

IEEE Guide for Protection, Interlocking, and Control of Fossil-Fueled Unit- Connected Steam Stations

Sponsor
**Power Generation Committee
of the
IEEE Power Engineering Society**

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Foreword

(This Foreword is not a part of IEEE Std 502-1985, IEEE Guide for Protection, Interlocking, and Control of Fossil-Fueled Unit-Connected Steam Stations.)

The introduction to protection, interlocking, and control for a fossil-fueled plant is written to furnish information which will help fill a need that exists within the industry to promote the use of sound engineering practices to provide a coordinated design for the protection, interlocking, and control of unit-connected boiler-turbine generators power plants. It covers what is good practice at the time of publication, but it is not intended to be a handbook of design practices. It is impractical to cover in detail all of the varied aspects of protection, interlocking, and control since there are a great number of different types of plants and equipment.

It should be remembered that the information presented here is typical of that available to provide protection to personnel and safeguard equipment against catastrophic damage which may result from equipment failure, inadvertent errors, or misoperations. The system diagrams and logic diagrams are only representative and do not depict all of the system design features or protective features required for any specific application. The diagrams are intended to suggest the design areas to be covered by the specific unit design and cannot replace a competently prepared design which meets the unique requirements of the specific generating unit. The material presented shall not be used by inexperienced personnel as a substitute for engineering competence.

The IEEE Standards Manual describes a guide as follows: *documents in which alternative approaches to good practice are suggested, but no clear recommendations are made.*

The information in this guide was first developed by the working group and paper presented as a five-part series and published in *IEEE Transactions on Power Apparatus and Systems*, vol PAS-92, no 1, pp 314–401.

The furnace air and fuel comments are in accordance with the National Fire Protection Association recommendations on gas, oil, and coal boiler operation. This publication is intended to be in accordance with NFPA recommendations, NFPA 85 Series.

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IEEE Guide for Protection, Interlocking, and Control of Fossil-Fueled Unit-Connected Steam Stations

1. Scope and References

1.1 Scope

This guide presents information regarding the essential subsystems that make up a fossil-fueled unit-connected boiler-turbine-generator (BTG) station and describes typical interlocking, control, and protection for operating them in a coordinated order to ensure proper start-up and safe shutdown. The primary purpose of this guide is to provide a basis for

- 1) Qualitative evaluating of overall design of a unit-connected fossil fuel plant
- 2) Writing general operating guides of an educational nature, thereby serving to aid in acquainting personnel with boiler-turbine-generator systems.

Every new fossil plant will have its own special operating sequence due to the type of equipment installed and its operating company's practices. However, this guide purports to include in one document a description of various cycles in a power plant, their sequence of operation, and protection procedures.

The information contained in this guide should be coordinated with manufacturers' recommendations to establish individual plant designs.

1.2 References

- [1] ANSI/NFPA 85A-1982, Furnace Explosions in Fuel Oil- and Natural Gas-Fired Single-Burner Boiler-Furnaces.¹
- [2] ANSI/NFPA 85B-1978, Gas-Fired Multiple Burner Boiler-Furnaces, Explosion Prevention.
- [3] ANSI/NFPA 85D-1978, Fuel Oil-Fired Multiple Burner Boiler-Furnaces, Explosion Prevention.
- [4] ANSI/NFPA 85E-1980, Pulverized Coal-Fired Multiple Burner Boiler-Furnaces, Explosion Prevention.

¹NFPA documents are published by the National Fire Protection Association, Publications Sales Division, Batterymarch Park, Quincy, MA 02269. Copies are also available from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

[5] ANSI/NFPA 85G-1982, Prevention of Furnace Implosions in Multiple Burner Boiler-Furnaces.

[6] ASME Boiler and Pressure Vessel Code.²

[7] NFPA 85F-1982, Pulverized Fuel Systems, Installation and Operation.

2. Introduction

The text material, simplified flow diagrams, and logic diagrams are presented in the proper sequence for start-up of a fossil-fueled boiler-turbine-generator unit. Section 10. describes overall protection of the systems, and Section 11. is a table which summarizes and supplements the guide material.

Figure 1 shows a simplified combined systems diagram in logic form.

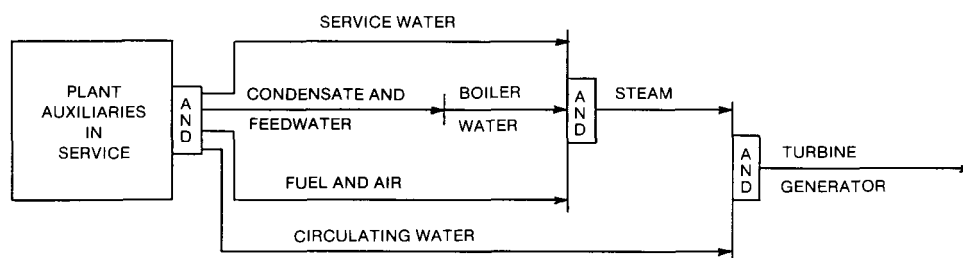


Figure 1 — Combined Systems Diagrams

²ASME documents are available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

Figure 2 shows a simplified arrangement of the major elements of a boiler-turbine-generator unit.

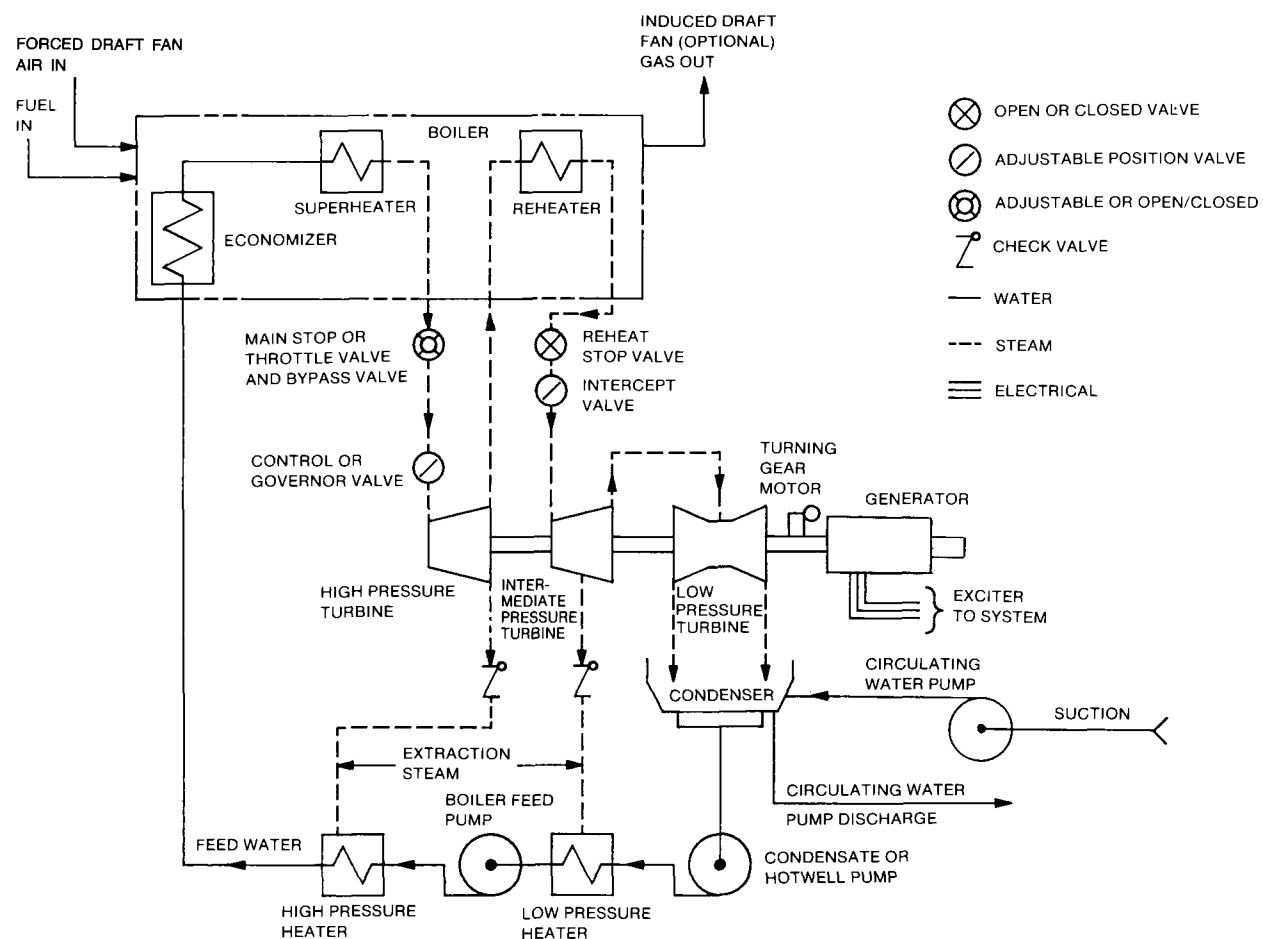
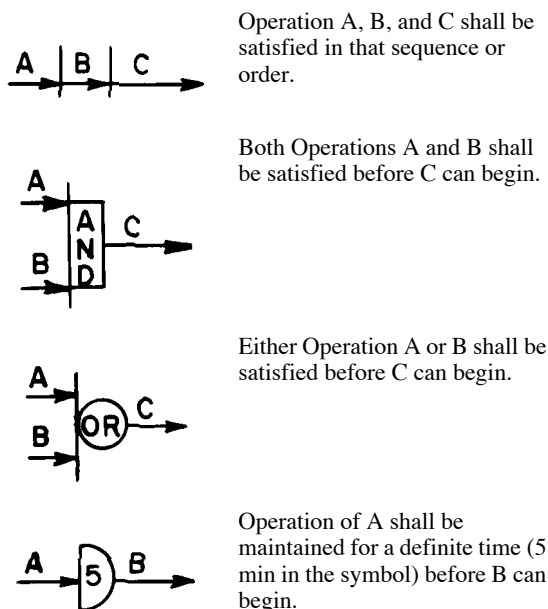


Figure 2—Simplified Arrangement: Boiler-Turbine-Generator

The logic symbols used are as follows:



The NOTES following the flow diagrams and the logic diagrams supplement the diagrams and differentiate between them. Corresponding reference numbers appear on the diagrams only where required for clarity.

3. Plant Auxiliaries in Service

Plant auxiliaries in service refers to the many plant subloops which shall be started and run prior to starting the main systems. These include electrical control (direct and alternating current), auxiliary power, control and station air, plant lighting, and communication systems. These will vary with the unit and are not detailed.

Major rotating equipment shall be started as shown in the various cycle logic diagrams. Such equipment includes fans and boiler feed, condensate, and circulating water pumps. A logic diagram, Fig 3, covers the steps for putting this type of equipment into service. A similar diagram would apply, with minor variations, to each piece of rotating equipment of the plant.

- 1) Prestart checks
 - Breaker control circuit*
 - Motor temperature*
 - Bearing temperature*
 - Power is available
 - Auto trip acknowledged
 - Hold-off tags removed
 - Review motor starting requirements
- 2) Lubrication checks
 - Oil level*
 - Oil temperature above minimum
 - Oil temperature below maximum
 - Oil cooling water on
 - Oil pump pressure* (if used)

- 3) Driven equipment checks
 - Checks required before starting motor
- 4) Process control checks
 - Damper positions
 - Valve positions
 - Permissive interlocks
- 5) Coupling checks
 - a) Magnetic
 - Control at zero speed
 - Power available
 - b) Hydraulic
 - Oil level*
 - Scoop at zero speed
 - Cooling water*
 - Freeze protection*
 - Oil pump pressure* (if used)
- 6) Poststart checks
 - Running checks
 - Vibration
 - Oil temperature
 - Oil pressure
 - Bearing temperature (cooling water*)
 - Motor current (if monitored)
 - Seal water*

*Visual, gauge, or meter checks

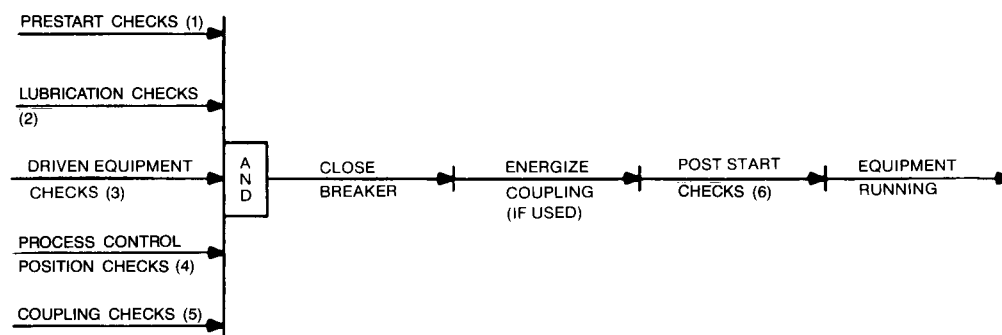


Figure 3—Large Motor Drive

4. Circulating Water Cycle

The circulating water system provides cooling and heat removal from the condenser and is normally the first cycle to be started. This is especially true if the circulating water pump provides a source of water for the cooling or service water cycle. The source of cooling water may be a lake, river, or other body of water. If environmentally acceptable, the discharge is generally not recycled; otherwise, a cooling tower or pond is added to the cycle with either an open or closed loop. Figure 4 is the circulating water flow diagram with variations shown.

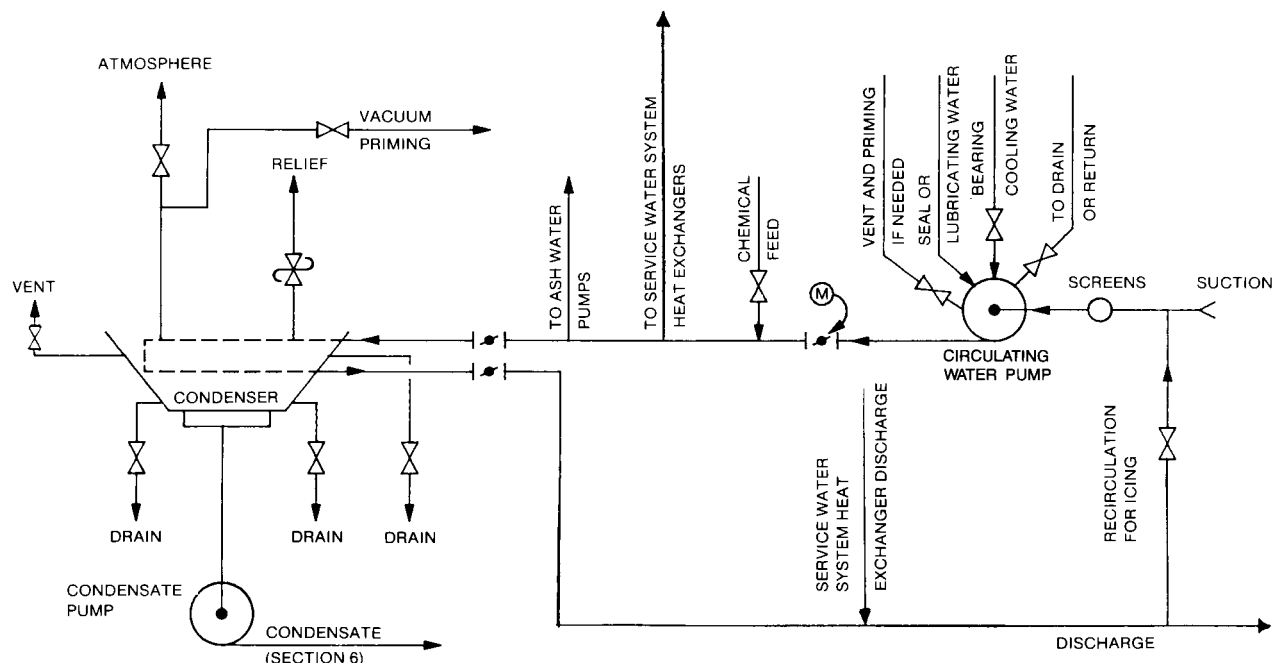


Figure 4—Circulating Water Flow Diagram

Figure 5 shows the logic sequence for putting the circulating water system into service and should be used in conjunction with Fig 4.

- 1) The seal water supply should be of sufficient pressure, volume, and cleanliness before a circulating water pump is started.
- 2) A horizontal pump or vertical dry-pit pump shall be primed before starting to prevent cavitation and overheating, and to establish a suction head. Vertical pumps are usually below the water level, and thus their pump casings are filled.
- 3) On systems where the condenser is above the circulating water supply reservoir, it is often necessary to fill the system using a fill pump (often the service water pump) before starting the circulating water to prevent water hammer.
- 4) When cooling towers are used, they may be open or closed, and natural- or forced-ventilation types. In areas where freezing can be a problem, proper precautions for protection shall be taken.
- 5) Refer to Fig 3 for prestart and poststart checks. Since circulating water pumps are single speed, a variable speed coupling is not used. With two pumps, each discharge valve should be opened after the pump starts and closed automatically when the pump stops to prevent reverse rotation when the other pump is running. Some pumps are built with antirotation devices or can run backwards for only a preset time.

Some circulating pumps shall be started with discharge valves initially open to prevent cavitation of the pump.

- 6) During the time delay while filling the system with water the discharge valve may be throttled to prevent water hammer.
- 7) If the water for the circulating water pump is taken from a lake or river, screens may be used to prevent debris from collecting at the pump suction and cavitating the pump. If excessive debris plugs the screens, the water-level on the discharge side will drop, causing loss of pump suction.
- 8) Another cause of water-level drop on the discharge side of the screen may be in climates where the temperature of the cooling water can drop to the point where ice will begin to form on the surface even though the water is moving. To prevent this icing condition, gates are built into the intake channel so that part of the discharge water may be circulated back into the intake.

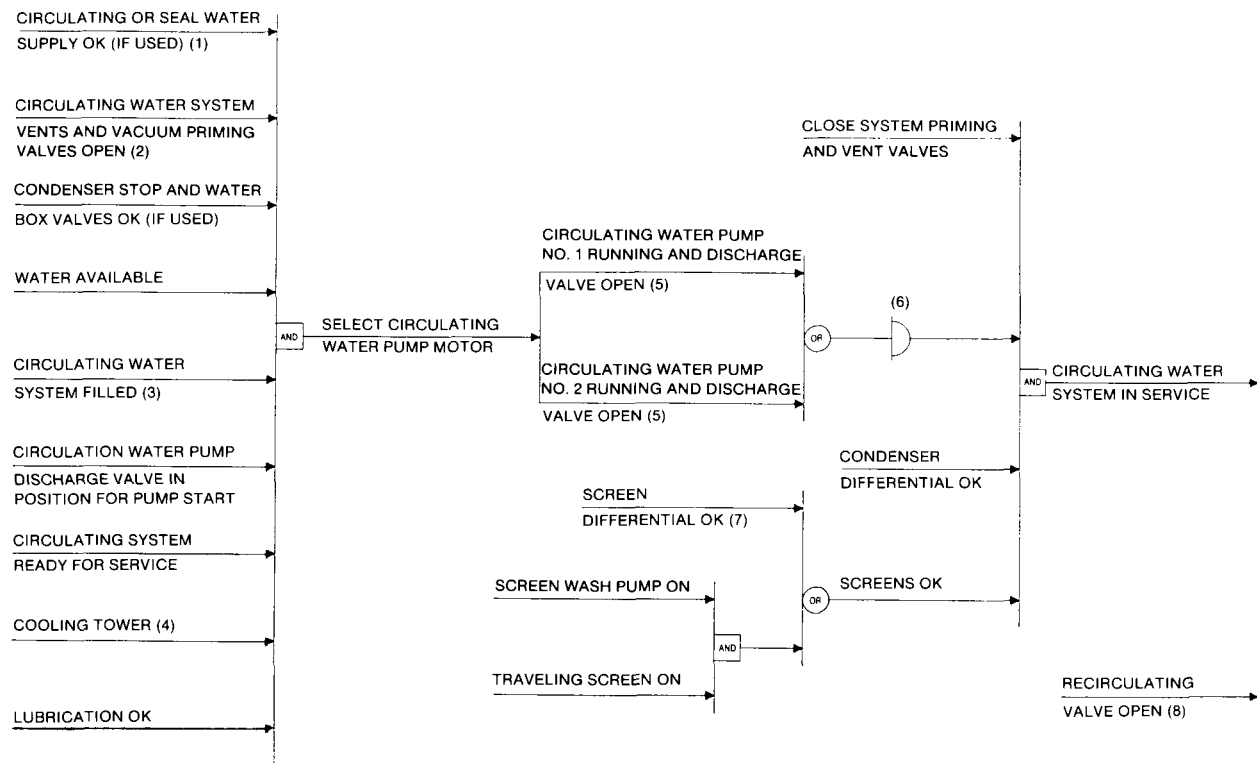


Figure 5—Circulating Water System

5. Service Water Cycle

The cooling or service water system provides cooling water to unit and auxiliary equipment to regulate temperatures and prevent damage from overheating.

Where possible, the source of pump suction should be cool, clean water; or if high head is involved, from a tap at the discharge of the circulating water pump. If the supply of cooling water is not large enough to handle the system's cooling requirements, a supplementary cooling system is employed which utilizes either an open or closed loop with a source of makeup water. As in the circulating water system, site climate may require freeze protection.

An isolated closed cooling water system for a water source that is dirty or brackish is often used for supplying cooling water to small passages such as bearings and coolers.

Figure 6 is a typical flow diagram for the service water system. The coolers referred to may include bearings, transformers, generator and hydrogen heat exchangers, and other equipment requiring water flow for cooling.

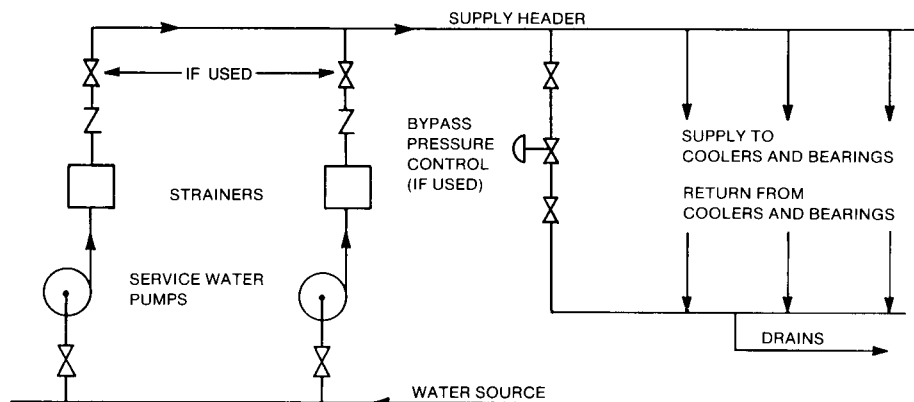


Figure 6—Service Water Flow Diagram

Figure 7 is the logic diagram for the service water system.

- 1) Water of sufficient head and volume should be available for cooling and sealing purposes before a service water pump is started. To ensure that the water is clean, strainers are used. With a heat exchanger system, an auxiliary circulating water pump(s) has to be put in service at this time.
- 2) The service water pump shall be properly primed.
- 3) Refer to Fig 3 for the details of prestart and poststart checks. In some cases, the checks represent a minimum list; in others, the checks do not apply.

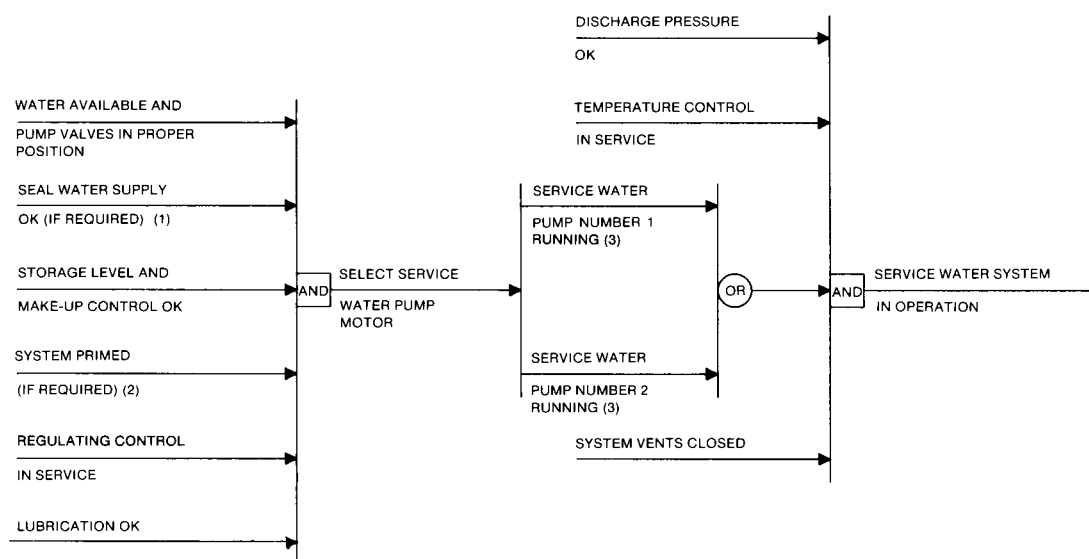


Figure 7—Service Water System

6. Condensate and Feedwater System

This system is the water system link between the hotwell and the boiler. Variations include using a deaerating condenser, or an open deaerating heater with a storage tank. The condensate pump shall provide sufficient head to overcome deaerator pressure or sufficient suction head for the boiler feed pump if no deaerator is furnished. The recirculating valve (minimum flow valve) is opened to ensure minimum flow through the pump.

With a deaerating condenser or an open deaerating heater with a storage tank, the vacuum system is started and condensate recirculated during low-load (low flow) conditions to prevent introducing aerated water to the boiler. Figures 8 and 9 represent typical flow diagrams for this system.

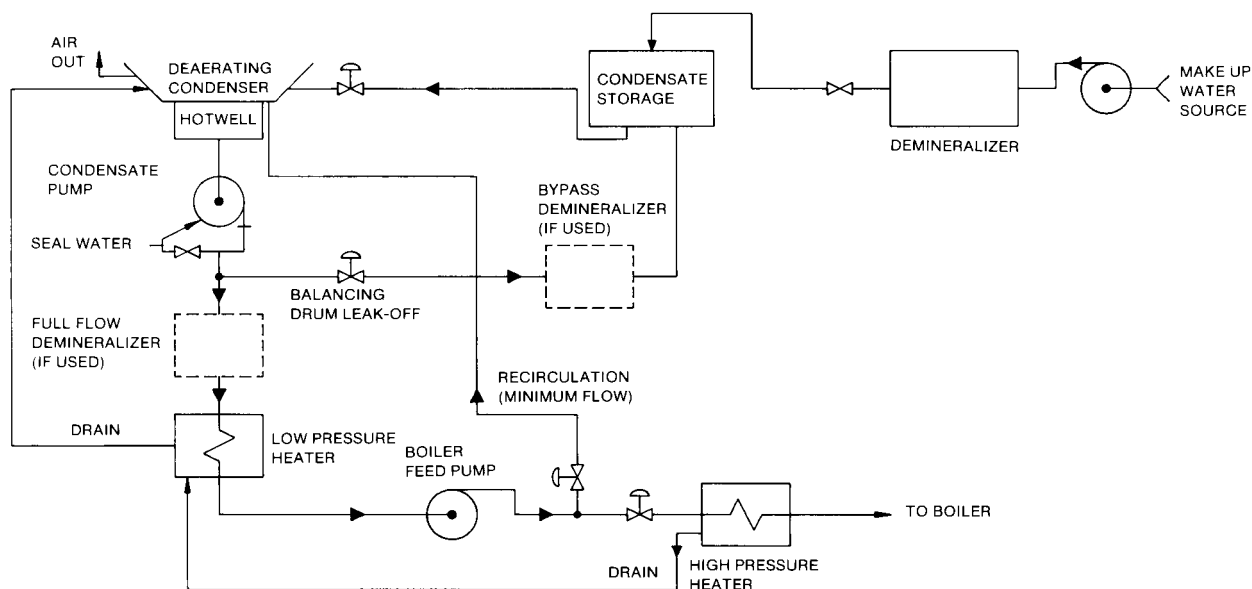


Figure 8—Typical Condensate and Feedwater (Deaerating Condenser)

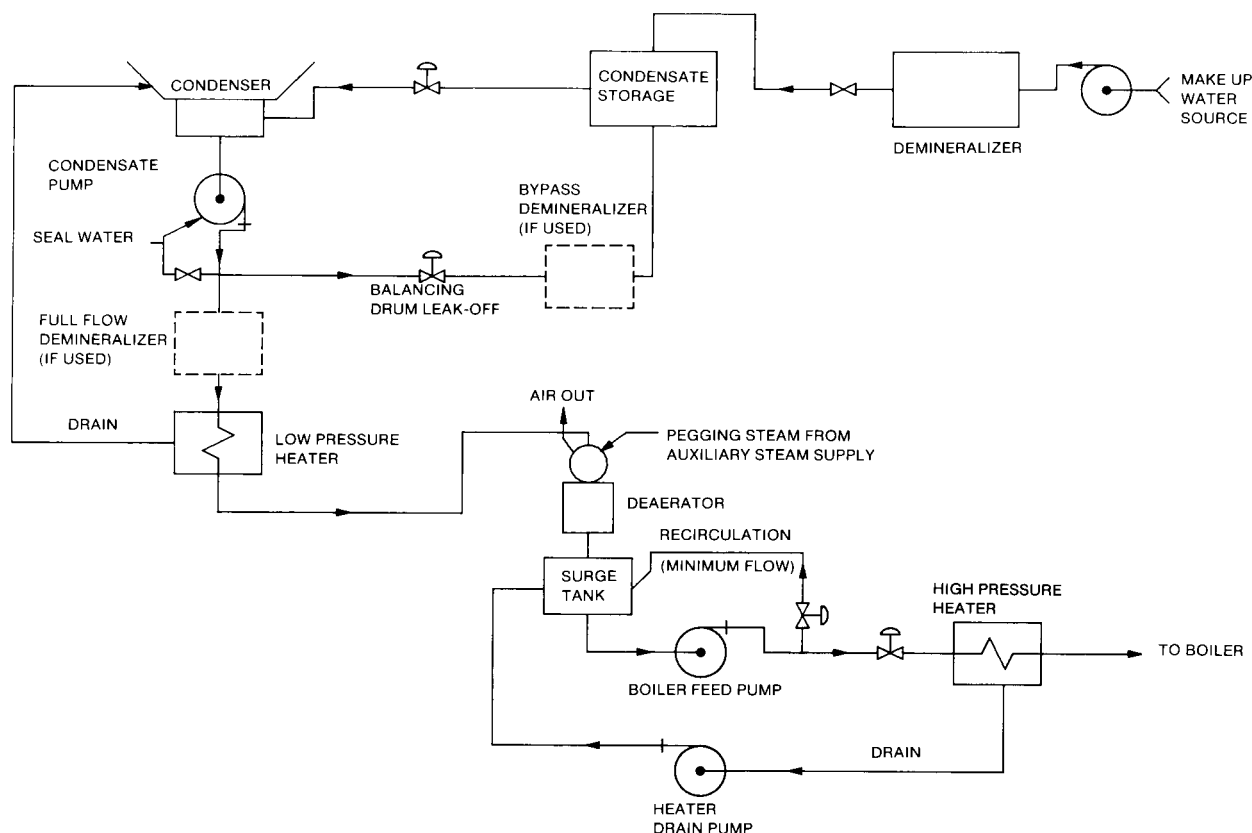


Figure 9—Typical Condensate and Feedwater (Open Deaerating Heater)

Heater and pumps have been grouped, since the quantity of each is a detail of the cycle design. Similarly, check valves and isolating valves associated with control valves have been omitted, as have the usual level control subloops on the heaters.

The condensate pump recirculation line has been combined with the return line to condensate storage for simplicity. In many cases, it is a separate line direct to the hotwell.

There are two cycles in use. One uses a deaerating condenser as shown in Fig 8. The other uses an open low-pressure heater as a deaerator and includes a surge or storage tank, as shown in Fig 9.

The basic difference in the two cycles is the location for deaeration of the condensate. In Fig 8, the deaeration is done in the condenser so that all drains are returned to the condenser with the boiler feed pump bypass discharge and balancing drum leak-off. The condensate pump has to provide the necessary net positive suction head (NPSH) for the boiler feed pump, or its suction booster if used. In Fig 9, the deaeration is done in the open deaerating heater which, with its storage tank, is usually elevated to provide NPSH for the boiler feed pump. In this case, the feed pump minimum flow bypass discharge and balancing drum leak-off are returned to the deaerator along with the high-pressure heater drains by the high-pressure drain pump.

Figure 10 is the logic diagram for the condensate and feedwater system with an open deaerating heater.

- 1) Refer to Section 3., Fig 3, for large motor starting logic diagram.
- 2) The condensate system is normally started with the condenser vacuum system in operation.
- 3) With the deaerating heater, low-pressure steam from an auxiliary source is introduced. When normal steam supply is not available to the deaerator, an auxiliary supply shall supply adequate pressure for pegging. When the deaerator storage tank level is adequate to provide sufficient NPSH, the feed pump may be started. With feed pumps running, water is recirculated back to the deaerator until the flow to the boiler exceeds the feed pump minimum flow.
- 4) Water quality is monitored by the operator to ensure that it is of sufficient purity before allowing flow into the boiler.
- 5) The boiler feed pump may be either motor driven or turbine driven. Some plants have a motor driven start-up boiler feed pump and then switch over to turbine-driven feed pumps after the boiler is up to pressure and the turbine-generator has been synchronized to the system.