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 (blowouts) 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 ft^3 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.