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MECHANICAL DESIGN CONSIDERATIONS FOR HYDROELECTRIC POWER PLANTS

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Exam Preview:

1. According to the reference material, the minimum shaft diameter for new construction should be computed on the basis of 5,500 psi maximum shear stress and unity power factor.
 - a. 4,500
 - b. 5,500
 - c. 6,500
 - d. 7,500
2. According to the reference material, the nominal pressure of governor-servomotor systems is selected from a series of standard pressures ranging from 2,067-6,890 kPa (300-1,000 psi).
 - a. True
 - b. False
3. It has been the Corps of Engineers practice to specify crane ratings that allow up to ___ percent overload for infrequent special heavy lifts such as the generator rotor when a preferred crane rating falls within this range.
 - a. 25
 - b. 20
 - c. 15
 - d. 10
4. According to the reference material, clean and dirty insulating oil tanks should each hold a minimum of 150 percent of the oil required to fill the largest transformer on the system.
 - a. True
 - b. False

5. According to the reference material, butterfly and spherical valves are generally available as a catalog item for heads up to 600 ft and in sizes up to _ ft.
 - a. 4
 - b. 6
 - c. 8
 - d. 10
6. According to the reference material, three or less operating levels with total vertical distance of __ m or less will seldom justify an elevator.
 - a. 12
 - b. 15
 - c. 18
 - d. 20
7. For higher head projects, above 150 ft, the usual source of cooling water is a pumped supply from tailwater. This normally provides water of essentially the same quality as the spiral case gravity system.
 - a. True
 - b. False
8. According to the reference material, oil system pumps should be the _____ type and should be provided with safety relief valves and high temperature shutdown.
 - a. Axial-flow
 - b. Centrifugal
 - c. Positive displacement
 - d. Negative displacement
9. According to the reference material, the use of copper and galvanized steel for hot water in the 60-77°C (140-170°F) range on a continuous basis should be avoided.
 - a. True
 - b. False
10. According to the reference material, the service air system is a nominal __-psi system providing air for maintenance and repair, control air, hydropneumatics tank air, charging air for the brake air system, and in some cases, air for ice control bubblers.
 - a. 125
 - b. 150
 - c. 75
 - d. 100

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**Engineering and Design
HYDROELECTRIC POWER PLANTS
MECHANICAL DESIGN**

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Chapter 1 Introduction

1-1. Purpose

This manual provides information and criteria pertinent to the design and selection of hydroelectric power plant mechanical equipment and systems for new and rehabilitation projects. It is applicable to all such work within the U.S. Army Corps of Engineers responsibility.

1-2. Applicability

This manual is applicable to all HQUSACE elements, major subordinate commands, districts, laboratories, and separate field operating activities having responsibility for civil works projects.

1-3. References

Required and related publications are listed in Appendix A.

1-4. Limitations

a. Information covered in other manuals. The selection, procurement, and specification of certain major mechanical equipment are covered in other existing or pending engineer manual and guide specifications, including turbines, pump-turbines, governors, and mechanical aspects of generators. Information contained herein pertinent to such equipment is principally to aid in preparation of contract specifications based on the guide specification.

b. Detail design. This manual is not intended as a comprehensive, step-by-step solution to powerhouse mechanical design nor as a substitute for sound engineering resourcefulness and judgment. Used as a “guide post,” not a “hitching post,” it provides experience-oriented guidance and a basis for resolving differences of opinion among the competent engineers at all levels.

c. Material generally available. The manual stresses information that is of particular applicability to powerhouses. Other material useful in powerhouse mechanical design which is readily available in standard publications is not generally repeated or referenced herein.

1-5. Contents

This manual is divided into 18 chapters, each covering one or more closely related items of powerhouse

mechanical equipment or system, a Chapter 19 on corrosion mitigation, and two appendices. Equipment and systems where the detail design responsibility is normally delegated to the contractor, or where other engineering manuals are applicable, are covered with the emphasis on application, selection, and specification aspects. Equipment and systems where the detail design is normally a Corps of Engineers office function are covered in greater detail or referenced to applicable standard design codes or handbooks. Appendix A lists references to other material such as guide specifications, codes, industry standards, and other engineering manuals provided throughout this manual as applicable. Appendix B contains specification excerpts, typical system schematics, and drawings of equipment and details typical of powerhouses and other information not readily available from commonly known sources.

1-6. Design Procedures

a. Standard procedures. Department of the Army Civil Works Guide Specification CE-4000 provides the standard procedure for development of a powerhouse design. These procedures include a Preliminary Design Report, Feature Design Memoranda, an Analysis of Design, Contract Drawings, Specifications, and Cost Estimates. CE-4000 prescribes the timing, preparation, and approval procedure for this material and also references other applicable manuals and guides. While the format and instructions of CE-4000 imply applicability only to Architect-Engineer design contracts, the design procedures noted therein should be followed by all district or division offices performing powerhouse mechanical design. Funding problems, fluctuations in planned manpower, and conflicts in design scheduling will tend to alter the prescribed order of procedures. However, all stated requirements should be met unless prior approval of an alternate procedure is obtained from higher authority.

b. Additional procedures.

(1) Shop drawing review. The checking of contractor shop drawings and other material for adequacy and compliance with specification requirements is normally assigned to the engineers who prepared the design.

(2) Operating instructions. The preparation of operating instructions for each item of equipment and system is normally a design office responsibility. This requires that all design considerations and assumptions be recorded and filed during the design development.

1-7. Other Design Information

a. Sources. Information which may be helpful in design is available from many sources other than prescribed Corps of Engineers material and standard handbooks. Design memorandums and drawings from other projects, manufacturers' catalog information, sales engineers, project operation and maintenance reports, field inspectors, operation and maintenance personnel, and the powerhouse electrical and structural design personnel are all valuable and readily available sources. Good communication with other Corps of Engineer District and Division offices can often expedite information on a particular problem.

b. Evaluation. Evaluation of available information should be approached with skepticism and judgment. Relying on previous satisfactory designs requires that the design conditions and requirements be carefully compared for applicability. The obtainment and evaluation of information from field sources is improved by the personal acquaintanceships and observations resulting from design engineer visits to under construction and operating plants as well as supplier plants. Office policies should permit and encourage these visits.

1-8. Deviations

Considerable flexibility in design is available to the design engineer within the manual provisions. It is recognized that new applications and techniques may justify deviations from the stated provisions. In such circumstances, advance consultation with higher authority is suggested.

1-9. General Design Practices

a. Factors during fabrication. Design should reflect the quality of materials, workmanship, and general quality control normally experienced. The engineer will not have absolute control over these factors during fabrication but can often make practical design concessions which will make the equipment or system less critical to deviations from specified tolerances.

b. Design computations. Design computations should be consistent with available data and assumptions. Precise computations are seldom justified with incomplete data and rough assumptions.

c. Simple designs. Designs should be as simple as practicable. Increased complexity for minor operational advantages is usually not warranted.

d. Backup requirements. Backup requirements should be evaluated both on the probability and effect of malfunction. Frequent, minor malfunctions can be expensive; a major-once-in-a-hundred year malfunction can be catastrophic.

e. Reducing personnel. The continuing emphasis on reducing operation and maintenance personnel should be reflected in designs requiring frequent operation and maintenance.

f. Generous tolerances. Tolerances and fits should be generous as practicable. Precision workmanship is expensive and undependable to obtain.

g. Design computations. The design computations should include the sources of all existing designs followed, sources of data, a record of alternate designs investigated, actual design computations used, and planned operating procedures. In providing design references, particularly where more than one reference is listed, a specific reference to the particular source is essential. A general listing of references potentially applicable to a system or item of equipment is of little value for review or record purposes. Providing specific references is essential in design memorandums as well as design computations in general.

h. Environmental quality. Incorporating environmental quality in project design is essential. Opportunities for enhancement through design will be vigorously sought. Specific ecological considerations in hydropower mechanical design include, but are not limited to, the use of environmentally safe lubricants, actions to preserve or enhance the survivability of fish (fish survival rate versus turbine efficiency), and actions to maintain or enhance water quality (location of the water intakes).

i. Infestations. In areas with potential for zebra mussel contamination, many hydropower components, such as cooling systems, will be at risk of failure or disruption due to zebra mussel infestations. Design considerations in preventing these infestations should be included. For control strategies, refer to Zebra Mussel Research Technical Note ZMR-3-05, compiled by Zebra Mussel Research Program at Waterways Experiment Station.

1-10. Safety Provisions

Certain safety provisions will be required by guide specifications, trade standards, codes, and other manuals referenced herein. In addition, the requirements of the

Occupation Safety and Health Administration (generally referred to as OSHA Standards) are to be considered minimum requirements in Corps of Engineers design (see EM 385-1-1). Areas of particular concern, to mechanical design, are noise levels, personnel access provisions,

working temperature conditions, air contamination, and load handling provisions. Modification and expansion of OSHA Standards are on a continuing basis, requiring conformance with the latest published requirements.

Chapter 2 Turbines and Pump Turbines

2-1. General

Mechanical design responsibilities in connection with turbines and pump turbines include selection of type of unit, power rating, operating characteristics and number of units, preparing contract specifications, checking contractors drawings, and coordinating related powerhouse facilities including generator, governor, air, water, and oil systems, handling provisions, and structural requirements. The guidance for turbine and pump-turbine selection is included in ETL 1110-2-317. Design of turbines is a contractor responsibility and is included under the supply contract used for turbine procurement. Coverage in this chapter is generally limited to considerations in preparation and completion of the project specifications. Turbines are a major and critical item in powerhouses and warrant maximum effort to assure practical, well-coordinated specifications with reasonable assurance of responsive bidding. In addition to the guidance referenced above, the specifications should reflect Corps experience with previous similar units and preliminary exchange of information and proposals with potential suppliers.

2-2. Francis-Type Turbines

a. Scheduling. Drawing and data submittal times, commencement and completion of work, delivery schedules, and installation work scheduling should be coordinated with general project scheduling and turbine manufacturers. Suppliers of hydraulic turbines are limited. Therefore, early contact with potential suppliers is advisable to determine their capability for bidding to the proposed dates and to assure a competitive bidding response.

b. Stainless steel runners. Stainless steel runners should be specified where possible. In many cases, they may be more economical than carbon steel runners with stainless steel overlay. However, where the benefits of stainless steel are not necessary, a carbon steel runner may be more feasible.

c. Runner overlay. The extent of chrome-nickel overlay on the runner, required for cavitation protection, is usually indeterminate at bidding time, but an estimated area is required in the specification for bid evaluation purposes. The estimate should be made on the basis of prebid information obtained from suppliers and comparisons with previous units. Extensive studies are not

warranted since required areas will be determined after runner design is complete and model tested, and payment will be adjusted accordingly. The final determination of required area made by the contractor is usually accepted since it would be a factor in the cavitation guarantee.

d. Shaft diameter. The minimum shaft diameter for new construction should be computed on the basis of 38,000 kPa (5,500 psi) maximum shear stress and unity power factor. On projects where the units are being uprated the limit should be set at 41,000 kPa (6,000 psi). The maximum torsional stress should be calculated using the Mohr's circle which combines the following stresses: stress due to the weight of all rotating parts carried by the shaft; stress created by the maximum steady-state operating hydraulic thrust; and the stress produced by the maximum torque the turbine would be allowed to produce, normally the maximum continuous duty rating (MCDR) at a power factor (PF) of 1.0.

e. Shaft length. The estimated elevation of the turbine shaft coupling should be set to realize a minimum required height of powerhouse walls, taking in to account required handling clearances of the generator rotor and shaft and the turbine rotor and shaft.

f. Shaft inspection hole. The minimum diameter of the axial hole through the turbine shaft for inspection purposes is about 100 mm (4 in.). Holes which have diameters of 150-200 mm (6-8 in.) are normally specified on the larger shafts where the reduction in strength would be insignificant. The larger holes expedite inspection and remove additional core material prone to shrinkage cavities.

g. Bearing oil heat exchanger. The pressure rating for the heat exchanger should be based on pump shutoff head if a pumped supply is required and on maximum pool plus surges where a spiral case source is to be used. The hydrostatic test should be at 150 percent of rated pressure. The maximum pressure differential across the cooler is usually specified at 68.9 kPa (10 psi) to assure satisfactory cooling. The cooling water temperature should be the maximum of the source water. However, this will usually be somewhat indeterminate, and the temperature specified should include an appropriate contingency. The cooling water source should be the same as for the generator air coolers, requiring coordination of supply heads and pressure drops. In powerhouses where available gravity head would be adequate for turbine requirements but marginal for the generator requirements a pumped supply should be provided for both. For additional comments on cooling water, refer to Chapter 10.

h. Guide bearing oil pumps. Pressurized lubrication systems are sometimes used for guide bearings, and the guide specification includes the pump requirements. However, self-lubricating bearings are practicable and are preferred for reliability and to reduce the connected DC load. An oil sump drainage pump is required when it is not practicable to drain the sump to the oil storage room by gravity. Capacity should usually be based on draining the sump in 3-4 hr. The installed pump option is preferred over a portable pump for convenience and savings in operational manhours.

i. Stay ring.

(1) Internal pressure. The stay ring should be designed for an internal pressure based on maximum pool head plus water hammer.

(2) Grout holes. Holes required for placing of grout under the stay ring are normally 50 mm (2 in.) in diameter. A diameter of 20 mm (3/4 in.) is satisfactory for vent holes.

j. Spiral case and spiral case extension. The specific requirement is dependent on the need for a field hydrostatic test, the need for a valve at the end of the penstock, and the method of connecting spiral case extension to the penstock or penstock valve.

(1) Hydrostatic test. Standard practice is to require a field hydrostatic test on all units requiring field welding. Elimination of field welding is practical only with very small cases permitting full shop assembly and shipping. The test should be specified at 150 percent of design head including water hammer. When a hydrostatic test is specified, the alternative of magnetic particle inspection for circumferential shop and field welded joints may be used. A field hydrostatic test will also require the alternative of providing a test pump and sealing off devices at the stay ring opening and inlet end of the spiral case extension. Also, when a field hydrostatic test is performed, the embedment of the case is performed while pressurized and the test pump is used to maintain design pressure in the case. The relief valve specified should be capable of being set at both the design pressure and test pressure. The pressure alarm should be actuated at a 68.9-kPa (10-psi) drop below design pressure. If circumstances are such that embedment with pressurized spiral case is impracticable, a mastic blanket covering the spiral case and extension is usually required to minimize the transmittal of operating head load to the concrete. An alternative requiring an additional 76-mm (3-in.) length of spiral

case extension is necessary for cutting and finishing when removing a test head.

(2) Penstock valve. Chapter 5 discusses factors relating to the requirements for penstock valves. Valves may be of either the butterfly or spherical type. The penstock extension-to-valve connection options are not influenced by the type of valve. Valves may be procured under the turbine contract or provided by a separate supply contract. A separate schedule should be provided when the valves are included so that award can be made by schedule or by a combination of schedules to eliminate undesirable effects on competitive bidding.

(3) Connection to spiral case extension. The choice of a flexible sleeve-type coupling or a welded joint for connecting the spiral case extension to the penstock valve or penstock depends primarily on structural considerations. These considerations involve the most practicable point at which to take the closed valve reaction and the probability of differential settlement or other structural factors affecting alignment of the penstock and spiral case extension.

(a) With penstock valve. Where a penstock valve is used, the reaction of the closed valve is generally taken by the penstock and a flexible coupling provided to connect the valve to the spiral case extension. This connection requires a straight section of penstock extension with tolerances to meet the coupling requirements and long enough to permit assembly and disassembly. Guide specification options are included for obtaining the straight section. A welded connection for valve-to-spiral case extension is satisfactory with closed valve reaction taken by the penstock and structural and foundation conditions indicating no potential misalignment problems.

(b) Without penstock valve. A welded connection should generally be used unless structural and foundation conditions indicate a possibility of misalignment problems. Where a flexible coupling is indicated, the straight penstock section will be required as with the valve-type installation.

(4) Service water. A service water connection on the spiral case extension is primarily for generator air coolers and generator and turbine bearing coolers. Unit gland water may also be from the service water connection, and in some powerhouses raw water for other powerhouse requirements is obtained from this source. The connection size specified should be based on preliminary estimates of cooling water requirements by potential

generator and turbine bidders, requirements at existing projects, crossover requirements, and the proposed powerhouse piping system. A connection is not required where a tailwater pumped supply is justified. If piping and valve location considerations warrant, the supply connection may be specified on the spiral case rather than on the spiral case extension.

(5) Drain. The spiral case-extension drain should be sized in accordance with the considerations noted in paragraph 11-2b(3).

k. Runner wearing rings. Wearing rings on the runner are not normally specified as operating experience has indicated little or no requirement for replacement. Stationary wearing rings above and below the runner should be specified.

l. Facing plates and wicket gate seals. Facing plates above and below the wicket gates are not required when gate seals are provided. Gate seals are usually justified. Rubber seals without facings are generally satisfactory to about 91 m (300 ft) of head. Bronze or stainless facings should be required over 91 m (300 ft) of head.

m. Air depression connection. Where an air depression system for depressing the draft water below the runner is planned, or is a future probability, a flanged connection in the head cover should be provided. Considerations pertinent to sizing the connection are discussed in paragraph 13-5.

n. Wicket gate shear pin detection. A pneumatic system for detecting a broken shear pin is not normally installed until operating experience indicates a need. The tapped hole option should be included in the specification as the cost is minimal.

o. Wicket gate servomotor pressure. Nominal system operating pressures (high end of operating range) range from 2,100-6,900 kPa (300-1,000 psi). Optimum pressure is dependent on a number of factors including: required pump displacement, pipe sizes, cost of hydraulic components, pumping horsepower, tank sizes, blade and gate servomotor sizes and location (see paragraph 2-4a), and service experience. Evaluation should be on the basis of overall cost of the turbine and governor system. The evaluation must be on the basis of advance information obtained from potential turbine and governor suppliers since the turbine and governor are normally obtained under separate contracts. When the advance information

indicates the cost of alternate pressure systems to be approximately the same, the lower pressure system should be specified. System piping, fittings, and packing appropriate for the operating pressure should be specified. A standard pressure should be specified (refer to Guide Specification CW-11290).

p. Gate locking device. A manual device is satisfactory for the open gate position. An automatic device for the closed gate position should be provided for all units to permit automatic locking on unit shutdown.

q. Pit liner. The minimum elevation of top of pit liner should be specified to be approximately 0.6 m (2 ft) above the servomotor elevation. Minimum plate thickness should be 13 mm (1/2 in.) to permit tapped holes for the mounting of piping and equipment. One personnel entrance to the turbine pit is sufficient unless safety regulations would require an additional access for emergency escape.

r. Draft tube liner. The minimum draft tube liner thickness is usually specified at 16-19 mm (5/8-3/4 in.) depending on the draft tube size. The liner should extend down to protect concrete from water velocities over 9 m/s (30 fps) and a minimum of 0.9 m (3 ft) below the main door.

s. Rotation. The direction of rotation of the turbine runner may be specified as either clockwise or counterclockwise as far as operating characteristics of the turbine and generator are concerned. However, direction of rotation affects powerhouse layout and handling facilities to some extent and should be specified for optimum convenience and economy. Considerations in the determination of the offset of the generators with respect to the center line of a powerhouse bay are as follows: the direction of rotation, the location of the assembly area, proposed bridge crane arrangement, and proximity of the closest end wall to the generator center line. Normally cranes are designed and specified to interpose no significant restrictions on turbine design. In the case of an additional unit to be installed in an existing powerhouse, however, space and crane limitations should also be considered in specifying turbine rotation.

2-3. Francis-Type Pump Turbines

The considerations noted under paragraph 2-2 are generally applicable in completing specifications for Francis-type pump turbines.

2-4. Kaplan-Type Turbines

Items listed in paragraph 2-2 are generally applicable to Kaplan units also. Additional considerations pertinent to Kaplan units are as follows:

a. Blade servomotor location. A location requiring removal and disassembly of the runner to effect repair or replacement of the servomotor is not recommended. This would normally rule out an upper hub location as an acceptable option. Location of the blade servomotor is a factor in selecting the governor operating pressure. When the servomotor is located in the shaft, higher pressures will permit a reasonable shaft and flange diameter at the servomotor. Locating the servomotor in the runner cone below the blades is an acceptable alternative to the shaft location.

b. Head cover drain pumps. Reliability of the head cover drain pumps and power supply is of primary importance to provide maximum safeguard against flooding of the turbine guide bearing and a prolonged unit shutdown. One AC and one DC pump will usually ensure the most reliable installation. However, there is normally considerable opposition to the additional load on the station batteries. The reliability of the AC supply depends on a number of factors involving inhouse and outside sources and inhouse distribution. If a reliable backup electrical source is not practicable to obtain, backup air operated pumps or water jet eductors may be justified. The mechanical design memorandum should include a discussion on the reliability of the power supply of the head cover drain pumps and backup provisions along with an evaluation of the seriousness of one or more units out of service for the necessary cleanup operation.

Chapter 3 Generators and Motor-Generators

3-1. General

Design of generators and motor-generators is specified as a contractor responsibility. Design requirements and specifications are the responsibilities of electrical discipline within the Corps of Engineers (see EM 1110-2-3006 for guidance). Guide Specification CW-16210 provides the basis for preparation of contract specifications. Mechanical design includes the following responsibilities: coordination of turbine and generator mechanical characteristics; required generator handling facilities; and oil, air, carbon dioxide (CO₂), and water service connections to the generator. Design considerations for the generator as related to the turbines, cranes, and piping systems are covered under the respective chapters of this manual. Discussion in this chapter pertains to mechanical considerations in completing generator guide specifications.

3-2. Turbine Considerations

Powerhouse scheduling normally requires contracting of the turbines prior to preparation of generator specifications. This permits the required turbine data for the generator specification to be obtained from the turbine specification, the turbine bid data, and the turbine model test. Preadvertising correspondence with turbine and generator suppliers should provide verification that the turbine related stipulations in the generator specification are practicable. The required flywheel effect of rotating generator parts must be computed on the basis of all related factors. This includes turbine characteristics as well as penstock, generator, governor, and power system characteristics. Maximum speed rise and pressure rise upon loss of generator load are normally the critical mechanical factors. Turbines and generators are specified to withstand stresses due to runaway speeds; however, the damaging effects of vibrations are indeterminate and require conservative limits on speed rise. Maximum speed rise should normally be limited to 40 percent above synchronous speed when the required WR^2 can be obtained with a normal generator design. When the 40 percent limitation would require a special generator rotor rim design or separate flywheel, a greater allowable speed rise may be warranted but should not exceed 60 percent in any case. Maximum pressure rise at the turbine is usually limited to 30 percent above the maximum static pressure.

3-3. Handling Provisions

The powerhouse crane is normally sized to handle the generator parts, and no size or weight restrictions should be included in the generator specification. Certain powerhouses may justify two (2) cranes coupled together for handling the heavier parts. These should also be designed to meet the generator requirements. Exceptions to this policy may be required where a new unit is being provided in an existing crane equipped powerhouse, or where scheduling revisions require a crane to be under contract before a generator contract is awarded. In either case, the appropriate crane limitation should be included in the generator specification. Ratings for a crane procured before generator data are available should be based on prebid exchange of information with generator suppliers. Crane design guidance is covered in Chapter 6 of this manual. For existing powerhouses, a crane clearance diagram, powerhouse access limitations, and other applicable physical limitations should be included in the generator specifications.

3-4. Service Systems

a. Oil. The powerhouse lube oil system supply and return lines which serve the generator bearing system are normally terminated within the generator housing near the top or bottom of the turbine pit. It is generally not practicable to determine exact locations at the preparation time of generator specifications, so it is satisfactory to negotiate final connecting points for generator and powerhouse piping during shop drawing review. Filtering and purifying of lube oil at the unit is normally not required except at the initial filling. This should be accomplished with government furnished filters and powerhouse portable purifiers. Oil coolers with water coils are normally supplied from the same cooling water system as the air coolers and turbine bearing coolers. Paragraphs 2-2g and 10-2 provide guidance concerning maximum differential pressure, design pressure, test pressure, cooling water temperature, and cooling water supply.

b. Air. Compressed air for operation of the generator brakes is supplied from the powerhouse brake air system as discussed in paragraph 13-3. Generator specifications should normally include values of 689 kPa (100 psi) as the nominal system pressure and 517 kPa (75 psi) as minimum system pressure. Piping terminations are generally as noted above in paragraph 3-4a for oil piping.

c. Carbon dioxide systems. The CO₂ piping terminations are generally as noted above in paragraph 3-4a for oil piping. In powerhouses where the CO₂ powerhouse headers are routed above the generator floor elevation, it may be preferable to route the connecting lines overhead to enter the generator housing near the top. Paragraph 15-4 provides guidance on generator CO₂ systems.

d. Water. Powerhouse cooling water supply and discharge lines serving the generator air coolers and bearing oil coolers are normally terminated in the lower generator housing. Cooling water head and temperature considerations and test pressures should be as discussed in paragraph 2-2g for turbine bearing coolers. Related comments

on generator cooling water supplies are included under paragraph 10-2. Temperature modulation of the generator cooling water should be provided for units where it is necessary to modulate the cooling water flow to assure a cooling water discharge temperature which meets powerhouse heating requirements. The generator specification should include a statement on the type of control that will be provided in the powerhouse cooling water piping and the modulated temperature. When modulation is proposed for other reasons, a statement to this effect should also be included in the generator specification. In all cases where the cooling water flow is modulated, a low-flow bypass should be provided around the modulating valve to allow minimum flow for startup.

Chapter 4 Governors

4-1. General

The design of governors for turbines and pump-turbines is specified as a responsibility of the governor manufacturer. In general, the governor operating requirements and characteristics will be determined from the electrical, mechanical, and hydraulic characteristics of the generator, turbine, and penstock. Guide Specification CW-16252 provides the basis for preparing specifications. EM 1110-2-3006 provides guidance for the electrical and electronic controls of the governor. Coverage in this chapter includes considerations pertinent to selecting the guide specifications mechanical options.

4-2. Considerations

a. System pressures. The nominal pressure of governor-servomotor systems is selected from a series of standard pressures ranging from 2,067-6,890 kPa (300-1,000 psi). Turbine requirements will usually indicate the desirable nominal pressure (refer to paragraph 2-2*o*). Since turbine contracts are normally scheduled in advance of governor contracts, the nominal pressure will have been determined before the governor specification is prepared. However, it is important to exchange information with potential governor suppliers during preparation of the turbine specification. The working pressure range should be appropriate for the nominal system pressure as indicated in the guide specification. The differential pressure across gate servomotor ports (and oil head ports of Kaplan units) is assumed 80 percent of the minimum working pressure range for figuring servomotor capacity. This assumed value allows for piping and valve losses and requires that the governor and turbine contractors cooperate to limit the pressure drop in the system accordingly. System design pressure should be at the pressure tank valve setting which is normally 110 percent of nominal system pressure.

b. Oil heaters. The minimum and maximum design ambient temperatures should be the heating and ventilating system design temperatures for the room with allowance for nonuniform temperature conditions in the room. The minimum ambient temperature stated may be of significance to the governor contractor in determining the need for oil heaters if oil of higher viscosity than standard turbine oil will be used in the governor system. If oil heaters are used, care must be taken to ensure that the

surface temperature of the oil heater does not cause any chemical change of the oil, such as chemical breakdown.

c. Pressure tank.

(1) Location. The powerhouse equipment layout should provide the pressure tank location(s) with the shortest and most direct lines practicable from the tank to the actuator and servomotors in order to minimize pressure losses.

(2) Tank design and pressure. The tank and safety valve shall be designed in accordance with the latest version of the American Society of Mechanical Engineers (ASME) "Boiler and Pressure Vessel Code." The tank design pressure should be a minimum of 115 percent of the maximum system operating pressure. This will allow for variations in the pump stop switch and oil pump pressure relief valve and safety valve blowdown pressure. A pilot-operated ASME safety valve should be used which has a 98 percent cracking pressure and a 4 percent blowdown. The safety valve setting should never exceed the stamped tank pressure rating but should be equal to or less than the stamped tank pressure rating. An example is as follows:

Stamped Tank Pressure	4,795 kPa (696 psi)
Stamped Safety Valve Setting	4,168 kPa (605 psi)
Safety Valve Cracking Pressure	4,086 kPa (593 psi)
Safety Valve Blowdown Pressure	3,996 kPa (580 psi)
Oil Pump Pressure Relief Setting	3,962 kPa (575 psi)
Governor Oil Pump High-Pressure Stop Switch (Maximum system operating pressure)	3,790 kPa (550 psi)

(3) Tank test pressure. Shop test pressure should be in accordance with the ASME "Boiler and Pressure Vessel Code." This is typically 150 percent of the stamped tank pressure.

(4) Tank height. A specification restriction on tank height should be avoided unless required by powerhouse structural configuration.

(5) Tank oil level alarms. High and low oil level alarms will normally be required to permit monitoring of pressure tank and sump tank oil level in the control room.

In addition, pressure tank high-level and sump tank low-level contacts are used for pump control to stop the pump and lock it out in case of pump unloader valve failure.

d. Distributing valve adjustment. The required setting for the wicket gate opening or closing rate is dependent on the design for maximum unit overspeed and the water hammer design stresses in the penstock and turbine. The timing usually stated in the specifications is between 8 and 20 sec. For turbine blade adjustment, a rapid response is not required and can impose undesirable stresses in the blade operating mechanism. Then the timing usually stated in the specification is between 20 and 60 sec.

e. Maximum runaway speed. The maximum runaway speed to be specified should be based on the turbine model test results.

f. Brake air valve. The air pressure for the brake air valve should normally be specified at a nominal 689 kPa (100 psi). If there is reason to expect the station service air will be controlled to a higher pressure, the powerhouse construction contract should require a pressure-reducing valve in the brake system air supply. If the turbine runner is below minimum tailwater elevation, a timer to effect intermittent operation of the brake air valve is seldom justified as satisfactory operation is normally possible by allowing the unit to decrease to 30 percent speed with no brake application, then apply brakes continuously.

Chapter 5

Penstock Shutoff Valves at the Powerhouse

5-1. General

Butterfly and spherical valves are typically used at Corps of Engineers projects when shutoff capability is required at the powerhouse end of the penstock. Mechanical design responsibilities for these valves include the determination of need, selection of type and size, selection of auxiliary equipment, coordination of location and space requirements, preparation of contract drawings and specifications, review of contractor submittals, and preparation of instruction manuals.

5-2. Valve Requirement

A shutoff valve may be required at the powerhouse end of penstocks for either turbine or pump-turbine units. The purpose of this valve is to provide emergency shutoff in case of flooding-type failure or loss of speed control, reduction of leakage through wicket gates, and for maintenance of the turbine. However, shutoff provisions are usually required at the intake of each penstock. As a result, a shutoff valve at the unit may not be required. Several factors should be considered when deciding the need for a shutoff valve at the unit. The factors include but are not limited to the following:

a. Type of shutoff at the penstock intake. A quick closing shutoff at the penstock intake, operable under emergency conditions, may be an alternative to a shutoff at the powerhouse. Where maintenance and emergency shutdown can be satisfied with the intake shutoff, the requirement for powerhouse valves can seldom be justified.

b. Length of penstock. A long section of penstock downstream of the shutoff will increase the time required to shut the unit down during an emergency closure, increase the time required to unwater the unit, and increase leakage losses. Maintenance and emergency shutdown requirements will usually justify a powerhouse shutoff when the penstock is several hundred feet long.

c. Head. A shutoff valve near the unit will reduce the effective head on the unit, which in turn will reduce the leakage.

d. Multiple units per penstock. Operational and maintenance flexibility will normally require a separate shutoff valve for each unit. Generally, maintenance requirements alone will justify powerhouse shutoff valves for multiple unit penstocks.

e. Type of wicket gate seal. A tight seal reduces leakage losses. However, deterioration of the seal with time should be considered when determining the effects of leakage.

Evaluation of the factors should consider their effects on maintenance, emergency operations, and costs. The factors considered and basis of determination should be included in the mechanical design memorandum.

5-3. Valve Selection

Butterfly and spherical valves are generally available as a catalog item for heads up to 183 m (600 ft) and in sizes up to 2.4 m (8 ft). Valves for conditions exceeding these limits are typically designed for the specific application. Factors to be considered include initial cost, maintenance, head loss through valve, and requirements for transition sections.

a. Spherical valves.

(1) General. Spherical valves consist of a valve body, valve rotor, bearings, and operator. In the open position, the rotor has a full diameter water passage axially aligned with the penstock. Head loss through the valve in the full open position is approximately the same as an equal length of penstock. When rotated 90 deg (the closed position), the valve presents a solid surface, closing the water passage. Movable seal rings permit tight shutoff. Wear of the sealing surfaces is minimized because the wear rings are not in contact with the mating surfaces until after valve rotation is complete. Fabrication and machining costs are relatively high when compared with butterfly valves.

(2) Detail requirements are as follows.

(a) Design conditions. Valves should be designed for maximum penstock head including water hammer. Because of the significance of a water hammer, studies should be conducted and documented in the design process. Since the valve may be used to test the penstock and/or spiral case, and during spiral case grouting, the design should also be adequate for these heads as

applicable. The installation may require the valve to withstand heads from either direction when closed. If the valve is to be used for emergency closure, the operator should be capable of closing the valve in 2-5 min as practicable for the size.

(b) Valve body. The valve body should be made in halves of fabricated or cast steel, properly annealed, and adequately designed to resist the hydraulic forces acting directly on the body and those resulting from the thrust for any position of the valve rotor. Integrally cast or forged (if fabricated) steel flanges, suitably machined, should be provided for bolting the body pieces together and circumferential flanges for bolting to the pipe extensions.

(c) Rotor. The valve rotor should be made in one piece of annealed cast or fabricated steel and should adequately resist the bending and shearing load resulting from the hydraulic and operating forces.

(d) Seals. Retractable seal rings should be provided to permit separation of the sealing surfaces during rotation of the rotor. Sealing surfaces should be corrosion resistant and of different composition and hardness to minimize galling. One seal of 300 series stainless and one of 400 series stainless will perform satisfactorily in most waters. However, the source water should be checked for unusual corrosiveness. Then the materials should be specified accordingly. Both sealing surfaces should be removable for replacement. The retractable seal ring should normally be oil-hydraulically operated. Both upstream and downstream seals may be justified to allow more flexibility in scheduling of seal replacement.

(e) Trunnion bearings. Trunnion bearing with renewable self-lubricating bronze sleeves and bronze thrust washers should be provided. Bearing housings should be integral to the body casting. A means of adjusting and centering the rotor should be provided. Pressure relief for leakage water through the gland should be verified.

(f) Bypass. A bypass valve permitting equalized pressure on both sides of the spherical valve before opening should be provided. The bypass is normally motor operated for automatic control.

(g) Valve operator. A double-acting hydraulic cylinder operator should be provided for opening and closing the valve. The operator should be capable of closing the valve at maximum pool head and maximum discharge. Opening capability should be at balanced head conditions. The operator should also be suitable for continuous

pressurization to hold the rotor in either the fully closed or open position. All valve and operator components subject to loading from operator action should be designed for the maximum hydraulic cylinder forces.

(h) Operator control. The type of control should be appropriate for normal unit operation and emergency shutdown requirements. Pumps are normally on pressure switch control and are protected with relief or unloading valves. Cylinder action is normally controlled with motor-operated tight sealing four-way valves and pressure-compensated flow control valves set to obtain the required opening and closing times. Spool-type control valves are not suitable for extended pressurizing periods in one direction. Impurities tend to filter out in the spool clearances causing sticking and failure to operate. Gauges, isolating valves, filters, alarms, control panels, and limit switches should be provided as applicable.

(i) Pipe extensions. Pipe extensions for connecting the valve to the penstock and spiral case extension are generally procured with the valve. The extensions should be designed on the same basis as the penstock. One end of each extension should be provided with a flange to connect to the valve flange. The other end of each extension should be prepared for a welded and or sleeve-type connection, as required. When required, the sleeve couplings are normally procured with the extensions.

(3) Safety provisions.

(a) A lockable, mechanical latch should be provided for securing the valve in the closed position. The latch should be capable of withstanding any opening force obtainable from the hydraulic operator to protect workmen from accidental opening of the valve.

(b) A mechanical hydraulic hand pump and manually operable control valves should be provided for manual operation of the valve in either direction.

(c) The valve operating cylinder should be cushioned to prevent damage due to the valve slamming in the event oil pressure is lost.

(d) Additional flow control valves should be provided in the hydraulic circuit at the cylinders. These valves should limit the flow to 125 percent of normal closure flow if line pressure is lost.

(e) Hydraulic pumping capacity should be provided with two pumps in a lead-lag control arrangement, either

of which is capable of performing a normal opening or emergency closing.

(f) Accumulators should be provided in the hydraulic system with capacity sufficient to fully close or open all spherical valves on the system with both pumps inoperative after the low system pressure alarm has been activated.

(g) All parts and components subject to loading from operation of the hydraulic operator should be designed for maximum stress of 75 percent of yield point with a maximum attainable pressure in the cylinder. Maximum attainable pressure should be assumed as either pump shutoff pressure or maximum setting of the relief valve sized for maximum pump delivery.

(h) Valve bodies and rotors should be hydrostatically tested at 150 percent of design head in both directions and with rotors open and closed.

(4) Design. Design of spherical valves and operators should be specified as a contractor responsibility. However, the valves are a critical item in obtaining and maintaining satisfactory unit operation. Therefore, the specifications should require equipment of a design proven in service. Standard catalog equipment is preferred when available. Where a size and head rating not previously in use is required, the specifications should require the bidder to have experience in designing and manufacturing similar valves of the approximate size and head rating.

b. Butterfly valves.

(1) General. Butterfly valves consist of a valve body, valve disc, bearings, and operator. Head loss through a butterfly valve is higher than for a spherical valve. Losses are higher for lenticular-type disks versus the open truss-type disc. Head loss may justify an oversize valve with suitable transition sections. Some leakage is characteristic of the metal-seated butterfly valves.

(2) Detail requirements.

(a) Design conditions (see paragraph 5-3a(2)(a)).

(b) Valve body. The valve body should be of either cast or fabricated construction and include connecting flanges. Design and fabrication should be in accordance with Section VIII of the ASME "Boiler and Pressure Vessel Code."

(c) Disc. The valve disc should be of cast or fabricated construction and either lenticular or open truss design. Design stresses should not exceed 50 percent of yield point or 25 percent of ultimate at design head. Fabricated designs should be stress relieved before machining. Disc design should provide for wedge sealing action with the disc at less than 90 deg to valve axis, and the disc should have positive overtravel limits. The limit may be provided by mechanical stops or by bottoming of operator piston.

(d) Seals. Valve body and disc seals should be of corrosion resistant steel of different composition and hardness to minimize galling. Both seals should be replaceable without dismantling the valve, and the body seal should be adjustable from outside the valve. Suitability of the seal composition to resist corrosion in the penstock water should be verified by prior operating experience or chemical analysis. Seal design should not be compromised to allow a manufacturer's standard design.

(e) Valve shaft. The valve shaft for lenticular discs should be one piece. Shafts for open truss-type discs may be bolted on. Corrosion resistant sleeves should be provided at the packing boxes if noncorrosion resistance shafts are used.

(f) Bearings. Shaft bearings should be sleeve type, self-lubricated and should include adjustable thrust surfaces for centering the disc.

(g) Bypass (see paragraph 5-3a(2)(f)).

(h) Valve operator (see paragraph 5-3a(2)(g)).

(i) Operator control (see paragraph 5-3a(2)(h)).

(j) Pipe extensions. Pipe extension provisions for butterfly valves are generally as described in paragraph 5-3a(2)(i) for spherical valves. In some cases, it may be hydraulically justified to design the downstream extension as a transition section to minimize the effect of the velocity change at the valve. The downstream end of the transition section should be as required to permit the welded or sleeve-type connection to the spiral case extension.

(3) Safety provisions (see paragraph 5-3a(3)).

(4) Design. The design of butterfly valves and operators should be specified as a contractor responsibility. However, the valves are a critical item in obtaining and maintaining satisfactory unit operation. Therefore, the specifications should require equipment of a design proven in service. Standard catalog equipment is

preferred when available. Where a size and head rating not previously in use is required, the specifications should require the bidder to have experience in designing and manufacturing similar valves of the approximate size and head rating.

Chapter 6 Cranes and Hoists

6-1. General

a. General. Cranes and hoists are used in powerhouses for operational functions and for maintenance and repair. The general hoisting functions involved are similar for most powerhouses, but loadings, frequency of usage, powerhouse configuration, installed equipment, value of downtime, and availability of portable equipment can affect the optimum provisions for a particular project. Normally, initial planning should be on the basis of an existing project with similar requirements, but careful consideration of the variables should precede final selection of cranes and hoists.

b. Terminology. “Cranes” and “Hoists” are somewhat interchangeable terminology since the actual lifting mechanism of a crane is commonly referred to as a hoist. For purposes of coverage in this chapter, “Hoists” will be considered as separate items of equipment that include installations where the hoist machine is fixed and there is no controlled lateral movement of the hook(s) or lifting block(s). Other applications are covered under “Cranes.”

c. Emergency closure. For safety reasons, two different closure methods to shutoff the water supply to the turbine are required. One method is considered to be the wicket gates. The other method shall be a penstock shutoff valve (refer to Chapter 5), or an intake gate lowered by a hoist. Fixed hoists at each intake gate slot are used to lower the intake gates in an emergency situation. Intake gantry cranes are not normally used to lower intake gates in an emergency because of the much slower response time and potential crane-capacity problems.

6-2. Cranes

a. Types. Cranes for powerhouse requirements include several types: bridge, gantry, monorail, jib, mobile, and floor cranes. Coverage in this chapter is as follows:

(1) Powerhouse bridge crane. The principal overhead traveling crane serving the turbines, generators, and auxiliaries in typical indoor powerhouses.

(2) Powerhouse gantry. A gantry-type crane serving the same functions as the powerhouse bridge crane for outdoor powerhouses or in unusual cases involving a special structural design of indoor powerhouses.

(3) Intake gantry. A gantry-type crane serving intake gates, trashracks, bulkheads, fish screens, and miscellaneous items on the intake decks of powerhouses.

(4) Draft tube gantry. A gantry-type crane serving stop logs, bulkheads, and miscellaneous items on the tailrace deck of powerhouses.

(5) Mobile crane. A self-propelled, rubber-tired crane for general use, principally on intake or tailrace decks and miscellaneous nonpowerhouse project functions.

(6) Maintenance shop bridge crane. A maintenance shop bridge crane, usually a trolley-mounted electric hoist suspended from a single girder bridge, serving equipment in the maintenance shop.

(7) Floor crane. A light, portable crane with wheels for mobility on powerhouse and maintenance shop floor areas, normally manually being propelled.

(8) Monorail crane. A trolley-mounted, motorized or manual, hoist running on an I beam track for special applications.

(9) Jib crane. A wall or pillar-mounted, rotating bracket with an electric or manual hoist for specialized lifts with limited horizontal movement requirements.

b. Preliminary considerations. For each powerhouse, the following preliminary considerations should precede design and specification work on the individual cranes:

(1) Items handled. A preliminary listing of all major items to be handled by powerhouse cranes during construction, operation, maintenance, and repair should be prepared. The listing should include estimated weights, pickup and set down points, and the crane to be used.

(2) Area layouts. For each crane, layout drawings should be prepared showing points at which the crane must pick up or set down material, including loading or unloading of trucks and railroad cars, intermediate or transfer points, maintenance and repair areas, and equipment installation points. These layouts should include points for required lifts and points or areas at which crane lifts may be desirable but not required. Areas which may be used as storage or warehouse areas should be indicated also. Lifting or handling of heavy items (e.g. a small transformer), which may require moving for which crane service is not planned, should be indicated along with the proposed means of handling.

(3) Coordination. The preparation of the listing of items to be handled and area layout drawings should include information exchanged with construction and operation divisions as well as other engineering responsibilities. All reasonable adjustments in equipment location to provide effective and economical crane service should be negotiated also.

(4) Miscellaneous preliminary considerations. Corrosion mitigation is discussed in paragraph 19-2.

c. Engineering and design. Most engineering and detail design criteria for powerhouse cranes are covered in engineering manuals and guide specifications as referenced herein under the particular crane type. Final detail design and construction of cranes are responsibilities of the supplier as provided under the procurement contracts. The responsibility of the powerhouse design office is to obtain and coordinate all preliminary information noted in paragraph 6-2*b*; to determine requirements for each crane based on the preliminary information; to prepare crane clearance drawings based on sufficient design studies; to assure a practical and economical crane; to prepare specifications; and to review shop drawings, design computations, and operating instruction manuals. Documentation of assumptions and reasons for selecting particular lifting procedures and equipment arrangements should be a part of the design records. The preliminary studies and coordination are important in obtaining the optimum crane for the required service, and shortcuts should not be made.

d. Bidder qualifications. Bidder qualifications are not normally an engineering responsibility, but in the case of powerhouse cranes, it is particularly important for the powerhouse mechanical designers to exert their influence in obtaining qualified contractors. Providing cranes ready for service on schedule is very important to avoid impact to overall powerhouse construction schedules. Contractors inexperienced in design and construction of cranes have caused costly delays and impacts to other construction work. Many times a two-step bidding process is prudent in order to obtain a quality product on schedule.

e. Powerhouse bridge cranes.

(1) General. General criteria and design procedures, along with data on existing cranes, are available in EM 1110-2-4203. Detail design criteria for indoor bridge cranes are covered in Guide Specification CW-14330. For outdoor powerhouses, the powerhouse crane will normally be a gantry type for which design criteria noted in Guide Specification CW-14340 should be used as indicated in paragraph 9 of EM 1110-2-4203. Coverage

herein is limited to additional general factors which enter into crane requirements and crane selection. The discussion is applicable particularly to powerhouses with conventional vertical units; however, most factors noted are also applicable to cranes servicing slant or bulb units. Some slant units may require two cranes, one upstream and one downstream, because of horizontal distance between generator and turbine. Special intermediate lift and handling facilities are usually involved with either slant- or bulb-type units. These special facilities should be determined and furnished by the generator and turbine contractors subject to the normal design office shop-drawing reviews.

(2) Number of cranes. The choice of providing one or two cranes is an important consideration in powerhouses with several units or heavy capacity requirements. Factors entering into this determination are:

(a) Procurement cost. This cost considers one crane versus two.

(b) Powerhouse structural costs. A single crane may increase structural costs because of greater physical size, though generally only moderate additional cost is involved.

(c) Construction and erection advantages of two-crane availability. Two cranes will usually be more beneficial in long multiunit powerhouses and may have significant advantages where the construction schedule requires continued erection work after several units are in operation.

(d) Additional crane clearance. The necessity to provide two-crane lifting beam configuration will increase the roof height.

(e) Hook coverage limitations. Unusually large capacity single cranes result in greater floor areas not accessible to a lifting hook.

(f) Additional maintenance cost. Maintaining two cranes versus one does increase this cost.

(g) Value of unit downtime. Two cranes may expedite maintenance or repairs.

(h) Comment relative to two cranes for bulb or slant units (see paragraph 6-2*e*(1)). Seldom will two cranes be justified in powerhouses with less than five units. For five or more units, the design memoranda should include

the considerations pertinent to the selection of one or two cranes.

(3) AC versus DC drive systems. Current technology of AC variable frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(4) Crane capacity. EM 1110-2-4203 includes guidance for determining crane capacity. In applying the criteria the engineer should be aware that numerous factors beyond engineering control tend to disrupt orderly scheduling, and it will frequently be necessary to prepare contract drawings and specifications for cranes before accurate final loads are determined. It is also sometimes necessary to firm up powerhouse structure design affected by crane capacity and clearances prior to final confirmation of lifting loads. In such cases, capacity should be based conservatively on estimated loads (to avoid later increases). Loadings due to planned or potential future units should also receive consideration in determining crane capacity and be included in the design computations. It has been the Corps of Engineers practice to specify crane ratings that allow up to 10 percent overload for infrequent special heavy lifts such as the generator rotor when a preferred crane rating falls within this range. For cranes designed in accordance with Corps of Engineers guide specifications, this overload is well within the allowable stresses permitted by the Crane Manufacturers Association of America (CMAA) standards and is in accordance with ANSI standards and OSHA'S interpretation of their regulations.

(5) Appearance. Powerhouse bridge crane appearance should be consistent with the interior finish of the powerhouse. It is usually advisable to rely on the powerhouse architect for determination of an acceptable appearance, but compromises are necessary where preferred appearance impairs maintenance, full utility, or safety.

(6) Access. In the early stages of powerhouse layout, convenient and safe access to bridge cranes should be considered. In larger powerhouses, the vertical distance from erection areas to the crane cab level may be 15 m (50 ft) or more. This makes it desirable to provide access from a level served by an elevator when practicable. Access via convenient stairs is preferred when elevator service is impracticable, but the most common access,

particularly in the smaller powerhouses, is via ladders. A ladder located to permit direct access to the cab elevation is preferred. Via corbel, bridge, and ladder descent into cab is the least desirable means of access but is acceptable when required by powerhouse arrangement. The crane "parking" location should be reasonably close to the principal crane use area. Safety is the first consideration in crane access, and architectural emphasis should not be at the expense of either safety or convenience.

(7) Drawing. Typical powerhouse bridge crane clearance and coverage diagrams appear in Appendix B, Figure B-1.

f. Powerhouse gantry cranes.

(1) General. General considerations noted in paragraph 6-2e(1) are applicable. Powerhouse cranes of the gantry type are usually limited to outdoor powerhouses. In the case of an indoor powerhouse such as Libby Dam in Montana with construction making it impractical to support bridge crane rails, a gantry or semigantry may be required. There has been very limited application for such cranes in Corps of Engineers projects, but data on the Libby crane are available from the Hydroelectric Design Center, North Pacific Division, Portland, Oregon, for reference purposes. The design generally should follow applicable criteria for outdoor powerhouse gantries.

(2) Number of cranes. More than one gantry crane will seldom be justified since cost and bulkiness tend to offset the advantages. Portable equipment can usually be utilized for major work at outdoor powerhouses further diminishing the value of a second crane.

(3) DC versus AC drive systems. Current technology of AC variable-frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(4) Crane capacity. Comments in paragraph 6-2e(4) are applicable. In cases where additional hoists are provided serving the functions of draft tube gantry cranes or intake gantry cranes, capacity of those hoists should be as described in paragraphs 6-2h(5) and 6-2g(5).

(5) Appearance. Comments in paragraph 6-2e(5) are applicable.

g. *Intake gantry cranes.*

(1) General. The powerhouse intake gantry crane may be utilized as a dual-purpose powerhouse intake-spillway crane but is more commonly restricted to powerhouse intake service. Intake deck-hoisting requirements vary widely from project to project, and good judgment is required to select the optimum provisions for each crane. Present publications of crane design data on existing projects do not include intake gantry cranes. However, data on existing cranes, to meet most new requirements, are available, and sources can be obtained on request from the Office of Chief Engineers, Washington, DC. Coverage herein includes general factors pertinent to the selection and type of equipment. Detail design criteria are included in Guide Specification CW-14340.

(2) Intake gantry lifting functions.

(a) Intake gates and bulkheads. The heaviest lifts normally involve handling of the intake gates and bulkheads. Trolley-mounted hoists permit handling of the gates and bulkheads with the same hoist. Routine raising and lowering, maintenance support, and transfer to storage slots or other repair locations are normal requirements. In some instances, the crane is used during gate delivery and erection; however, construction scheduling usually requires contractor cranes being available for gate erection. Intake gantry cranes are not used to lower intake gates in an emergency because of the potential load capacity problems resulting from gate hydraulic downpull in addition to the slow response. The total time for a crane crew to come on site, pick up an intake gate, travel to the affected generating unit, lower the intake gate, and repeat the sequence to install the other two intake gates is much too long to avoid major damage to the unit and protect the integrity of the powerhouse. Even if the intake gantry crane was built with three hoists to carry three intake gates to provide faster closure, the response time is still too long.

(b) Fish guidance equipment. Raising and lowering fish guidance equipment, such as submerged traveling screens or submerged bar screens, and vertical barrier screens, is a major task for intake gantry cranes at some powerhouses. Additional provisions are needed to handle fish guidance equipment, such as tugger hoists, an auxiliary hoist, faster main hoist speeds, and additional lifting devices. Careful planning is needed to assure all needed provisions are included in the crane design.

(c) Trashrack service. Raising and lowering of trashrack sections and raking of trashracks are common intake

gantry crane functions where distances from gate and bulkhead slots to trashracks are moderate. For wider decks, use of a standard commercially available rake and hoist unit or a separate trashraking crane is more practical.

(d) Handling of individual gate hoists. Where individual gate hoists are provided, placement and removal is normally an intake gantry crane function, and the clearances for hydraulic cylinders, load transfer supports, and procedures for raising and lowering cylinders between vertical and horizontal positions require careful planning.

(e) Transformer handling. Where main power transformers located on intake decks are within the crane load rating otherwise required, loading and unloading of the transformers is a common crane function. Increasing crane capacity, hook coverage, or number of hoists for transformer handling alone is seldom justified as temporary facilities are practical for the infrequent movements.

(f) Loading and unloading of rail cars and trucks. Intake decks are usually accessible to trucks and, in some cases, rail cars. Crane clearances and hook coverage should provide convenient handling.

(g) Miscellaneous lifts. As applicable, miscellaneous lifts should also be considered in crane design. Lighter lifts may be made using mobile cranes, but availability, accurate control, and safety usually favor the use of an intake gantry crane.

(3) Number of cranes. More than one intake gantry crane will seldom be justified.

(4) AC versus DC drive systems. Current technology of AC variable-frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(5) Crane capacity. Crane capacity should be determined in accordance with Guide Specification CW-14340.

(6) Appearance. Intake gantry crane appearance should be consistent with the intake deck area of the powerhouse. It is usually advisable to rely on the powerhouse architect for determination of an acceptable appearance, but compromises are necessary where preferred appearance impairs maintenance, full utility, or safety.

(7) Dual-purpose cranes. Use of the intake gantry for both intake deck and spillway deck functions should be considered where usage for routine operational purposes is not required on either deck. Agreement should be obtained from the operations division involved on the acceptability of a dual-purpose crane.

h. Draft tube gantry crane.

(1) General. The principal function of a draft tube gantry crane is to handle the draft tube bulkheads. Alternate provisions are sometimes practical and should receive consideration. This includes using a monorail hoist where deck configuration and slot location are unsuitable for a gantry or a mobile crane, or where there will be only one to three units. Then the project will have a mobile crane available full time for other purposes. Commercial monorail hoists are generally restricted to about 4.5-tonne (5-ton) lifts. Mobile cranes are less desirable for operating convenience and safety reasons, so procurement of a mobile crane specifically for handling draft tube bulkheads is not recommended. Detail design criteria for draft tube gantry cranes are included in Guide Specification CE-1603.

(2) Lifting functions.

(a) Draft tube bulkheads. This function will determine the crane rating.

(b) Deck slot and hatch covers.

(c) Fish facility equipment. At projects where fish facilities are incorporated in the draft tube structure, the draft tube crane may be required to handle gates, bulkheads, stop logs, machinery, weirs, diffusers, etc.

(3) Number of cranes. One draft tube gantry will provide all required service.

(4) DC versus AC drives. Current technology of AC variable-frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(5) Crane capacity. Guide Specification CE-1603 should determine this capacity.

(6) Appearance. Draft tube crane appearance should be consistent with the tailrace area of the powerhouse. It is usually advisable to rely on the powerhouse architect for determination of an acceptable appearance, but compromises are necessary where preferred appearance impairs maintenance, full utility, or safety.

(7) Trolley. For draft tube bulkhead service alone, a fixed hoist in accordance with Guide Specification CE-1603 is adequate. If other service such as fish facility handling is required, a trolley-mounted hoist in accordance with Guide Specification CW-14340 may be justified.

i. Mobile cranes. Mobile cranes will seldom be furnished specifically for the powerhouse since they are normally an item of general project equipment. They are usually specified to match an existing, commercially available item. The powerhouse design should consider which powerhouse lifts will be handled with a mobile crane, the loads, and required hook travels and boom lengths. Special slings, lifting beams, and lifting eyes to achieve required safety factors usually have to be provided for each type of lift.

j. Maintenance shop bridge crane.

(1) General. All required lifting and transporting operations in the maintenance shop can be accomplished with an economical floor crane plus a minimum of temporary rigging. The provision of the more costly bridge crane requires considerable justification. Since a bridge crane can expedite handling, the potential for a heavy volume of essential work in the shop at one time would be the principal justification. Project work external to the powerhouse, as well as work from other projects, should be considered. For powerhouse work alone, 10 or more main units along with a fully equipped shop will usually justify a bridge crane in the maintenance shop. Design criteria for maintenance shop bridge cranes are available in Guide Specification CW-14601.

(2) Crane characteristics. It is preferable that the crane be kept as simple as practical, avoiding the more sophisticated control options and writing the specifications around generally available catalog equipment. Single-speed hoist control in the range of 0.06-0.09 m/s (12-18 fpm) is satisfactory. Powered trolley travel is available as a catalog item and is justified. Powered bridge travel is also justified, particularly in the case of a long narrow shop. Hoist and powered travel push-button

controls should be located in a pendant-type box. Capacity should be 1.8-4.5-tonne (2-5-tons).

(3) Precautions.

(a) When a bridge crane appears justified, early planning is required to assure a powerhouse structural layout permitting adequate shop ceiling and lighting clearance for the bridge.

(b) Structural support for the crane rails is an early planning consideration.

(c) Specifications should require a bridge and hoist capable of withstanding pullout torque forces applied to the hook.

k. Floor cranes. Maintenance shops not equipped with a bridge crane should be provided with a portable floor crane. This will include essentially all shops in 1-4-unit plants and many shops in 5-10-unit plants. The crane should be a standard catalog item, preferably hydraulically-operated, manually-powered, and equipped with antifriction bearing wheels and casters. A 1.8-2.7-tonne (2-3-ton) capacity should be specified.

l. Monorail cranes. The most common powerhouse application for monorail cranes is handling of draft tube bulkheads at small powerhouses where the slot location is close to the downstream wall. Rated capacity and maximum lifting stresses should meet Guide Specification CE-1603 requirements. Standard catalog units are preferred, but proof-testing of the hoist and rail to pullout should be required. Other powerhouse handling applications with lifting and travel requirements in restricted areas may warrant monorail installations. Before a monorail decision is made, each requirement should be carefully evaluated for practical alternate provisions, such as embedded lifting eyes and portable hoists or crane hook access hatches permitting lifts to be made with the bridge crane or a deck gantry. Monorail hoists have had some application in maintenance shops but lack the versatility of a bridge or floor crane. Design criteria for monorail cranes are available in Guide Specification CW-14340.

m. Jib cranes. Jib cranes have limited application in powerhouses since most areas with adequate head room to accommodate a jib can be serviced with the bridge crane or a deck gantry. They are most suited to hoisting applications requiring limited horizontal movement, as on or off a truck, or a limited transfer movement to or from a location just beyond bridge or gantry crane hook coverage, and locations where an embedded eye and portable

hoist are impractical. Mounting of a jib crane on a gantry crane leg to handle hatch covers, gratings, or heavy maintenance equipment is sometimes an advantage. A good selection of standard catalog jib cranes is available. Manual winches or chain hoists are normally adequate for jib use. Electric hoists are justified if they will be used frequently. The uncertainty of maximum loading with a manual hoist makes it important that jib structural members and anchor bolts be designed with high safety factors. Design criteria for jib cranes are available in Guide Specification CW-14340.

6-3. Crane Lifting Accessories

a. General. Crane lifts may require one or more intermediate devices connecting the crane hooks or blocks to the load. Certain lifts require a device for supporting the load in storage or intermediate positions. These devices include lifting beams, adapters, spreader beams, support beams, and "dogs." Standard rigging-type slings should normally be selected and procured by construction or operations offices. Spreader beams, support beams, and "dogs" will usually be either bought with the crane or equipment. Powerhouse bridge-gantry equipment differs appreciably from intake gantry and draft tube crane equipment, and coverage herein is divided accordingly.

b. Powerhouse bridge-gantry lifting accessories.

(1) General. Lifts made by the powerhouse bridge or gantry cranes are accessible for visual observation and also to personnel for attachment and release. This permits design based on known loads and manual means of connection and release.

(2) Lifting beams.

(a) General. Cranes with more than one main hook require lifting beams to connect the hooks to generator rotor and turbine runner assemblies. A single beam is required with a single, two-hook crane and three beams with two, two-hook cranes. The beams should provide convenient manual connections of the load to the crane hooks, essentially moment free, vertical lifting forces on the load, and stable operation under all loaded or unloaded conditions. These lifting beams are normally designed and furnished under the crane contract.

(b) Design. Data on existing beams are included in EM 1110-2-4203, and detail design requirements are in Guide Specification CW-14330. Cooperation between the crane contractor and generator-turbine contractors to assure fit and utility of the lifting beams will be required

under the supply contracts. However, it is a responsibility of the contracting office to monitor the exchange of information for timing and accuracy. The design office is usually required to do preliminary design and beam layout to assure a practical powerhouse structural layout and crane clearance diagram.

(3) Adapters and attaching devices. Adapters for fitting the lifting beam to the generator rotor and turbine runner assembly are made a responsibility of the generator-turbine contractor under the supply contracts.

(4) Slings. Slings for major lifts of the powerhouse bridge-gantry cranes are not required. Lifts requiring slings utilize standard rigging.

(5) Drawings. Figure B-1 illustrates conventional lifting beam configuration as part of a typical crane clearance diagram.

c. Intake gantry and draft tube gantry crane lifting accessories.

(1) General. Intake gantry and draft tube gantry cranes are regularly used for handling gates, bulkheads, stoplogs, and fish guidance equipment below the water surface where the point of attachment to the load is non-visible and nonaccessible to operating personnel. Obstructing debris or silt can hinder operations, and “cocking” or “binding” of the load or lifting beam in the slots can occur. Slings remaining attached to the submerged load or lifting beams with dependable remote control of latching and unlatching are required. Most lifts can be made with either an attached sling or a lifting beam, and the selection should be made only after careful consideration of the following factors:

(a) Dependability. In all cases, dependability favors an attached sling since the potential for latching and unlatching problems, as well as the uncertainty of a secure latch having been effected, is eliminated.

(b) Sling size. Sling size may become large enough to cause handling and storage problems.

(c) Hook travel limitation. Limited crane hook travel combined with deep load settings may require several dogging operations with slings and a consequent impractical time requirement.

(d) Multiple unit loads. Where more than one gate, bulkhead, or stoplog section are required in a single slot, slings are usually impractical. Design of lifting

equipment for underwater loads should normally be based on pullout or maximum controlled torque lifting forces. Exceptions should be clearly noted and justified in the mechanical design memorandum. The expense and hazards of diver operations to remedy faulty operation plus monetary loss from delay in returning generator units to service warrant maximum design emphasis on reliability.

(2) Lifting beams.

(a) General. Lifting beams may be provided for intake gates and bulkheads, draft tube bulkheads, trash-racks, fish guidance equipment, and for miscellaneous small gates and bulkheads in water conduits, fish channels, and sluices. Weight-operated latching mechanisms with manual tagline unlatching is preferred except where physical size of latches or pins make manual operation nonfeasible. Tagline operation should be assumed a one-man effort, and maximum required rope pull should not exceed 223 N (50 lb_p). The design should have clearances and dimensions that provide source engagement of alignment pins with sockets, hooks with latches, and latching pins with sockets with all accumulated construction and installation tolerances considered. Beam length to guide height proportions should minimize wedging tendencies in guides, or end clearances should preclude wedging. Weight of lifting beams is normally a minor factor in total lifting loads; therefore heavy and rugged designs are desirable to stand up under severe operating conditions and to ensure positive lowering and latching through debris. Multipurpose beams requiring a variety of special adapters, special guide shoes, length or offset adjustments, and interchange of hooks are not recommended. An assembly drawing for each beam should be included in the mechanical design memorandum showing slots, load pins, beam hooks, aligning pins when applicable, guide shoes or rollers, operating mechanism and critical dimensions, tolerances, and clearances indicating correct operation under all conditions. Figures B-2 and B-3 include drawings of a typical intake gate-bulkhead lifting beam and a manual hook-release type lifting beam, respectively.

(b) Intake gate, bulkhead, and fish guidance equipment beams. A single lifting beam is normally provided for intake bulkheads, gates, and fish guidance equipment. Early coordination of gate, bulkhead, fish guidance equipment, and slot design to assure a practical single lifting beam without adapters is necessary. Procurement is usually included in the intake gantry crane supply contract, and final design is made a contractor's responsibility. Initial design criteria are included in Guide Specification CW-14340.

(c) Miscellaneous beams. Basic structural and mechanical unit stresses should be in accordance with the applicable requirements of Guide Specification CE-1603 with normal loadings considered as lifting loads plus friction and pullout loadings based on the applicable crane hoist. Pullout loadings for mobile cranes should be considered as boomup tipping load. Hooks should be mechanically linked together to assure simultaneous movements.

(3) Slings. Special purpose slings for intake gantry and draft tube gantry crane use should be made of corrosion resistant rope and galvanized fittings. Ultimate strength of sling assemblies should provide a safety factor (FS) as shown in Table 6-1 based on the maximum load. The slings should normally also have a FS of 2 based on the hoist pullout torque, maximum controlled torque, or crane-tipping load. Exceptions should be clearly noted and justified in the mechanical design memorandum. A lesser FS may be used provided that by detailed analysis, it can be shown that under imbalanced load conditions a FS of 5 is provided for the sling leg or lifting beam components having increased loads. Sling clevis pins and other pins requiring disassembly under normal use should have ample clearance to minimize binding under average field-handling conditions. A 1.6-3.2-mm (1/16-1/8-in.) clearance is preferred for average field-handling convenience. Design of intermediate links, storage links, support beams, and sling storage provisions should consider convenience and safe handling along with required strength.

6-4. Hoists

a. General. Fixed hoist applications in powerhouses include operation of intake gates requiring emergency closure capability, operation of gates and weirs requiring automatic or remote control, and miscellaneous lifts non-accessible to a crane. Fixed hoists may be of several

types, the most common being hydraulic and drum-wire rope. Portable equipment is preferable to fixed hoists from a maintenance standpoint and should be considered for all applications with infrequent, noncritical usage.

b. Intake gate hoists.

(1) General.

(a) Fixed gate hoists. These hoists are applicable for vertical lift, wheeled, or roller-mounted gates. The main purpose of fixed hoists is to provide emergency closure. The normal use of fixed hoists will be for maintenance and repair operations. Potential conditions which could require emergency closure include loss of wicket gate control, head cover failure, an inadvertently opened or failed access hatch, or precautionary closures during abnormal operation. The frequency of such emergencies is recognized as remote. However, the potential for major damage does exist, and the emergency closure provisions of fixed hoists are justified. The design should provide maximum dependability and rapid closure under remote control plus backup manual closure under power failure. In addition, necessary provisions for normal gate operations should be included. The type of hoist selected will depend upon the size of gates involved and the configuration of the intake structure. The three types of fixed hoists generally considered are direct acting hydraulic hoists, hoists consisting of hydraulic cylinders connected by wire rope through deflector sheaves to the gates, and drum-wire rope hoists.

(b) Performance criteria. Closure of all gates on a single unit should be accomplished simultaneously and within 10 min from initiation of the closure sequence. The lowering speed of the gate at the point-of-contact with the sill should not exceed 0.05 m/s (10 fpm). Gate-raising speeds are not critical. Depending on size, it is

Table 6-1
Safety Factors

Application	FS for Load Visually Observed	FS for Load not Visually Observed
For permanent crane or hoist not involving slings	5 x ML*	5 x HC*
For permanent crane or hoist utilizing bridle slings	5 x ML	8 x HC
For permanent crane or hoist lifting beam (without slings)	5 x ML	5 x HC
For mobile crane use	5 x ML	8 x ML

* ML = Maximum load to be picked up; HC = Hoist capacity rated.

** FS to be increased in cases where a significant load imbalance between two or more slings is possible (based on the maximum possible load imbalance which the hoist can exert on a sling or lifting beam member, such member shall have a FS of 5).

usually satisfactory to take 10-20 min to open a gate. When the penstock or power tunnel is filled by cracking the intake gate, it is essential to fill the tunnel slowly in order to avoid sudden changes in pressure. This is done by allowing the intake gate to creep to about 3 percent open before opening at normal speed. Intakes utilizing gates with upstream seals and a limited area behind the gates have developed dangerous gate-catapulting forces during filling. Emergency closure should be possible under complete failure of the normal power supply.

(2) Hydraulic hoists.

(a) General. Hydraulic hoists normally consist of a single acting cylinder, pumps, reservoir, controls, and piping. The preferred arrangement is to place the cylinder above the gate and support it in the slot. The rod is connected to the gate, and the gate and rod hang from the piston. Adding or releasing oil from the cylinder controls the gate position. Two cylinders per gate are common for large gates. Where intake and deck elevations do not permit hanging the gate below the cylinder, it may be necessary to recess the cylinders within the gate structure. All intake gate hoists in a powerhouse are normally connected to a common pump-piping system, and system pressure is maintained above the minimum pressure required to prevent gate drift. A typical hydraulic circuit and cylinder drawing are shown in Figures B-4 and B-5, respectively. Guide Specification CW-11290 provides guidance for hydraulic power systems for civil works structures. Complete drawings and specifications of existing satisfactory designs can be obtained from the Hydroelectric Design Center (HDC), North Pacific Division, Portland, Oregon.

(b) Hoist capacity. Maximum hoist capacity will be determined by the load because of emergency shutdown of the unit, or opening the gate to equalize unit to pool head.

- Hydraulic downpull load. The emergency shutdown load is composed mainly of gate deadweight, hydraulic downpull load resulting from high-velocity flow under the gate, head on the gate upper seal, and deadweight of the rod. Hydraulic downpull will vary greatly, depending on configuration of the gate bottom, static head, and location of the skin plate and seals. In most cases, the load caused by the hydraulic downpull will be the major load that the hoist will see in emergency shutdown. Extreme care must be taken when determining these loads. More information on hydraulic downpull can be obtained from the HDC.

- Seal breakaway load. The equalizing load is composed mainly of gate deadweight, seal friction, roller chain or wheel tractive load, and rod weight. Seal breakaway friction tends to be unpredictable as it depends on type of seal, surface condition, seal material, elapsed time with seal under head, and seal preload. However, it can be of greater magnitude than the maximum downpull forces. Maximum downpull load should not occur simultaneously with seal breakaway load. Normal gate movements are made under balanced head conditions and usually involve essentially only gate and rod buoyant weights, seal friction, and roller chain tractive load. The design hoist capacity should be conservative, reflecting the indeterminate nature of major loads. Hoist loadings on a variety of existing gates, based on hydraulic system pressure gage readings, can be obtained from the HDC.

(c) System design operating pressure. A 20,670-kPa (3,000-psi) design system pressure is recommended. Hydraulic components for this pressure are very common. Required hoist capacity can usually be obtained with practical cylinder sizes using 20,670-kPa (3,000-psi) pressure as well. Operating pressures for normal balanced head gate movements or for holding gates in the open position will usually be within 8,270-13,780-kPa (1,200-2,000 psi) when cylinders are designed for maximum downpull and breakaway loads at 20,670-kPa (3,000-psi) operating pressure.

(d) Cylinder. Internal diameter and nominal external dimensions of the cylinder should be determined by the design office, but final cylinder design should be made a contractor's responsibility. The cylinder should be of one section with heads bolted onto the cylinder flanges. There are different types of flanges that could be used and should be open to the contractor.

(e) Rod. The outside finish of cylinder rods must be of corrosion resistant material. Base material should be of high strength to minimize rod displacement and, in most cases, must have good welding and machining properties. Specifications and contract drawings should include material options appropriate to the required rod, rod dimensions, coupling provisions, finishes, physical properties, and special fabrication and testing techniques. The following four satisfactory options for the base material are normally available:

- Chromemolybdenum steel rods with hard chrome-plated surface. This option provides an excellent

rod at reasonable cost when rod dimensions are within capacity of commercial plating facilities.

- Chromemolybdenum steel rods with formed and welded on monel cladding. Although satisfactory service is obtainable by this method, fabrication problems are to be expected unless the fabricator is experienced in such work. Specifications should emphasize to prospective bidders the requirement for fabrication experience.
- Solid, age-hardening, stainless rods. Rod materials of this type offer good strength, weldability, and corrosion resistance. They are becoming increasingly available and are an acceptable alternate when competitively priced.
- Ceramic-coated rods. These rods have a sprayed-on ceramic coating that is very durable and impact and corrosion resistant. Care should be taken to assure qualified fabricators apply this type of coating.

(f) Latch. A manually engaged latch should be provided to lock the piston and rod in the retracted position for raising the gate to the dogging position with the crane. The engagement is normally a threaded connection in the top of the piston rod with the latch pin located in an oil-sealed hole in the cylinder head. The latch pin should be of corrosion resistant material. A removable T-wrench should be provided to permit convenient operation of the latch pin.

(g) Pumps. Pumps are positive displacement piston or vane type with standard catalog ratings to provide required displacement and pressure. Delivery should be sufficient to open a single gate in approximately 20 min or less. It is usually desirable to provide the required displacement with two identical pumps to provide backup in the form of reduced speed raising in event of pump failure. It is usually also desirable to provide makeup oil to maintain pressurization of the system with a separate small displacement pump to avoid frequent starting or continuous unloading of one of the raising pumps. Delivery should be 150-200 percent of anticipated leakage. The small displacement pump may have a higher pressure rating than the raising pumps to aid in breaking loose a gate for equalizing. Pumps should be mounted to provide a positive suction head and be equipped with auxiliaries recommended by the manufacturer. Relief or unloading valves should be provided to limit maximum stress in hoist components to 75 percent of yield point. The

75 percent yield-point pressure should be the maximum relieving pressure to which the valves can be adjusted.

(h) Valves.

- Lowering valves. Lowering valves should be essentially drop tight at gate support pressure, should operate within their catalog flow rating at required lowering flows, and should be suitable for remote control of opening. Cylinder-operated, shear-seal type valves and pilot-operated check valves are two that are in satisfactory service. Solenoid valves in the pilot circuit are normally used for remote control to open the valve. Valve closing should be manual only to minimize possibility of accidental raising of a gate on an unwatered unit. Two valves in parallel should be provided to allow emergency closure in event of a single-valve malfunction. The lowering valves should be suitable for emergency manual operation, or separate manual lowering valves should be provided.
- Flow control valves. An adjustable pressure-compensated flow control valve should be provided in the high-pressure line from each cylinder to regulate gate lowering speed and to match lowering speeds where more than one gate per unit is required.
- Manual valves. Manual valves should be of the quick-acting, low-operating force type suitable for panel mounting. A valve should be provided in the high-pressure line to each cylinder to permit individual manual gate control and to isolate the cylinder from the hydraulic system.

(i) Pump controls.

- Pressurization-breakaway pump control. The pressurization pump should be on automatic start-stop pressure control to maintain system pressure above minimum no-drift pressure. A manual momentary-contact override switch should be provided at each panel to permit applying temporary breakaway pressure. Pump relief-unloading valve settings should normally be about 5 percent above normal maximum system operating pressure.
- Raising pump controls. Raising pumps should be on manual start with adjustable time-switch

shutdown. Remote start should be provided at each unit hydraulic control panel.

(j) Control panels. Gate movement controls and valves for one main unit should be mounted on one common control panel at each unit, generally in a gallery near the gate slots. A steel panel designed for standard panel-mounted hydraulic valves is preferred. A similar panel should be provided near the pumps for pump controls.

(k) Piping. High-pressure piping of Schedule 80 seamless with socket welding fittings is satisfactory. Low-pressure piping is normally Schedule 40 with socket welded fittings. Due to both internal and external corrosion problems, the piping should be stainless steel such as American Society of Testing and Materials (ASTM) A312, Grade TP304. If it is necessary to utilize two oil reservoirs on a single system, the equalizing header between them should be substantially oversized to preclude overflow from unbalanced return flows. Low-pressure piping should be sized to provide a positive head throughout the system unless there are minor, short duration, negative pressures under emergency closure operation.

(l) Reservoir. A reservoir sized to contain the displacement of all piston rods on the system plus the volume of one cylinder, 15 percent reserve oil, and 15 percent air volume should be provided. Reservoirs should have an interior painted finish conforming to MIL-C-4556. Reservoirs should be located to assure a positive system head and should be heated as required to preclude condensation.

(m) Accumulators. Accumulator capacity on the system should be sufficient to ensure a pressurizing pump cycling time of not less than 10 min.

(n) Support beam. The cylinder support beam of structural steel should be accurately fabricated, stress relieved after welding, and machined on bearing surfaces to assure uniform bearing loading. Connection of the cylinder to the beam with separate nuts on extended cylinder head bolts is recommended. The support beam should fit over locating dowels on the support pads and should be bolted down to preclude movement if subjected to upward forces transmitted through the cylinder rod.

(o) Gate position indicator. When gate position indicators are not otherwise provided, they should normally be included with the hydraulic hoist design. They are essential with hydraulic hoists to monitor gate position and to obtain prompt indication of gate drift. Stainless

tapes connected to the gate tops with tension maintained by counterweighing or spring take-up reels have given satisfactory service.

(p) Design. Design of the hydraulic hoist system is usually a responsibility of the government. Service and size requirements are usually not compatible with commercially available catalog equipment, and suppliers' special designs are contractually difficult to control. The design should be adaptable to a variety of pumps and control valves, seals, piston rings, cylinder construction, etc., to avoid unnecessary bidding restrictions.

(3) Wire rope hoists.

(a) General. Wire rope hoists are applicable to intake configurations requiring gates with deep submergence or gates with shallow settings, either of which make hydraulic hoists undesirable. Unusually deep gates require several rod extensions resulting in slow installation and removal of cylinder-operated gates. Shallow gates may require portions of a hydraulic hoist to be above deck level interfering with movement of vehicles over the deck. Individual stationary hoists are usually provided for operating each service gate. The gates are normally held by the motor brake in the operating position just above the waterway, and control switches are provided at the unit governor cabinets and in the control room to permit rapid closure in an emergency. Arrangement of the hoists varies greatly depending on the intake configuration. Hoists may be located below or on the intake deck adjacent to or over the gate slots. When located on the deck over the gate slots, provisions should be made for uncoupling the hoist blocks when the gates are in the upper dogged position, and for removal of the hoists from over the gate slots to permit transfer of the gates to the gate repair pit by use of the intake gantry crane.

(b) Description. Each hoist consists of a cable drum or drums and a system of sheaves and blocks which are electric motor driven through an arrangement of shafts, speed reducers, and spur or helical gears. The motor is usually 460-V, 3-phase, 60-cycle, squirrel-cage, induction type with suitable enclosure. Two speeds are sometimes provided to permit lowering at approximately twice the raising rate. The hoist brake is of the shoe type, spring set, DC magnet-operated type, with a watertight enclosure and a capacity of not less than 150 percent of the full-load torque of the motor. The wire rope is of stainless steel with an independent core. During normal operation, the lower block is immersed, with part of the associated reeving immersed and part exposed. When the hoist is

located on the intake deck over the slots, the hoist machinery should be mounted on a platform of sufficient height, so that the gate can be hoisted to a dogging position where it can be readily uncoupled at intake deck level. With this arrangement, the hoist machinery frame and support columns form an integral structure designed to support the hoisting machinery and gate including provisions to permit its removal from over the gate slot by use of the intake gantry crane. Base plates with locating pins should be provided in the intake deck structure to permit quick and accurate resetting of equipment. Machined bearing pads to support machinery components, necessary openings to provide clearance for ropes and moving parts, and grating to permit inspection and maintenance should be provided. A minimum area of open grating should be provided for airflow when the supply is through the service gate slots in which the required area should be based on a maximum air velocity of 45 m/s (150 fps). Sockets embedded in the intake deck concrete permit installation of safety handrailing around the gate slots when grating and/or hoists have been removed. The motor controller for each hoist should be housed in a watertight control cabinet supported from the hoist frame. A traveling nut-type or intermittent geared type high-accuracy limit switch and a dial-type gate position indicator, as well as a slack cable limit switch, balanced pressure switch, and an extreme upper travel limit switch, are provided. Accuracy of limit switch trip and reset should be considered when gate cracking or other similar accurate positioning is needed, especially for gates with long travel. Removable power and control plugs should be furnished to permit disconnecting of all incoming leads to the hoist prior to its removal.

(c) Design. Each gate hoist should be designed for a rated capacity equal to the sum of the gate weight, roller chain tractive load, seal friction, and maximum hydraulic vertical forces with normal stresses. Mechanical parts of the hoists should be designed for the rated capacity with a minimum FS of 5 based on the ultimate strength of each component. In addition, mechanical components should be designed to withstand the forces produced by hoist motor-stalled torque with resultant stresses not in excess of 75 percent of yield point of the materials involved. Reducers should be sized in accordance with American Gear Manufacturers Association (AGMA) Standard for Class I Service using conservative values for starting and running efficiencies. Wire rope hoists should be in accordance with the requirements of Section 5 of Guide Specification CW-14340. Hoist capacity and speeds should follow paragraphs 6-4b(1)(b) and 6-4b(2)(b). Wire rope should be of corrosion resistant material.

(d) Location. Wire rope hoists should be located on the deck when practicable. Locations in recesses below the deck may be required where deck access would be impaired by a deck location. Controls along with reliable gate position indicators should preferably be located in a gallery close to deck elevation.

(e) Power failure operation. When it is necessary to make provisions to lower the gates without power, brake release and means of speed control should be provided, such as a hydraulic pump driven by the hoist motor with an oil reservoir and flow control valve. If a hydraulic pump is used, a dual-purpose hydraulic pump-motor replacing the electric hoist motor should be considered.

c. Miscellaneous wire rope hoists.

(1) General. Fixed wire rope hoists may be required for lifting applications inaccessible to cranes or for control gate operation where frequent adjustments or automatic controls are necessary. Portable commercial equipment is preferred whenever practicable. Powerhouses with fish passage facilities frequently require fixed hoists for weir adjustment and control gate operation. Fixed hoists may occasionally be justified for ice and trash sluice control gates. Fish facility equipment criteria are normally supplied by fishery agencies; however, powerhouse design responsibility includes safety, dependability, and satisfactory service life.

(2) Design. Wire rope hoists should comply with the applicable requirements of Section 5 of Guide Specification CW-14340. Corrosion resistant wire rope should be used for all applications where any part of the line will operate submerged. Underwater bearings should be water lubricated except where presence of abrasive silt requires sealing. The cost of miscellaneous wire rope hoists is often moderate and may not appear to justify extensive engineering. However, several factors can affect satisfactory operation, maintenance, and service life. The design procedure should not shortcut the necessary investigations which include the following:

(a) Climatic conditions. These conditions include the effects of icing, moisture, and heat.

(b) Water quality. The presence of abrasive silt or unusually corrosive materials in the water should be considered.

(c) Gate guide alignment, material, and clearances. These factors, while not primarily a mechanical design

responsibility, can materially affect hoist operation, so coordination with the responsible design group is necessary. The possibility of gates temporarily “hanging-up” is often overlooked.

(d) Water hydraulic conditions. The possibility of unusual turbulence, surging, or wave action causing added hoist loading, uplift, or vibration should be investigated.

Chapter 7 Elevators

7-1. General

Principal considerations relative to powerhouse elevators include justification, location, size, type, and operating characteristics. Design criteria are available in Corps of Engineers Guide Specification CW-14210 and industry standards ASME A17.1 and A17.2.

7-2. Justification

a. General. The justification for powerhouse elevators rests on a number of interrelated factors, the combination of which can indicate a clear requirement, no requirement, or be equivocal. Many existing powerhouses are satisfactory without elevators, and rather definite justification should be apparent to warrant including one or more in the powerhouse design.

b. Principal factors.

(1) Powerhouse location. Powerhouses forming a portion of the dam invariably have considerable foot traffic between the intake deck and powerhouse levels, and the vertical distances are considerable. Such powerhouse locations usually justify one or more elevators.

(2) Number of units. The number of main units is not directly related to elevator requirements, but conventional-type powerhouses with six or more main units will have maintenance schedules and repair requirements requiring considerable interlevel foot traffic and also be subject to heavy interlevel foot traffic during installation. Such traffic normally justifies one or more elevators.

(3) Number of operating levels. Three or less operating levels with total vertical distance of 12 m (40 ft) or less will seldom justify an elevator. When the importance of various operating levels is assessed, the type and amount of foot traffic should be considered. For example, a drainage gallery with seldom operated valves requiring little foot traffic and infrequent tool movements would not require elevator service. A maintenance shop and tool room located above or below the erection and principal maintenance level could require a great deal of up and down movement of personnel, tools, and equipment and could be a strong factor in justifying an elevator.

(4) Visitors. Where visitors are to be permitted and their entry to, or movements within, the powerhouse

involve more than a single level, access for the handicapped may well override all other elevator justification factors and dictate an elevator.

(5) Portable equipment movement. Movement of portable equipment such as an oil purifier or floor crane should not normally be used as justification for an elevator as it will usually be more economical to provide duplicate equipment. Where an elevator is otherwise justified, the movement of portable equipment should be considered in sizing and locating the elevator. Design memoranda should include the factors considered in the decision for or against provision of an elevator.

7-3. Location

Elevator location should be considered early in the general powerhouse layout to provide the best access to the control room, locker and rest rooms, maintenance shop, erection bay work level, and where applicable, external decks. A common location is in or near the upstream wall of the main generator-turbine room in the erection bay. Where a second elevator is justified in a long powerhouse for operation and maintenance purposes, the second elevator is usually located to minimize as much as practicable the distance from all points in the powerhouse to the closest elevator.

7-4. Size

a. Small powerhouse. For small powerhouses with service requirements limited to operators and maintenance personnel, a 5,340-N (1,200-lb_f) elevator approximately 1.5 × 1.2 m (5 × 4 ft) is usually adequate. Should the elevator be justified on the basis of visitors, the size and capacity should be increased as required to accommodate the projected visitor traffic.

b. Large powerhouse. Large powerhouses (6 or more main units) with service limited to operators and maintenance personnel will usually be adequately served with a 11-kN (2,500-lb_f) elevator approximately 2.1 × 1.5 m (7 × 5 ft). A powerhouse with a construction schedule requiring joint use of the elevator by project personnel and contractor personnel should be provided with up to a 18-kN (4,000-lb_f) elevator with proportionately larger dimensions. In the case of very large powerhouses (12-20 units) with powerhouse elevator service to the intake deck and extended joint construction-operation usage, it may be justified to provide two elevators in the erection bay area to reduce waiting time. Joint visitor-construction elevator service is usually impractical and should not enter into elevator sizing.

c. Standard size. In all cases the size selected should be a standard size and capacity from the elevator manufacturers.

7-5. Type

Elevators should be basically the passenger type for conventional powerhouses. Freight or combination freight-passenger types may be required where powerhouse areas are planned for warehousing or when needed for the maintenance shop. Finish and appointments should be appropriate to the architecture of the levels served.

7-6. Speed

Operating speeds in the 0.5-0.8-m/s (100-150-fpm) range are adequate for elevators not carrying traffic to or from an intake deck level. Elevators serving the intake deck level and with potential for heavy construction or visitor traffic may be up to 1.3 m/s (250 fpm).

7-7. Control

Selective-collective control is justified for most powerhouse elevators with visitor or extended construction

usage. Nonselective-collective automatic control is satisfactory for other installations. Alternate manual control may be justified where heavy visitor traffic is projected. Door opening should be automatic.

7-8. Design

Design of elevators and appurtenances should be a contractor responsibility and be in accordance with applicable provisions of Guide Specification CW-14210 and codes referenced therein. Powerhouse mechanical design sections should perform required studies, coordinate architectural, structural, and electrical requirements, and prepare contract drawings and specifications in accordance with instructions included with CW-14210.

7-9. Procurement

Procurement is normally under the powerhouse construction contract.

Chapter 8 Engine-Generator Set

8-1. General

Engine-generator sets are provided as a source of emergency electric power when there is a loss of station service power. The requirements for an emergency engine generator is dependent on the reliability of station service power and usually is justified for plants without station service generators. The decision for or against providing an engine-generator set should be made during the preliminary design memorandum stage. The power requirement is normally moderate, being confined to the required power to return a main unit to service along with critical control and pumping requirements. The mechanical design responsibility includes location; engine specifications; and exhaust, cooling, and fuel and ventilation provisions. Further guidance is provided in Corps of Engineers Guide Specifications CE-16263 and 16264.

8-2. Location

a. General. To determine a suitable location for an engine-generator set, access, space for maintenance, noise, ventilation, exhaust piping, fuel piping, humidity, and temperature are all factors that must be considered. A location within the powerhouse structure with dependable, controlled temperature conditions and moderate noise isolation from the main working areas and other occupied areas is preferred. An above tailwater gallery location is frequently used.

b. Access. Personnel access should be reasonably convenient for routine inspections. Access for installation or replacement of the complete unit need not be convenient but should be practicable, and it should be verified that future powerhouse construction or equipment installation will not preclude replacement of the complete diesel-generator unit.

c. Maintenance. Space for normal in-place maintenance and overhaul should be provided.

d. Noise. Practically all unit operation will occur during routine testing; therefore extensive sound isolation provisions are unnecessary. A gallery location or other location away from principal working areas will usually be satisfactory as far as noise problems are concerned. Vibration isolators for mounting of the engine-generator set should be provided in the procurement contract.

e. Ventilation. A location where normal ventilation with the engine nonoperational can be provided from the general powerhouse system.

f. Exhaust piping. The location should permit a short, direct routing of the exhaust pipe to an outdoor termination which will not exhaust directly on personnel nor near an intake vent.

g. Fuel piping. The engine-generator location relative to the outside oil storage tank should permit practical routing of the oil supply piping of reasonable length and free of unnecessary offsets and changes in slope. The fuel transfer pump is normally located at the engine, limiting maximum allowable suction losses.

h. Humidity. The generally high-humidity characteristic of below tailwater galleries is undesirable for long-term maintenance. An above tailwater location is preferred.

i. Temperature. A location free from subfreezing temperatures is preferred for all installations but is essential when heat exchangers utilizing river water for engine cooling are used.

8-3. Engine

a. General. The engine should be a diesel, a standard product of the manufacturer, and should be a model which has performed satisfactorily in an independent stationary power plant for a minimum of 8,000 hr in a two-year period of base-load operation. Options should be permitted in the type of engine and number of cylinders.

b. Detail requirements. Typical detail specification requirements pertinent to the engine and auxiliaries procured with the engine can be found in "Piping-Cleaning, and Flushing," Appendix B-1, which is an excerpt from an existing diesel-generator procurement specification. To determine the requirements for a new installation, all of the provisions noted should be considered and modified as appropriate for the size of unit required, powerhouse location, and cooling water conditions. Each requirement specified should be consistent with equipment normally available as standard or optional in the industry.

8-4. Exhaust Provisions

The muffler should be furnished with the diesel-generator unit, and exhaust pipe size should be as recommended by

the engine supplier. Black steel pipe is satisfactory. That portion of the exhaust pipe located within the powerhouse should be insulated. The muffler is usually located outdoors, and protection provided as required for personnel safety.

8-5. Cooling

Powerhouse locations usually provide reasonable access to cooling water from a piping system, pool, or tailwater making the heat exchanger the preferred option for engine cooling water heat rejection. An exhaust fan removing air heated by engine surfaces and generator-exciter unit may discharge to either outdoors or main generator room, depending on the most practicable fan and ducting installation.

8-6. Fuel System

a. General. The engine-mounted portion of the fuel system, day tank, and transfer pump are specified and provided with the engine-generator set. The storage tank, piping from storage tank to the transfer pump-day tank unit, piping from day tank to engine, and day tank installation details are normally mechanical design responsibilities.

b. Storage tank. The storage tank is preferably a commercial steel aboveground tank coated externally and internally with suitable epoxy paint for corrosion protection. Capacity for approximately 24 hr of full-load diesel-generator operation is normally provided. Auxiliaries include a foot-valve, fuel level indicator with remote indication transmitter, and magnesium anodes for external corrosion protection. Underground tanks should be avoided because of environmental concerns caused by leaking tanks.

c. Piping. Piping from the storage tank to the day tank and from the day tank to the engine should be hard

drawn copper tubing with solder joint fittings. If the line is buried, it should be coated and the couplings insulated at the tank connections (see paragraph 19-2). Size should limit suction lift on transfer pumps to 4.6 m (15 ft). No galvanized pipe or fittings should be used in the fuel piping system. The capacity of unenclosed day tanks should not exceed a total of 2,498 L (660 gal) in accordance with National Fire Protection Association (NFPA) Standard 37 (see paragraph 6.3.2.3.1).

8-7. Installation

a. General. The installation of the engine-generator set and all auxiliaries is normally accomplished under a general powerhouse construction or installation contract. Contract drawings and specifications should be coordinated with the installation recommendations of the engine-generator supplier.

b. Engine. The engine should be supplied on a common base with the generator. Anchor bolts and vibration isolating pads should follow the supplier's recommendation.

c. Fuel oil storage tank. This tank should be installed as close to the engine-generator set as possible and at an elevation limiting maximum suction lift on the fuel oil transfer pump to 4.6 m (15 ft). If installed underground, the tank should be installed in sand bedding material and have a total containment system as required by Environmental Protection Agency (EPA).

d. Day tank. The fuel oil day tank should be located near the engine at an elevation with maximum tank oil level 127 mm (5 in.) below the injector pump.

e. Piping-ventilation. Piping and ventilation installation provisions should be generally in accordance with Chapter 17 of this manual.

Chapter 9 Maintenance Shop

9-1. General

Maintenance shops are provided in powerhouses to facilitate preventive maintenance and to provide moderate repair capability. The intent is that each powerhouse have the capability to take care of the average work promptly and efficiently. Capability for all possible required repairs is not intended even in the most well-equipped shop as factory replacements or contract work can be more practical. Normally, the operations divisions will determine the requirements for hand tools and portable equipment, and procure all equipment. The maintenance shop layout should provide adequate space and power for both initial and future requirements of installed and portable equipment. Most powerhouses will require an in-house shop. However, shops may be omitted where an adequately equipped project shop is to be provided outside the powerhouse at a nearby location, or where a small powerhouse is located close enough to an adjoining project with an adequate maintenance facility to permit practical joint usage.

9-2. Shop Room

a. Location. A location close to the erection area and on the same elevation is preferred. Convenient transfer of material, equipment, and parts from the powerhouse bridge crane and trucks to the shop transporting facility should also be planned. The location should permit the shop to be enclosed and be provided with a large access door permitting free movement of material and the transporting facility.

b. Area. Shop area should provide adequate space for the planned equipment with consideration for the following: size and configuration of pieces to be worked on; space for dismantling and reassembly; and space for safe, efficient movements of personnel. An area of about 75-95 m² (800-1,000 ft²) should be the minimum area for a reasonably equipped shop in a small plant. An area of 150-170 m² (1,600-1,800 ft²) may be justified for a large multiunit plant or a central facility serving several small projects. An adjoining area for a lockable tool and storage room should be available and should be a minimum of 10 m² (100 ft²).

9-3. Equipment Selection

a. Factors. Factors affecting the selection of equipment include the following:

- (1) Size of plant (volume of work).
- (2) Physical size of parts to be repaired.
- (3) Location of plant (access to other government or commercial facilities).
- (4) Equipment cost (probable usage to justify investment).
- (5) Available shop space.
- (6) Personnel planning (type of equipment to be consistent with personnel skills).

b. Equipment guides.

(1) For small to medium powerhouses with well-equipped commercial or government shops available 1-4-hr travel time away, the following equipment, or equivalent, should be planned:

- (a) 1.8-tonne (2-ton) floor crane.
- (b) 300-amp welder.
- (c) Welding hood and exhaust fan.
- (d) 50-mm (2-in.) pipe threading machine (portable).
- (e) 150- x 150-mm (6- x 6-in.) power hacksaw or bandsaw.
- (f) 50-tonne (60-ton) press.
- (g) 250-mm (10-in.) pedestal grinder.
- (h) 380-mm (15-in.) floor-mounted drill press.
- (i) 300-350-mm (12-14-in.) lathe.

(2) For large multiunit powerhouses, shops serving several projects, or for smaller powerhouses in remote locations, the following equipment, or equivalent, should be planned:

- (a) 1.8-tonne (2-ton) floor crane.
- (b) 300-amp welder.
- (c) Welding hood and exhaust fan.
- (d) 50-mm (2-in.) pipe threading machine (portable).
- (e) 150- x 150-mm (6- x 6-in.) power hacksaw or bandsaw.
- (f) 50-tonne (60-ton) press.
- (g) 300-mm (12-in.) pedestal grinder.
- (h) 200-mm (8-in.) bench grinder.
- (i) 1.0-m (3-ft) radial drill press.
- (j) 300-mm (12-in.) bench-mounted drill press.
- (k) 450-mm (18-in.) engine lathe.
- (l) 250-mm (10-in.) bench lathe.

- (m) 0.2- x 1.0-m (10- x 40-in.) milling machine.

A 2.5-tonne (3-ton) bridge crane can be justified for heavy work volume shops.

9-4. Shop Layout

Machines should be located to provide good access for placing parts and materials in each machine. Repair-oriented shops normally require more free area around machines than production shops where specific operations can be scheduled. Space for two to four 1.0- x 3.0-m (3- x 10-ft) work benches will usually be required. Open floor area for assembly, disassembly, and short-term storage of parts is desirable. The welding area, burning area, and grinders should be away from precision machine work and assembly areas. Power should be provided for all fixed machines to be installed and for portable tools at benches and assembly areas.

9-5. Drawing

Figure B-6 is a layout of a shop typical of the type described in paragraph 9-3b(1).

Chapter 10 Water Supply Systems

10-1. General

a. Water supply. The water supplies covered in this chapter provide water for the following requirements:

- (1) Generator air coolers and bearing coolers.
- (2) Turbine bearing coolers, wearing rings, and glands.
- (3) Transformer cooling.
- (4) Fire protection.
- (5) Potable water (domestic water).
- (6) Air conditioning systems.
- (7) Pump bearing prelube.
- (8) Compressors and aftercoolers.
- (9) Deck washing.

The various requirements are divided into several powerhouse systems for convenience in coverage. However, powerhouse and project requirements, interconnection of systems, and suitable water sources vary from project to project, and the designer will be required to apply the information noted to the best advantage for each particular powerhouse. General piping requirements for all systems are covered in Chapter 17, "Piping."

b. Zebra mussel. It is expected that zebra mussels (*Dreissena polymorpha*) will eventually infest all major fresh water bodies of the continental United States except the southernmost portion of the Gulf Coast states. ETL 1110-2-333 provides monitoring guidance for determination of presence/absence of zebra mussels and collection of information for detailed studies of zebra mussel populations. Technical Note ZMR-3-05 provides control strategies for zebra mussel infestations of various hydro-power plant components.

10-2. Generator and Turbine Cooling Water System

a. General. The generator and turbine cooling water system provides cooling water for generator air coolers, generator and turbine bearing oil coolers, and when of suitable quality, the turbine glands and wearing rings. The overall system is a joint design effort involving the water supply, discharge, and external equipment determined by the powerhouse designers, as well as the unit requirements and equipment determined by the generator and turbine manufacturers. Close coordination between the design responsibilities is required.

b. Water requirements.

(1) Cooling water. The water flow requirements are determined by the generator and turbine suppliers but are dependent in part on water supply temperatures furnished by the powerhouse designers. The temperatures should be verified by all available sources and take into account the extremes in climate conditions for the site. Flow requirements are usually large, in the 25-100-L/s (400-1,600-gpm) range for typical units, requiring major, dependable sources. Purity requirements are moderate, permitting nonpotable supplies with limited silt in suspension.

(2) Gland and wearing ring. Gland and wearing ring flow requirements must be obtained from the turbine supplier. Turbine contracts require the supplier to furnish these figures, and turbine guarantees are in part dependent on the stated flows being provided. Previous projects show little correlation between unit size and shaft size or speed with required flows. However, they can total a significant demand as stated requirements have been up to 3 L/s (35 gpm) or more per unit. Rough figures should be obtained in the preadvertising correspondence that takes place with prospective turbine bidders, and final water supply design should be based on turbine contract figures. Quality requirements are nominal requiring only the removal of abrasive material.

c. Sources.

(1) Spiral case. For units with heads up to about 76 m (250 ft), the preferred source of cooling water is a gravity supply from an inlet in the spiral case or spiral

case extension. In multiunit plants, an inlet is provided for each unit with a crossover header connecting all units to provide a backup water supply to any one unit. Cross-overs between pairs of units only are not regarded as adequate since there would be no emergency source from an unwatered unit. The spiral case source is usually satisfactory for unit bearing coolers, as well as the generator air coolers, and can be adequate for gland and wearing ring use with proper filtering and adequate head.

(2) Tailwater. For higher head projects, above 76 m (250 ft), the usual source of cooling water is a pumped supply from tailwater. This normally provides water of essentially the same quality as the spiral case gravity system.

(3) Other sources. It is unlikely that other suitable sources will be available or required for cooling requirements, but alternate sources should be considered for gland requirements. Silt or other abrasive material is usually present in varying degrees in reservoir water, at least seasonally, and since abrasive material is injurious to glands, an alternate source or additional treatment is usually required. The potable water system is normally the best alternate if the supply is adequate or could be economically increased. This would usually be in the case of a well supply requiring little chlorination. Where potable water is used, cross connections from the cooling water source, with backflow protection, should be provided for emergency use.

d. Head requirements. Normally the cooling water supply should provide a minimum of 68.9-kPa (10-psi) differential across the connection to the individual cooler headers. Available gravity head, cost of a pumped supply, and cost of coolers all enter into an optimum cooler differential requirement and require early design consideration to assure a reasonable figure for the generator and turbine specification. Gland and wearing ring differential head requirements should be obtained from the turbine supplier.

e. Treatment. Water for coolers, glands, and wearing rings will normally require only straining or filtration. This should be verified from operating experience at nearby existing plants on the same stream. Where existing plants are remote or the project is on a previously undeveloped stream, a water analysis should be the basis of determining the likelihood of corrosion or scale deposits and the need of additional treatment. Typical strainer requirements for coolers permit 3-mm (1/8-in.) perforations, but strainer specifications for existing projects should be obtained as a guide to complete design

requirements. Strainers should be the automatic type unless the system provides other backup provisions for continuous water supply or the p.h. is small. Unnecessarily fine strainers requiring more frequent servicing should be avoided. Filters are required for gland water unless the supply is the potable water system. The system should provide for continuous operation when an individual filter requires cleaning.

f. Pumps. A pumped cooling water supply requires a standby supply for a pump out of service. This can be provided with two pumps per unit, each of which is capable of supplying cooler requirements, or one pump per unit consisting of a common pump discharge header to all units and one or more backup pumps. Other arrangements to provide backup pump capacity may also be acceptable. Pumps should be located such that flooded suction occurs at minimum tailwater. Continuously rising pump performance curves are required, and the pump should not exceed 1,800 rpm.

g. Piping.

(1) Refer to Chapter 17 for general piping considerations.

(2) Water takeoffs from the spiral case or the spiral case extension should be within 30 deg of horizontal center line to minimize debris and air.

(3) A valve should be located as close to the casing as practicable for emergency shutoff.

(4) Balancing valves should be located in cooler supply lines.

(5) A removable 0.9-m (3-ft) section of straight pipe should be provided in the generator bearing supply line for temporary installation of a flow meter.

h. Drawings. Typical generator and turbine cooling water systems are shown in Figure B-7.

10-3. Transformer Cooling Water

Most plants now utilize air-cooled transformers, so there is very limited application of transformer cooling water systems. The general principles noted in paragraph 10-2 are applicable for transformer cooling water except where transformers are located on the intake deck of a dam-powerhouse structure. There the pumped supply would normally be from pool water rather than tailwater. Water pressure in heat exchangers should be less than the oil

pressure to prevent water from entering the transformer oil under minor seepage conditions. Transformer cooling water systems must be protected from freezing where freezing can occur.

10-4. Fire Protection Water

The requirement for fire protection water is normally limited to deluge systems for main power transformers. Refer to Chapter 15, "Fire Protection Systems," for discussion of deluge systems. The deluge system water supply will normally be from the pool and should be a gravity supply if practicable. A booster pump should be provided if required. A pumped tailwater source is an acceptable alternate. Two water intakes are required either of which can supply the rated delivery of the pump. Consideration must be given to providing a source of power for pumping when the circuit breakers supplying the transformer are automatically tripped because of a transformer fault. The pump, piping, appurtenances, and installation should conform to the applicable provisions of NFPA Standard 851.

10-5. Potable Water System

a. General. The primary demand on the potable water system is drinking and sanitation water for the powerhouse. In addition, the potable water system is often used as the main source for gland and wearing ring water and, in some projects, supplies other potable water requirements, external to the powerhouse.

b. Water requirements. The powerhouse drinking and sanitation flow demand, including provision for visitors, should be determined in accordance with TM 5-810-5. This will normally be on a fixture unit basis. However, in the case of large powerhouses, the main rest rooms near the service bay are usually adequate for all personnel requirements, and additional facilities are provided, remote from the service bay, for convenience. These require the piping design on a fixture unit basis, but a reduction in the fixture unit basis water demand, commensurate with the intended usage, can be justified. Gland and wearing ring flow requirements are as determined under paragraph 10-2b(2). Principal quality requirements are safety in health considerations and acceptable taste qualities consistent with the area in which the project is located.

c. Sources.

(1) General. Sources for powerhouse requirements include the following: pool water, tailwater, powerhouse

well, general project supply, existing construction supply, and local public supply. The order of preference depends on several variables, but it is generally preferable to supply all project potable water requirements from one system whether it be a powerhouse or nonpowerhouse source. All sources should be considered, and a choice made on the basis of reliability, purity, required treatment, and cost. For nonpowerhouse sources, the powerhouse design responsibility is limited but includes mutual verification of demand, supply, reliability and cost, and provisions for necessary standby sources.

(2) Wells. Good wells usually provide the best source of potable water from purity, treatment, and temperature considerations. The existence of good wells in the vicinity along with favorable geological indications would suggest serious consideration of a well supply. The system No. 1 well and storage reservoir should be adequate for all initial and potential expansion demands, and there should be a backup well at least adequate for system operation under conservation operation. In the evaluation of a potential well supply, other considerations should include the following: water rights; probability of increased domestic, agricultural, or commercial demand for underground water; and effects of pool raising and pool level variations. The power plant design analysis should include a record of all factors considered in the selection of a well supply.

(3) Pool or tailwater supply. Reliability is the major advantage of either a pool or tailwater source. Quality is usually questionable, and treatment plants providing coagulation, chlorination, sedimentation, and filtration may be required. It will usually be desirable to combine a pool or tailwater potable supply with other nonpotable, powerhouse raw water requirements as far as intakes, intake piping, and strainers are concerned. Intakes from either pool or tailwater should not be located in penstocks, unit intakes, or draft tubes in such a way that system water is not available 100 percent of the time.

(4) Construction source or public supply. An adequate existing construction source or public source is unlikely but should be investigated in view of the obvious advantages, particularly of a substantial, state-regulated system.

(5) General project supply. A general project supply may be from one or more of the previous sources discussed and may originate under powerhouse design or nonpowerhouse design. It will usually be the optimum arrangement for the project as a whole. If the design is nonpowerhouse, all powerhouse requirements should be

determined, and adequacy of the supply verified by the powerhouse design office.

(6) Factors. TM 8-813-1 provides a discussion of factors to consider in evaluating water supplies.

d. Pump versus gravity considerations (pool-tailwater source).

(1) High head projects. Projects with over 76-m (250-ft) head should be provided with a pumped potable water supply with the pumps taking water from a tailrace intake. Pressure-reducing valves to utilize gravity heads from higher pools are not recommended unless tailwater is excessively contaminated or not always available.

(2) Low head projects. Project with under 76-m (250-ft) head may utilize gravity head to good advantage, providing pool fluctuations will not result in less than 103-kPa (15-psi) pressure at the highest fixture served. Pressure-reducing valves with downstream relief valves can be used to provide a reasonably constant pressure if necessary. Temporary failure of a pressure-reducing or relief valve will not endanger fixtures or piping up to 76 m (250 ft) of head.

e. Pump requirements (pool-tailwater source). Pumped potable water requirements should be provided by two pumps with either pump capable of pumping the total system peak demand. Pumps should normally be either vertical or horizontal centrifugal with constant rising characteristic curves and should be located to ensure a flooded suction under all operating conditions. Turbine-type pumps should also be considered for low-flow higher-head requirements. Controls should be conventional lead-lag for a hydropneumatic tank or gravity tank as applicable. Unless the potable water pumps are pumping from a strained raw water supply, duplex suction strainers are required.

f. Water treatment. A water quality analysis should be obtained to determine the treatment required. In event that full treatment is not initially indicated, space, piping sizes, and connections should be provided to expand treatment facilities should subsequent changes in water quality so require. Power plant uses do not require all water qualities considered desirable for domestic use, so judgment in applying treatment criteria is necessary. Potable water should meet the minimum requirements as specified in ER 1130-2-407. For treatment plant design, refer to ASCE-AWA-CSSE published by American Water

Works Association (AWWA). Other references include TM 5-813-3, applicable state plumbing codes, and EPA requirements.

g. Storage tank.

(1) Gravity tank. A gravity tank, or other gravity sources, with capacity and head to sustain the project for a week or more under conservation operation is the most desirable storage facility. When a suitable tank location is available, and particularly where there is a substantial nonpowerhouse project demand, design emphasis should give first priority to a gravity system. The design responsibility for the storage facility will usually be nonpowerhouse for such systems. Refer to TM 5-813-4 for water storage considerations.

(2) Pressure tank. Where a gravity system is not feasible, a hydropneumatic tank located in the powerhouse is normally provided for the powerhouse requirements. The tank should be sized so that in combination with high-average system demand and pump delivery, it will provide a minimum 30-min chlorine contact period and allow approximately 10 min between pump starts. Tanks should conform to Section VIII of the ASME "Boiler Pressure and Vessel Code." Tanks smaller than about 1,676 mm (66 in.) in diameter should be galvanized inside and out depending on plant capabilities in the supply area. Larger tanks should be painted inside and out.

h. Hot water.

(1) Powerhouse fixture requirements. The type, number, and location of fixtures requiring hot potable water are normally determined by architects. The piping system designer should cooperate in the planning to effect the most practical grouping of fixtures for efficiency of hot water distribution.

(2) Demand. Demand should be computed on the basis of Table B-2 and information noted in Appendix B, paragraph B-5, "Powerhouse Electric Water Heaters."

(3) Heaters. Heaters should be the electric tank type and should be selected in accordance with Appendix B, paragraph B-5. Where fixtures are isolated by more than 18-24 m (60-80 ft) of piping, the provision of separate heaters may be more economical and should be investigated. Electrical load should be coordinated with the electrical design.

i. *Piping.* Refer to Chapter 17 for general piping considerations. Disinfecting of potable water piping in accordance with AWWA Standard C 601 should be provided. Backflow preventers are required between the potable water system and gland water piping also in any other interconnection between potable water piping and piping with the potential for containing nonpotable water.

j. *Drawing.* Figure B-8 presents a plan of a typical potable water system.

10-6. Raw Water System

a. *General.* The raw water system normally provides water for the following requirements:

- (1) Air compressors and aftercoolers.
- (2) Air conditioning cooling water.
- (3) Fire protection-deck washing.
- (4) Pump prelube.
- (5) Unwatering and drainage deep well.

In addition, certain projects may utilize water from the raw water system for gland water, transformer deluge system, station transformer cooling water, and a source for the potable water system.

b. *Water requirements.* Flow requirements for air compressors, aftercoolers, and pump prelube should be obtained from equipment suppliers and verified against existing projects with similar equipment. Air conditioning flows will be as computed for the air conditioning system. Fire protection - deck washing hose valve requirements should be based on 3-L/s per 40-mm (50-gpm per 1.5-in.) hose and should assume three hoses operating at one time. Quality requirements for the raw water system are nominal, requiring straining only unless water analysis indicates a need of treatment to limit scale formation in cooling coils.

c. *Sources.*

(1) General. Raw water should normally be obtained from the pool or tailwater. Other reliable sources are unlikely to be economically available; however, an existing or planned adequate gravity project source would offer some advantages and should be considered.

(2) Pool. For projects up to about 76-m (250-ft) head, a gravity pool supply is usually preferable.

(3) Tailwater. For projects over 76-m (250-ft) head, or where pool head fluctuates over a wide range, a pumped tailwater supply will normally be utilized. For high head projects in tidal locations with brackish tailwater, special materials and/or equipment will be required.

d. *Head.* Optimum head for raw water requirements can vary considerably depending on the particular equipment selected and its location. System design should consider the inherent flexibility in required differentials across coils and heat exchangers, as well as locations, to effect the simplest and most dependable system. The provision of booster pumps or pressure-reducing relief valve stations to provide different head in a portion of the system should be evaluated on the basis of requirement rather than desirability. The fire protection-deck washing hose cabinets are intended as backup fire-protection only, permitting reasonable fluctuations in available head.

e. *Treatment.* Strainer perforations of 3 mm (1/8 in.) will normally be adequate for all raw water system requirements (see paragraph 10-2e for further recommendations).

f. *Pumps.* The pump principles noted in paragraph 10-2f are generally applicable. The system design should provide standby pump capacity for all pumped requirements. For pumped tailwater systems, the raw water system requirements can be included in the generator cooling water pumps capacity and supplied through the crossover header, with booster pumps provided if required.

g. *Piping.*

(1) Refer to Chapter 17 for general piping considerations.

(2) The generator cooling water crossover header should normally be the supply to the raw water system.

(3) Where the generator cooling water is a gravity supply which is not always available, a standby raw water supply intake and piping should be provided.

(4) Piping for fire protection-deck washing hose cabinets subject to freezing should be provided with automatic drainage.

(5) A 20-mm (3/4-in.) hose valve should be provided at each turbine head cover for cleanup.

(6) A 40-mm (1.5-in.) hose connection should be provided near turbine access hatches to wash down the turbine.

h. Fire protection-deck washing hose cabinets. The fire protection-deck washing provisions are intended basically to meet the normal standards of a deck washing system and to further serve as a backup means of fire control. Powerhouses are considered to be low fire hazard structures with code fire protection provisions limited to generators, oil storage and pump rooms, paint storage rooms, and in some cases, transformers. Protection for

these hazards are covered in Chapter 15, "Fire Protection Systems." To provide backup protection, the fire protection-deck washing system should include 40-mm (1.5-in.) hose connections, hose and reels, spaced throughout the powerhouse and decks, to permit minimum hose nozzle coverage of all occupied areas except drainage galleries and locations where a stream could contact high-voltage electrical equipment. Areas used for loading or unloading from vehicles or railroad equipment, heavy maintenance areas, potential storage areas, and where there is oil piping should be accessible to simultaneous hose-nozzle coverage from two directions. Where the fire protection-deck washing system is supplied by pumps, the pump and standby pump should receive power from separate sources.

i. Drawings. Figure B-9 shows typical raw water systems.

Chapter 11 Unwatering and Drainage System

11-1. General

The unwatering and drainage system provides the means for unwatering main unit turbines and their associated water passages for inspection and maintenance purposes, as well as the collection and disposal of all powerhouse leakage and wastewater other than sanitary. The provisions for equalizing (filling) are closely related to unwatering and are included in this chapter. The safety of personnel and plant is of vital concern in this system and should have continuing priority throughout the design.

11-2. Unwatering System

a. General. The principal volumes to be unwatered in all powerhouses are the spiral case and draft tube. In addition, there is usually a considerable volume downstream of the headgates or the penstock valve. Some projects include extensive fish passage facilities with large volumes of water in pumps, channels, and conduits to be unwatered.

b. Detail requirements.

(1) Unwatering procedure. Normal procedure after unit shutdown requires the following: closing of the headgates or penstock valve; drainage of all unit water above tailwater to tailwater elevation through the wicket gates, and spiral case or spiral case extension drain; placement of draft tube bulkheads or stoplogs; and draining the remaining unit water to sump with the sump pumps operating.

(2) Unwatering time. Aside from safety, the required elapsed time for completing a unit unwatering is the major factor in unwatering system design. Unit downtime will usually be of a value justifying facilities to accomplish unwatering in 4 hr or less. This can mean that in a typical plant all necessary valve, gate, and stoplog or bulkhead operations should be done in approximately 1 hr and draining of the pumping system in approximately 3 hr. Such a schedule has been attainable and justifiable on existing projects.

(3) Spiral case drains. Spiral case drains should normally be sized to preclude draining of the spiral cases from becoming a controlling factor in total unwatering time. Oversizing to the point where misoperation could result in excessive unseating head and damage to draft

tube stoplogs or tailrace structure must be avoided, particularly in plants where opening the drain valve is part of the equalizing procedure. It will usually be found that with properly sized drains the unseating force on the draft tube stoplogs will result in enough leakage to prevent a damaging pressure rise. The drains should normally be provided with manually operated rising stem-gate valves for control. However, portable or fixed power operators can be justified on the larger sizes. Maximum flow velocities will usually render butterfly valves unsuitable. The designer should be aware of the flooding hazard resulting from a failure in this line and provide a layout with conservatively rated components and in which alignment and necessary flexibility can be reasonably attained. Typical sizes in existing plants are in the 100-200-mm (4-8-in.) range for small Francis unit plants and in the 400-500-mm (16-20-in.) range for large Kaplan unit plants. Spiral case drains should discharge to the draft tube to preclude pool head on the unwatering sump. A connection for introducing station compressed air immediately upstream from the control valve to dislodge packed silt and debris is normally required.

(4) Draft tube drains.

(a) Draft tube drains should be sized with consideration for leakage from the following: intake gates, intake valves, and structural relief drains; draft tube bulkheads or stoplogs; the required unwatering time; and the assurance of seating the draft tube bulkhead or stoplogs. With average design and workmanship on bulkheads, stoplogs, and guides, the 3-hr draining requirement usually will result in a large enough draft tube drain to seat the bulkhead or stoplogs. A short drain line discharging into a large conduit and sump results in a high initial flow rate ideal for the seating requirement. Where drains are manifolded directly into the pump intakes, the individual draft tube drains tend to be smaller, and the maximum capacity of the entire system should be evaluated for the possibility of unseated leakage, plus other leakage, which equals or exceeds the drainage capacity.

(b) Valves for the draft tube drains are usually either a submerged rising plug type (mud valve) or standard in-line rising stem-gate valves. The rising plug type offers a drain line installation not subject to plugging from packed silt and no exposed components subject to flooding hazard failures. Its disadvantage is the head requirements, for large units with deep submergence are usually not within standard valve ratings which result in nonstandard equipment. Attempts to upgrade standard valves usually causes problems in obtaining valves with adequate safety factors for all hydraulic forces and

operator forces. Standard gate valves and operators are available as off-the-shelf items for installations in a dry pit location accessible to the embedded drain line, but the potential for line plugging between the draft tube and valve is disadvantageous. Short lines with compressed air blowout connections will minimize unplugging problems. This type of valve installation is ordinarily restricted to smaller plants without an unwatering header or tunnel. For the larger units with deep submergence, the preferred valve is either a standard design gate valve suitable for submergence in a draft tube recess or special design plug-type valve with design for the required head completely detailed in the contract drawings. Stainless steel water-type knife-edge gate valves suitable for submerged extended stem operation have been used at several recent projects and are expected to give reliable service. Two valves should be installed in draft tube locations to provide unwatering capability with one valve inoperable, but required unwatering time should be on the assumption that both valves are operable. Powered operators, either portable or fixed, are usually justified for the larger installations. Butterfly valves are generally unsuitable because of high velocities.

(c) Draft tube drains may be run individually to the unwatering sump in small plants but are usually discharged into a large pipe header or formed conduit leading to the sump in large plants. The formed conduit has definite advantages in large Kaplan unit plants as it can be large enough for inspection and cleanout, can form an effective addition to sump capacity, and is often more economical than a pipe header.

(d) The flooding hazard precautions noted in 11-2b(3) are also applicable to draft tube drains.

(5) Unwatering sumps.

(a) Sump provisions in most projects require either joint usage in both the unwatering and drainage systems, or separate sumps with the unwatering sump serving as a backup or overflow for the drainage sump. Size and configuration specifications require close coordination with the planned pumping provisions and inflows to permit practical pump cycles with adequate backup and effective high-level warning provisions. Whenever space and reasonable cost permit, it is preferable to provide oversized sumps to allow more flexibility to accommodate unexpected leakage, additional or larger pumps, or revised operating procedures.

(b) Sumps should be designed for maximum tailwater head with assumed pump failure and be vented above maximum tailwater.

(c) Floors should be graded to a small sump within a sump to permit use of a portable pump for maintenance unwatering the main sump.

(d) With separate sumps, the drainage sump overflow should be above the lag pump "on" elevation and be provided with a check valve which has a pressure rating based on maximum tailwater.

(6) Unwatering pumps. The unwatering and drainage pumping provisions require, along with the sumps, consideration of their individual and joint usage requirements. Usually, more than one combination of pumps will be practical for any application. However, the following general principles should be observed:

(a) Sump configuration and automatic start-stop settings should allow a minimum of 3-min running time per cycle for all pump selections.

(b) Pumps should be suitable for operation at zero static head.

(c) Pumps should have continuously raising performance curves.

(d) Pump motors and controls should be located above average peak flow tailwater.

(e) Silent-type check valves should be used in pump discharge lines.

(f) Where space is available, the preferred provisions should include the following: separate unwatering and drainage sumps, separate unwatering and drainage pumping provisions, and automatic overflow from the drainage sump to unwatering sump.

(g) With separate systems, unwatering pump capacity should permit unwatering in 3 hr or less of pumping time with total capacity divided in two pumps of the same capacity. Either pump used alone should be capable of accomplishing an unwatering. Since unit unwatering will not be scheduled under powerhouse design flood conditions, rated unwatering pump discharge should be for a maximum planned tailwater under which unwatering will

occur. To provide backup for the drainage system, the unwatering pumps should have a reasonable capacity at powerhouse design flood conditions.

(h) With separate systems, the drainage pump capacity should be divided between two pumps of the same capacity. Each should be capable of pumping a minimum of 150 percent of maximum estimated station drainage at an average peak-flow tailwater and with combined capacity to handle estimated station drainage at powerhouse design flood.

(i) With combined single-sump systems, the drainage-unwatering two-pump capacity should meet the stated minimum requirements for separate systems. The two pumps should pump from an in-sump manifold with valved connections from unwatering lines and a valved inlet from the sump. The manifold inlet valves should be manual, and design should be based on station drainage accumulating in the sump during an unwatering operation. A third manually controlled pump of the same capacity should be installed as backup for the drainage function. Suction for the third pump should be directly out of the sump, not through the header.

(j) Pumps of the deep well water-lubricated type will usually be preferred. Water jet educators can seldom be justified from an efficiency standpoint, and dry pit pump installations are less desirable in safety and cost considerations. Submersible motor and pump combination units mounted on guide rails permitting the pump units to be raised or lowered by the powerhouse crane have been used on several recent jobs. Provisions are included for automatic connection to the pump discharge line. This design eliminates the long pump shafts and simplifies maintenance.

(k) Either pneumatic bubbler-type or float-type controls are satisfactory for pump control. A separate float type of control should be provided for the drainage sump (or combined drainage-unwatering sump) for high-water alarm. Automatic lead-lag with manual selection of the lead pump is preferred.

(l) Whenever practicable, minimum piping (particularly embedded), sump capacity, and pump arrangement backup provisions should permit the addition of future pumping capacity.

(7) Discharge piping. Unwatering system discharge lines normally terminate above the average peak-flow tailwater. Therefore, reliance is on the discharge check valves for prevention of backflow at high tailwaters and

permission of line and check valve maintenance at lower tailwaters. Individual pump discharges to the tailrace are preferable, but a single discharge header for combined unwatering-drainage pumps and a single header each for separate unwatering and drainage systems will usually be found more practicable to use.

(8) System diagrams. Figure B-10 shows typical unwatering-drainage systems.

c. Miscellaneous.

(1) Unwatering of nonpowerhouse facilities. It is acceptable to utilize the unwatering conduit, sump, and pumps for unwatering of fishway conduits, channels, and pumps as well as other facilities in or adjoining the powerhouse. However, frequency of use, length of lines, line plugging, safety, required unwatering time, cost, and possibility of conflicting unwatering schedules should be carefully evaluated. Portable equipment is frequently a preferable choice.

(2) Construction usage. Use of the unwatering facilities for construction requirements or for maintaining skeleton (future) powerhouse bays in an unwatered condition should not be planned. Questionable condition of equipment and fouling of lines with construction debris after such usage will be usually experienced.

11-3. Drainage System

a. General. The drainage system handles three general types of drainage as follows: rain and snow water from roofs and decks, leakage through structural cracks and contraction joints, and wastewater from equipment. Discharge is to tailwater either by gravity or by pumping from a drainage sump.

b. Roof and deck drainage. Roof and deck drainage should normally be directly to tailwater by gravity. However, where the powerhouse forms a portion of the dam structure, it may be feasible to drain the intake deck to pool. A minimum of two roof drains per bay should be provided to minimize flooding from plugging. Deck drains should be located to eliminate standing water and should consist of short vertical runs of piping wherever practicable in freezing areas. Decks with open block-out type of rail installations should be provided with block-out drains. Size of roof and deck drains should be based on the greater of applicable code requirements or maximum 1-hr rainfall figures for the area. Deluge system flows should be added where applicable.

c. Floor drainage.

(1) Drainage galleries. Drainage galleries and other galleries with a wall in contact with water or a fill below high tailwater should be provided with a drainage trench. The trench should be sized and graded for maximum estimated leakage based on existing similar powerhouses. Unless located in grouting galleries, trenches should not cross contraction joints without provision of water stops. Conduits connecting the trenches to the drainage sump and the conduit entrances should be carefully designed to preclude overflow of the trench onto the gallery floor. Contraction joint drains should discharge visibly into the drainage trench to permit monitoring of joint leakage. A float-operated alarm should be provided to indicate flooding of the lowest gallery.

(2) Oil storage and purifier rooms. Where oil storage or purifier rooms are provided with sprinkler systems, provide a chilling drain with a gravel pocket of sufficient capacity to handle the sprinkling system flow. When a CO₂ protected room is drained, the floor drain should be of nominal size and provided with a normally closed manual valve. Oil storage or purifier room drains should not drain directly to tailwater. They should first be routed to an oil separator facility.

(3) Battery room. Battery room floor and sink drains should be of acid resisting material, have a minimum 2 percent slope, no pockets or traps, and should discharge directly to the sump or tailrace.

(4) Miscellaneous area floor drains. Miscellaneous area floor drains should be provided in accordance with ASME A 31.1 and the Unified Plumbing Code. All floor areas below average peak-flow tailwater, and all other floor areas subject to flushing, leakage from, or periodic disassembly of water-filled equipment or piping should be drained. Any drains that come from a source that can add oil to the water should not drain directly to tailwater but should first be routed to an oil separator facility. The following areas are typical of most powerhouses, but the required areas of each powerhouse should be determined individually:

- (a) Turbine rooms.
- (b) Galleries.
- (c) Water treatment room.
- (d) Pump rooms.

- (e) Locker rooms.
- (f) Toilet rooms.
- (g) Machine shop.
- (h) Heating and ventilating equipment room.
- (i) Gate repair pits.
- (j) Gate and bulkhead storage pits.
- (k) Pipe trenches.
- (l) Elevator pits.
- (m) Rigging rooms.
- (n) Valve pits.

(5) Location of floor drains. Locating floor drains requires close coordination with structural and architectural requirements, but the following general considerations should apply.

(a) All areas where leakage, rainwater, water from disassembly, flushing, etc., is normally expected should have floors with continuous slope to the drain location. Examples of these areas are around pumps, strainers, janitor closets, outside decks, shower rooms, unloading areas, and drainage galleries.

(b) In other areas with unfinished level floors, it is desirable to locate drains in the center of a 910-1,220-mm (36-48-in.) depressed area to assist in directing water to the drain.

(c) In finished areas (terrazzo, tile) where slope or a depressed area can not be obtained, the drain location and elevation should be determined by the architect.

d. Equipment wastewater drainage.

(1) Gravity wastewater. The following equipment wastewater is normally drained to the sump through the drainage system piping:

- (a) Pump gland drainage.
- (b) Strainer drains.
- (c) Condensate.

- (d) Air compressor cooling water.
- (e) Turbine head cover leakage.
- (f) Heat exchanger.
- (g) Turbine pit liner drainage.

Drainage should be collected and piped to the floor drains, sealed connections, or sight funnels. Open flows running horizontally across floors or drain lines should be avoided. Francis-type turbines are normally drained by gravity, and drainage from propeller turbines is normally pumped out of the turbine pits with pumps furnished by the turbine manufacturer. Capacity of gravity drain pipes may be estimated from Appendix B, paragraph B-6, "Capacity of Cast Iron Drain Lines."

(2) Pressure wastewater.

(a) Wastewater from generator air coolers and bearing coolers are normally piped directly to the tailrace. Some powerhouses also require pressure drains for transformer cooling water and air conditioning cooling water.

(b) The point of discharge for pressure drains requires careful consideration as several factors are involved. These include the following:

- Tailwater fluctuations.
- Available head (where the source is pool water).
- Pumping costs.
- Pressure conditions in coils and other equipment.
- Icing conditions.
- Requirement for flap valves or other protective shutoff valves.
- Line and valve maintenance.
- Esthetics (visibility of discharge).
- Fish passage channels.

An optimum discharge location would be above maximum tailwater for safety reasons. Where this is not practicable, a location above normal operating tailwater and the provision of a readily accessible shutoff valve at the point where the line becomes exposed in the powerhouse are

preferred. A vented loop to prevent backflow from tailwater is satisfactory, but space requirements and the additional piping can make this provision impractical.

(c) Pressure discharge lines should be designed for maximum obtainable pressure conditions, and if an isolating valve is used, the effect of an inadvertent closure should be considered. Flap valves located below minimum tailwater are unsatisfactory because of inaccessibility for inspection and maintenance.

e. Drainage piping.

(1) General. Refer to Chapter 17 for general piping considerations.

(2) Embedded detail requirements.

(a) Embedding piping should be cast iron soil pipe.

(b) Horizontal turns should be long sweep.

(c) Vertical turns may be quarter bend.

(d) Minimum line size is 76 mm (3 in.).

(e) Slope in horizontal lines is preferably 2 percent and a minimum of 1 percent.

(f) Routing should be generally parallel with building lines to minimize interference with reinforcing steel and other embedded material.

(g) Lines crossing contraction joints require provision for flexibility. See detail in Appendix B, paragraph B-6.

(h) Lines more than one-third the thickness of wall or slab should not be embedded.

(3) Backflow valves. Drains in lower powerhouse areas may be fitted with backflow valves to minimize flooding under adverse conditions. However, such devices are not considered as positive protection against backflow in system design.

f. Drainage sump. The provisions noted in paragraph 11-2b(5) are applicable to drainage sumps. The drainage sump or joint unwatering-drainage sump should be located low enough to provide gravity flow from all drained areas under all dry powerhouse design tailwater conditions and up to the float-operated alarm, sump water elevation. Deviations from this requirement can occur in

the case of certain low-drainage galleries deemed noncritical for short-term drainage interruptions. However, such applications should be discussed with review offices before proceeding with design.

g. *Drainage pumps.* Drainage pumps, whether separate or as combined drainage-unwatering pumps, should meet the provisions of paragraph 11-2b(6).

h. *Drainage pump discharge.* Refer to paragraph 11-2b(7) and Chapter 17 for pump discharge requirements.

i. *Drainage sump overflow.* The drainage sump should be provided with an overflow to the unwatering sump where separate drainage and unwatering sumps are provided. The overflow should be located slightly above the high water-level alarm elevation and should be provided with a flap valve to prevent flow from the unwatering sump to the drainage sump. The flap valve should be reasonably accessible for maintenance. It should be sized to bypass the drainage sump inflow capacity or unwatering pumps combined capacity to permit maximum utility in the event of an accident or flooding in the powerhouse.

j. *Safety pool.* Some projects with separate sumps provide for a "safety pool" of water in the draft tube when work is being done on the turbine runners. This is usually accomplished by allowing the unwatering sump water level to rise and overflow into the drainage sump through a valved opening. Thus, a valved opening between sumps is required. Drainage pump capacity has to handle the increased flows from all leakage into the unwatering sump.

k. *Estimating drainage leakage.* Leakage through contraction joints and cracks in floors and walls is usually the major uncertainty in estimating total drainage facility requirements. Where the powerhouse is a structure separate from the dam, 0.2 L/s per meter (1 gpm per foot) of powerhouse length is sometimes used. This tends to increase appreciably when the powerhouse is integral with the dam. Drainage to the powerhouse from a separate intake structure frequently is routed to the powerhouse drainage sump, and this is subject to the same uncertainty as the powerhouse leakage itself. The most reliable estimate is one based on an existing powerhouse of comparable size, configuration, and head conditions. Information on existing designs and operational experience is readily obtainable from district offices and through review offices.

l. *External drainage.* For some projects, it is expedient to route some of the drainage from the dam or other project facilities to the powerhouse drainage system. Such drainage should be limited to minor flows totalling not more than 10 percent of the estimated powerhouse drainage since any significant addition to potential flooding of the powerhouse should be avoided. Estimated drainage from such sources are subject to many variables, and it is a responsibility of the powerhouse designer to verify the estimates.

m. *Transformer vault drains.* Drains from areas in which oil-filled transformers are located should be discharged to draft tube gate slots when the water above the draft tube exit is confined to a holding pond, or to a similar method of storing spilled oil for later pumpout and disposal.

11-4. Equalizing (Filling)

a. *General.* A number of methods have been employed for equalizing at existing projects, but two preferred methods are described. Other methods involving equalizing headers or crossover connections are satisfactory in operation but introduce additional piping and valves along with increased flooding hazards in event of failure.

b. *Low head projects.* Low head projects up to about 38m (125 ft) usually have one or more intake gates and a set of draft tube bulkheads or stoplogs. Equalizing on these projects can be accomplished by opening the spiral case drain, cracking the intake gates, and filling the draft tube to tailwater then lowering the gates. After removing the bulkheads or stoplogs and closing the spiral case drain, the intake gates are again cracked open, and the spiral case and intake allowed to fill and equalized to pool head. The entire operation takes place with the wicket gates closed. No additional piping or valves are provided.

c. *High head projects.* Higher head projects provided with a penstock valve have a bypass valve for equalizing pressure across the penstock valve. Equalizing on these projects can be accomplished by filling to tailwater through valves provided in the draft tube bulkhead or stoplogs, removal of the bulkhead or stoplogs and filling, and equalizing the spiral case through the penstock valve bypass. The entire operation takes place with the wicket gates and spiral case drain closed. Additional equipment involved consists of one or more tag-line operated valves

in a draft tube stop log or bulkhead. The tag-line operated valves should be a balanced type of valve to permit convenient tag-line operation in both directions and should be located near the top of the bulkhead or stoplog. Valve sizes should be consistent with the unwatering time noted in paragraph 11-2b(2). When upstream intake gate seals are used, cracking the gates to fill the penstocks should be avoided because of the possibility of gate catapulting during filling. For more information, see the April 1977 WES publication TRH-77-8. This publication can be purchased from the National Technical Information Center (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 as report AD A043 876. Costs of hard copies or microfiche copies of such reports are available from the NTIS on request.

11-5. Venting

When a penstock valve is utilized, the spiral case requires an air and vacuum relief valve to permit filling and unwatering. This valve and line should be sized to prevent less than one-half atmospheric pressure developing in the spiral case and should open to release air under pool pressure. The takeoff should be from the top of the casing or spiral case extension, and the vent line should be provided with a cutoff valve located as close to point of takeoff as practicable. Termination should be in a screened opening, above maximum tailwater, and clear of personnel areas.

Chapter 12 Oil Systems

12-1. General

Installed systems for two types of oil, governor-lubrication oil (governor-lube) and insulating oil, are required in most powerhouses. The systems are based on the use of a common oil for unit lubrication and governor-systems and for transformers and circuit breakers. Should there be uncertainty regarding the common use of these oils, pre-design discussion with review offices is recommended. Other powerhouse oils which may be necessary are handled in portable containers and are not covered in this chapter. The storage, pumping, purification, and piping facilities for governor-lube oil and insulating oil are similar, but the design must be based on maintaining complete separation of the two oils through the use of separate facilities due to the special purification requirements of insulating oil. Separation is not necessary in disposal. Design emphasis should provide maximum protection against misrouting and mixing of oils and fire hazards resulting from spillage (see paragraph 15-2). Separate piping systems should be provided insofar as possible for insulating oil for the transformers and circuit breakers to minimize the chance of mixing these oils. Additional guidance can be found in Guide Specifications CW-15487 for turbine lubricating oil and CW-16321 for electrical insulating mineral oil.

12-2. System Requirements

a. Governor-lube oil. The following operations are normal system requirements:

- (1) Filling dirty oil storage tank from tank car or truck.
- (2) Moving oil from clean oil storage tank by either the purifier or transfer pump to the generator-turbine unit.
- (3) Draining or returning overflow oil from the generator-turbine unit to the dirty oil storage tank.
- (4) Moving oil from either storage tank to a tank car or truck for disposal.
- (5) Flushing of any supply line to generator-turbine units.
- (6) Recirculating oil in any equipment on generator-turbine unit through purifier and back to equipment.

(7) Recirculating oil from any storage tank through purifier and back to tank.

b. Transil oil. The system requirements for insulating oil are essentially as for governor-lube oil in 12-2a with each operation relative to transformers or circuit breakers instead of generator-turbine units.

12-3. Oil Storage Room

The oil storage room should be located at a low elevation in the powerhouse. A depressed area in concrete should be provided below all openings in the room of sufficient volume to contain all oil stored in the room. Space for purification equipment in the same room is desirable to simplify CO₂ fire protection. The room should be in mass concrete but, in any case, should be of fire resistant construction and have automatic closing fire doors. The floor should slope to a sump to collect small oil spills for removal. A valved, inverted outflow line should drain water from the bottom of the sump. A personnel emergency escape door or hatch should be provided in a desirable location away from the main door. If separate oil storage and purification rooms are provided, the room requirements are similar.

12-4. Oil Storage Tanks

a. Capacity. Clean and dirty insulating oil tanks should each hold a minimum of 110 percent of the oil required to fill the largest transformer on the system. Clean and dirty governor-lube oil tanks should each hold a minimum of 110 percent of the oil required to fill the governor system and all the bearings of the largest generator-turbine unit.

b. Design. Storage tank design should conform to the applicable requirements of American Petroleum Institute (API) Standard 650, Underwriters Laboratories (UL) Standard 142, or ASME "Boiler and Pressure Vessel Code" (design pressures 15 psi and over). Minimum wall thickness should be 6.4 mm (1/4 in.). To determine the type and configuration of tanks, the following factors should not be overlooked:

- (1) Shipping limitations.
- (2) Shipping costs.
- (3) Space and scheduling for field erection.
- (4) Testing of field-erected tanks.

- (5) Limitations on oil room configuration.

Tanks should be provided with direct reading liquid-level gauges and the interior finish should be an epoxy-based paint system.

12-5. Pumps

a. General. Oil system pumps should be the positive displacement type and should be provided with safety relief valves and high temperature shutdown. Suction lift should not exceed 4.5 m (15 ft), and pump speed should be limited to 1,200 rpm. Control should be manual, but timer switches should be used to prevent continuous pump operation beyond the normal time required for each oil transfer. Pump capacity may be provided in single or duplex units, but if single, a standby pump for convenient exchange should be available.

b. Dirty oil pumps.

(1) Waste oil. A pump should be provided to pump waste oil to a deck waste valve. Capacity should permit emptying the largest tank in approximately 8 hr or less. The pump should have a hose valve suction connection for the hose connecting to the insulating oil tank, governor-lube oil tank, or floor sump. A suction line filter is required to protect the pump from foreign material. Manual-timer switches should be located in the oil room and at the deck valve.

(2) Nongravity return oil. Projects where it is not feasible to return oil from generator-turbine bearings and governor to the dirty oil tank by gravity should be provided with pumps for this service. The location will usually be in the turbine pit at each unit.

c. Clean oil pumps.

(1) Governor-lube oil. A governor-lube oil pump sized to fill the bearings and governor of the largest unit in approximately 8 hr or less should be installed in the oil storage room. An adjustable back pressure valve and the safety relief valve should bypass excess oil back to the clean governor-lube oil tank. The safety relief valve should be set to maximum system operating pressure, and the adjustable back pressure valve to pump rating but not higher than 95 percent of the safety relief valve setting. Manual-timer switches should be located in the oil room and at each unit.

(2) Insulating oil. The insulating oil pump should have approximately 105-110 percent of the capacity of the

purifier to be used at the transformers. Back pressure and relief valve provisions should be as noted in 12-5c(1). Manual-timer switches should be located in the oil room and at each deck valve.

12-6. Oil Piping

a. General. Refer to Chapter 17 for general piping considerations. Figures B-11 and B-12 show typical oil systems. Appendix B specification, "Powerhouse Piping," provides flow losses for oil in tubing (see paragraph B-3).

b. Special provisions.

(1) Supply piping should be sized to deliver full pump flow to the most remote outlet without exceeding allowable tubing pressure.

(2) Return piping should be sized to drain the most remote transformer or generator-turbine-governor within 8 hr.

(3) Return lines should be routed to avoid air traps. Loops discharging to the bottom of tanks should be vented to the top of the tank.

(4) Flushing connections are required between ends of each supply line and return line. Connection should include a check valve.

(5) Normal overflows and leakage should generally drain by gravity to the dirty oil tank. Where this is not possible, an automatic float-operated pump and sump should be provided.

(6) The piping layout should provide for pipe drainage back to the tank wherever practicable.

(7) Pressure gauges with isolating cocks should be provided on the suction and discharge of each pump.

(8) Sampling cocks should be provided at bottom of tanks and at one-fourth points up to the top.

(9) Fixed piping connections are used for generator and turbine bearing sumps and governor tanks.

(10) Hose valves and hoses are used for connections to transformers and circuit breakers.

(11) The piping material schedule, Figure B-13, provides for type K hard drawn copper tubing for oil system piping. Soft solder connections are normally satisfactory.

(12) Overflow drains to the dirty oil tank should be installed without valves.

(13) Purifier hose connections should be provided in the oil storage room, transformer locations, and at generator-turbine units.

12-7. Oil Purifiers

a. General. Each powerhouse should be provided with a governor-lube oil purifier and with, or have convenient access to, an insulating oil purifier. Portable purifiers are preferred. Overall purifier dimensions, access doors and ramps, and elevator sizes must be coordinated in the early powerhouse planning to permit purifier access to the oil storage room, transformer locations, and purifier connections at generator-turbine units. For additional guidance, refer to ETL 1110-8-12.

b. Governor-lube oil purifier. The governor-lube oil purifier should be either a centrifuge or coalescent type. A low-vacuum purifier may be added to remove excess water and dissolved gases. The purifier should be capable of processing oil with up to 1 percent water and 0.5 percent solids by volume to no more than 0.25 percent water

and 0.02 percent solids and remaining solids not exceeding 40 microns in size. The separated water should not contain more than 0.5 percent oil by volume. Purification should be attained in one pass. The purifier rating should normally provide for purification of the dirty oil tank capacity within 8 hr. However, in the case of very large tank requirements, reasonable access for the portable purifier may limit its size and justify longer periods. Purifier units should include required pumps, oil heaters, controls, and wheeler carriage.

c. Insulating oil purifier. The insulating oil purifier must be designed so that the processed oil meets the transformer oil purity requirements. This normally consists of a filtration system and a high-vacuum purifier.

12-8. Alternate Systems

For small powerhouses with reasonable availability of insulating oil supply via tank truck to source, it can be practicable to omit the installed insulating oil storage facilities and service the transformers directly from the truck via the purifier.

Chapter 13 Compressed Air Systems

13-1. General

Compressed air systems are required in powerhouses for operation and to facilitate maintenance and repair (see TM 5-810-4). Service air, brake air, and governor air comprise the three systems needed in all powerhouses. Some powerhouses will require a draft tube water depression system in addition. Reliability, flexibility, and safety are prime design considerations.

13-2. Service Air System

a. General. The service air system is a nominal 700-kPa (100-psi) system providing air for maintenance and repair, control air, hydropneumatic tank air, charging air for the brake air system, and in some cases, air for ice control bubblers.

b. Service air requirement.

(1) Routine maintenance. Supply 25-40 L/s (50-80 cfm) for wrenches, grinders, hammers, winches, drills, vibrators, cleaning, unplugging intakes and lines, etc.

(2) Major maintenance and repair. Supply 140-190 L/s (300-400 cfm) for sandblasting, painting, cleaning, etc. Normally this capacity should be provided with portable equipment. For projects too remote from a government or commercial source of temporary portable equipment, installed capacity should be provided.

(3) Ice control bubblers. Supply 1-2-L/s per 3-m (2-4-cfm per 10-ft) width of trashrack with bubblers operating on intakes for up to four units simultaneously.

(4) Operational requirements. Supply 7-12 L/s (15-25 cfm) with individual assumptions as follows:

- (a) Brake system charging air
1-2 L/s (2-4 cfm) per unit
- (b) Hydropneumatic tank
3-5 L/s (5-10 cfm) per unit
- (c) Control bubbler
1-3 L/s (2-5 cfm) per unit

- (d) Leakage
1-3 L/s (3-5 cfm) per unit

(5) Total service air.

(a) Computed basis. The total service air requirement may be computed on the basis of the previously mentioned (1) to (4) individual allowances. The figures noted are representative estimates from several existing projects and should be modified as appropriate for the particular project with due regard for planned operation and maintenance, equipment sizes, number of units, service factors, and information from existing similar projects.

(b) Standard provision basis. It will be found that the computed basis will usually require several arbitrary assumptions and service factors to arrive at a total service air requirement. In lieu of the computed basis, the following standard provisions may be used as the basis of total air requirement:

- 1-2 unit plants 40 L/s (75 cfm)
- 3-4 unit plants 50 L/s (100 cfm)
- Over 4 unit plants 60 L/s (125 cfm)

In addition, provide 175 L/s (375 cfm) for major maintenance and repair. If this will be supplied with portable equipment, add computed ice control bubbler requirement to the above standard provisions. If the 175 L/s (375 cfm) is to be installed, assume that ice control and major maintenance will be nonsimultaneous requirements, and the 175 L/s (375 cfm) will cover the ice control bubbler requirements.

(6) Service air pressure. A nominal 700-kPa (100-psi) pressure with system variations from 580-760 kPa (85-110 psi) is satisfactory.

c. Compressors. Compressors should be heavy duty, water cooled, flood lubricated, and cooled rotary screw type rated for continuous duty. Normally, aside from major maintenance, service air should be supplied by two identical compressors each of which is capable of supplying approximately 75 percent of the requirement. Where ice control bubbler demand exceeds 12 L/s (25 cfm) and there is no installed major maintenance compressor, it will usually be preferable to supply the bubbler demand from a separate compressor. Installed major maintenance and

repair capacity should be provided with a single compressor.

d. Receivers. Each air receiver should conform to design, construction, and testing requirements of the ASME, "Boiler and Pressure Vessel Code." Receiver capacity should provide a minimum 5 min-running time with no air being used from the system for the largest connected compressor on automatic start-stop control. One or more receivers may be used for the system. However, galvanized receivers are preferred, and sizes should be checked against galvanizing plant capabilities.

e. Controls. The two service air compressors should each be provided with selective manual or automatic control. They should have pressure switch lead-lag control automatic selection and conventional load-unload operation for manual selection. A major maintenance compressor or a separate ice control bubbler compressor should be on manual control with conventional load-unload provisions. Cooling water should be controlled to flow only when the compressor motor is energized. Automatic shutdown should be provided for low oil pressure, low oil level, and high-discharge air temperature.

f. System details.

(1) Control air. Control air is provided for bubbler-type controls and gauges. The flow is minor but is a continuous system load. A 700-kPa (100-psi) air supply is satisfactory, but instruments and gauges operate at lower pressures, and reducing valves are normally included with the control equipment. Pneumatic air conditioning control and operators are sometimes supplied from the service air systems. However, package air supply units supplied with the air conditioning equipment are preferred to avoid possible contamination problems.

(2) Hydropneumatic tank. Refer to Chapter 10 for hydropneumatic tank requirements.

(3) Ice control bubblers.

(a) General. An ice control bubbler system will ordinarily be supplied from the power plant at projects where the powerhouse structure forms a portion of the dam and includes the intake provisions. A bubbler system is usually provided where severe freezing conditions over an extended period of time could result in heavy ice accumulation at the reservoir surface and cause damage to the trashracks. Where freezing weather is probable, but bubbler installation is to be postponed until icing conditions are determined, minimum required embedded piping

should be installed. The principle on which the bubbler system operates is the raising of warmer subsurface water to prevent surface freezing. Nozzles will operate effectively with a minimum submergence of 3.0 m (10 ft) and are effective to a submergence of 7.6 m (25 ft), permitting a single-level installation of nozzles to function satisfactorily over a 4.6-m (15-ft) range of reservoir water level. Each nozzle will provide an approximate 3.6-m (12-ft-) diam ice-free area above the nozzle.

(b) Design. Nozzle orifice should be 6 mm (1/8 in.) in diameter and 10 mm (3/8 in.) in length. Nozzles should discharge down. The maximum distance between nozzles should be 3 m (10 ft). Nozzles should be located close to trashrack bars and clear of trashraking equipment. A control valve at each takeoff from the service air header is required to match the differential across the orifice as closely as practicable to that required for the submergence. Excessive differential can result in nozzle freezing from air expansion.

(c) Piping. The bubblers for each main unit should be on a separate branch from the service air header with an isolating valve, throttle valve, pressure gauge, and vacuum release for automatic draining of air lines to nozzles. Piping should be pitched to assure drainage through nozzles when bubblers are off and there is a drop in pool level. Embedded piping should be plugged prior to pouring to prevent the entry of foreign material.

(4) Intake and line clearing. Water intakes, suction lines, and drains subject to plugging with debris or silt should be provided with service air connections (blow-outs) to assist in unplugging. A manual valve should be located near the blowout connection.

(5) Hose connections. Hose connections should be provided throughout the plant in galleries, on decks, in the generator-turbine room, in turbine pits, in generator housings, and in the maintenance shop. Generally, it should be possible to reach any area where maintenance air may be required without exceeding 30 m (100 ft) of hose. In the maintenance shop, hose connections should be located at each bench and machine tool. A hose connection should be provided at each governor tank for precharging the tank to service air pressure.

(6) Brake air. The brake air system is one or more separate storage and distribution systems supplied from the service air system and is covered under paragraph 13-3. Piped connections to the brake air systems should be made from the service air headers.

(7) Portable compressor connections. For powerhouses where the major maintenance and repair air is to be supplied with portable compressors, deck hose connections should be provided at intervals along the decks connecting to the main headers. The location of connections should permit convenient compressor location and reasonably short runs to the location of expected major maintenance or repairs. Headers should be sized accordingly.

g. Drawing and material schedule. Figure B-14 shows a typical compressed air system, and B-13 presents a material schedule.

13-3. Brake Air System

a. General. The brake air system comprises one or more semi-independent storage and distribution installations for providing a reliable supply of air to actuate the generator braking systems. Air is supplied from the service air system, stored in receivers, and distributed through the governor actuator cabinets to the generator brake systems.

b. Air requirement. Air is required in the system to stop all generator-turbine units simultaneously without adding air to the system and without reducing system pressure below 520 kPa (75 psi). Each unit may be assumed to require 42.5 L at 520 kPa (1.5 ft³ at 75 psi). When this figure is being verified from generator manufacturers' data, the storage capacity computations should consider the number of brake applications per stop, the maximum brake cylinder displacement with worn linings, and the volume of all piping downstream from the control valve.

c. Piping-receivers. Each subsystem includes a receiver, piping from the service air system to the receiver, piping from the receiver to the governor cabinets, and piping from each governor cabinet to the respective generator brake system. Normally, a separate subsystem will be provided for each pair of generator units. In the case of plants planned for an ultimate odd number of units though, one of the subsystems may serve one to three units. Each receiver should be sized to supply air for the units connected thereto and should be designed, manufactured, and tested in accordance with the ASME "Boiler and Pressure Vessel Code." Each receiver should be supplied with air from the service air system through an isolating valve, strainer, dryer, and check valve to make the subsystem unaffected by a temporary loss of pressure in the service air system. A bleed-off valve should be provided between the isolating valve and the

check valve to permit convenient testing of check valve tightness. A pressure reducing valve preceded by a strainer should be provided at the discharge from each receiver to limit brake air pressure to 700 kPa (100 psi). Piping should be in accordance with the piping schedule, Figure B-13.

d. Control. Control for application of the brakes is normally included in the governor cabinets and provided by the governor supplier.

e. Drawing. Figure B-14 shows a typical brake air system in a powerhouse.

13-4. Governor Air System

a. General. The governor air system provides the air cushion in the governor pressure tanks. When the governor system is to be placed in operation, the pressure tank is filled approximately one-fourth full with oil, and the tank is then pressurized to governor-operating pressure from the governor air system. Corrections to maintain the proper oil-air ratio are required at intervals during plant operation. The governor pressure tank size and operating pressure will be determined by the turbine servomotor volume. Pressures for various sizes of units currently vary 2,100-6,900 kPa (300-1,000 psi). Guide Specification CW-16252 provides additional guidance for tank and pump capacities.

b. Air requirements.

(1) Quantity. Compressor delivery should be sufficient to effect a complete pressurization of a governor tank with the proper oil level in 4-6 hr. The pressurization time should include prepressurizing to service air system pressure by hose connection where such procedure is warranted.

(2) System pressure. The operating pressure should be approximately 10 percent above the rated governor system pressure.

c. Compressor. The total air-delivery requirement should be provided by two identical compressors, each rated at not less than 50 percent of the requirement. Compressors should be heavy duty, reciprocating, water or air cooled, and rated for continuous duty. "Package units" are preferred. Each package should include compressor, motor, base, aftercooler, controls, and other accessories recommended by equipment manufacturers to provide a complete air-system supply except for the air receiver.

d. Receiver. Since manual-start, automatic-unloading control is used for governor air compressors, receiver capacity is required only to assure reasonable control action. A receiver capacity which will provide 3-5 min-compressor running time to raise receiver pressure from atmospheric to system pressure will normally be suitable. Receivers should be galvanized and conform to design, construction, and testing requirements of the ASME, "Boiler and Pressure Vessel Code."

e. Controls. Each compressor should be provided with manual start-stop and automatic load-unload control.

f. Drawing and material schedule. Figure B-14 shows typical piping in the air compressor system. Material should be in accordance with Figure B-13.

13-5. Draft Tube Water Depression System

a. General. A draft tube water depression system is required in plants with submerged turbine or pump-turbine runners where planned operations include the operation of one or more main units for synchronous condenser operation, motor starting for pumping, or spinning reserve. The system function is to displace and maintain draft tube water to a level below the turbine runner permitting the runner to turn in air. Normally, the system should be independent of other powerhouse air provisions, although some plants have been designed with connections to permit using the draft tube air depression system to supply station air. System components, particularly receivers and piping, will generally be of large physical size, and preliminary design should take place concurrent with first powerhouse layouts to assure space for a practical system arrangement. Refer to NFPA "Hydraulic Turbine Water Depression Systems for Synchronous Condenser Operation" by J. R. Taylor and ASME Paper No. 66-WA/FE-9 for discussion on these systems.

b. Air requirement. The system should supply sufficient air to displace the draft tube water clear of the turbine runner in approximately 10 sec, and down to 1.0 m (3 ft) below the bottom of the runner in approximately 60 sec plus additional volume to cover air losses during initial depression. Loss of volume during initial depression should be calculated at 10 percent of the required water displacement air volume with an assumed adiabatic expansion of the air in the receivers. Deviation from true adiabatic in the receivers during a 10 sec-depression is minor, and the additional air resulting therefrom should be neglected in the computations. Air must also be available after initial depression to maintain the water level approximately 1.0 m (3 ft) below the runner. A close estimate

of this air requirement is difficult since it is primarily dependent on leakage of air through the shaft gland and water leakage through the wicket gates. For design purposes, it can be assumed that gland leakage will be controlled to a minor flow and that required makeup air due to wicket gate water leakage will approximate 3 L/s per meter (2 cfm per foot) of unit diameter at the wicket gates. Unit operating head, type of unit, workmanship, and wear can all influence the leakage figure, and the design should include minimum provisions for doubling this assumption if required. The air requirement for initial depression must be available in receivers because of the high, brief flow requirement. Capacity for depressing more than one unit at a time or in rapid succession will seldom be justified except for motor starting for pumping. Additional capacity should be provided when supported by a favorable benefit to cost ratio. Air requirement for maintaining depression must be based on the planned maximum number of units requiring depression within a specified period of time.

c. System pressure. The minimum system operating pressure during initial depression should be approximately 100 kPa (15 psi) higher than the pressure required to depress the draft tube water 1.0 m (3 ft) below the runner. Maximum system pressure depends on required displacement volume and receiver capacity, but a nominal 700-kPa (100-psi) system will usually provide a practicable compressor-receiver-operational pressure. For large Kaplan units with deep submergence, an economic study should be made to determine possible economies from higher system storage pressure. Included should be costs of compressors, power and receivers, receiver configuration and location, and piping costs.

d. Compressors. Compressors should be heavy duty, water cooled, reciprocating, or flood-lubricated and cooled rotary screw type rated for continuous duty. The initial depression air and maintaining air usually are supplied by the same compressors. The required capacity should be based on raising receiver pressure from minimum to maximum operating pressure while supplying makeup air to maintain depressed units. To provide a minimum of standby with a compressor out of service, the required capacity should normally be provided in two identical compressors, each rated at 50-60 percent of the total required capacity. For a project requiring several large units on motoring operation at one time, the design studies should include providing the maintaining air with one or more low-pressure compressors.

e. Receivers. Receiver capacity should be provided in one or more receivers conforming to design,

construction, and testing requirements of the ASME, "Boiler and Pressure Vessel Code." Configuration and individual volumes will often be determined by space available. Consequently, early preliminary planning is necessary to secure a desirable receiver location in the powerhouse. Outdoor locations may be required in the case of large units. Receivers should normally be sized for the full initial depression requirement. Additional capacity should be provided when needed. Due to cost and space problems, an air storage facility other than ASME code tanks may sometimes appear desirable. In such a case, advance discussions with review offices is recommended.

f. Control. Compressor start-stop control, automatic shutdown control, and cooling water control should be as described in paragraph 13-2*e* for the service air compressors.

g. System details.

(1) *Piping.* Depression system air piping will tend to be appreciably larger than conventional air lines. Besides the additional air storage provided, successful air depression depends on the rapid injection of air under the head cover. Coordination is necessary to assure adequate space, especially in the congested areas around the turbines. A material schedule and a typical draft tube water system are included in Figures B-13 and B-15, respectively.

(2) *Valves.* Control valves for initial depression and for maintaining depression should be quick acting with remote control. An air cylinder-operated, rubber-seated, butterfly valve will usually be satisfactory for control of the initial depression. Remote electrical control should actuate a four-way solenoid valve in the air cylinder-operating air line. For maintaining depression, air flow will be small enough to permit use of a solenoid valve in a small line bypassing the butterfly valve.

13-6. Miscellaneous Provisions

a. Compressor room. The compressor room should be located in a noncritical noise area on a solid foundation free from vibration. The room requires adequate ventilation for temperature control and compressor intake.

b. Compressor discharge lines. Compressor discharge lines to aftercoolers and receivers should not be smaller than compressor outlet and should generally not include shutoff valves.

c. Ample space. Compressors, intercoolers, aftercoolers, and receivers should be located with ample space for disassembly, maintenance, and safety of operating personnel.

d. Piping. Piping generally should be sized to hold pressure loss from compressor to point-of-use to 10 percent.

e. Loop headers. Loop headers offer pressure loss and reliability advantages and should be utilized, particularly in multiunit powerhouses with headers required in upstream and downstream galleries.

f. Automatic traps. Automatic traps should be provided at moisture separators, on receivers, and at low points in piping.

g. Compressor, intercooler, and aftercooler water discharge. Compressor, intercooler, and aftercooler water discharge should be through sight funnels.

h. Headers. Headers should be sized adequately for planned plant expansion.

Chapter 14 Plumbing Systems

14-1. General

Powerhouse plumbing systems include the following fixtures: water supply piping from in-house treatment plant, storage tank or main at building line, hot water supply, fixture drains and vents, in-house sewage treatment facility, and effluent and sludge pumps. The basic code for design is the National Association of Plumbing-Heating-Cooling Contractors (NAPHCC) 1265, "National Standard Plumbing Code." Refer to TM 5-810-5 which is intended basically for military construction but contains design data that can be useful in powerhouse design. Also, Guide Specification CE-15400 is basically intended for military construction but is a useful reference for powerhouse specifications. Its value as a powerhouse guide specification is limited because of the large quantity of nonapplicable material.

14-2. Fixtures

Fixtures of the system that may be included are listed in Table 14-1. Location, selection, and quantities of fixtures are normally architectural determinations. The mechanical design engineer should be involved in early coordination to assure practical pipe routings and space, facilities consistent with proposed water supplies and sewage treatment, and optimum groupings of fixtures. Tank-type water closets in lieu of flush valves are acceptable in small plants with minimum rest room requirements.

14-3. Water Supply

a. Cold. Cold water from the potable water system (see paragraph 10-5) is provided to all fixtures.

b. Hot. Hot water should be provided to all fixtures listed in paragraph 14-2 except water closets, urinals, drinking fountains, and deluge shower-eyewash. See paragraph 10-5h(3) for water heater provisions.

c. Piping. Hot and cold water mains, branches, and risers should normally be sized for 2.4-3.7-m/s (8-12-fps) velocity on flows obtained from fixture-unit flow demand curves in ASME A 31.1. Where flow is continuous in copper lines, the velocity should not exceed 2.1 m/s (7 fps). Continuous temperatures in the range of 60-77°C (140-170°F) for both copper and galvanized steel should be avoided. Individual fixture supply pipes should be

15 mm (1/2 in.) except for 25-mm (1 in.) supplies to flush valve fixtures and deluge shower-eyewash. Shutoff valves should be provided in supply lines to groups of fixtures to facilitate maintenance. Refer to Figure B-8 for typical potable water and sanitary system, Figure B-13 for material schedule, and Chapters 17 and 19.

14-4. Sanitary Piping

a. Drains. Drains from sinks, water closets, standard showers, and lavatories should be routed to the septic tank or other treatment facility. Drains from battery room sink and deluge shower-eyewash are normally routed to the station drainage system. Water coolers may be drained either through sanitary drains or drainage system piping. Sizing should be on fixture unit basis in accordance with ASME A 31.1. Minimum slope on drains 80 mm (3 in.) and smaller is 2 percent. Minimum slope on larger drains is 1 percent with 2 percent preferred. Minimum size of any drain line subject to flow of raw sewage from a water closet is 80 mm (3 in.). (See Figures B-8 and B-13.)

b. Vents. Vents should be provided as required by ASME A 31.1. Termination of vent stacks will normally be above roofs. However, other code termination locations may be acceptable subject to architectural approval. Minimum slopes noted in paragraph 14-4a are also applicable to vents.

14-5. Sewage Treatment

a. General. Sewage treatment should generally be combined into one facility for the entire project. The facility will frequently be located away from the powerhouse and coordination will be required. The powerhouse design will usually be limited to collecting and possibly pumping of the raw sewage. When a powerhouse location is most practical, the treatment plant will be included in the powerhouse design. The Corps of Engineers policy is to comply with federal and state sewage treatment requirements. The requirements vary considerably from project to project, in part due to site differences, but to a greater extent from revisions in the federal and state regulations. The design office should obtain the earliest possible approval for proposed facilities at each project to permit an orderly development of piping, pump, and treatment design.

b. Septic tanks.

(1) General. Septic tanks are the preferred treatment facility from design, cost, operation, and maintenance

Table 14-1
Powerhouse Plumbing Fixtures

Fixture	Size and Type of Power Plant			
	2 Unit Unmanned No Visitors	2 Unit Manned No visitor Facilities Moderate Visitor Load	6 Unit Manned Visitor Facilities Moderate Visitor Load	14 Unit Manned Visitor Facilities Heavy
Water Closet	1**	2	9	11
Lavatory	1	2	5	11
Urinal	1	1	6	8
Service Sink	1	1	3	2
Drinking Fountain	1			2
Water Cooler		2	3	7
Fountain Wash			1	1
Eyewash *	1	1	1	1
Safety Shower *	1	1	1	1
Kitchen Sink		1	1	1
Battery Room Sink	1	1	1	1
Shower		1	1	2
First Aid Sink		1	1	1

* Fountain eyewash and safety shower are currently required at all powerhouses with a battery room.

**Figures indicate fixtures installed at four types of existing plants but are for reference only. For new plants, figures should be modified as required to suit personnel and visitor requirements, available water supplies, waste disposal, and other project facilities.

standpoints and should be provided whenever an approved leaching field location is reasonably available. Septic tank effluent discharge directly to tailwater is not permitted.

(2) Location. A septic tank may be located either in the powerhouse or away from the powerhouse. In-house tanks are normally located in mass concrete at a low elevation providing gravity drainage from all fixtures. The location should permit access to the tank through man-holes and adjoining space for installation and servicing of effluent pumps, sludge pumps, and chlorinating equipment.

(3) Design. Septic tank design and chlorination equipment should conform to state code requirements for the state in which the leaching field will be located. Mechanical design responsibility will include coordination of piping, pump, chlorination, and valve locations with a suitable tank location.

c. Other treatment facilities. Facilities other than septic tanks will normally be a civil engineering responsibility and will involve one of several types of secondary on tertiary treatment processes. Mechanical design

responsibility will include piping, valves, pumps, ejectors, chlorination, and coordination.

d. Nongravity sewage. Where it is impractical to move raw sewage from the powerhouse collection point to the treatment facility by gravity flow, a duplex pneumatic sewage ejector or duplex nonclog centrifugal pumps capable of passing a 51-mm (2-in.) sphere should be provided. Duplex nonclog pump installations require the following: all sewage to be screened before entering the sump pump, the screen to be self-cleaning with each pump operation, pumps to be of the wet pit type, automatic interchange of the operating and off pumps on every start, and each pump capable of handling rated system inflow. These requisites can be accomplished by connecting the inflow line from the powerhouse sanitary system into the pump discharge lines with commercially available equipment and collecting the solids on the discharge line screen of the off pump while the liquids are backed through the off pump to the sump. The subsequent pump operation will clear the screen. Valving, screens, and interconnections should follow manufacturers' recommendations. The smallest capacity pneumatic sewage ejectors and nonclog pumps tend to be higher than the required capacity for most powerhouses, and the specifications should permit

the contractor the option of supplying either ejectors or nonclog pumps.

e. Sludge and effluent provisions.

(1) General. Effluent will be pumped via fixed piping to leaching fields or, in the case of approved secondary or tertiary treatment plants, may be pumped or discharged by gravity to tailwater through an underwater discharge. Sludge will normally be pumped via fixed piping to a deck hose valve accessible to trucks. Minimum line size should be 80 mm (3 in.).

(2) Pumps. Sludge and effluent pumps should have not less than a 40-mm (1.5-in.) inlet and outlet and should pass a 25.4-mm (1-in.) sphere. Where both effluent and sludge pumps are required for the same treatment plant or septic tank, it is preferable to provide identical pumps to allow each pump to serve as backup for the other.

Backup operation is temporary only and should be provided for by hose and hose valves, tied to the suction and discharge piping of each pump rather than fixed piping. Alternate backup provision is a spare pump and piping connections suitable for rapid exchange of pumps. Control of effluent pump should be automatic and provided by either float or bubbler control. Control of sludge pumps should be manual and should include an adjustable timer switch to limit pump operation to the normal sludge pumping time requirement.

(3) Line losses. Pumping head computations for sludge pumps should reflect the higher line losses due to entrained solids. Computing overall losses on basis of water and using a multiplying factor of 2.5-3 will be satisfactory for most powerhouse applications. If velocities exceeding 1.5 m/s (5 fps) are encountered, the factor may be reduced to 1.5.

Chapter 15 Fire Protection Systems

15-1. General

Powerhouses are generally low fire hazard structures with special installed fire protection usually limited to the following four specific hazards: oil storage and purification rooms, a paint and flammable storage room, main power generators, and transformers. The principal fire protection for all other areas and hazards is portable extinguishers and fire hoses. Manned fire hoses are not generally relied on as a first line fire protection because of the potential damage to equipment inherent in powerhouses except as noted in paragraph 15-10. The deck washing systems provided in all powerhouses offer limited fire protection in most areas (see paragraph 10-6*h* for further discussion of backup provisions). NFPA Standard 851 and ETL 1110-2-311 provide guidance for fire, protection for hydroelectric generating plants, and hydroelectric power plants, respectively. Fire protection systems using Halons are prohibited.

15-2. Oil Storage and Purification Rooms

a. General. Oil storage rooms contain large quantities of transformer oil and lubricating oil with the potential for fire. Because of the seriousness of such a fire, an automatic carbon dioxide (CO₂) extinguishing system is provided to limit damage within the rooms and to limit the spread of smoke and noxious fumes through the powerhouse. Normal practice is for the design office to perform preliminary design to determine the approximate number and location of CO₂ bottles and nozzles, location of controls and piping, and to prepare design memoranda and contract specifications. Final system-design responsibility is normally assigned to the contractor. Safety of personnel should have continuing design priority since the discharge of CO₂ can impair visibility, will result in loss of consciousness from oxygen shortage in total flooding spaces, and may impair breathing in low-elevation areas exposed to drifting gas. Planned use of the room should not include storage of volatile, low flash-point materials susceptible to explosion. Miscellaneous combustible materials, especially paper products, should not be stored in the oil storage room.

b. Room construction. Oil storage and purification facilities are preferred to be in a common space but may be in separate rooms when required for structural reasons. Rooms should be in mass concrete, but in all cases should be of 2-hr minimum fire-resistant construction with

automatic fire doors or dampers at all openings. Where separate rooms are used, independent CO₂ systems are usually provided. However, a combined system may be provided where room locations and relative volumes would result in a lesser cost and there is no connecting door between the rooms.

c. System design.

(1) General design considerations are as follows:

(a) The system should be a total flooding type with minimum design concentration of 34 percent and without extended discharge.

(b) The amount of CO₂ discharged from the nozzle that is effective in extinguishing a fire varies from 70-75 percent of the total quantity of CO₂ contained in the cylinder. Therefore, for design purposes, it is necessary to increase the nominal cylinder capacity by 40 percent (see NFPA Standard 12).

(c) A CO₂ release should be actuated by a room thermostat, manual operation of a switch outside the room at the exit, and manual operation of a cylinder release.

(d) A 20-sec delay should occur between actuation and release of CO₂ from cylinders with a continuous alarm sounding in the room.

(e) A CO₂ release should stop oil pumps and fans and close fire doors and dampers.

(f) Piping should be sized to preclude freezing of lines.

(g) Refer to Figure B-16 for a typical CO₂ fire protection system.

(2) Detail system design and materials should comply with applicable provisions of NFPA Standard 12 and Corps of Engineers Guide Specification CW-15360.

15-3. Paint and Flammable Liquid Storage Room

a. General. Projects lacking outside facilities for the storage of paint, lacquers, thinners, cleaners, and other volatile, low flash-point material should be provided with a room in the powerhouse for such storage. Operating experience at some projects indicates a tendency to utilize the oil storage rooms for storage of hazardous materials because of a lack of adequate space in the paint and flammable liquid storage room. Therefore, space in the paint

and flammable liquid room should be generous, on the order of 9.3-11.2 m² (100-120 ft²) of floor area.

b. Room and system design. The provisions of paragraph 15-2a, b, and c apply generally except for references to oil and tanks. Refer to Figure B-16 for a typical CO₂ fire protection system.

15-4. Generators

a. General. Generators with closed air-circulation systems should be provided with automatic CO₂ extinguishing systems. Up to four generators may be on one system, with CO₂ cylinder storage based on discharge in a single unit. Design responsibilities and safety concerns noted in paragraph 15-2 are applicable. Piping within generator housings is normally provided by the generator contractor.

b. System design.

(1) General design considerations are as follows:

(a) The contractor shall coordinate his design with the generator contractor to assure that a CO₂ concentration of 30 percent will be maintained within the generator housing for a minimum period of 20 min without the use of an extended discharge. See NFPA Standard 12 and Guide Specification CW-15360.

(b) CO₂ release should be actuated by the following:

- Generator differential auxiliary relay.
- Thermostats in the hot air ducts of each air cooler.
- Manual operation at the cylinders.
- Remote manual electrical control.

(c) Refer to Figure B-16 for a typical CO₂ fire protection system.

(2) Detail system design and material should comply with applicable provisions of NFPA Standard 12 and Guide Specification CW-15360.

15-5. Motors

Larger motors with a closed air-circulation system are occasionally used in powerhouses. CO₂ fire protection should be provided similar to that indicated for generators.

15-6. Transformers

a. General. Fire protection at a transformer is provided to limit damage to other nearby transformers, equipment, and structure. It is assumed that a transformer fire will result in loss of the transformer. Deluge systems are provided for outdoor oil-filled transformers and CO₂ systems for indoor oil-filled transformers.

b. Outdoor transformers.

(1) General. Main power transformers are commonly located outdoors, on intake or tailrace decks, in the switchyard, or on an area adjoining the powerhouse upstream wall. They are sometimes individually semi-isolated by walls on three sides. The frequency of transformer fires is extremely low, but the large quantities of oil involved and absence of other effective fire control measures normally justify installation of a deluge system where there is a hazard to structures.

(2) System design.

(a) The system should be a dry pipe, deluge type. Deluge valves should be actuated automatically by a thermostat, manually by a switch in a break-glass station located in a safe location near the transformer, or manually at the valve. Where exposed transformers (without isolating walls) are located closer together than the greater of 2-1/2 times transformer height or 9 m (30 ft), the system should be designed for spraying the adjoining transformers simultaneously with the transformer initiating deluge.

(b) System detail design should be in accordance with NFPA Standards 851 and 15.

(c) The deluge system water supply is discussed in paragraph 10-4.

(3) Figure B-17 presents a typical transformer deluge system.

c. Indoor transformers. Oil-filled indoor transformers should be protected in accordance with NFPA 70 "The National Electric Code."

d. Outdoor oil-insulated. Oil-insulated power transformers located outdoors should be provided with chilling sumps which consist of a catchment basin under the transformer filled with coarse crushed stone of sufficient capacity to avoid spreading an oil fire in case of a tank rupture.

15-7. Portable Fire Extinguishers

Portable CO₂ handheld extinguishers are the first line fire protection for powerhouse hazards other than those specifically covered and should be provided in locations in accordance with NFPA Standard 10.

15-8. Detections

a. *Thermal detectors.* Thermal detectors are best suited for locations within equipment such as generators or near flammable fluids.

b. *Ionization detectors.* Ionization detectors are best suited for gases given off by overheating, such as electrical cables or a smoldering fire. Location near arc-producing equipment should be avoided. They are not suited for activating CO₂ systems.

c. *Photoelectric detectors.* Photoelectric detectors are best suited for the particles given off by an open fire as caused by a short circuit in electrical cables. Their use in staggered locations with ionization detectors along a cable tray installation would provide earliest detection. They are not suited for activating CO₂ systems.

d. *Location.* Detectors should be located at or near the probable fire source such as near cable trays or in the path of heating and ventilating air movement. In areas where combustible materials are not normally present, such as lower inspection galleries, no coverage may be appropriate.

e. *Reliable detection.* The earliest “reliable” detection is required. The detector type or types, location, and adjustment should be carefully considered. The detector sensitivity adjustment should be adjusted to eliminate all false alarms. A fire detector system should be provided in the cable gallery and spreading rooms of all powerhouses.

f. *Alarm system.* The power plant annunciation and, if applicable, the remote alarm system should be used to monitor the fire detection alarms. An alarm system should be provided for each area. Properly applied, these systems will provide more reliable and useful alarm data than the alarm monitor specified in the fire codes.

15-9. Isolation and Smoke Control

Smoke and fire isolation is probably the most important fire control item. Smoke inhalation is one of the major causes for loss of life. The toxic fumes from a minor fire

could require total evacuation of the powerhouse. Many of the existing heating, ventilating, and air conditioning systems contribute to spreading the smoke as they encompass the entire powerhouse or have a vertical zone composed of several floors. The fire area should be isolated by shutting down the ventilating system or exhausting the air to the outside where feasible to prevent the spread of smoke and to provide visibility for fire fighting reentry to the area. In most cases, the available oxygen is sufficient to support combustion, and little can be gained by not exhausting the smoke. Smoke and fire isolation should be provided in areas where isolation can provide a real benefit. The requirements for fire stops should be considered on a case-by-case basis. Where cable trays pass through a floor or wall which could be considered a fire wall, or where cables leave a tray and enter a switchgear or switchboard through a slot, a fire-stop should be considered. A 12.7-mm (1/2-in.) asbestos-free fireproof insulation fireboard can provide the basic seal with the voids being closed by packing with a high-temperature ceramic fiber. Single conduit or single cables which penetrate a fire wall can be sealed with a special fitting. Thick seals should be avoided as they could contribute to an excessive cable insulation operating temperature. For fire-stopping, refer to TM 5-812-2. A HVAC system using outside makeup air solely dedicated for the control room should be provided to maintain isolation and smoke control. The HVAC system should be capable of pressurizing the control room with outside air during a fire alarm to prevent smoke infiltration. Stairways in manned powerhouses that are used for emergency access and egress should be pressurized with outside air in accordance with ASHRAE recommendations.

15-10. Fire Hose

Certain conductor insulation or cable jackets have been associated with fires that resisted extinguishing with conventional fire control methods. These fires are easily extinguished using water. Water should be considered as a safe and effective electrical fire-fighting method. NFPA Standard 803 lists the required consideration for use of water on energized electrical equipment. The safe approach distance to live electrical apparatus with handheld fire hoses connected to the power plant raw-water system has been established by tests. The following discussion is based on using water at 689 kPa (100 psi), water resistance of 1,524 ohm cm (600 ohm in.), and a current of 3 mA or less in the fire hose stream. The safe approach distance varies with the water resistance, pressure, and type of water stream (i.e., solid stream or spray stream). The solid stream water pattern and conductivity is maintained for a greater distance as the size of the solid

stream nozzle and the water pressure is increased. Solid stream nozzles less than 32 mm (1.25 in.) in size can be used on live low-voltage (less than 600 V) circuits at all distances greater than 1.5 m (5 ft). Table 15-1 should be used to establish the safe approach distance to electrical equipment. Floor drains, trenches, or curbs should be

provided to remove or contain the water and prevent damage to other equipment and areas. Powerhouse designs should provide fire hoses with spray nozzles in all cable galleries and spreading rooms. The use of fixed mounted spray nozzles should be avoided.

Table 15-1
Safe Distance

Kilovolts		Safe Distance			
Line to Line	Line to Ground	Solid Stream		Spray Stream	
		(m)	(ft)	(m)	(ft)
4.16	2.4	4.6	15	1.3	4
8.32	4.8	6.1	20	1.3	4
13.80	8.0	6.1	20	1.3	4
44.00	25.4	9.2	30	1.9	6
115.00	66.4	9.2	30	2.5	8
230.00	130.0	9.2	30	4.3	14

Chapter 16 Piezometers, Flow Meters, and Level Gauges

16-1. General

Piezometers, flow meters, and water level gauges are utilized in a variety of powerhouse applications to determine flows, water levels, and differential heads. The readings obtained are necessary in the evaluation of turbine performance, operational monitoring, trashrack clogging, fish facility conditions, and for control purposes. All piezometer taps, installed piping, and floatwells are a mechanical design responsibility. However, control designers and structural designers are usually involved with the design process.

16-2. Turbine Piezometers

a. General. Turbine piezometer taps are provided for Pressure-time and Winter-Kennedy tests and to operate flow meters. Applicable embedded provisions are considered justified on all units.

b. Pressure-time provisions.

(1) Applicability. Piezometer taps and embedded piping should be provided for all turbines where the penstock is of sufficient length to meet the minimum requirements. (The majority of Kaplan units do not have suitable intakes for Gibson tests.)

(2) Location of taps. The test section should be located in conduit meeting the following conditions:

- (a) Length should be a minimum of 9 m (30 ft).
- (b) Length should be greater than two times the diameter.
- (c) Length times mean velocity should be less than 200.
- (d) Diameter should be uniform.
- (e) Bends in the test section should be avoided.

Four taps are provided at each end of the test section. Final location of the test section and taps should be determined by the organization which will make the official Gibson tests.

(3) Tap design. Figure B-18 shows details of the recommended Gibson test piezometer tap.

(4) Piping. An individual line should be run from each tap to a convenient access location in the powerhouse and terminated with a globe valve. All lines should terminate at the same location to permit manifolding. Depending on powerhouse configuration and access, the manifolding location may also be the location for connecting the test equipment. Where this is not convenient, two lines should be run from the manifolding location to the test equipment hookups. Piping will normally be 20-mm (3/4-in.) hard-drawn copper tubing. However, piping must be checked for suitability at maximum conduit head including water hammer. Each line should slope continuously toward the manifolding connections at not less than 2 percent to minimize air pockets and permit purging. Piping adjacent to taps on embedded conduit and spiral case should be arranged and wrapped as shown in Figure B-18 to prevent high stresses from developing following release of conduit pressure after embedment. Also refer to Figure B-18 for typical piezometer piping installation. Consideration should be given to providing bleed valves at high points in the piping system.

(5) Coordination. Coordination of tap and piping installation may be required where tap locations are in a portion of the conduit that is not part of powerhouse design.

c. Winter-Kennedy.

(1) Applicability. Piezometer taps and embedded piping for Winter-Kennedy tests should be provided on all Kaplan and Francis units.

(2) Location of taps. Taps are located on a radial plane near the middle of the first quadrant of the spiral case. One tap is located on the outside wall at the spiral case horizontal center line while one to three taps are located on the inside wall above the stay ring. One outer and one inner tap is required for the tests. However, two additional inner taps are normally provided to aid in achieving the appropriate pressure differential. In steel spiral cases, the taps are normally installed by the turbine contractor. In concrete semispiral cases, the taps are furnished and installed under the construction contract.

(3) Tap design. Tap design should be as shown in Figure B-18.

(4) Piping. Piping provisions noted in paragraph 16-2b(4) are applicable except that wrapping of piping is not required with concrete spiral cases. Lines should terminate at location selected for connection of test equipment. See Figure B-18 for typical installation.

d. Net head piezometers.

(1) Applicability. Piezometers upstream of the spiral case are required on all units for use in conjunction with tailwater sensors to determine net head on the unit. Tailwater sensors are covered in paragraph 16-3b.

(2) Location of taps.

(a) Francis units. For Francis units, taps are located by the turbine contractor in the spiral case entrance or spiral case extension. Four or more taps are provided in the conduit wall, equally spaced on a plane normal to the flow. Detail of the location and number of taps is determined by the turbine manufacturer.

(b) Kaplan units. For Kaplan units, two taps are located opposite each other in the sidewalls of the turbine intake, about half way between the floor and roof and 1.5-3 m (5-10 ft) upstream of the upstream intersection of the cone with the intake floor and roof.

(3) Piping. Piping should be as noted in paragraph 16-2c(4) for Winter-Kennedy taps.

e. Flow meters using Winter-Kennedy taps. Flow meters are used in most powerhouses for measuring and recording turbine discharge. When an in-plant central processor is available, either unit output and net head or output from a differential pressure transducer can be used to calculate flow. Differential pressure can be obtained from the Winter-Kennedy taps for input to the flow meter or central processor.

f. Ultrasonic flow meters. Recent advances have made ultrasonic flow meters a realistic means of measuring flow in Francis and Kaplan units. ASME PTC 18 should be used as a guide for selection and installation of ultrasonic flow meters in Francis units. Manufacturer recommendations should be considered for Kaplan units.

16-3. Miscellaneous Piezometers

a. Trashracks.

(1) General. Where the powerhouse forms a portion of the dam, minimum provisions for monitoring or alarm

of high differential heads across the intake trashracks should be considered. Trashrack design may not be based on full clogging of the racks with attendant differential heads so abnormal trash accumulations could cause rack failure. Loss of efficiency due to partial clogging may also be significant. The requirement for a separate trashrack monitoring system is a joint electrical-structural-mechanical determination.

(2) Minimum provision. When the decision has been made to provide an independent trashrack monitoring system, minimum provisions should include a piezometer tap upstream of the racks to sense pool level, a tap downstream of each trashrack, and embedded piping from the taps to a gallery location convenient for connecting to differential pressure switches or manometers. The pool tap should be located in a pier nose, and the tap downstream of the rack should be in a pier wall between the rack and intake gates. Pool tap elevation should be below minimum operating pool, and downstream tap elevation should be at an elevation to record maximum allowable differential across the racks. The control system may be such that the pool level indication could come from the pool level floatwell. When this is practicable, the trashrack upstream pool tap will not be required.

(3) Tap design. Tap design should be as shown in Figure B-18 for concrete installation. If the complete system will not be installed for an indefinite period, a closure plate or plug should remain in place to protect the orifice and embedded piping from silting up. Plate or plug design should permit convenient removal by air pressure or divers.

(4) Piping. Piping should be 20-mm (3/4-in.) hard-drawn copper tubing and should slope continuously toward the gallery connection valve at not less than 2 percent.

b. Pool and tailwater sensors. Where suitable locations for float-type water level gauges are not practicable, bubbler-type pressure sensors have some application. However, with the bubbler-type control, it is difficult to obtain the required dampening without a well, and reliability is not as good as with the float type. Bubbler lines should be sloped as indicated for other piezometer lines and should be provided with a source of clean dry air.

16-4. Water Level Gauges

a. General. This paragraph covers water level gauges of the float type only. Water level gauges based on pressure sensing are covered in preceding paragraphs

of this chapter. Gauges of the staff type for visual reading of water levels should be installed in both tailwater and poolwater locations but are normally designed and provided under miscellaneous structural provisions. Float gauges with the floats confined in wells are the preferred type for remote water level indication and control purposes. The required sensitivity (dampening) is readily attainable, and good reliability has been experienced at existing projects.

b. Gauge locations. Gauges are required for tailwater levels and pool levels at all projects and for monitoring and control of fish facility water levels at certain projects. In some cases, more than one gauge may be required to provide accurate measurement. The general location of the gauge will usually be determined by the control function, pool or tailwater hydraulics, or structural considerations. Detail of the location should permit a short straight sensing line, provide safe physical access to top of well, and avoid a sensing line terminating in an eddy where trash concentration and silt deposits are likely. Normally a well location on a pier center line with the sensing line orifice at the outer pier face will be optimum for tailwater and pool gauging. Where the pool gauge will be located in a nonpowerhouse location, coordination of the design with others may be necessary. The top of the tailwater floatwell should be above maximum tailwater.

c. Floatwell design.

(1) Size. The minimum size of a floatwell will usually be determined by the required floatwell to orifice dampening ratio and minimum orifice size to minimize clogging. A 1,000:1 area ratio and 16-mm (5/8-in.) orifice diameter are considered appropriate for most applications. This results in a well of approximately 510-mm (20-in.) inner diameter. The adequacy of the well diameter and length should be verified for the float and counterweight of the intended control.

(2) Material. Floatwell material should be steel pipe and couplings with neoprene gaskets. The sensing line material should be 50-mm (2-in.) Schedule 40 brass pipe.

(3) Installation. Drawings should stress the requirement that the floatwell be smooth and plumb for its entire length. A drain for the instrument blockout at the top of the well should be provided.

(4) Freezing. Where freezing of a floatwell is anticipated, 0.6-0.9 m (2-3 ft) of oil in the top of the floatwell is usually the best solution. An alternative is to provide electric heaters.

Chapter 17 Piping

17-1. General

The provisions of this chapter are applicable to all equipment and systems covered in this manual, wherever piping is required.

17-2. Design Considerations

The design considerations noted in the following paragraphs are those more frequently encountered in the design of powerhouse systems but are not intended as a complete listing. Other factors pertinent to the cost, life, and utility of piping in each particular powerhouse should also receive proper consideration in the design and design analysis. Caution and judgment are essential in applying factors and criteria available to ensure a satisfactory and economical design. The extent and degree of precision in design analysis should be consistent with the assumptions and other information available. For example, quantities or flow rates are often necessarily based on rather rough assumptions, and where this is true, a brief and approximate analysis with conservative pipe sizing should be the rule. Complex and extensive systems with well-verified assumptions warrant more detailed and exact analysis to match pipe sizes as near as possible to requirements.

a. Pipe sizing. The following factors should be considered in determining suitable pipe sizes. Most of these are interactive in their effect on pipe size, and care in selecting the critical factor is essential.

(1) Velocity. Velocity in itself will occasionally become a limiting factor in piping design, but this is usually only when erosion or cavitation would cause premature failure, noise could be a problem, or, in the case of pipe used to transport fish or other materials, velocities are determined by other than piping considerations. Even when these limiting factors appear to apply, full consideration should be given to whether the limiting velocity is normal, infrequent, or temporary. An infrequent or temporary eroding velocity may well be justified in the interest of overall economy. For waterlines, velocities in the range of 2.4-3.7 m/s (8-12 fps) are usually considered reasonable, but there is often good justification for higher or lower velocities. Copper waterline velocities should not exceed 2.1 m/s (7 fps) continuously.

(2) Pressure loss. Pressure loss is often a limiting factor on pipe sizing when a fixed gravity head is

available or where the pipe is a minor part of a pumped system with the pump head determined by other major requirements.

(3) Pumping cost. Pumping cost can be a significant factor in sizing pipe and requires careful analysis for extensive systems with high use factors, both in regard to energy cost and connected electrical load.

(4) Corrosion allowance. Allowance for restriction and increased pressure loss due to corrosion or mineral deposits is necessary, depending largely on pipe material and water chemistry. For steel pipe under average water conditions, a reduction in cross-sectional area of 15 percent is a suitable corrosion allowance. Average pressure loss computations should be based on moderately corroded pipe.

(5) Code requirements. Minimum pipe sizes specified by NAPHCC 1265, "National Standard Plumbing Code" or applicable state code should be complied with.

(6) Previous projects. Previous installations of similar systems can be a valuable guide in selecting pipe sizes, particularly when complete design analysis along with good service records are available.

(7) Other factors.

(a) Equipment connection sizes. These sizes are generally significant only for short runs of connecting piping.

(b) Mechanical strength. When the pipe is small, consider where shock conditions could disturb pipe alignment. It can be more satisfactory to use a larger size pipe than to provide the additional supports for a very small pipe.

(c) Temperature. The use of copper and galvanized steel for hot water in the 60-77°C (140-170°F) range on a continuous basis should be avoided.

(8) Precautions.

(a) Equipment demand forecasts. Where sizing is based on advance equipment demand estimates, the analysis should so note, and office procedures should provide for rechecking analysis against contract figures.

(b) Coordination. Much of the information on which pipe sizing is based comes from equipment supplier representatives, other engineering disciplines, and operation

sources. Many costly design changes, change orders, and poor operating conditions have resulted from this exchange of information. It is the design engineers responsibility to ask the right questions, make sure the listener understands the purpose of the question, and verify, reverify, and coordinate answers from all available sources.

(c) Plant expansion. Allowance in pipe sizing for possible plant expansion is often warranted, particularly in embedded piping.

(d) Corrosion. See Chapter 19 for additional considerations on corrosion control.

b. Materials. A material schedule with recommended materials for all standard powerhouse applications is included in Figure B-13. Except as noted in the piping schedule, whenever possible nonmetallic pipe should be used when buried outside of the powerhouse.

(1) Applying material schedule. To apply the material schedule, pipe wall thickness, fitting ratings, and valve ratings should be verified for each application. Particular attention is due unusual pressure or shock possibilities which could occur from misoperation, high pool or tailwaters, or equipment changes. The existence of unusual corrosive characteristics of the fluid being handled should be investigated, and material adjustments justified accordingly.

(2) Deviations. In evaluating a proposed deviation the following factors should be considered:

- (a) Procurement cost.
- (b) Installation cost.
- (c) Life.
- (d) Normal availability.
- (e) Replacement cost.
- (f) Maintenance.
- (g) Appearance.
- (h) Reliability.

Design memoranda should include justification for deviations, and advance consultation with review offices is warranted, particularly in the case of new products.

(3) New products, testing, or experience record. Lack of a comprehensive experience record could justify a limited trial in a noncritical application if significant improvements are otherwise indicated.

c. Routing.

(1) Embedded versus exposed. Embedded piping has several inherent problems and should be avoided whenever practicable (see Figure B-19). Some problems with embedded piping are as follows: proper placement during construction is difficult to enforce; damage from aggregate may go undetected; filling with concrete occasionally occurs; it is difficult to obtain the necessary flexibility in crossing contraction joints; and corrosion, particularly near the point of emergence from concrete, is impossible to completely monitor or control. For these reasons, exposed piping is generally preferred. Usually drainage and vent lines are not practicable to run exposed.

(2) Routing considerations. The bulk of exposed piping is generally placed in galleries, vertical pipe chases, and covered pipe trenches. Obtaining adequate space in these areas is often difficult and requires early planning to avoid later compromises in good operation and maintenance. As soon as Preliminary Design Report has been approved, preliminary layouts showing tentative equipment locations and preferred routing of all interconnecting piping should be developed as a basis for requesting the necessary structural and architectural provisions. The most effective approach to this layout is to refer to drawings of other recent, similar powerhouses and when possible obtain comments from operating and maintenance personnel on the pipe locations in these powerhouses. Design offices without file copies of recent powerhouses should obtain drawings from other offices and consult with experienced piping layout personnel in other offices. The following factors enter in to optimum routing and should receive continued consideration during the design process:

- (a) Dismantling and assembly.
- (b) Valve maintenance and replacement.
- (c) Supports.
- (d) Draining.
- (e) Provisions of sleeves and blockouts through concrete walls, floors, and columns.
- (f) Length of lines.

(g) Insulation.

(h) Expansion.

(i) Sound.

(j) Line failure.

(k) Corrosion.

(l) Leakage.

(m) Condensation.

(n) Appearance.

(o) Coordination with electrical and structural requirements.

Blockouts are usually preferred over sleeves since they permit more flexibility in modifying the piping arrangement during design and construction and expedite installation.

d. Supports and anchors.

(1) General. Supports and anchors may be separate units or may be combined in single units. Loadings are normally quite readily determined, and commercial units with established load ratings should be used for most applications.

(2) Design practice.

(a) In horizontal lines, normally locate anchors approximately midway between expansion joints or loops. In longitudinal galleries, this usually results in anchors located near the center of each bay and expansion joints or loops at the building contraction joints. However, it is often expedient and satisfactory to provide the required expansion joints or loops at other locations more convenient for assembly and disassembly.

(b) In vertical lines, locate anchors at upper ends when practical to minimize the required number of guides.

(c) A guide spool should be located close to and on each side of expansion joints and loops.

(d) Multiple-type supports should provide space for servicing individual lines.

(3) Precautions.

(a) Where several pipes are to be mounted on one series of supports, spacing and load ratings should be as determined for the critical line.

(b) Supports at branches should be considered for required expansion in both lines.

(c) Friction in sleeve-type expansion joints should be considered in anchor design.

(d) Consider all possibilities for longitudinal forces because of valve operation at changes in direction, including safety and relief valves.

(e) Include both pipe movement and structural displacement as contraction joints.

(f) All guide-type supports should provide free longitudinal movement of lines. On the U-bolt type, two nuts, one on each face of the supporting member to ensure a proper clearance, are required.

(g) Lock washers or double nuts should be used on all supports to avoid loosening from normal powerhouse vibration.

(h) Anchor design should provide for forces imposed during testing and any unusual temperature conditions during construction.

(i) Supports for copper lines should be copper plated, or the dissimilar metals isolated by a nonconducting medium such as electrical insulating tape.

e. Pipe joints.

(1) General. The preferred types of joints for each piping system are listed in the "pipe" column of the piping material schedule, Figure B-13.

(2) Location. Most joint locations will be determined by available pipe lengths, the requirements for fittings, valves and connected equipment, fabrication process, and installation requirements. In addition, the following should be provided:

(a) Union or flanged joints in all steel lines should be downstream from valves.

(b) Exposed sleeve-type joints are adjacent to the point at which embedded piping is continued with exposed piping.

(c) Sleeve-type joints should generally be provided where piping connects with pumps or other equipment, unless the piping involved is small and obviously flexible enough to eliminate concern for vibration effects and strain due to misalignment. Vibration and strain effects should be considered both on piping and the connection equipment.

(d) Two sleeve-type couplings should be provided where embedded piping passes through valve pits (one on each additional line that may enter the valve pit).

(e) Sleeve, U-Bends, or bellows-type flexible joints should be provided in exposed piping at, or near, contraction joints.

(f) Insulating (dielectric) connections should be provided between lines involving dissimilar metals and between ferrous pipe lines exposed in the powerhouse which continues buried in soil outside. Fittings should be located immediately inside of the powerhouse wall, and precautions should be taken to assure that the pipes are isolated from the copper ground mat.

(3) Expansion joints.

(a) Flexible element. A number of flexible element-type joints are available as catalog items. These joints have the capability for good service under severe conditions within their capabilities. Their principal advantages over sleeve-type couplings are freedom from leakage as long as they remain intact, lesser frictional forces, and the ability to accept greater misalignment, except torsional. Their disadvantages are the necessity for immediate replacement in case of failure and a lack of a recognized specification standard. Where predictably ideal design conditions can be obtained and maintained, their use can be justified.

(b) Sleeve-type joints. Sleeve-type joints are well suited for expansion and contraction, as well as torsional displacement, but are not suitable for radial misalignment and will accommodate angular misalignment to only a very limited degree before axial displacement forces become unpredictable. All sizes are commercially available and should be applied in accordance with their limitations. Two joints in close proximity on the same line can be used to provide for some radial displacement.

(c) U-Bends. U-Bends are an excellent type of joint for all movements in piping and are trouble free when properly designed and installed. Space considerations are often a problem in powerhouse application of U-Bends, and their cost is usually higher than other types of flexible joints. Their use has generally been confined to long, high-pressure, hydraulic oil headers in galleries. Commercially available U-Bends are available and should be specified in accordance with their catalog ratings.

f. Valving.

(1) General. Valves regularly used in powerhouse piping include gate, globe, plug, ball, butterfly, check, pressure reducing, and relief valves. Valves should be provided as required for control (open-closed-modulating); isolating; bypassing; prevention of backflow; protection against overpressure; and in many cases, where not an actual requirement, for convenience of operation and maintenance. They should be located, whenever practicable, for convenient access. If convenient access is not practicable, they should generally be provided with remote control unless their only use would be a very infrequent noncritical maintenance operation. For maintenance purposes, design consideration should be given to minimizing the number of types of valves in a particular powerhouse. Backseating valves or other types permitting repacking under pressure should generally be provided.

(2) Valve selection.

(a) Gate valves. Rising stem, single-wedge gate valves fulfill the bulk of the requirements for nonmodulating control valves. Nonrising stem gate valves with indicators can be used in special applications where space does not permit a rising stem. However, the operating disadvantage of having the screw threads in the contents of the pipe should be considered.

(b) Globe valves (including angle valves). For modulating requirements and some critical drop-tight shutoff requirements, globe valves should normally be used.

(c) Plug valves. Plug valves may be used for applications where operation would be infrequent, a relatively fixed modulation is required, or in some cases, where quick operation is a requirement. They have the disadvantages of a tendency to get frozen in a particular setting, developing small seepage leaks, and requiring lubrication in some applications, so careful consideration is necessary as to the actual overall benefits of their use.

(d) Ball valves. Full-ported, nonmetallic, seated ball valves are becoming increasingly available at competitive prices and offer tight shutoff, quick operation, and relatively easy maintenance. Their use can be justified for many applications and locations, especially in smaller sizes, 80 mm (3 in.) and less.

(e) Butterfly valves. Butterfly valves of the rubber-seated type offer significant cost advantages for some low-pressure larger size applications. In some cases, their relatively low operating forces permit elimination of powered operators. Butterfly valves may be used to modulate flow under certain circumstances but only through disc opening angles of 45 to 90 deg. Their relatively inexpensive production plant requirements have made them a popular production item with many manufacturers of limited experience. Particular care in obtaining a reputable product in accordance with the material schedule is necessary.

(f) Check valves. Conventional ball check, lift check, and swing check valves are all used regularly in powerhouse piping. Applications involving frequent flow reversals should generally be of the nonslam type. Some applications requiring low-pressure loss and minimum shock can justify selection of one of several patented "silent" check valves.

(g) Pressure-reducing and relief valves. When pressure-reducing valves are required to maintain a lower pressure system supplied by a higher pressure source, the lower pressure side should be further protected by one or more relief valves. A slightly undersized relief valve is preferable to an oversized valve to minimize erosion due to near shutoff operation. A manual bypass around the pressure-reducing valve is permissible; however, the maximum flow capacity of the bypass should be less than the relief capacity of the low-pressure system. A pressure gauge should be provided on the low-pressure system. The designer should be aware that pressure-reducing valves, as well as relief valves, are subject to wear and malfunctions, and great care is essential in their application, particularly in systems with maximum to zero flow requirements. Where the pressure differential is sufficient to jeopardize plant operation or safety, a positive stand-pipe overflow relief system or an alternate low-pressure source would be preferable.

g. Miscellaneous.

(1) Cleaning. In Appendix B specification, "Piping-Cleaning and Flushing," the cleaning and flushing procedure of piping is covered (see paragraph B-2). Similar

provisions should be included in all powerhouse contract specifications. The piping designer should be aware of the cleaning provisions and layout of the piping, particularly the embedded portion, to permit the best access possible. Wherever practicable, provide straight runs without bends or offsets between access points.

(2) Testing. As a general rule, all pressure piping should be tested to 1.5 times the maximum working pressure (embedded piping prior to embedment) with a minimum of 689 kPa (100 psi). Drainage waste and vent piping should be tested to a minimum 3-m (10-ft) head. The designer should consider the testing during design and include any required special provisions to protect specialized components of systems against the test pressure. Code test provisions are included in NAPHCC 1265 and ASME A 31.1. A typical test paragraph, "Pressure Tests," is included in Appendix B specification, "Powerhouse Piping," (see paragraph B-3).

(3) Insulation. Insulation should be provided to prevent condensation on water and drain pipe passing over electrical equipment or over suspended ceilings and on exposed interior roof drains. The requirement for insulation on water or drain piping to prevent freezing should also be investigated. Wherever practicable, freeze protection should be accomplished by protected routing of the lines or by planned draining of the lines in cold weather. Where this is not practicable, insulation (plus heating if necessary) should be provided. To evaluate the need for heating, all potential extended time no-flow conditions should be considered. Figure B-20 (sheets 1-6) shows a typical pipe insulation specification provision. Also refer to Guide Specification CE-15250.

(4) Painting. Painting of piping is covered in EM 1110-2-3400 and Guide Specification CW-09940. However, the cost of painting and maintenance is affected by pipe material routing and mounting and should be considered during design. Nonferrous piping is normally left unpainted. The cost of painting and maintenance should also be considered in the selection of galvanized or black piping since painting of galvanized piping in non-painted areas is normally not required. In areas where condensation is likely to be continuous on cold water lines, galvanized piping and supports may need to be supplemented with coatings or pipe insulation.

(5) Identification. A pipe and valve identification system is required for each project. Specification provisions for a typical powerhouse are included in Appendix B, paragraph B-4, "Piping System Identification."

(6) Hydraulic piping. Piping for high-pressure hydraulic-operating systems is a specialty-type piping and is covered separately along with the hydraulic equipment as a complete system.

h. Design analysis. A design analysis should be prepared for each piping system. Included should be

criteria, system assumptions, flow requirements, velocities, heads, losses, pipe sizing and materials, pump requirements, routing considerations, expansion and contraction of piping and structure, expansion joint requirements, support and anchor loadings and selections, and other factors considered during system design.

Chapter 18 Heating, Ventilating, and Air Conditioning System

18-1. General

Powerhouse heating, ventilating, and air conditioning are required to maintain temperature and air quality conditions suitable for operating equipment, plant personnel, and visitors. Maintaining required conditions for operating equipment is essential under all weather conditions at the site. Personnel and visitor design conditions are also important, but temporary deviations under weather extremes can be tolerated and should be reflected in the design. Energy conservation is a prime consideration. Figures B-21 and B-22 present typical heating, cooling, and ventilation systems. Drawings and specifications on a variety of systems in existing plants are available through inquiry to review offices. Adaptations of existing designs to new plants should consider the increased emphasis on energy conservation. The use of Class I ozone depleting chemicals (ODC) including all chlorofluorocarbon compounds (CFC), Halons, and their mixtures are prohibited.

18-2. Design Conditions

a. General. Assumed design conditions, both outside and inside the powerhouse, have major effects on system adequacy, construction costs, and operating costs since they influence the type of equipment provided. Sufficient engineering time for research and coordination of available data is essential to a practical design.

b. External conditions.

(1) Weather.

(a) Data sources. Sources of weather data include the following: American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) "Handbook-Fundamentals," TM 5-785, U.S. National Weather Service, power plants in the area, and miscellaneous private and public records. The ASHRAE Handbook is a reliable source for the locations listed therein, but power plant locations will frequently be some distance away from a listed location, and design conditions can be appreciably different in 50 miles (80.6 km) or less. In such cases, the designer should research other available data for applicability and authenticity. When other reliable data are unavailable, the interpolation procedure outlined in the ASHRAE Handbook should be used.

(b) Data required. Weather data and design conditions as listed in the ASHRAE Handbook are preferred and should be included in the mechanical design memorandum. Duration of hot and cold extreme temperatures is not usually included but is valuable when available to permit the design to reflect the "flywheel" effect of the normal massive construction of powerhouses. Outdoor design temperatures for comfort heating and comfort cooling should be based upon the 97.5 and the 2.5 percent dry bulb and corresponding mean coincident wet bulb temperatures, respectively. Outdoor design temperature for heating to prevent freezing conditions should be based upon the 99 percent dry bulb temperature.

(c) Evaluation. Data other than ASHRAE should be evaluated on the basis of location of readings, periods of record, probable dependability, and cross-checking to arrive at appropriate outside design conditions. The data should be combined and presented as nearly as practicable in the form noted in ASHRAE. Mechanical design memoranda should include the evaluation factors along with basic data and the assumed design conditions.

(2) Water temperatures. Streamflow temperatures will usually be available from the general design memorandum or other previous memoranda. Groundwater use is seldom economical for heating and cooling purposes, but temperature conditions are usually available through the U.S. Geological Survey offices. Probable pool water temperatures should be available in the Environmental Impact Statement, General Design Memorandum, or generator cooling water studies. Summer and winter water temperatures should be included in the design conditions data along with the data source.

(3) Ground and rock temperatures. General information on ground and rock temperatures is available in the ASHRAE Handbook. Because of the limited effect on system design, extensive research is usually not warranted. The design memorandum should include the ground and rock design temperature and the source or basis of assumption.

c. Indoor conditions.

(1) General. Indoor design conditions are on the following bases: project personnel requirements, taking into account the type of activity, visitor requirements, and equipment requirements. Personnel and visitor requirements are somewhat flexible allowing deviations during extreme outside conditions. Equipment maximum and

minimum conditions are more critical as deviations could affect plant capability or subject equipment to damage.

(2) Temperature-humidity. Indoor design temperature will vary with many factors, such as occupancy of the powerhouse, type of equipment, and sponsor/owner requirements. The control room office and visitor type of rooms should be heated and cooled to 20°C (68°F) and 24°C (75°F), respectively. Rooms with equipment which is sensitive to freezing conditions should be heated to a minimum of 4.5°C (40°F). Maximum humidity conditions should generally be limited to 50 percent in the office, control room, and visitor area. Minimum humidity control will seldom be justified.

(3) Ventilation. Ventilation rates should be in accordance with ASHRAE 62. Equipment/gallery rooms, battery rooms, and turbine pits generally should have minimum air exchange rates of 1, 2, and 4 air change per hour, respectively.

18-3. Design

a. General. The system design should be based on criteria, factors, and details recommended or indicated in the ASHRAE Handbook except as modified herein. The design should be conservative while providing acceptable operation with normal decreases in operating efficiency and average maintenance. Unnecessary complications to achieve ideal conditions under all operating extremes should be avoided. Heat gains from lights and equipment should be included in both heating and cooling load requirements with due reward for both initial and long-range plant operations.

b. Insulation. Powerhouse insulation is not normally a direct mechanical design responsibility. However, because of its influence on the required heating and cooling provisions and energy requirements, the mechanical designers should be involved in the initial powerhouse planning affecting insulation provisions. The most practical applications for insulated construction are usually the powerhouse walls above the bridge crane rails and roof. The “U” factors in the 0.05-0.09 range are practical for these surfaces. The use of windows should be minimized, and double-pane windows used where justified.

c. Heating.

(1) General. With the required emphasis on energy conservation, studies on the heat source and type of conversion equipment merit major design attention. Several options are open in most cases, and the factors pertinent

to the selection should be included in the design studies and the design memorandum. System layout, equipment, and details in accordance with ASHRAE Handbook and reflecting previous powerhouse experience are normally satisfactory.

(2) Heat sources.

(a) Generator cooling water. The waste heat available in generator cooling water should be the prime source in all powerhouses where planned unit operation provides a reliable supply, or where practical modifications in unit scheduling could assure a reliable supply. Any plant with three or more units on baseload operation should have the capability for a continuous supply. Plants with planned intermittent or basic peaking operations may also provide a practical source if agreement on the necessary modifications in unit scheduling can be obtained. One or two unit plants located in areas subject to extended periods of subfreezing temperatures should not be dependent on generator cooling water as the basic heat source because of the limited backup capability. Preferred source water temperature in the 16°-24°C (60°-75°F) range can be obtained with reasonable modulation; however, the generator specifications should include a stipulation to this effect.

(b) Solar heat. Solar heat should be investigated for the powerhouse and visitor facilities. Solar heating studies should be based on the Department of Defense (DOD) criteria which are current at the time the powerhouse is being designed.

(c) Outside air. Outside air, using air-to-air or air-to-water heat pumps, has limited potential as the basic heat source because of reduced efficiency during subfreezing conditions. A study may be warranted for plants without a dependable water heat source, located in moderate climates.

(d) Pool water. Pool water may be a practical heat source where winter water temperatures above 7°C (45°F) can be assured. Caution in accepting pool water temperature estimates near 7°C (45°F) is advisable as the margin for safe operation is limited, and there are many variables affecting pool water temperatures. The existence of a similar project nearby on the same stream could provide a reliable indication of expected pool water temperatures.

(e) Miscellaneous water sources. Groundwater from wells or foundation relief flows can provide water of desirable temperature, but assurance of continued supply

is questionable and these sources are not normally recommended.

(f) Electricity. Electricity utilized in resistance heating is an available and reliable source at most power plants. In many plants, it may be the most economical. Its disadvantage is the relatively low efficiency in the overall energy supply. Its use in resistance heating as the basic heat source should be limited to plants which meet the following scenarios:

- Where a reliable more efficient heat source is not available.
- Where total annual costs of an alternate more efficient source would exceed the cost of resistance heating by more than 25 percent.
- Where the total yearly heating energy demand is under 100,000 kW hours per year. Electrical energy used in resisting heating may be employed as required for auxiliary heat in occupied areas and temporary heat for maintenance and repair purposes.

(g) Oil-gas. These sources may be practical in some areas. The use of oil or gas is preferred over electrical resistance heating where a reliable source is available.

(3) Conversion equipment. Equipment to be considered for heating is water-to-air coil-type heat exchangers, heat pumps, and resistance heating coils. Heat pump capacity should be sized, or backup resistance heating provided, to assure capacity for maintaining above freezing temperatures within the powerhouse under minimum outdoor temperature with one compressor inoperable.

(4) Source water piping. Source water taps and headers should assure required water to the coils or heat pumps at all times. Generator cooling water should be supplied through a header connecting to a minimum of three units but may be justified to all units depending on plant size, proposed plant operation, and weather conditions. Pool water should not be subject to interruption from main unit shutdown involving placement of stoplogs or closure of gates. Strainers in the source water supply should be duplex, with strainer perforations as large as practicable and consistent with heat exchanger requirements.

(5) Heat distribution. The bulk of the powerhouse heat requirements will be distributed through the ventilation system with water-to-air coils. Resistance elements

located in air-handling units or ducts should not be used unless resistant heat is the only practical method of heating the powerhouse. Heat distribution requirements may determine air quantities in the ventilation system.

d. Cooling.

(1) General. Cooling should be provided to meet the design conditions noted in paragraph 18-2. Wherever practicable, cooling should be provided by circulation of outside air through the ventilation system or by circulation of pool or tailwater through water-to-air coil-type heat exchangers in the ventilation system depending on which method is most economical. Where suitable outside air or water temperatures are not obtainable, cooling may be provided with chilled water coils in the ventilation system or package-type air conditioning units.

(2) Cooling load.

(a) Outdoor. Outdoor design temperatures should be based on ASHRAE summer design conditions as noted in paragraph 18-2. Allowance for sun exposure is particularly important for exposed gallery structures containing power cables or busses and heat sensitive equipment.

(b) Indoor. Indoor heat gains are essentially electrical and should be based on equipment manufacturers' data or connected load with conservative efficiencies. It is essential that adequacy of the cooling provisions not be a limiting factor in equipment or electrical conductor operation. It is also important that heat gain estimates for critical areas such as galleries with concentrations of electrical load be verified. Design memoranda should recognize such areas, show source or basis of heat gain estimates, and include appropriate factors for contingencies. In plants provided with indoor emergency diesel generators sets, the heat gains therefrom may be of significance and should not be overlooked.

(3) System and equipment.

(a) General. The bulk of the cooling requirements will normally be provided through the ventilation system either with outside air or water-to-air coils located in the air handling units or ducts. Auxiliary or isolated zone cooling using package-type air handling units or package-type air conditioners may sometimes be most practical. Cooling requirements will frequently determine maximum ventilation rates.

(b) Heat pumps. The joint use of heat pumps for heating and cooling requirements is the preferred method

of heating and cooling if direct cooling from outside air or water is not practical.

(c) Compressors. Where cooling by mechanical refrigeration is justified, the compressor capacity should be provided with two or more compressors rated to provide approximately two thirds of system requirements with any one compressor out of service.

(d) Humidity control. Dehumidification will normally be accomplished, as required, in the system cooling coils. This may be a factor in determining required cooling water temperature.

(e) Direct expansion coils. Direct expansion coils in the main air system should be avoided. Chilled water coils are preferred. Direct expansion coils may be used where self-contained package-type air conditioners are justified.

(f) Precooling coils. A combination of precooling coils using pool or tailwater and chilled water coils may be used to conserve energy where economically justified.

(g) Package-type air conditioners. Simplification of the main powerhouse system and overall increased flexibility may frequently favor the use of package-type air conditioners with coil, blower, and filter for areas requiring special temperature control. This should be considered in the early design stage to assure space for appropriate locations. Required ventilation and exhaust air and chilled or heated water are normally provided from the central system when package-type air conditioners are used. Locations should provide for convenient access for servicing. Completely self-contained units with direct expansion coils, electric heaters, fans, and filters may occasionally be justified for small areas remote from the central system.

e. Air filters.

(1) General. Filters should be provided in all ventilation systems to reduce powerhouse cleaning and maintenance costs, aid in maintaining coil efficiencies, and improve air quality for personnel.

(2) Type. Several types of filters are satisfactory, including the following: electronic precipitator in combination with automatic roll type, throw away type, replaceable dry media type, traveling screen oil bath type, and automatic replacing roll type. Electronic precipitators are the most efficient in removing both coarse and fine foreign material from the air but will range up to double

in annual costs over the other types. The other types have similar performance characteristics but differ in maintenance requirements. Normally, the choice of filter should be from the nonelectronic type with the selection made on the basis of lowest annual cost. Electronic types may sometimes be justified on the basis of unusually clean air requirements for certain equipment or to obtain better air quality for personnel in areas subject to unusually severe pollen conditions.

(3) Location. Filters are normally installed in air handling units, ahead of the coils, and in a position to filter both recirculating and outside air.

f. Ventilation.

(1) General. Ventilation is required as a minimum to assure reasonable air quality conditions throughout the powerhouse. Recirculation normally provides the principal ventilation air with the balance provided from outside air. The minimum outside air is based on the system requirements for rooms requiring outside exhaust, for direct use of compressors and gas or diesel engines, plus an allowance to assure a positive pressure within the powerhouse. Actual ventilation system air-handling capability will usually be determined by heating or cooling requirements. Provisions for heating, cooling, filtering, and humidity control are included in the system as required.

(2) Equipment. The principal supply and recirculating fans are normally installed in or adjoining air handling units containing heating and cooling coils and filters. Auxiliary heating or cooling coils, booster fans, and exhaust fans are located as required in the overall system. Automatic dampers are normally provided in generator room roof-exhaust ventilators to control the powerhouse positive pressure to approximately 2.54 mm (0.1 in.) of water.

(3) Miscellaneous considerations.

(a) Paint spray areas. Repair rooms or repair pits with paint spray equipment should be provided with supplemental ventilation for use during painting operations. The total ventilation provided should be at least 60 changes per hour. In addition, the installation should conform to the applicable provisions of NFPA 33 and 91.

(b) Emergency generator rooms. Rooms with gasoline or diesel engine-driven emergency generator sets should be provided with ventilation to remove heat given off by the generator, exciter, engine surfaces, exhaust

pipings, and heat exchanger, as well as with ventilation for engine combustion. Ventilation should be provided as stated in paragraph 18-2c(3) when the generator is not in use.

(c) Control room ceiling. Space above the control room ceiling should be provided with sufficient ventilation to remove the heat given off by the high-intensity control room lighting. Outlets and inlets should be arranged to provide uniform cooling and to avoid hot spots.

(d) Exhaust provisions. Toilet rooms, a battery room, oil storage rooms, paint storage rooms, control rooms, rooms with mechanical refrigeration, and similar spaces should be provided with exhaust to the outside during all seasons. Air from other spaces is usually recirculated when ventilation with outside air is not necessary for cooling. Automatic dampers and variable speed fans are generally used where two or more rates of ventilation are required. Provisions are sometimes made to discontinue or reduce the exhaust from public toilets and similar spaces during periods of peak heating loads in order to reduce the amount of makeup air required during the peak periods.

(e) Ducts. Ducts are usually constructed of galvanized sheet iron with suitable stiffeners. Vertical building chases and galleries are often used as ducts where economical. Galleries or corridors are often practicable for large volume air movements but should not be used where normal traffic in and out is heavy and door opening or closing would materially effect the operation of the ventilating system. Unbalanced pressure effect on door operation should also be considered, particularly where visitors may have access. Galleries with concentrations of heat-generating equipment may require metal ducts to permit concentrated delivery of cooling air or pickup of exhaust air. Use of louvered doors and corridors as a substitute for a return duct on an air conditioning system is unsatisfactory. Insulation for ducts should be provided where required to avoid condensation or where justified to

conserve energy. All insulation should be of a fire resistant type.

g. Controls.

(1) General. Controls should be of the automatic type wherever feasible to minimize required manual adjustment and to discourage random "personal preference"-type adjustments. In summer-winter air conditioning systems, however, the master changeover should generally be manual to avoid unnecessary heating-cooling cycling during mild weather.

(2) Design. The general control system for each powerhouse should be developed along with the overall system layout to assure a well-coordinated design. Emphasis should be on minimizing energy usage and obtaining good average conditions in the powerhouse with minimum complexity and maximum dependability. In most powerhouse areas there is considerable latitude in acceptable conditions, which should be reflected in the control method as well as the system layout. In the interest of energy conservation, control requiring simultaneous cooling and heating should be avoided. Final control system design should be a contractor responsibility. Specifications should permit the contractor's choice of pneumatic, electrical, or electronic control or a suitable combination.

18-4. Design Memorandum

The design memorandum should include the background information essential to selection of design conditions. The choice of methods of heating and cooling should be discussed and justified. Special conditions that warrant departure from the usual design criteria should be explained. Heat gains and losses should be tabulated by room or space and summarized by system. A flow diagram for each system should be furnished. Separate control diagrams for heating and cooling seasons are desirable on the air conditioning systems.

Chapter 19 Corrosion Mitigation Considerations

19-1. General

a. The intent of this chapter is to supplement specific recommendations on corrosion control made in the preceding chapters.

b. Corrosion is a problem because of the ease with which it takes place on low-cost construction metals. The requirements for corrosion are the presence of a conducting fluid on a metal (or metals in intimate contact) and a flow of DC current. The presence of corrosion stimulators, such as oxygen or chlorides, contribute to a more rapid attack.

19-2. Design Considerations

a. General. To control corrosion, it is necessary to eliminate one or more of the above-mentioned requirements for corrosion. The following considerations suggest ways to exclude the conducting fluids from metals, suppress or halt the flow of DC current, and control corrosion stimulators.

b. Goal = least cost programmed life. As prices of labor and materials change and information on the performance of materials becomes available, past practice should be reviewed to determine if the goal is being achieved. For example, bare steel with an appropriate corrosion allowance may provide programmed life at lower cost than a coated structure.

c. Environment. It is sometimes useful to consider the possibility of altering the environment in which the equipment will be placed. The cost of protecting equipment from its environment can be changed significantly. For example, consider whether the equipment can be placed indoors rather than outdoors. Once the environment is set, proceed to select appropriate materials to withstand the environment or means of excluding fluids from a metallic structure, such as coatings.

d. Design geometry. Outdoor equipment in particular should avoid designs which allow water to be trapped or include sharp edges, crevices, numerous bolts, etc., which make coating application difficult. Similarly, places inside the powerhouse may require extra attention such as in water and sewage treatment rooms.

e. Material selection. In general, the Corps of Engineers engineering manuals and guide specifications provide conservative advice. The environment for some power plants (weather, water quality, etc.) may be more severe or less severe to such a degree that deviation from established guides may be warranted and should be documented in design memoranda. Also, the consequences of placing dissimilar metals in contact where moisture can be present should be evaluated. An alternative may be the use of nonmetallic materials.

f. Protecting metals. Methods of protection for various environments are indicated below. Actual choices should consider the aggressiveness of the environment (e.g., water analysis, soil resistivity).

(1) Immersed. This method includes structures immersed in water and the interior of water piping systems. The choices include corrosion resistant metals, metallic and nonmetallic coatings, dielectric isolators between dissimilar metals, and cathodic protection. Closed systems may also employ chemical treatment.

(2) Underground/embedded. The choices for underground are the same as for immersed described previously. Embedded structural metals normally do not require protection, except for aluminum or at the point of emergence from concrete.

(3) Atmospheric. The choice is usually made between corrosion-resistant metals and alloys or the use of coatings to protect ferrous materials in exterior exposures. Similar choices are used for interior exposures, dehumidification, and insulation.

g. Galvanic couples. Where galvanic coupling of dissimilar metals is expected to cause corrosion problems, the choices for prevention include dielectric isolation, coating of both metals, or cathodic protection. Unintentional galvanic couples such as ferrous underground or immersed piping, which is metallogically connected to the copper station ground mat or coated steel piping adjacent to stainless steel tracks in an intake gate slot, will also create problems. In these latter cases, the relative area of noble metal is high due to the coating on the steel, and pitting can be rapid.

h. Future maintenance. Give consideration to how corrosion damage may be further retarded by renewing coatings, anodes, components, etc.

i. Safety and critical items. Items which involve life safety and require regular inspection (e.g., pressure vessels, hoist cables, etc.) should be planned to make such inspections or tests easily accessible for accomplishment.

j. Miscellaneous factors. Other factors which affect corrosion and require consideration in design are temperature, velocity, chemical concentration, contamination, and absence of film-forming properties in some waters.

Appendix A References

A-1. Required Publications

TM 5-785

Engineering Weather Data

TM 5-810-4

Mechanical Design; Compressed Air

TM 5-810-5

Plumbing

TM 5-812-2

Firestopping

TM 5-813-1

Water Supply Sources and General Considerations

TM 5-813-3

Water Supply; Water Treatment

TM 5-813-4

Water Supply; Water Storage

ER 1130-2-407

Operating and Testing Potable Water Systems in Compliance with the "Safe Drinking Water Act"

EM 385-1-1

Safety and Health Requirements

EM 1110-2-3006

Hydroelectric Power Plants Electrical Design

EM 1110-2-3400

Painting: New Construction and Maintenance

EM 1110-2-4203

Design Data for Powerhouse Cranes

ETL 1110-2-311

Fire Protection-Hydroelectric Power Plants

ETL 1110-2-317

Selecting Reaction-Type Hydraulic Turbines and Pump Turbines and Hydroelectric Generators and Generator-Motors

ETL 1110-2-333

Sampling Methods for Zebra Mussels

ETL 1110-8-12 (FR)

Testing and Purification of Lubricating Oil for Hydroelectric Power Plants

CE-1603

Draft Tube Gantry Cranes

CE-4000

Lump Sum Contract for Engineering Services for Design of Hydroelectric Power Plant

CE-15250

Thermal Insulation for Mechanical Systems

CE-15400

Plumbing, General Purposes

CE-16263

Diesel-Generator Set Stationary 100-2500 kW, with Auxiliaries

CE-16264

Diesel-Generator Set Stationary 10-99 kW, with Auxiliaries

CW-09940

Painting; Hydraulic Structures

CW-11290

Hydraulic Power Systems

CW-14210

Elevators, Electric AC and/or DC

CW-14330

Indoor Traveling Cranes (AC/DC)

CW-14340

Dam Gantry Cranes

CW-14601

Cranes, Bridge and Gantry, Top-Running, 30-Ton Maximum Capacity

CW-15360

Carbon Dioxide Fire Extinguishing Equipment

CW-15487

Turbine Lubricating Oil

CW-16210

Hydraulic Turbine-Driven Alternating Current Generators

CW-16321

Electrical Insulating Mineral Oil

CW-16252

Governors for Hydraulic Turbines and Pumping Turbines

A-2. Related Publications

Federal and Military Specifications

SS-C-160

Cement, Insulation, Thermal

L-P-535

Plastic Sheet (sheeting), Plastic Strip, Vinyl Chloride Polymer and Vinyl Chloride Vinyl Acetate Copolymer, Rigid

VV-F-800

Fuel Oil, Diesel

W-B-133A

Battery, Storage (Lead-acid Industrial for Cycle Service)

W-H-171

Hangers and Supports, Pipe

MIL-C-20079

Cloth, Glass, Tape, Textile, Glass, and Thread Glass

MIL-C-4556

Coating for Steel Fuel Tanks

American Petroleum Institute (API)

American Petroleum Institute (API). API-650 - 1993, Welded Steel Tanks for Oil Storage

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). ASHRAE - 1993, Handbook-Fundamentals

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). ASHRAE 62 - 1989, Ventilation for Acceptable Indoor Air Quality

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME). ASME A 17.1 - 1993, Safety Code for Elevators and Escalators

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME). ASME A 17.2 - 1988, Inspector's Manual for Elevators and Escalators

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME). ASME A 31.1 - 1992, Power Piping Code

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME). ASME PTC 18 - 1992, Hydraulic Turbines (Performance Test Codes)

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME). ASME Paper 66-WA/FE-9, Analysis and Solutions of a Draft Tube Water Depression Problem

American Society of Mechanical Engineers (ASME)

American Society of Mechanical Engineers (ASME). ASME 1992, Boiler and Pressure Vessel Code

American Society for Testing and Materials (ASTM)

American Society for Testing and Materials (ASTM). ASTM A 312 - 1993, Seamless and Welded Austenitic Stainless Steel Pipe

American Water Works Association (AWWA)

American Water Works Association (AWWA). AWWA C 601 - 1992, Disinfecting Water Mains

American Water Works Association (AWWA)

American Water Works Association (AWWA). AWWA Paper ASCE-CSSE, Water Treatment Plant Design

National Association of Plumbing-Heating-Cooling Contractors (NAPHCC)

National Association of Plumbing-Heating-Cooling Contractors (NAPHCC). NAPHCC 1265 - 1993, National Standard Plumbing Code

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 10 - 1990, Portable Fire Extinguishers

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 12 - 1993, Carbon Dioxide Extinguishing Systems

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 15 - 1990, Water Spray Fixed Systems for Fire Protection

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 33 - 1989, Spray Application Using Flammable Combustible Materials

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 37 - 1994, Stationary Combustion Engines and Gas Turbines

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 70 - 1993, National Electric Code

National Fire Protection Association (NFPA)

National Fire Protection Association (NFPA). NFPA 91 - 1992, Installation of Exhaust Systems for Air Conveying of Materials

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Appendix B Reference Drawings and Data

B-1. General

System drawings (Figures B-1 through B-22) and specification excerpts presented next in paragraphs B-2, B-3, and B-4 are essentially systems and equipment used in various existing powerhouses, but both have been modified in certain respects to make them more generally applicable. However, their use for new powerhouse design will seldom be practical due to the differing requirements characteristic of each new project. They are included to acquaint the designer with satisfactory designs typical of one or two sizes and types of powerhouse. Certain line sizes and elevations have been retained on the drawings as an aid in visualizing the particular system layout but should be regarded as relative only. Where a figure includes two, three, or more separate drawings, appreciable differences in powerhouse requirements and system provisions will be noted. These figures and specifications are referenced in the manual write-ups and as otherwise needed during design.

B-2. Piping-Cleaning and Flushing

a. General. Prior to installation, piping, fittings, and valves shall be cleaned as required to remove all foreign matter. During installation, openings in the piping shall be covered to prevent entry of foreign material. Concrete, curing water, or construction debris shall not be washed into drains. Piping shall be kept clean, and the contractor shall demonstrate that the pipes and drains are unobstructed when so directed by the Contracting Officer. Any stoppage or other damage to materials, equipment, or parts of the building due to the contractor's failure to properly clean the piping systems shall be repaired by the contractor without cost to the government. The contractor shall provide all materials and equipment required to clean and flush the piping systems including temporary piping, solvent, and circulating pump except as otherwise noted. After installation and prior to connection to equipment, each system shall be thoroughly flushed until clean. Unless otherwise noted, the flushing and cleaning fluid shall be the same as medium specified for the pressure test. Temporary cross connections shall be installed between supply and return lines at each branch extremity, and each branch shall be cleaned and flushed in a separate operation. The supply and return lines in the oil room shall be isolated from the tanks and pumps until testing and flushing operations have been completed. Oil used for flushing shall not be drained to the dirty oil tank but

shall be collected for disposal by the contractor. All such oil shall be drained from the low points in the lines.

b. Cleaning oil system. Special care shall be taken to ensure that materials used in the oil system are clean and that shavings, solder, or other foreign materials do not enter the system. The contractor shall obtain approval for his cleaning and flushing procedures by the Contracting Officer prior to starting cleaning operations. An organic solvent which will remove the flux residue and also will be soluble in the subsequent hot oil flush shall be passed through the piping until the flux residue is removed. Prior to this solvent cleaning operation, the contractor shall demonstrate by the use of test sections of soldered copper tubing and fittings that the solvent cleaning operation will effectively clean out the flux residue left in the soldering process. Lines shall be drained of solvent and shall be blown out prior to being pressure tested.

c. Flushing oil system. After the piping has been solvent cleaned and pressure tested, but before the oil lines are connected to the generators, turbines, governor equipment, and oil storage tanks and pumps, oil shall be circulated through the supply and return lines at a minimum velocity of 4.6 m/s (15 f/s) for 8 hr or until they are clean. An 80- by 80-mesh screen or comparable filter shall be installed at the end of the return oil line. Clean warmed oil shall be circulated through all circuits of the piping until the screen remains clean. The oil temperature shall be between 60-66°C (140-150°F). The oil used for the pressure testing shall be used for flushing. The oil shall be recirculated so that the quantity required will not be excessive. The contractor may use the oil purifier to heat the oil. The purifiers and government-furnished oils will be made available to the contractor at the locations needed. Oil circulating pumps used in conjunction with the oil purifier shall be matched to the volume flow rate of the purifier and shall be equipped with a bypass. A detailed drawing of the proposed circulating pumps-oil purifier joint operation shall be submitted for approval. If an extension power cord for the oil purifier is needed, it shall be provided by the contractor. The purifier shall be cleaned and serviced after use.

B-3. Powerhouse Piping

a. Pressure tests.

(1) General. The contractor shall furnish all equipment and materials required to make complete tests, except as otherwise specified. The tests shall be made with blank flanges or with suitable caps on ends of the

pipe sections to be tested. The pipings tests shall be conducted before the equipment has been connected to the piping. All sections of the piping specified herein shall be tested by the contractor and approved by the Contracting Officer before acceptance. Any defects or leaks disclosed by tests shall be satisfactorily repaired and retested by the contractor at no additional cost to the Government. The contractor shall notify the Contracting Officer in sufficient time before starting any test to permit a representative of the Contracting Officer to witness the test. Each welded joint shall be hammered while under test pressure. All piping shall be tested at the pressure shown in Table B-1 for a length of time sufficient in the opinion of the Contracting Officer to determine tightness but in no case less than one hour except as noted. Air lines tested with water shall be thoroughly dried after testing and before connecting to equipment.

(2) Test pressure and mediums. The test pressures and mediums are shown in Table B-1 for the following categories of piping:

b. Carbon dioxide piping. The carbon dioxide piping, including that portion in the generator housing, shall be pressure tested as follows. All piping including the flexible tubing shall be subjected to a gas pressure test of 6,894 kPa (1,000 psi). Only nontoxic and nonflammable gases shall be used to test. The gas pressure shall not fall below 6,205 kPa (900 psi) at the end of a test period of 5 min. All personnel shall be removed to positions of safety while the systems are under test pressures, with the pressure gauge used for testing being the only pressurized component directly exposed to personnel. Examinations for leaks shall be conducted only after the maximum pressure test pressures have been reduced below 2,068 kPa

Table B-1
Test Pressures and Mediums

	Test Pressure kPag (psig)	Test Medium
Unwatering and Filling Piping	689 (100)	Water
Service Air Piping	1,724 (250)	Water
Governor and Lubricating Oil Piping (distribution)	1,551 (225)	Lubricating Oil at 100°F
Generator Cooling Water Piping	689 (100)	Water
Piezometer Piping	1,034 (150)	Water
Low Pressure and Brake Air Piping	1,379 (200)	Air
Governor Air Piping	1 1/2 times Max. Governor Operating Pressure	Water
Potable and Raw Water Piping	1,034 (150)	Water
Gland Water Piping	1,034 (150)	Water
Carbon Dioxide Piping	See above (para B-3b)	
Roof Drainage Piping	1.5 m (5 ft) Head at Roof Surface	Water
Drain, Waste, and Vent Piping	3.0 m (10 ft) Head at Floor Surface	Water

(300 psi). Before making the specified pressure test, the contractor shall submit for approval a description of the method to be followed and the type of gas to be used to produce the required pressure for the leakage test.

B-4. Piping System Identification

a. General. All exposed piping and valves including those furnished by the government and by the contractor as specified in other sections shall be identified as herein specified. Identification includes the following:

(1) Piping system designations and flow direction arrows on the piping.

(2) Gauge nameplates.

(3) Painting valve control handles to indicated normal valve position.

b. Piping system designation. Pipes and tubing having an outside diameter including pipe covering of 20 mm (3/4 in.) or larger shall be identified, and the direction of flow indicated on the piping by means of colored prefabricated labels on pressure sensitive self-adhesive cloth tapes. The labels shall have black lettering and flow arrows on a yellow background. The labels shall adhere tightly and neatly on the pipe. Any labels that do not adhere completely shall be removed and reapplied. Letter and arrow size shall comply with the schedule below:

Outside Diameter of Pipe or Covering		Minimum Size of Letter		Minimum Length of Arrow Marker	
mm	(in.)	mm	(in.)	mm	(in.)
20-32	(0.75-1.25)	13	(0.5)	102	(4)
38-51	(1.5-2.0)	19	(0.75)	102	(4)
64-152	(2.5-6.0)	32	(1.25)	178	(7)
203-254	(8.0-10.0)	64	(2.5)	178	(7)
Over 254	(10.0)	89	(3.5)	178	(7)

Piping and tubing less than 20-mm (3/4-in.) outside-diameter shall be identified with engraved laminated sheet plastic or anodized aluminum flow arrows and nameplates with standard Gothic lettering not less than 6 mm (1/4 in.) in height similar to the nameplates used on control centers. Nameplates shall be firmly attached to the piping. The markings shall be applied after cleaning, painting, and insulation of the piping is completed. Identification and direction of flow arrows shall be provided on each side of walls, partitions, floors, or similar barrier which interferes with tracing a line, at all valve locations and near branch lines. Wherever two or more pipes run

parallel, the designations shall be applied in the same relative location so as to be in either vertical or horizontal linearity, whichever the case may be. The markings shall be located so as to be readily conspicuous at all times from any reasonable point of vantage but in no case at intervals greater than 14 m (45 ft).

c. Pipe marking schedule. The following marker legends are typical:

RAW WATER-DECK WASHING

RAW WATER-GEN COOLING

RAW WATER-THRUST BEARING

RAW WATER-TURBINE BEARING

RAW WATER-GEN GUIDE BEARING

RAW WATER-TURBINE PKG GLND

RAW WATER-AIR COMPR

CO₂

CO₂-GEN NO. 1

AIR 2590 KPA (375 PSI) GOV

AIR 830 KPA (120 PSI)

AIR 690 KPA (100 PSI) GEN BRAKES

ROOF DRAIN

SPIRAL CASE DRAIN

SPIRAL CASE FILL

TURBINE PIT LINER DRAIN

TURBINE VACUUM BREAKER VENT

LUBE OIL-DRAIN

LUBE OIL-SUPPLY

LUBE OIL-RETURN

LUBE OIL-BYPASS

LUBE OIL-THRUST BEARING

LUBE OIL-TURBINE BEARING

LUBE OIL-GEN GUIDE BRG

LUBE OIL-GEN JACK SUPPLY

LUBE OIL-GEN JACK RETURN

GOV OIL

GOV OIL-RETURN

GOV OIL-SUMP UNIT NO. 1

GOV OIL-SERVO OPEN

GOV OIL-SERVO CLOSE

GOV OIL-TURB BLADES RAISE

GOV OIL-TURB BLADES LOWER

d. Valve tagging. The contractor shall provide approved identifying tags complete with engraved plastic, aluminum, or brass plates with attaching chain for valves in the powerhouse. The government will prepare and furnish to the contractor a list showing the required numbers, letters, and descriptive information to be used for each valve and will mark the piping diagrams indicating their location. The list and marked diagrams will be furnished to the contractor not later than six months prior to the scheduled completion of all work under this contract. The valve list will include all operating and isolating valves installed under this contract and those which are furnished with the government-and contractor-furnished equipment but will exclude check valves, relief valves, gauge cocks, receiver drain valves, valves mounted on control panels, and air and water service connection valves. For estimating purposes, the following may be considered a typical example of the valve designations:

1 - CW - 1, #1 Generator thrust bearing cooling water supply.

Valve tags shall be securely fastened to handwheel-operated valves with approved brass-jointed ball chain approximately 200 mm (8 in.) long, size No. 6, 8 or 10. The chain shall be passed through grommets in the envelope, around the valve stem, and the ends shall be joined together with a reusable coupling. In cases where the valve handwheel is below the valve, the chain shall be passed through the handwheel rather than around the

stem. On other than handwheel-operated valves the tags shall be attached by securing the brass ball chain around the valve body with a figure-8 wrap or around a suitable part of the valve.

e. Painting valve handwheels. Valve handwheels or operating levers shall be painted in accordance with the following listed colors to indicate the normal position of the valve:

<u>Normal Operating Position of Valve</u>	<u>Color of Handwheel of Operating Lever</u>
Closed	Red
Open	Green
Either Open or Closed or Throttling	Yellow

B-5. Powerhouse Electric Water Heaters

The method of water heater selection is as follows:

a. Obtaining volume flow rate sum. From Table B-2 below obtain the sum of the volume flow rate served by the heater.

Table B-2
Hot Water Demand

Fixture	Demand	
	L/s	(gph)
Fountain, Wash 1.4m (54 in.)	0.105	(100)
Lavatory	0.008	(8)
Shower	0.105	(100)
Sink, Battery Room	0.021	(20)
Sink, First Aid	0.008	(8)
Sink, Kitchen	0.010	(10)
Sink, Service	0.021	(20)
Conversion Factor:		
Storage	0.30	
Recovery Rate	0.20	

b. Obtaining tank size. Multiply this sum by the storage factor to obtain tank size.

c. Standardized heating elements. Since recovery rate is unlikely to be a factor in powerhouses where demand briefly occurs at lunch time and at end-of-shift, heating elements should be standardized as indicated below.

d. *Check recovery rate.* In the case of public lavatories where visitor use may be heavy at times, the recovery rate should be checked. Multiply the sum of the volume flow rate (step 1) by the recovery rate demand factor. If this value exceeds the capacity of standard heaters, then select other heaters or call for simultaneous operation of standard dual elements. The heating capability of standard heaters for a 38°C (100°F) rise are:

2,500-W element - 0.6 L/s (10.2 gpm)
4,500-W element - 1.2 L/s (18.4 gpm)

B-6. Capacity of Cast Iron Drain Lines (Water)

The following data are provided to estimate the capacity of gravity drain pipes:

Pipe Inner Diameter	Slope 1%		Slope 2%	
	Velocity	Flow	Velocity	Flow
mm (in.)	m/s (fps)	L/s (gpm)	m/s (fps)	L/s (gpm)
102 (4)	0.6 (1.8)	4.5 (72)	0.8 (2.6)	6 (100)
152 (6)	0.8 (2.5)	14.2 (225)	1.1 (3.6)	20 (315)
203 (8)	1.0 (3.2)	31.5 (500)	1.4 (4.5)	45 (710)
254 (10)	1.2 (3.9)	60.9 (965)	1.7 (5.4)	83 (1310)
305 (12)	1.3 (4.4)	97.2 (1540)	1.9 (6.2)	138 (2190)
381 (15)	1.6 (5.2)	181.7 (2880)	2.3 (7.4)	255 (4050)
457 (18)	1.8 (6.0)	299.7 (4750)	2.6 (8.4)	416 (6600)
533 (21)	2.0 (6.7)	454.2 (7200)	2.9 (9.4)	637 (10100)
610 (24)	2.3 (7.4)	662.4(10500)	3.2(10.4)	927 (14700)
686 (27)	2.5 (8.1)	908.5(14400)	3.4(11.1)	1274 (20200)
762 (30)	2.7 (8.7)	1205.0(19100)	3.7(12.2)	1697 (26900)
914 (36)	3.0 (9.8)	1955.8(31000)	4.2(13.9)	2776 (44000)

Assumed Conditions:

1. Water level a top of pipe at inlet.
2. Free discharge at outlet.
3. Cast iron pipe--coated--good to fair condition. (Also, visitor load applies to concrete or vitrified clay pipe in average condition.)