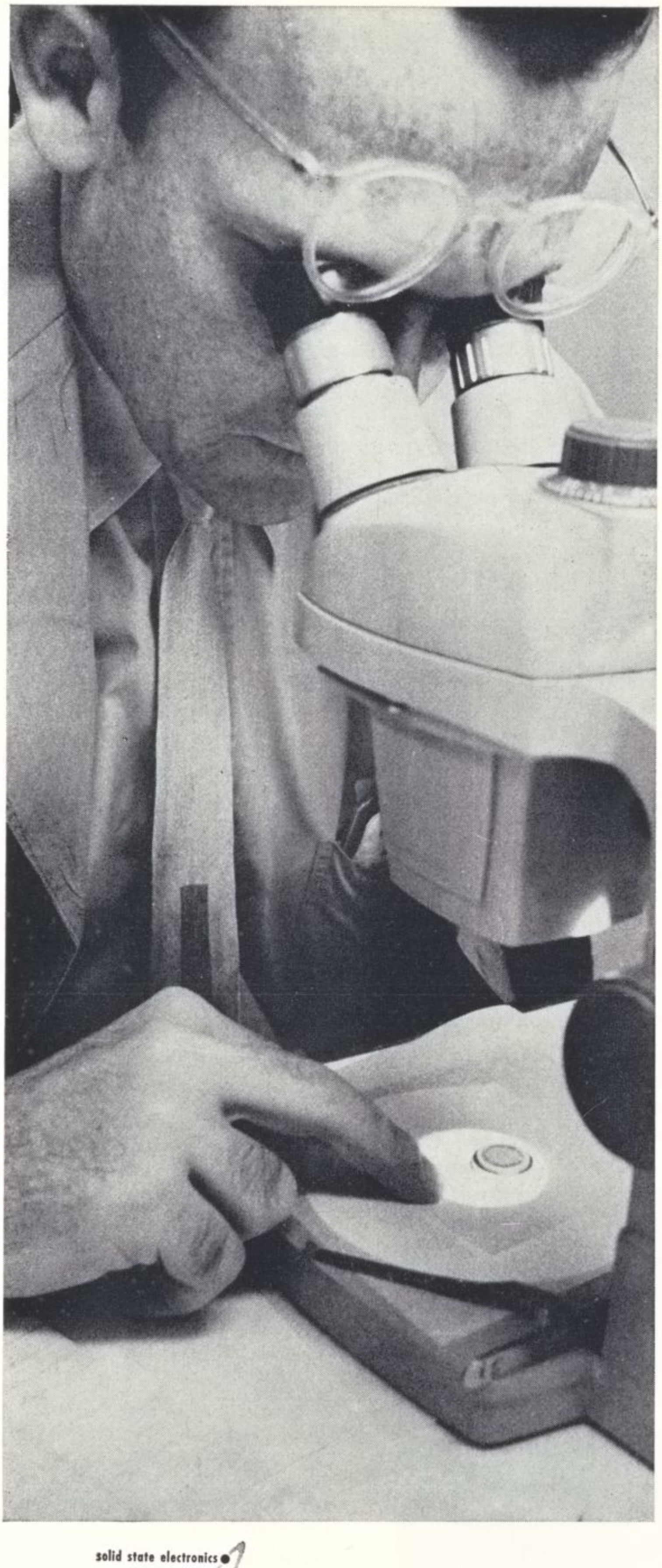
"SUFFICIENT DATA NOW AVAILABLE . . .
LET THERE BE LIGHT."

■





NAVY



Delco Means Opportunity to George Fitzgibbon

■ George Fitzgibbon is a Senior Experimental Chemist at Delco Radio. He's pictured here examining silicon rectifier sub-assemblies for microscopic solder voids during the development stage.

George received his BS in Chemistry from the University of Illinois prior to joining Delco Radio. As he puts it, "I found, at Delco, an opportunity to take part in a rapidly expanding silicon device development program. The work has proved to be challenging, and the people and facilities seem to stimulate your best efforts."

The young graduate engineer at Delco will also find opportunity—and encouragement—to continue work on additional college credits. Since our inception, we've always encouraged our engineers and scientists "to continue to learn and grow." Our Tuition Refund Program makes it possible for an eligible employee to be reimbursed for tuition costs of spare time courses studied at the university or college level. Both Purdue and Indiana Universities offer educational programs in Kokomo, and Purdue maintains an in-plant graduate training program for Delco employees.

Like George Fitzgibbon, you too may find challenging and stimulating opportunities at Delco Radio, in such areas as silicon and germanium device development, ferrites, solid state diffusion, creative packaging of semiconductor products, development of laboratory equipment, reliability techniques, and applications and manufacturing engineering.

If your training and interests lie in any of these areas, why not explore the possibilities of joining this outstanding Delco—GM team in forging the future of electronics? Watch for Delco interview dates on your campus, or write to Mr. C. D. Longshore, Dept. 135A, Delco Radio Division, General Motors Corporation, Kokomo, Indiana.

An equal opportunity employer

solid state electronics

DELCO RADIO DIVISION OF GENERAL MOTORS CORPORATION
KOKOMO, INDIANA

BOILERMAKERS

By Dave Miller, MetE '65

PROFESSOR Landgrebe did all of his graduate and undergraduate work right here at Purdue. So perhaps he more than any other man on campus knows what the engineering problem facing students here is and how it could be improved. Professor Landgrebe received his Bachelor's Degree in EE in 1956 his master's '58 and his Ph.D. in '62.

Professor Landgrebe felt that one of the major problems facing the engineering student is the student himself. By this, he meant that a large majority of the students who enter engineering are not more interested in engineering than they are any other field. Engineering in today's day and age is regarded to be quite glamorous and exciting. Partly due to the recent plunge into a technological race with the U.S.S.R. Many parents encourage their children to enter the engineering profession just as they used to toward becoming a doctor or lawyer. High schools also tend to encourage students who have done well in math, physics or chemistry to enter the engineering field. A large majority of these students would probably be just as well off majoring in chemistry, physics or math alone. And as is often the case many do switch into one of these fields after entering college. Engineering is a tough road to travel and many students just aren't that interested in engineering to stick it out. Professor Landgrebe is very suspicious of the student who comes to college and tells his counselor that he has had ambitions to become an engineer since he was a boy. This person is eventually due for a shock because in all likelihood his idea of engineering and what engineering actually is may be quite different. Professor Landgrebe said it is far sadder to see the students who stay in engineering who want to transfer out of engineering but due to the stigmas attached, they are hesitant to transfer into the school of field they really are interested in. The freshman engineering staff is trying to improve the counseling section in order that the new engineering student will be more able to decide whether he is in the right engineering field or whether he should be an engineer at all.

When asked about the tendency at Purdue to put all of the students in a large lecture type class, Professor Landgrebe said that at first he opposed this type of class but also stated that a small group is not a necessary requirement for learning. He felt that large lecture classes require the professor to strive harder to get and maintain his audience's attention. One bad effect of large classes is that the student feels sort of lost in the crowd. The student doesn't have the pressure exerted upon him to do the homework as when he was in a smaller class and the professor could more readily check on what progress the students are making. Professor Landgrebe feels that certain courses need to be kept small simply because of the nature of the material being presented. At this time, Purdue has a sophomore course in circuits which is monitored on television.

Holder of three degrees here . . .

. . . Professor Landgrebe.

When asked about the attendance problem, he felt that the students in many cases have to be made to attend or else they would slowly slip into habitual absence. The same is true on homework. If the student is not required to hand in any homework, the student will have the tendency to brush over the work lightly rather than really work on the problems until he has the assignment mastered. Professor Landgrebe told of a summer shop session held here in which people in various industries were brought in to learn new techniques and ideas. They weren't given any formal homework assignments—only reading material. At the end of the course, the primary complaint that the class had concerning the course was that the students felt they needed to be pushed more into studying by having to hand in written assignments. Even these men and women who were from industry found that they had the tendency to leave the reading go until it was actually too late.

Perhaps students of all ages need to be forced to keep up in their studies; but after reaching college level courses, students should realize that cutting classes or ignoring homework assignments only cheats themselves.

Professor Landgrebe concluded: "Every student has paid, in one way or another, for his education. Therefore, he isn't hurting the university or his professor by sloughing off—he's only limiting his own success in his field after graduation. ■

Editor—Bob Hostetler.

"ALTHOUGH I'm definitely glad to have an engineering education under my belt, I'm not sure if I would choose to go through it all over again," admitted Bob Hostetler, Editor-in-Chief of the *Purdue Engineer,* when asked about his decision to go into engineering. He seems to have stated well the feeling of many engineering seniors. "Engineering gives the individual a tremendous background for many fields. Unfortunately, it may, at the same time, force the serious student to neglect many of the non-academic experiences that should be gained as a college student," Bob further relates.

Bob, a senior in Engineering Sciences, has not let this happen to him. Coming from a small high school, he was admittedly a "closet case" his first semester on campus. "Learning how to study and giving myself a good foundation for future studies was very valuable to me later," he states. He has continued to do creditable academic work as evidenced by his membership in Tau Beta Pi and Phi Eta Sigma honoraries and his 5.22 graduation index.

The fall of his sophomore year, he joined the *Engineer* staff as assistant articles editor, and since has served as articles editor and as editor-in-chief for the past year. He has also been active in his fraternity, Triangle, on the rush committee, as steward, and as a member of the executive committee. His achievements in campus activities have been recognized by his election to the Gimlet Club and Omicron Delta Kappa.

He is convinced that the smaller activities like the *Engineer* are the best place for those people desiring either an activity requiring only a small amount of work, or one in which quick advancement can be found.

Without prompting, Bob offered his views on how to obtain, as he calls it, a "complete education" at college. "As no one will deny, the academic education is of first importance. The best way to take care of this is to study very hard the freshman year and to establish oneself scholastically. But after this has been accomplished, students must look around their college environment and begin participating in and learning from extra-classroom activities. Pity the graduate who realizes too late the many opportunities that college life offered him." ■

JOHN FARIS, eighth semester E.E., came from a small town in Missouri half the size of Purdue and settled immediately into activities. His first efforts included radio station KMRX in H-3, where he spent his freshman year, and the Purdue Amateur Radio Club before starting at the *Engineer* his second semester at the university. John has served for three years in the Business Department being Advertising Manager, Finance Manager, and presently Business Manager. However, these are not his only accomplishments since entering Purdue. John is presently finishing his term as the *Engineer's* representative on the Engineering Council, Purdue's engineering student's representative council, and, finally, pledge trainer of his fraternity, Triangle.

Brothers at Triangle.

Business Manager—John Faris.

Faris is also active in Army ROTC where he is a cadet major in the Signal Corps and last semester was named a Distinguished Military Student. He has been elected a member of the Purdue Order of Military Merit, Army honorary, and Scabbard and Blade, national tri-service military honorary. When asked about his decision to "go advanced," Faris replied, "I decided long before I came to Purdue I wanted to serve as an officer. I think two years experience as an officer will be invaluable when I enter the industrial world." John plans to enter the service in the spring of 1965 and to be sent to Japan or some other Far Eastern post.

I asked if he had any particular views he would like to air to the public to which he replied in his Missouri twang, "Yeah, as a matter of fact I've got a couple of things about Purdue I would like to say. First, I believe the engineering curriculum would be more valuable to the student if it were a five year program, much heavier in liberal arts and electives. In this way the student could not only dig deeper into subjects of special interest, but also have a better perception of the truly fine and magnificent things that take place in this world. Then too, I would like to see more personal inter-relations between students and faculty. I feel that most professors are deeply interested in what the student thinks and feels and also desire closer relations between the two groups but somehow at Purdue the spark to achieve strong student-faculty relations is missing."

In summing school up John said, "The house, activities, dating, studying, the people—man it's a way of life! ■

Help Wanted–Male

MACHINIST

Steady work; must be experienced; overtime; paid vacations and insurance; 1st or 2d shift.

Help Wanted–Male

MOLDER

SQUEEZER

Must be experienced, 2d shift; liberal employee benefits.

MANAGER

We have an opening for a registered professional electrical engineer with 10-15 years extensive experience in all phases of engineering design, including system planning, electronic controls, relays, transmission & distribution systems, etc. Applicant should also have experience in directing the work of engineers & technicians, and be willing to assume full responsibility for the development, planning and organization of a major engineering division. Only recognized experts in the field of power engineering need apply. Salary commensurate with experience and past record.

POSITIONS OPEN AFTER JANUARY 1975

YOUNG ENGINEERS

We have several openings for recent college graduates who have degrees in electrical engineering for assignment to a comprehensive training program in the field of engineering design. Qualified applicants will receive training in system planning, station design, transmission and distribution design, etc., and will, upon completion of their training, assume responsibility for the direction, organization and completion of engineering projects in the utility industry. Starting salary will be dependent upon the qualifications of the applicant.

POSITIONS NOW AVAILABLE

WHY WAIT?

WISCONSIN ELECTRIC POWER COMPANY SYSTEM

Wisconsin Electric Power Co. MILWAUKEE, WIS.

Wisconsin Michigan Power Co. APPLETON, WIS.

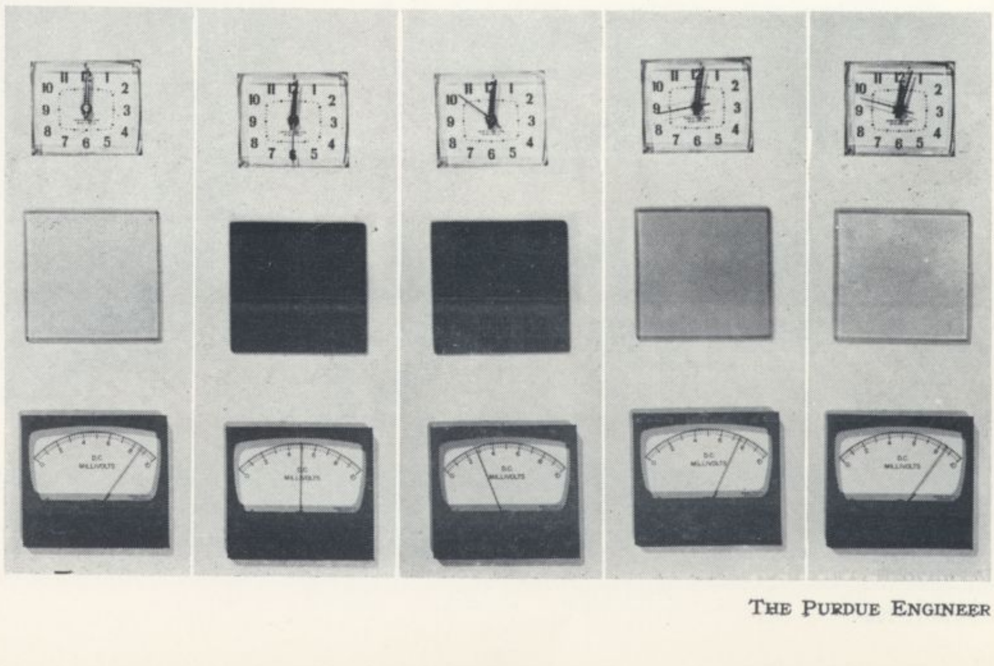
Wisconsin Natural Gas Co. RACINE, WIS.

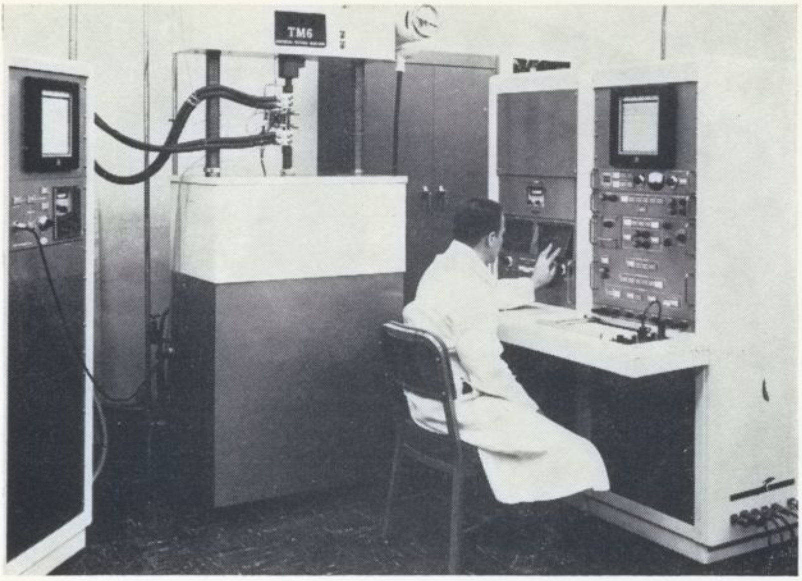
OF ENGINEERING INTEREST

By Al Hribar, ME '65

At left, U. S. Steel's new heat treated "Curvemaster" rail, designed for curves where freight and passenger traffic is heavy, will be heat treated on the head only as illustrated by the black-to-gray shading on the rail section. Through a new process developed by U. S. Steel the rail head is hardened to depths below those normally worn away under severe service. Full heat treatment of rail base and web is unnecessary since the head is the only rail surface which must withstand abrasive forces of car wheels. A two year study and test of rails in actual service indicate that this new rail will last several times longer than a conventional carbon rail.

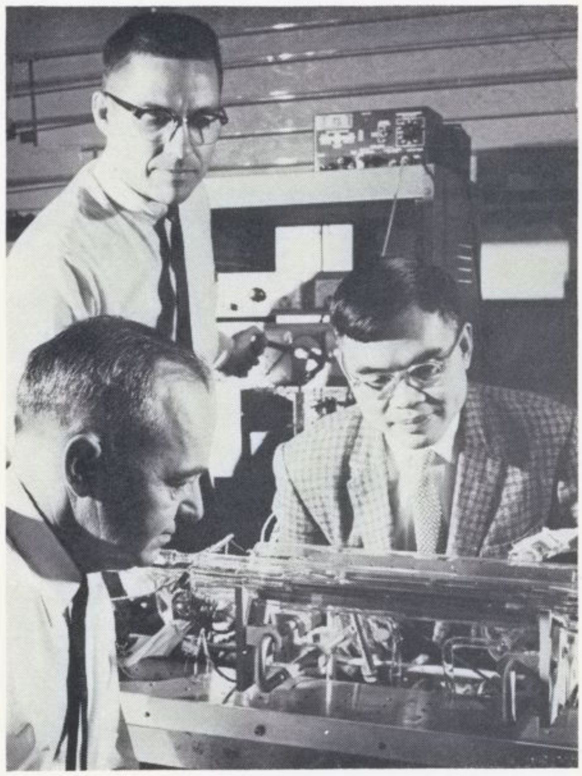
Bottom, photochromic glass, invented by scientists at Corning Glass Works, will darken to precise densities when exposed to light, and then clear to transparency when the light radiation is removed. In this series, the clock indicates the time of a complete darkening and clearing cycle. A device to register light transmission through the glass is below the glass sample. The full cycle takes less than three minutes. The Corning Glasses have not deteriorated during two years of day and night outdoor exposure or through darkening-clearing cycles performed thousands of times in the Corning laboratory.



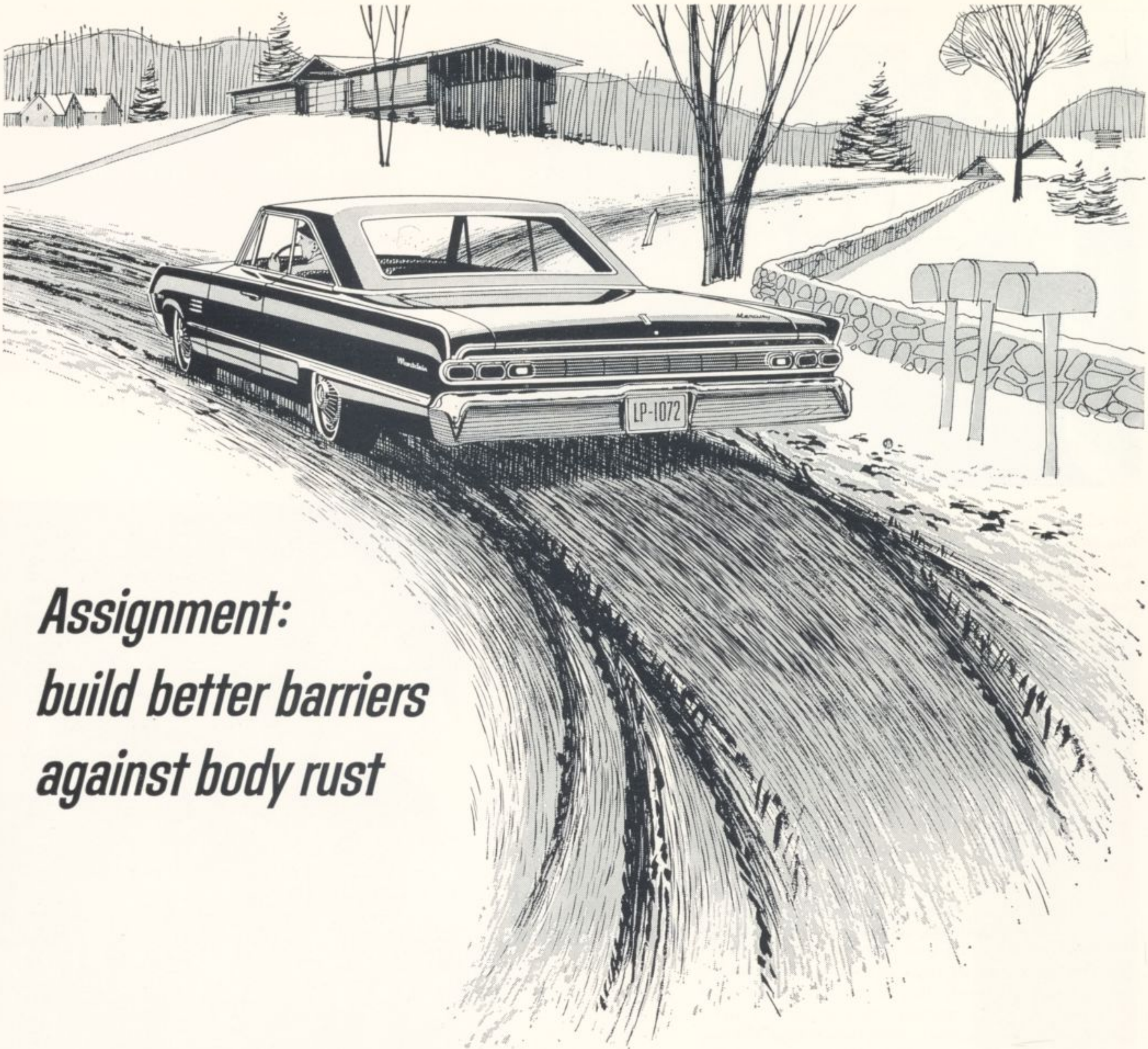


At left, Bell Telephone Laboratories scientists P. K. Tien (right), D. MacNair (left), and H. L. Hodges (center), examine the new triode laser. The intensity of the laser light can be modulated like a triode by varying the voltage of a grid inside the laser tube. Excited by a beam of electrons of nearly identical energies emitted from a hot oxide cathode, the triode laser oscillates without the usual glow discharge present in ordinary gas lasers. The result of this is a hundredfold increase in efficiency per electron over ordinary lasers. There are two lasers parallel to each other in this photograph.

At right is a new servo-controlled testing machine available from MB Electronics, a division of Textron Electronics, which determines not only when a product fails but why it fails. The machine can assist research, development or production engineers study the behavior of practically any material including metals, plastics, elastomers, ceramics, cloth and paper. It can perform any test requiring the application of a precisely known and controlled force or deflection. Because the control console is entirely separate from the test bed, remote operation is possible for testing of dangerous materials.



At left, one of the new 42 cubic yard GMC tandem rear axle tractor rigs is dumping clay. Each tractor pulls a triple-axle dump semi-trailer and a five axle dump full trailer. These light-weight, high-strength diesel trucks form the base of a new firm led by veteran industrialist Roy Fruehauf. The tractors were designed and constructed for the construction industry and adapted for hauling peak payloads under Michigan's axle weight laws. This fleet of trucks is considered by veteran construction men to be breakthrough in the field of tandem earth moving.



Assignment: build better barriers against body rust

Result: More rust-resistant steel than ever before on 1964 Ford-built bodies!

Ford Motor Company, pioneer in the use of galvanized (zinc-clad) steel, long noted for its ability to fight off rust, is using increased amounts of this superior material in 1964 car models. This marks further progress in our continuing efforts to solve the problems of metal corrosion in car bodies.

Other Ford-developed rust fighters include special zinc-rich primers . . . aluminum and stainless steels in mufflers, moldings and body fasteners . . . quality baked-enamel finishes—all powerful barriers against rust in Ford-built cars and trucks.

A new process, now in limited test production, is the electrocoating of entire car bodies. This involves electrical attraction between positively charged metal surfaces and negatively charged paint particles. When the body is dipped in an aqueous solution containing the paint particles, a form of "electroplating" occurs, the paint seeking those areas with the least coverage, until a complete and uniform coating is deposited.

More examples of engineering leadership at Ford Motor Company bringing better products to the American Road.

Ford

MOTOR COMPANY

The American Road, Dearborn, Michigan

WHERE ENGINEERING LEADERSHIP BRINGS YOU BETTER-BUILT CARS

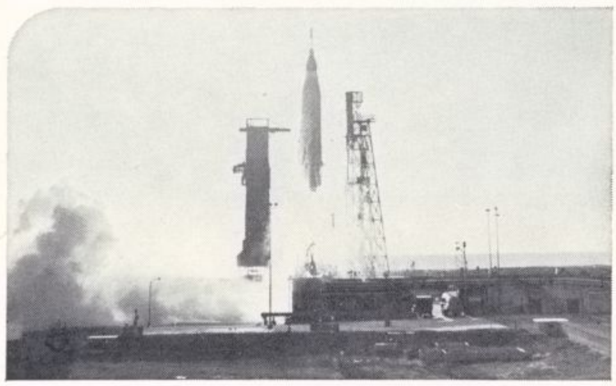
GRADUATING ENGINEERS & SCIENTISTS:

Some sound reasons why you should consider General Dynamics | Astronautics for a challenging and rewarding aerospace career are pictured below. We urge you to learn still more about Astronautics—the important completely space-oriented division of General Dynamics Corporation—by listening to the 33⅓ rpm recording offered below and by following news of Astronautics' activities and accomplishments in your newspaper, trade magazines and technical journals. For more information and a personal interview, visit the Astronautics representative who will be on your campus soon.

Advanced Programs An array of active projects and widely varied studies at Astronautics range from Atlas SLV-3, Centaur and Glotrac to Manned Space Stations, Lunar Base Support Systems and Orbiting Research Laboratory.

Modern Facilities More than $50 million have been invested in Astronautics' plant and equipment. Complete laboratory, test and computer facilities are established in-plant to enhance the performance of Astronautics' engineering tasks.

Ideal Location San Diego, California is the capital of moderate climate in the nation. Outdoor sports and recreation are year-round activities for enjoyment of your leisure hours. There is an abundance of academic and cultural opportunity in this city of more than 600,000 — a vigorous and growing community.



Inspiring Achievements The reliable Atlas, first ICBM in the free world, has also established a remarkable record as a launch vehicle — boosting more pounds of payload from the earth than any other vehicle in the free world to date. The impressive list of Atlas achievements includes a perfect performance in the Atlas-Mercury series—four for four!

WE WILL VISIT YOUR CAMPUS FEBRUARY 27 AND 28

HEAR "THE GENERAL DYNAMICS | ASTRONAUTICS STORY" as told by the men who have had major responsibilities in the direction of such dramatic technological advancements as the Atlas-Mercury manned orbital flights and Centaur, the free world's first liquid hydrogen-fueled space vehicle. See your placement office for your personal copy of this 33⅓ rpm recording, or write to Mr. R. E. Sutherland, Chief of Professional Placement and Personnel, Dept. 130-90, General Dynamics | Astronautics, 5882 Kearny Villa Road, San Diego, California 92112.

GENERAL DYNAMICS | ASTRONAUTICS

An Equal Opportunity Employer

THE LIONS ROAR

by Sue Sulzycki

OXIDATION:
His love reached out for me
As rust reaches out for new steel.
His passion weakened the structure
Of my resistance, and . . .
I rusted.

A young engineer in the service of our country called on a sixteen-year-old girl, and remarked to her parents that he was from Iowa State.

The girl's father commented that he and his wife were married there seventeen years ago. A startled expression passed over the soldier's face.

The next morning, the daughter said in disgust, "That certainly did it, Father, I told him I was eighteen. So then, of course, I had to tell him I was illegitimate."

Lulu is so thin that when she swallowed an olive 8 guys left town.

"What's the hurry?"

"I bought a new textbook and I'm trying to get to class before the next edition."

Several engineers were exchanging stories about their experiences with the opposite sex.

"Aw," sniffed one. "Girls are a dime a dozen!"

"Gee," sighed a Bus. Ad. who had remained silent until now, "and all this time I've been buying jelly beans!"

The Alabama farmer passed away and the preacher came to his wife to get some information about the poor man to use in his eulogy at the funeral. "Is he a Mason, an Elk, a Woodsman? Did he belong to the Chamber of Commerce, the Ku Klux Klan?"

The bereaved wife asked, "What's the Ku Klux Klan?"

The preacher explained, "Well, I guess you might say that's the devil under a sheet."

With a timid smile, she said, "THAT he was!"

"I seem to have run out of gas," he said softly.

Her face, small and white, was turned up to his, her eyes growing from beneath heavy lids. Her head swam.

Slowly he bent over her.

Relax . . . He was her dentist.

Sig: "You have a faculty for making love."

Chi O: "Just a student body."

A girl was driving in her new car when something went wrong with the engine. The traffic light changed from green to red and back to green and still she couldn't get the car to budge. Soon a traffic cop came up.

"What's the matter, miss?" he inquired. "Ain't we got the colors you like?"

There are only two kinds of parking left on campus—illegal and no.

"See this jewelry?" said the sorority pledge. "It once belonged to a millionaire."

"Gosh," gasped an impressed sister, "what was his name?"

"Woolworth," the pledge replied.

Newton's tenth law — the dimmer the porch light the greater the scandal power.

The father had not informed his little son of the impending arrival of the stork, but as the months passed the secret grew more and more difficult to conceal. Finally the stork dropped his bundle from heaven and the father broke the news to his son.

"The stork has been flying over the house," explained the father. "He's swooping around."

"I hope he doesn't scare mommy," the lad replied, "She's pregnant you know."

Girls in tight sweaters pull my eyes over their wool.

I think that I shall never see
A girl refuse a meal that's free;
A girl with hungry eyes not fixed
Upon the drink that's being mixed;
A girl who doesn't like to wear
A lot of junk to match her hair;
But girls are loved by guys like me
'Cause I don't like to kiss a tree.

I never kiss, I never neck.
I never say hell, I never say heck.
I'm always good, I'm always nice.
I play no poker, I play no dice.
I never drink, I never flirt.
I never gossip or spread the dirt.
I have no lines or funny tricks,
but what the heck—
I'm only six.

You can never tell about men, says Phyllis. Either they're so slow you want to scream, or so fast you have to.

Coed: "Do you think I'm conceited?"

M.E.: "No, why?"

Coed: "Girls who are as good looking as I am usually are."

A man's face may not be familiar to the luscious young thing he's speaking to, but his proposition nearly always is.

Scene: A lonely corner on a dark night.

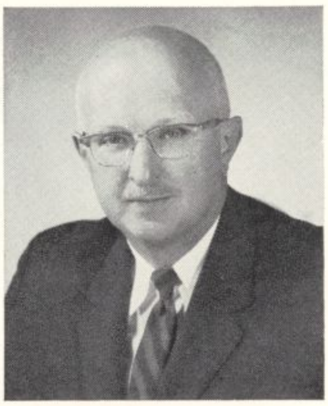
A voice: Would the gentleman be so kind as to assist a poor hungry fellow who is out of work? I haven't a thing in the world except this revolver.

Then there was the Army wife whose husband had been in the South Pacific for three years. She started receiving letters from him in which he told of the beautiful South Sea Island belles, and of their growing fascination for him.

Worried at this, she went to her physician for advice. "Well," said the doctor, "There is a chemical that can be introduced into an man's food to lessen his natural emotions. Here's a prescription; get some of this and put it into some cookies or candy, then send it to him and see what happens." The wife got the chemical and, wishing to be certain, put a triple dose of it into some cookies, which she sent to her husband. She didn't get another letter from him for seven months. When a letter finally arrived, she opened it hurriedly with trembling fingers. The letter began:

"Dear Friend . . ."

An interview with G.E.'s Dr. George L. Haller Vice President— Advanced Technology



As Vice President—Advanced Technology Services, Dr. Haller is charged with coupling scientific knowledge to the practical operating problems of a Company that designs and builds a great variety of technical products. He has been a radio engineer, both in industry and the armed services (Legion of Merit for development of radar counter-measures); physics professor at Penn State and dean of its College of Chemistry and Physics; and a consulting engineer. With G.E. since 1954, he has been manager of its Electronics Laboratory, and general manager of the Defense Electronics Division. He was elected a vice president in 1958.

For complete information on opportunities for engineers at General Electric, write: Personalized Career Planning, General Electric Company, Section 699-09, Schenectady, N. Y. 12305

GROWTH THROUGH TECHNOLOGICAL CHANGE

The Role of R&D in Industry

Q. Dr. Haller, how does General Electric define that overworked term, Research and Development?

A. At General Electric we consider "R&D" to cover a whole spectrum of activities, ranging from basic scientific investigation for its own sake to the constant efforts of engineers in our manufacturing departments to improve their products—even in small ways. Somewhere in the middle of this range is an area we call simply "technology", the practical know-how that couples scientific knowledge with the engineering of products and services to meet customer needs.

Q. How is General Electric organized to do research and development?

A. Our Company has four broad product groups—Aerospace and Defense, Consumer, Electric Utility, and Industrial. Each group is divided into divisions, and each division into departments. The departments are like separate businesses, responsible for engineering their products and serving their markets. So one end of the R&D spectrum is clearly a department function—engineering and product design. At the other end is the Research Laboratory which performs both basic and applied research for the whole Company, and the Advanced Technology Laboratories which also works for the whole Company in the vital linking function of putting new knowledge to practical use.

Having centralized services of Research and Advanced Technology does not mean that divisions or departments cannot set up their own R&D operations, more or less specialized to their technical or market interests. There are many such laboratories; e.g., in electronics, nuclear power, space technology, polymer chemistry, jet engine technology, and so on.

Q. Doesn't such a variety of *kinds* of R&D hamper the Company's potential contribution? Don't you find yourselves stepping on each other's toes?

A. On the contrary! With a great many engineers and scientists working intensively on the problems they understand better than anyone else, we go ahead simultaneously on many fronts. Our total effort is broadened. Our central, Company-wide services in Research and Advanced Technology are enhanced by this variety of effort by individual departments.

Q. How is Advanced Technology Services organized?

A. There are three Advanced Technology Laboratories: Chemical and Materials Engineering, Electrical and Information Engineering, and Mechanical Engineering; and the Nuclear Materials and Propulsion Operation. The Laboratories do advanced technology work on their own, with Company funds, and on contract to product departments or outside customers and government agencies. NMPO works for the AEC and the military to develop materials and systems for high-temperature, high-power, low-weight nuclear reactors. ATS is the Company's communication and information center for disseminating new technologies. It also plans and develops potential new business areas for General Electric.

Q. So R&D at General Electric is the work of a great many men in a great many areas?

A. Of course. The world is going through a vast technological revolution—in the ways men can handle energy, materials, and information. Our knowledge is increasing exponentially. In the last five years we have spent more than half the money ever spent for research and development. To keep competitive, and to grow, industry must master that mountain of new knowledge and find ways to put it to practical use for mankind. Only by knowing his field well and keeping up with the rush of new developments, can the young engineer contribute to the growth of his industry—and society as a whole.

Progress Is Our Most Important Product

GENERAL ELECTRIC

An Equal Opportunity Employer