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Fossil Fuel Plant Feedwater Control System — Drum Type

ANSI/ISA-S77.42 — Fossil Fuel Power Plant Feedwater Control System – Drum-Type

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ISA
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, North Carolina 27709

Preface

This preface is included for informational purposes and is not part of ISA-S77.42.

This standard has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static, but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms, and asks that they be addressed to the Secretary, Standards and Practices Board, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709, Telephone (919) 549-8411, e-mail: standards@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to U.S.A. users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavor to introduce SI-acceptable metric units in all new and revised standards to the greatest extent possible. *The Metric Practice Guide*, which has been published by the Institute of Electrical and Electronics Engineers as ANSI/IEEE Std. 268-1982, and future revisions will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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The information contained in the preface, footnotes, and appendices is included for information only and is not part of the standard. Functional drawings in the appendix are provided using both ANSI/ISA-S5.1-1984 symbology and established power industry conventions.

This standard is part of a series of standards resulting from the efforts of the ISA SP77 Fossil Power Plant Standard Committee's Subcommittee SP77.40, "Boiler Controls." It should be used in conjunction with the other SP77 series of standards for safe, reliable, and efficient design, construction, operation, and maintenance of fossil-fired power plants. It is not intended that this standard establish any procedures or practices that are contrary to any other standard in this series.

A variety of feedwater control systems have been developed and used over the years to maintain drum level within limits at the required set point. This standard is intended to establish minimum requirements for feedwater control.

The following people served as members of ISA Subcommittee SP77.42, "Feedwater Committee."

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*One vote per company

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*Director Emeritus

Contents

1 Purpose

The purpose of this standard is to establish minimum criteria for the control of levels, pressures, and flow for the safe and reliable operation of drum-type feedwater systems in fossil power plants.

2 Scope

The standard is intended to assist in the development of design specifications covering the measurement and control of feedwater systems in boilers with steaming capacities of 200 000 lb/hr (25 kg/s) or greater. The safe physical containment of the feedwater shall be in accordance with applicable piping codes and standards and is beyond the scope of this standard.

3 Definitions

The following definitions are included to clarify their use in this standard and may not correspond to the use of the word in other texts. For other definitions, reference ANSI/ISA S51.1-1979, "Process Instrumentation Terminology."

3.1 Boiler: The entire vessel in which steam or other vapor is generated for use external to itself, including the furnace, consisting of the following: waterwall tubes; the firebox area, including burners and dampers; the convection area, consisting of any superheater, reheater, and/or economizer sections, as well as drums and headers.

3.2 Cascade control: Control action in which the output of one controller is the set point for another controller.

3.3 Controller: Any manual or automatic device or system of devices for the regulation of boiler systems to keep the boiler at normal operation. If automatic, the device or system is motivated by variations in temperature, pressure, water level, time, flow, or other influences.

3.4 Drum (steam): A closed vessel designed to withstand internal pressure. A device for collecting and separating the steam/water mixture circulated through the boiler.

3.5 Feedwater control system: A control system using input signals derived from the process for the purpose of regulating feedwater flow to the boiler to maintain adequate drum level according to the manufacturer's recommendations.

3.6 Mass feedwater flow rate: The mass flow rate of all water delivered to the boiler, derived either from direct process measurements and/or calculations from other parameters. When volumetric feedwater flow rate measurement techniques are employed and the feedwater temperature at the flow-measuring element varies 100°F (37.8°C), the measured (indicated) flow shall be compensated for flowing feedwater density to determine the true mass feedwater flow rate.

3.7 Mass steam flow rate: The mass flow rate of steam from the boiler, derived either from direct process measurements and/or calculations from other parameters. If volumetric steam flow-rate measuring techniques are employed, the measured (indicated) flow shall be compensated for flowing steam density to determine the true mass steam flow rate.

3.8 Primary/secondary control loop controller: The controller which adjusts the set point for the secondary control loop controller in the cascade control action scheme.

3.9 Protective logic circuits: Logic circuits designed to prevent damage to equipment by related system equipment malfunctions, failure, or operator errors.

3.10 Pump drive control: A control component of the final device that translates a control system demand signal into an electronic, hydraulic, pneumatic, or mechanical signal which affects pump speed.

3.11 Redundant (redundancy): Duplication or repetition of elements in electronic or mechanical equipment to provide alternative functional channels in case of failure of the primary device.

3.12 Runback: An action by the boiler control system initiated by the loss of any auxiliary equipment that limits the capabilities of the unit to sustain the existing load. Upon runback initiation, the boiler demand signal is reduced at a preset rate to the capability of the remaining auxiliaries.

3.13 Rundown: An action by the boiler control system initiated by an unsafe operating condition —i.e., fuel/air limit (cross-limiting), temperature limits, etc. Upon rundown initiation, the boiler demand signal is reduced in a controlled manner to the load point where the unsafe operating condition is eliminated.

3.14 Shall, Should, and May: The word "SHALL" is to be understood as a REQUIREMENT, the word "SHOULD" as a RECOMMENDATION, and the word "MAY" as PERMISSIVE, neither mandatory nor recommended. (Reference: ISA-RPA-1a-1970, "Style Manual.") *

3.15 Shrinkage: A decrease (shrinkage) in drum level due to a decrease in steam bubble volume. This condition is due to a decrease in load (steam flow), with a resulting increase in drum pressure and a decrease in heat input.

3.16 Single-element feedwater control: A control system whereby one process variable, drum level, is used as the input to the control loop that regulates feedwater flow to the drum to maintain the drum level at set point.

3.17 Steady-state: A characteristic of a condition, such as value, rate, periodicity, or amplitude, exhibiting only negligible change over a long (arbitrarily chosen) period of time.

NOTE: It may describe a condition in which some characteristics are static, others dynamic.

3.18 Swell: An increase (swell) in drum level due to an increase in steam bubble volume. This condition is due to an increase in load (steam flow), with a resulting decrease in drum pressure and an increase in heat input. Swelling also occurs during a cold start-up as the specific volume of the water increases.

3.19 Three-element feedwater control: A control system whereby three process variables (steam flow, feedwater flow, and drum level) are used as inputs to the control loop that regulates feedwater flow to the drum to maintain the drum level at set point. This is a cascaded feedforward loop with drum level as the primary variable, steam flow as the feedforward input, and feedwater flow (feedback) as the secondary variable.

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*See Section 5 for bibliographic information on references.

3.20 Transient: The behavior variable during the transition between two steady states.

3.21 Two-element feedwater control: A control system whereby two process variables (steam flow and drum level) are used as inputs to the control loop that regulates feedwater flow to the drum to maintain the drum level at set point. The feedforward input is steam flow, with the output of the drum level controller as the primary control signal.

3.22 Two-out-of-three logic circuit (2/3 logic circuit): A logic circuit that employs three independent inputs. The output of the logic circuit is the same state as any two matching input states.

4 Minimum design requirements for a feedwater control system

The control system shall meet operational requirements and correctly interface with the process. To accomplish this objective, the following requirements are defined for minimum system design:

1) Process measurement requirements
2) Control and logic requirements
3) Final control device requirements
4) System reliability and availability
5) Alarm requirements
6) Operator interface

4.1 Process measurement requirements

4.1.1 Instrument installation for feedwater control

4.1.1.1 Instruments should be installed as close as is practical to the source of the measurement, with consideration being given to excessive vibration, temperature, and accessibility for periodic maintenance. Recommendations for the location of instrument and control equipment connections can be found in the joint publication by SAMA (Scientific Apparatus Makers Association) and ABMA (American Boiler Manufacturers Association), "Recommendations for Location of Instrument and Control Connections for the Operation and Control of Watertube Boilers." Specific requirements for the location of drum water level measuring devices are contained in Section 1 of the American Society of Mechanical Engineers' *Boiler and Pressure Vessel Code*.

4.1.1.2 Separate isolation valves, head chambers (when used), and impulse lines shall be provided for each instrument. (See Figure 1.)

4.1.2 Drum level measurement

A drum level signal is required for single-element, two-element, and three-element feedwater control systems. (See Figures 1, 2, 3, and 4.) If the instruments used to measure drum level are sensitive to density variation, then density compensation techniques shall be employed.

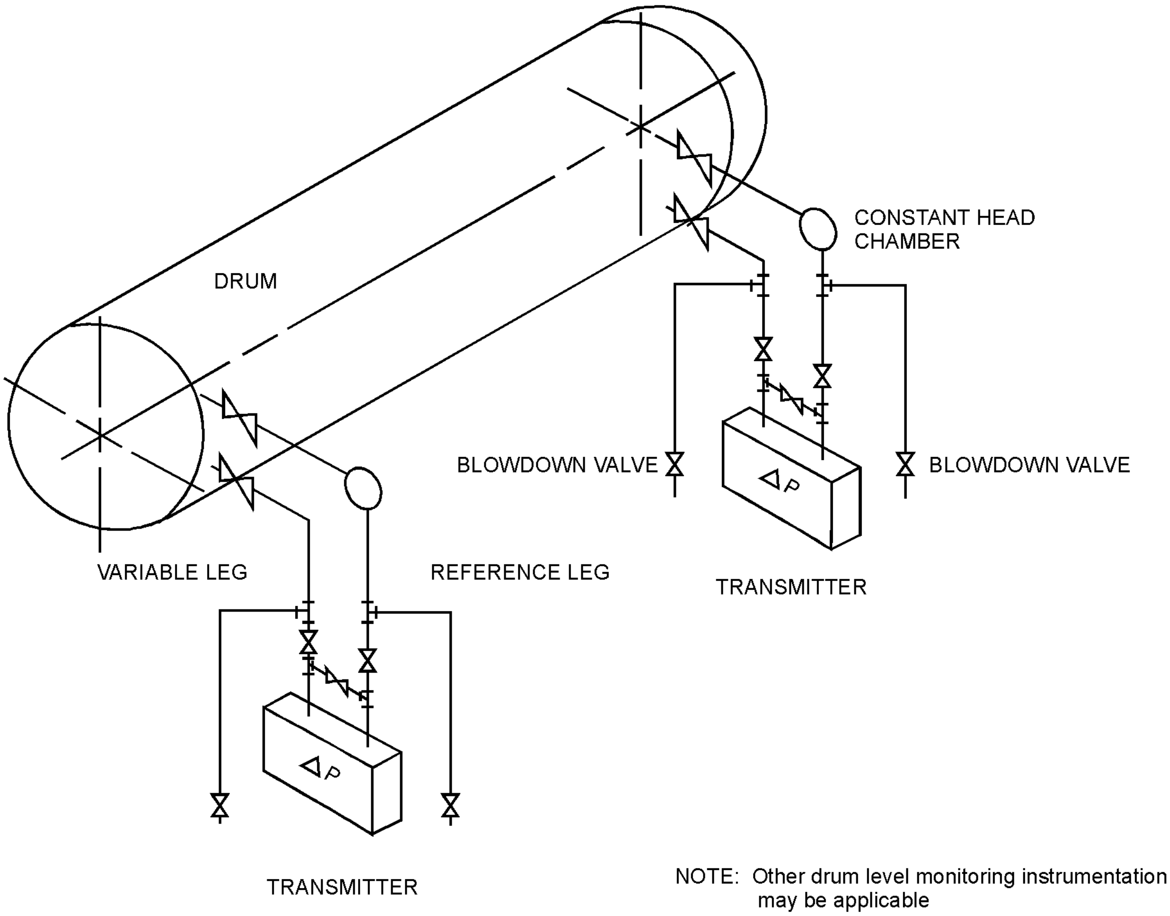


Figure 1 — Typical drum level differential pressure transmitter connections

4.1.3 Steam flow measurement

A mass steam flow signal is required for two-element and three-element feedwater control systems.

4.1.4 Feedwater flow measurement

A mass feedwater flow signal is required for three-element feedwater control systems.

4.2 Control and logic requirements

The function of the feedwater control system is to maintain drum water level within the boiler manufacturer's specified limits. The flow of feedwater to the drum is controlled by the variation of boiler feedpump speed and/or by the action of a control valve(s). Feedwater control can be accomplished by using the following control strategies:

1) Single-element control

2) Two-element control

3) Three-element control

4.2.1 Single-element feedwater control

Single-element control is the minimum feedwater control system and shall be used for the following applications:

1) During start-up or at low-load operation, when flow measurements are generally not accurate.

2) When steam flow rate of change is nominal and feedwater supply pressure is essentially constant.

4.2.2 Two-element feedwater control

Two-element control is the minimum feedwater control for a variable steam flow application and is not recommended for new applications.

4.2.3 Three-element feedwater control

Three-element control shall be used for variable steam flow applications.

4.2.4 Feedwater protective logic

Requirements for protective logic signals shall be those determined by the specific equipment manufacturers. Protective logic signals to trip the fuel to the boiler may include high drum level and low drum level.

The following conditions shall produce a signal usable by other control systems, as covered under other standards within the SP77 series:

1) Loss of a boiler feedpump shall result in a unit load runback to the remaining on-line boiler feedpump capacity.

2) Exceeding the maximum capability limit of the feedwater system shall result in a unit load rundown to return the feedwater system to a controllable range.

4.2.5 Feedwater flow control

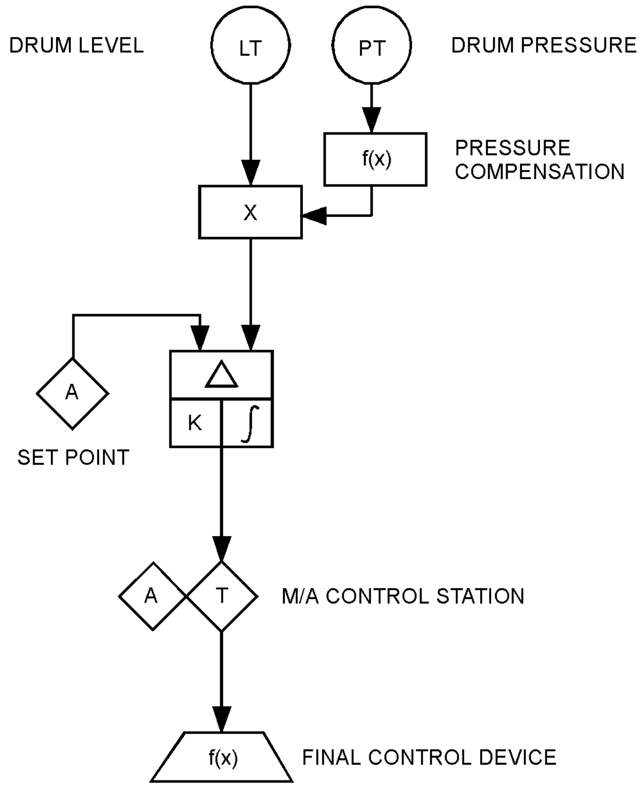
Feedwater flow shall be controlled by varying the speed of the boiler feedpump(s) and/or by varying the position of the feedwater control valve(s).

4.2.5.1 Variable-speed pump control

When feedwater flow is controlled by the use of a hydraulic coupling, or by a variable-speed motor, or by varying the speed of a turbine-driven pump, the following features shall be provided:

1) In the automatic mode the output of the flow controller shall have an adjustable limit. This limit is a direct function of the operating pressure. Since the output of the flow controller is speed demand (position demand of the hydraulic coupling), the limit will be a pump demand low limit. The low limit should be set to maintain minimum pump flow.

2) When using a flow controller with a speed controller, the flow controller sets pump flow demand. The speed controller shall serve in a cascade configuration to linearize the flow response of the pump.



Typical single-drive control system. For simplicity, redundant transmitters have not been shown on this typical control drawing. See Figure 2A for ANSI/ISA-S5.1-1984 format.

Figure 2 — Single-element feedwater control (functional control diagram)

4.2.5.2 Feedwater control valve control requirements

When feedwater flow is controlled by valve(s), a single or multiple feedwater control valve(s) may be used. Choice of valve configuration shall be based on a consideration of the pressure drop across the valve, rangeability, cavitation, and excessive valve wear with the valve nearly closed during low-load operation. If multiple valves are used, the control system shall provide for a smooth transition during the crossover to each additional valve, both on flow increases and decreases.

To minimize wear across the main control valves and to improve controllability, the control system should be configured to close off the start-up valve(s) as the main control valve(s) assumes the load.

4.2.6 Boiler feedpump minimum flow

Minimum flow recirculation is required for pump protection — based on the manufacturer's requirements. Control can be modulating or open/close and provided by remotely controlled or self-contained automatic regulating valves. As a minimum design, separate dedicated flow-monitoring systems consisting of flow elements, transmitters, and/or switches shall be provided for each individual boiler feedpump.

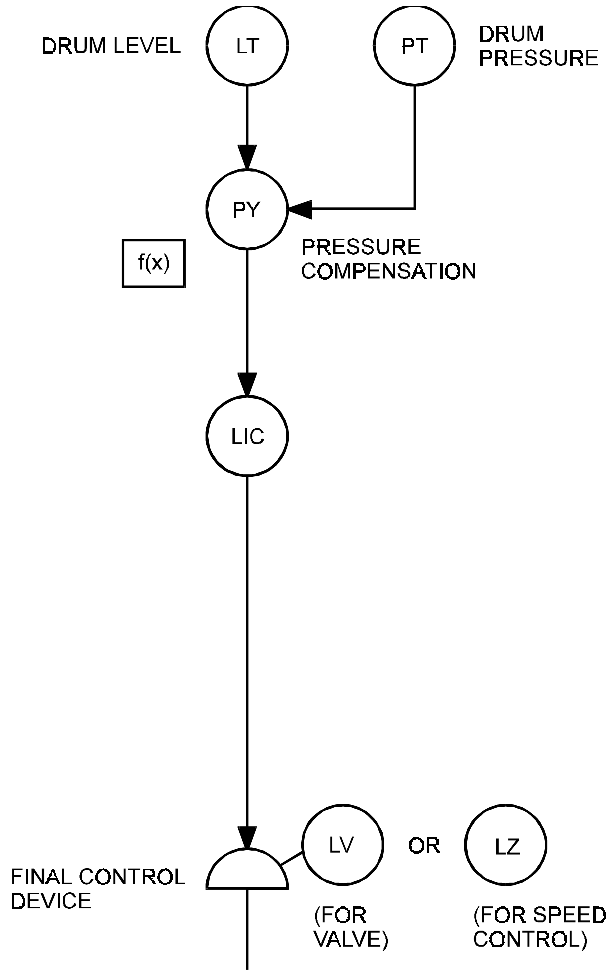
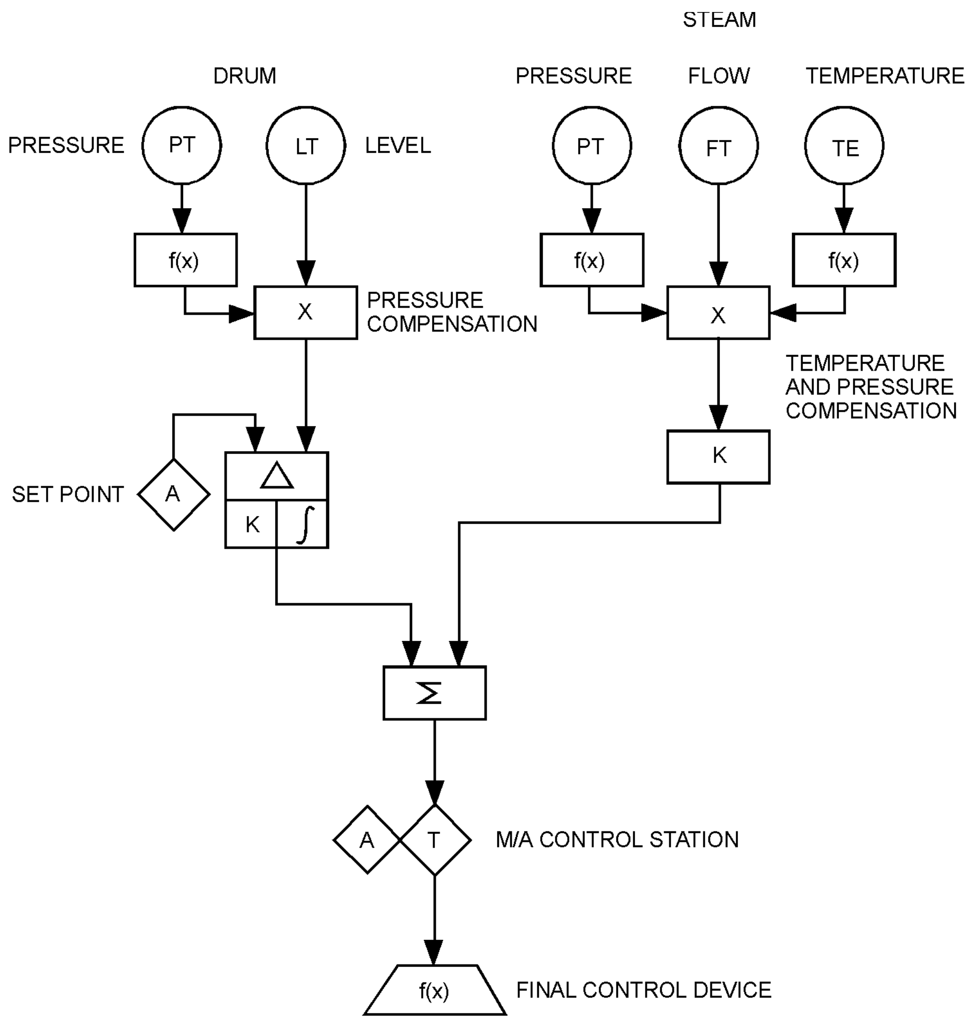


Figure 2.A — Single-element feedwater control (functional control diagram using the ANSI/ISA-S5.1 format)



Typical single-drive control system. For simplicity, redundant transmitters have not been shown on this typical control drawing. See Figure 3A for ANSI/ISA-S5.1-1984 format.

Figure 3 — Two-element feedwater control (functional control diagram)

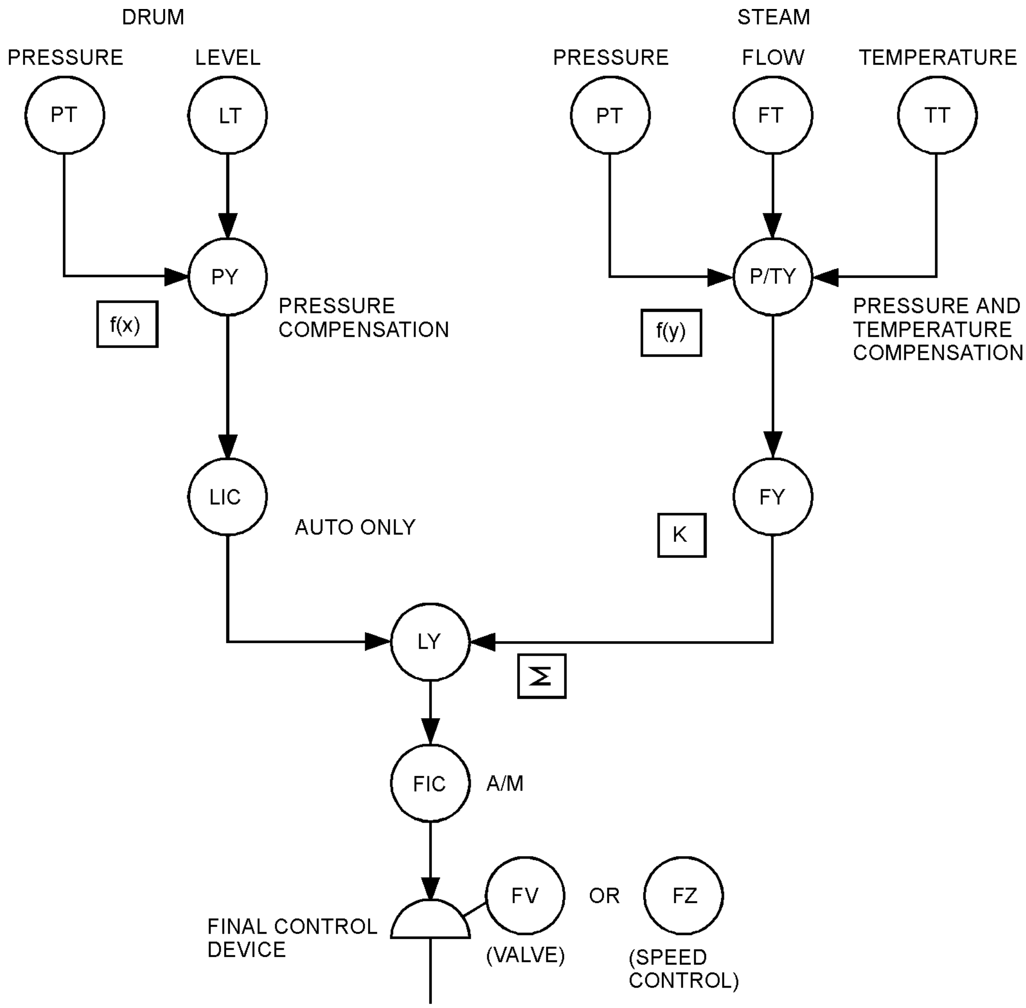
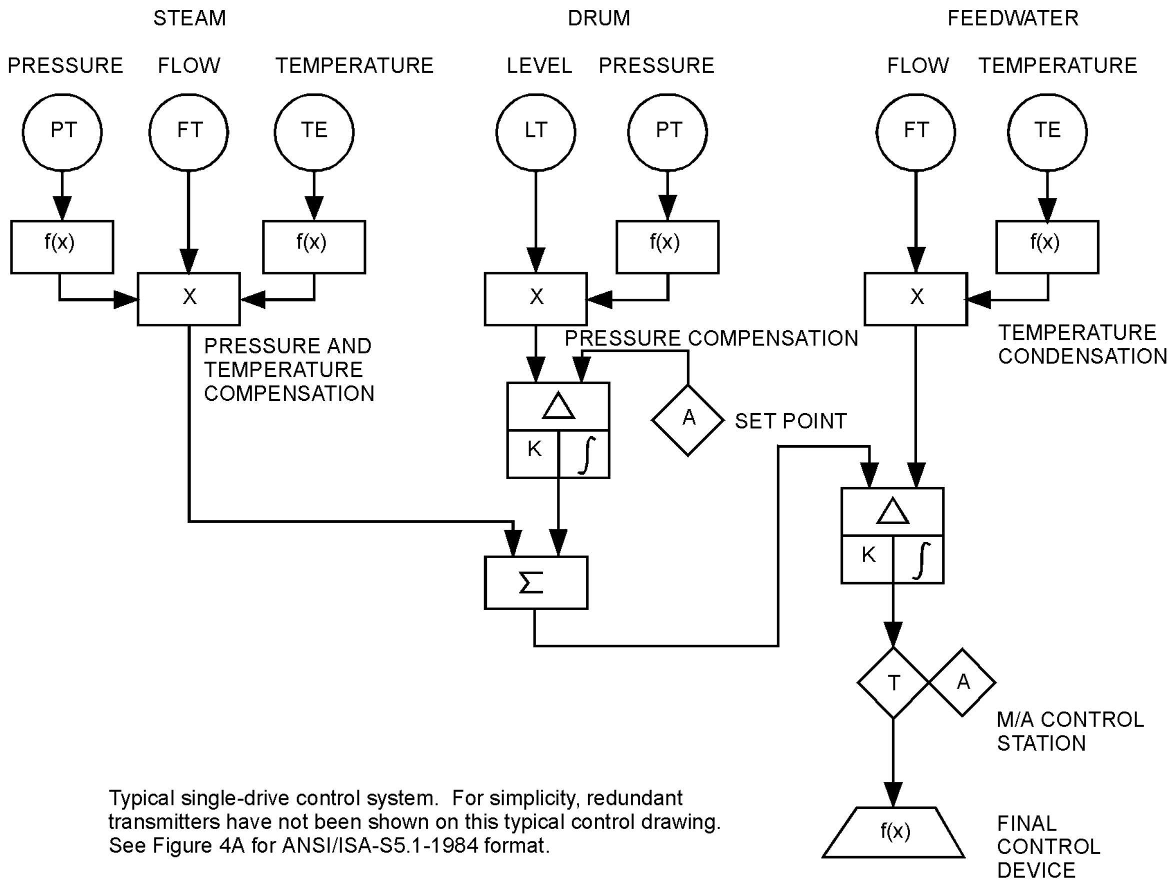


Figure 3.A — Two-element feedwater control (functional control diagram using the ANSI/ISA-S5.1-1984 format)



Typical single-drive control system. For simplicity, redundant transmitters have not been shown on this typical control drawing. See Figure 4A for ANSI/ISA-S5.1-1984 format.

Figure 4 — Three-element feedwater control (functional control diagram)

When flow switches are used, an adjustable dead band shall be provided. When an operator's manual override station is used, setting the control to "manual" shall always open the valve.

When minimum flow recirculation for a high-pressure booster stage is required by the pump manufacturer, it shall be provided using the same criteria as the main recirculation flow, but with its own flow measurement device.

4.3 Final control device requirements

All final control devices shall be designed to fail safe on loss of demand signal or motive power — i.e., open, close, or lock in place. The fail-safe position shall be determined by the user based upon the specific application. Minimum flow recirculation valve(s) shall open on any failure in the minimum flow control system.

4.4 System reliability and availability

4.4.1 In order to establish minimum criteria, the feedwater control system specification shall include the following as part of the system design base:

1) Maximum unit load/steaming capacity

2) Normal operating load range

3) Anticipated load changes (transients)

4) Start-up and shut-down frequency

5) Degree of automation

6) Boiler feedpump maximum and minimum capacity

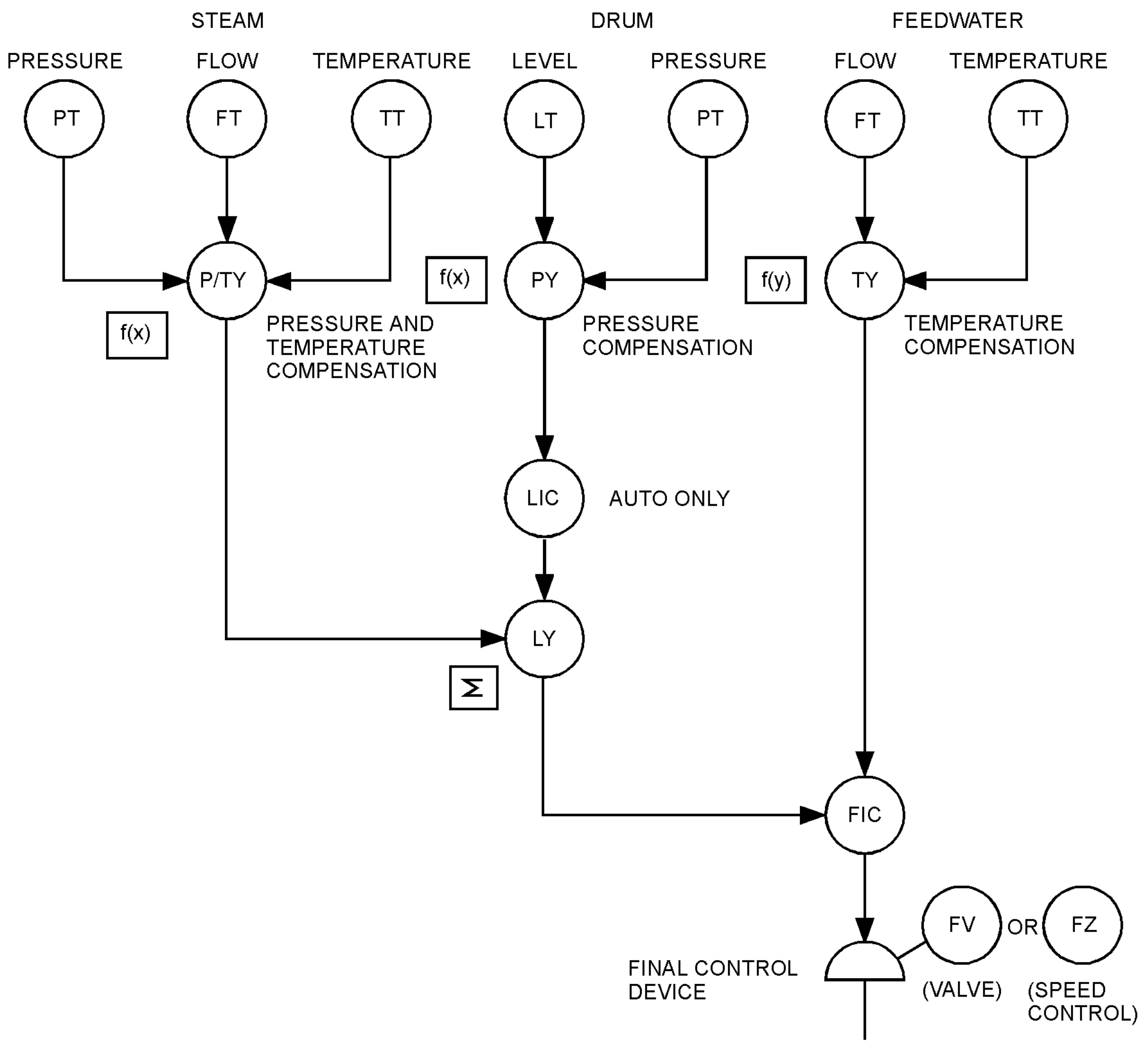


Figure 4.A — Three-element feedwater control (functional control diagram using the ANSI/ISA-S5.1-1984 format)

4.4.2 All control transmitters shall be redundant. The following conditions apply:

1) When two transmitters are employed, excessive deviation between the transmitters shall be alarmed and the associated control loop shall be transferred to manual.

2) When three transmitters are employed, excessive deviation between the transmitters shall be alarmed. A transmitter select scheme shall be used for control purposes.

4.5 Minimum alarm requirements

Minimum alarm requirements shall include the following:

1) High and low drum level

2) Loss of control power

3) Loss of final drive power

4) Control loop trip-to-manual

5) Feedwater flow/system flow deviation (three-element control)

6) Loss of control transmitter (arming of the trip circuit)

4.6 Operator interface

4.6.1 The following information used in the feedwater control system shall be made available to the operator. These shall include the following:

1) Drum level

2) Drum pressure

3) Feedwater flow

4) Feedwater temperature

5) Steam flow

6) Steam temperature

7) All alarms

8) Automatic/manual control loop status

9) Main steam pressure (where applicable)

4.6.2 In addition to the above, the following information should be made available to the operator:

1) Final drive position(s)

2) Valve position(s)

3) Pump speed(s)

4) Single- or three-element control status

5) Individual boiler feedpump flow

6) Drum level set point

4.6.3 The system shall include capabilities for the automatic/manual control of each individual final device (except for the boiler feedpump minimum flow valve[s] as discussed within Section 4.2.6).

5 References

1) *ACVS Drive 1983 Catalogue*, Reliance Electric Company, Cleveland, Ohio, 1983.

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17) Singer, Joseph G., *Combustion*: *Fossil Power Systems*, 3d ed., Combustion Engineering, Inc., 1981.

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Appendix A — Feedwater control

This appendix is included for informational purposes only and is not a part of ISA Standard S77.42.

A.1 Purpose

The purpose of this appendix is to provide tutorial information on the philosophy underlying this standard and to assist the user of this standard in specifying and applying feedwater control schemes.

A.2 Introduction

A.2.1 Design specification requirements

To adequately specify a feedwater control strategy, the following three fundamental questions must be addressed:

1) What are the anticipated process operational requirements — e.g., steady-state or cyclic operations, rates of change, etc.?

2) What equipment and operating parameters are required to properly interface the control system?

3) What characteristics must the control system possess to maintain the desired performance?

The extent to which these questions are answered will directly determine how well the control system is fitted to the design and operating requirements. A misapplication, at the least, could result in poor operating performance, and, at worst, could result in extensive boiler damage. The following subsections are intended to supplement good engineering judgment with a consistent means of communicating design requirements to suppliers, designers, or constructors.

A.2.2 Summary of process performance requirements

A significant factor to consider in control system selection is the intended boiler usage. Since the operating requirements of the boiler define the required control system capabilities, design specifications must address the following unit characteristics:

1) Unit load/steaming capacity

2) Normal operating load range

3) Anticipated load changes (transients)

4) Start-up and shut-down frequency

5) Degree of automation

A complete description of the anticipated load characteristics will allow the engineer/supplier to properly evaluate the system and propose a control strategy. When the control strategy is preselected, these characteristics should still be defined as part of the design basis.

Table A.1 provides a general comparison of typical control systems for the engineer's use in specification development and evaluation. This table is not intended to be all-inclusive; rather, it is a summary of commonly used control strategies. The important conclusion to be drawn from the table is that all control systems are not the same, and therefore selection of a specific system requires careful consideration of design parameters.

Table A.1 — Summary of typical control systems

	Single-element	**Two-element**	**Three-element**
Prerequisite	Slow rate of change of steam flow	Constant feedwater pressure	Feedwater flow/steam signal available
Steady-state operability	Good	Good	Good
Transient operability	Poor	Good	Good
Response to load change	Slow	Fast	Fast
Control response type	Feedback	Feedforward	Feedforward
Compensation for drum shrink and swell	None	Partial	Effective
Potential for flow imbalance during load change	Probable	Dependent on final drive linearity and repeatability through the load range	Minimal

A.2.3 Single-element control (see Figure 2)

Single-element control requires a pressure-compensated drum level signal (if the instruments used to measure drum level are sensitive to density variation) and requires a desired set point signal. Proportional-plus-integral-action controllers maintain level by sending an output to the final control device. Single-element control in fossil-fired power plants should be used for start-up control before steam flow is delivered to the process. Single-element control is the minimum feedwater control system and is applied where steam flow is constant or at low loads when steam flow measurements are not available. When single-element control is combined with two- or three-element control, the mode selection may be automatically selected or operator selected.

A.2.4 Two-element control (see Figure 3)

Two-element feedwater control requires (1) a pressure-compensated drum level signal if the instruments used to measure drum level are sensitive to density variations, and (2) a desired set point signal for level, along with a feedforward signal from a temperature-compensated steam flow transmitter. The error from the proportional-plus-integral-action level controller is summed with the steam flow signal to determine the demand to the final drive element.

A.2.5 Three-element control (see Figure 4)

Three-element feedwater control requires a pressure-compensated drum level signal (if the instruments used to measure drum level are sensitive to density variations), a desired set point signal for level, a feedforward signal from a temperature-compensated steam flow transmitter, and a signal from a feedwater flow transmitter. The feedwater flow transmitter should be temperature-compensated if the measurement is affected by feedwater temperature. The three-element control shall make feedwater flow follow steam flow and use the deviation in level as a resetting action to bring the required water inventory back to balance. Feedwater demand shall be derived from the error between the feedwater/steam flow error and the drum level. Consideration should be given to the inclusion of superheater spray flow in the total measurement of feedwater flow.

A.2.6 System description and interface requirements

To achieve the performance objectives, the control system interface with the process must be considered carefully. At a minimum, a detailed process description should be provided which includes the following:

1) An instrumentation drawing defining all process design parameters such as temperatures, pressures, and normal flows.

2) Final drive descriptions of sufficient detail that a control strategy could be selected to provide an appropriate control action. Specifically, system head curves should be provided regardless of the method of feedwater regulation. Rated flows and minimum flows should be noted, in addition to pump recirculation flow requirements.

3) Boiler interface requirements defining drum level trip points, unmetered flow requirements (to include blow-down and superheat sprays), as well as any other boiler/feedwater interface requirements.

4) Existing process measurement interfaces, dimensioned sketches or diagrams. New flow element installations should be designed in accordance with the ASME MFC Series Standards. Drum level measurements should be in accordance with Section 1 of ASME's *Boiler and Pressure Vessel Code*. All measurements should be taken where vibrations, pulsations, and other flow disturbances are at a minimum.

5) A description of available electrical power and pneumatic supplies.

6) Control interlocks, set points, and alarm points.

7) Instrument loop diagrams, as defined by ISA S5.4-1976 (R1981).

A.3 Boiler drum

The drum of a subcritical boiler serves the following functions: (1) to maintain an adequate water level in the boiler tubes to prevent thermal damage; (2) to separate steam from the mixture of water and steam discharged into it; and (3) to house equipment to dry the drum steam after it is separated from the water.

The quantity of water contained in the boiler below the water level is relatively small compared to the total steam output. Primarily, the space required to accommodate steam-separating and -drying equipment determines the size of the drum.

The weight of the water in the mixture delivered to the drum for separation depends on the temperature and/or pressure and may range from less than two to over 25 times the weight of steam. To reduce this water to the small fraction found in the steam requires a high efficiency of water separation.

The factors that affect the separation of water from steam are:

1) The density of water with respect to steam

2) The available pressure drop

3) The amount of water in the mixture delivered to the steam drum

4) The quantity or total through-put of the water and steam to be separated

5) Viscosity, surface tension, and other such factors affected by pressure

6) Water level in the drum

7) The concentration of boiler water solids

A.4 Density

The ratio of the density of steam to the density of water increases as pressure increases. This relationship is shown in Figure 5, which is a plot of the ratio of the density of water to the density of steam as a function of pressure. The density of water at 1200 psig (8.3 Pa) is approximately 16 times that of steam. At 2800 psig (19.1 Pa), the density of water is approximately three times that of steam.

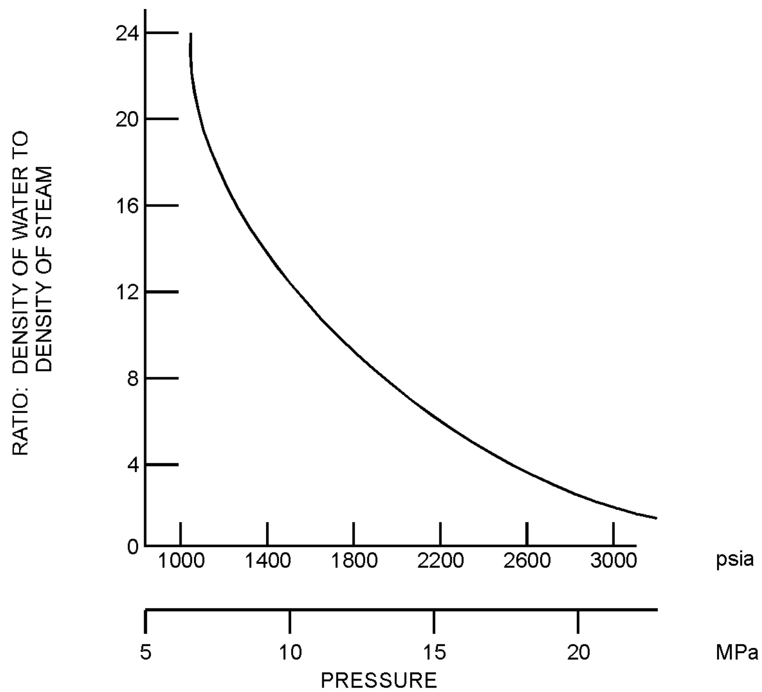

Figure 5 — Water/steam density relationship

The difficulty of measuring water level in a drum because of the variable density is shown in Figure 6. This drawing shows the relationship of the drum water with steam bubbles, the water level in a hot-gauge glass, the water level in a cold-gauge glass, and a method used to measure uncompensated drum level using a differential pressure transmitter. The level in the hot-gauge glass represents an undisturbed column of water, with saturated steam above that level.

A.5 Carryover

As operating pressures increase, the steam phase exhibits greater solvent capabilities for the salts that may be present in the water phase. These salts will be partitioned in an equilibrium between the steam and water, known as "vaporous carryover." The phenomenon will contribute additional boiler water solids directly to the steam, independent of the efficiency of steam-water separation components.

A more serious problem with boilers below 2600 psig (17.9 Pa) is carryover occasioned by priming. Priming occurs when the water level is carried excessively high in the steam drum. The high water level can impair the discharge of the steam-water separators and result in water being carried through the driers.

Most materials that form boiler deposits originate in the preboiler system. Adherence to recommended operating procedures during start-up, normal operation, shutdown, and outages of a power plant is vital to minimize corrosion. The rate of deposition of preboiler corrosion products increases with increasing heat flux. Deposition is substantially greater on the hot side of the tube where boiling occurs. To minimize carryover, accurate drum level indication and controls should be primary considerations in the design of a feedwater control system.

A.6 System hydraulics

A system head curve represents the relationship between flow and hydraulic losses in a system. The representation (see Figures 7, 8, and 9) is in a graphical form — i.e., friction loss is shown to vary as the square of the flow rate; thus, the system curve is of parabolic shape.

Hydraulic losses in piping systems are comprised of pipe friction losses, valves, elbows, and other fitting losses — including losses from changes in pipe size. The parabolic shape of the system curve is determined by the friction losses through the system — including all bends, fittings, and valves. The static head does not affect the shape of the system curve or its steepness, but it does dictate the head of the system curve at zero flow rate. The operating point is at the intersection of the system curve and the pump curve. The flow rate can be reduced by throttling a discharge valve (see Figure 7), or by reducing pump speed (see Figure 10).

Pumps are usually operated in parallel when the heads are relatively low, but flow rates vary considerably. In this case, the pumps take their suction from a common supply and discharge into the same header. They may be required to operate independently or in combination. When shown superimposing the system curves, the pump performance curves clearly indicate the flow rates that can be expected and the heads at which each of the pumps would be operating (see Figure 8).

In some installations, the static system losses produce a head too high for one pump to obtain the required flow rate. In this case, two or more pumps are positioned in series, where the second and subsequent units take their suction directly from the discharge of the pump preceding it. The pumps are usually identical in size, speed, and impeller diameter. The combined pump performance curve is produced from the addition of heads for each pump at given flows (see Figure 9).

The slope of the system head curve can be adjusted by varying the friction loss in the pipeline. This can be accomplished either by throttling with a valve or (the more common way) by adjusting the capacity flow rate of the pump by reducing the pump speed. Variable speed is the most effective way of varying the flow rate (see Figure 10).

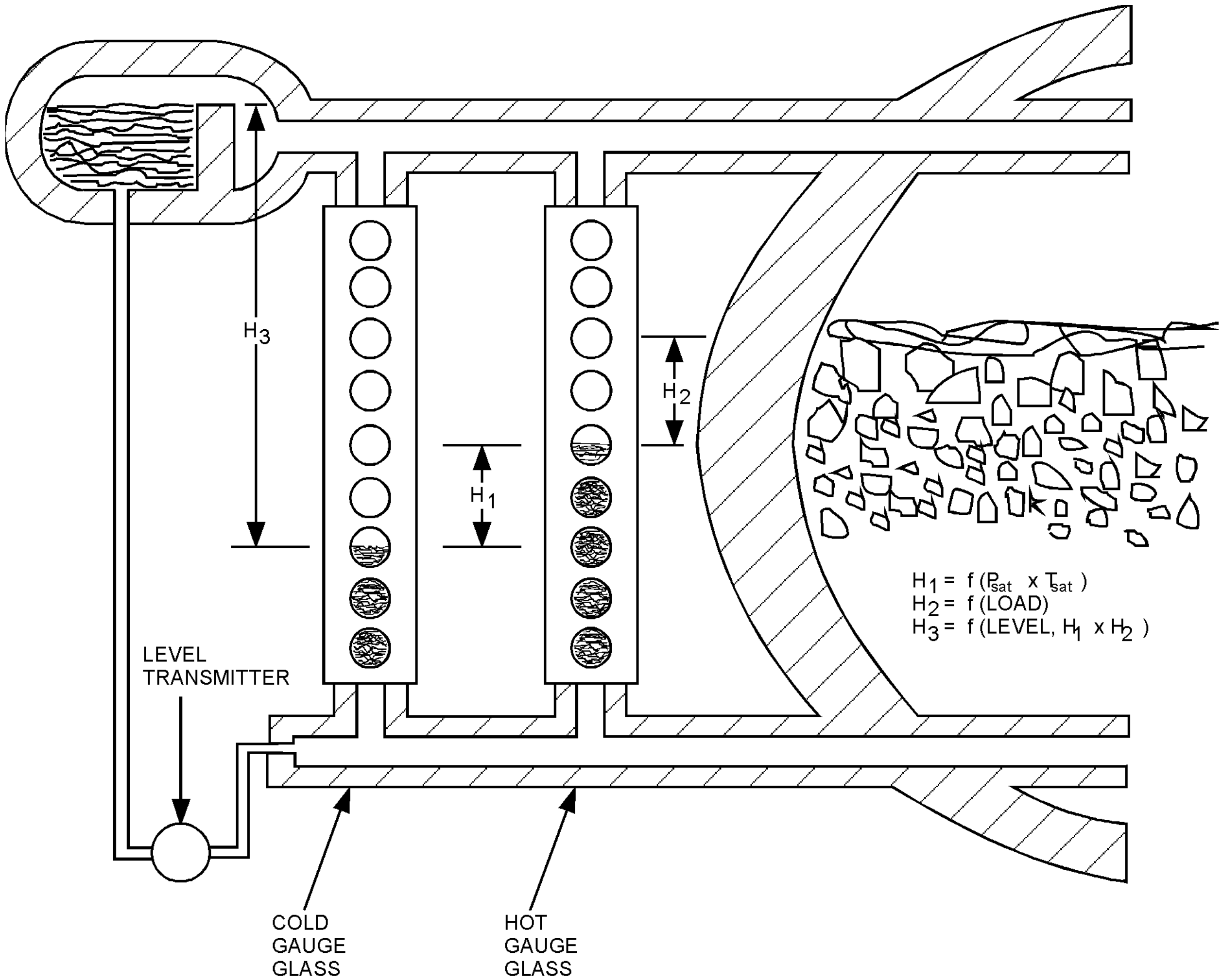

Figure 6 — Level measurements and corrections

A.7 Pump drive speed control

A.7.1 Turbine drives

For automatic control of turbine speed in response to boiler feedwater demand, a control system signal is sent to the pump turbine speed controller.

Below the minimum governing speed, the turbine motor control unit's manual selector switch allows the turbine to be controlled manually, similar to the way a valve positioning device can be controlled. To operate the feedwater control on the pump turbine over the entire speed range from minimum to maximum speed, the manual motor speed changer must be in the high-speed stop position.

The pump turbine speed control should be designed to be compatible with the feedwater control system signal. The minimum signal represents the minimum operating speed, and the maximum signal represents maximum operating speed, with the turbine developing its maximum specified capability.

A.7.2 Variable-torque drives

Variable-torque drives vary pump speed from minimum to full speed. This is usually accomplished by a mechanical positioning of the drive regulator.

A process controller interface package must be specified to provide necessary interface circuitry between the process control system and the drive regulator. The interface package matches the drive operation's speed range with the process control system's signal range.

A.7.3 Variable-speed motor drives

Variable-speed ac drives vary pump speed from minimum flow to full flow.

A.8 Boiler feedpump minimum flow

The boiler feedpump is required to pass a minimum flow for internal cooling any time the pump is running. The minimum flow rate GPM (m^3/s) is available from the pump manufacturer.

Normally, recirculation flow is taken from the pump discharge and returned to the deaerator via the minimum flow line. A valve in the minimum flow line is actuated either by modulating control or on/off control.

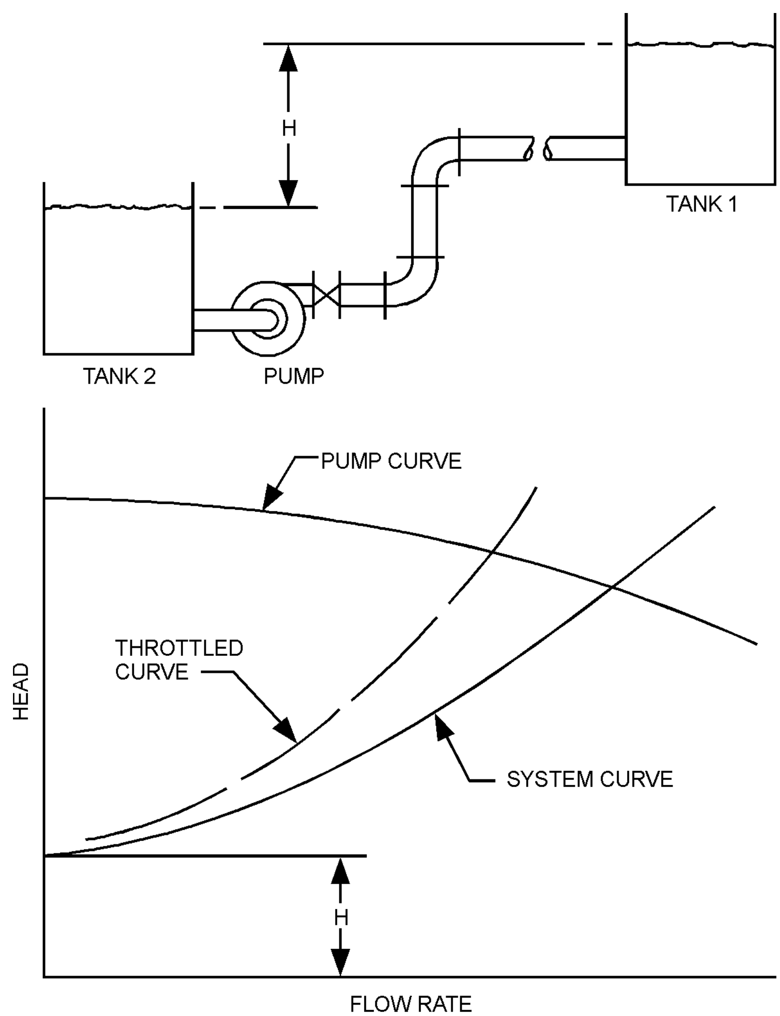

Figure 7 — Positive static head curves

A flow transmitter is used in the boiler feedpump suction or discharge line to measure flow through the pump. Any time this flow drops below the minimum rate specified by the pump manufacturer for adequate cooling flow, a controller actuates the valve in an opening direction to assure adequate flow.

A.9 Redundancy

Redundancy is employed when system reliability will be seriously affected by a component failure. Redundancy also permits on-line maintenance of components. For maximum availability, redundancy should always be considered. Deviation alarms and automatic failure detection/transfer should be considered in order to maximize the usefulness of the application of redundancy.

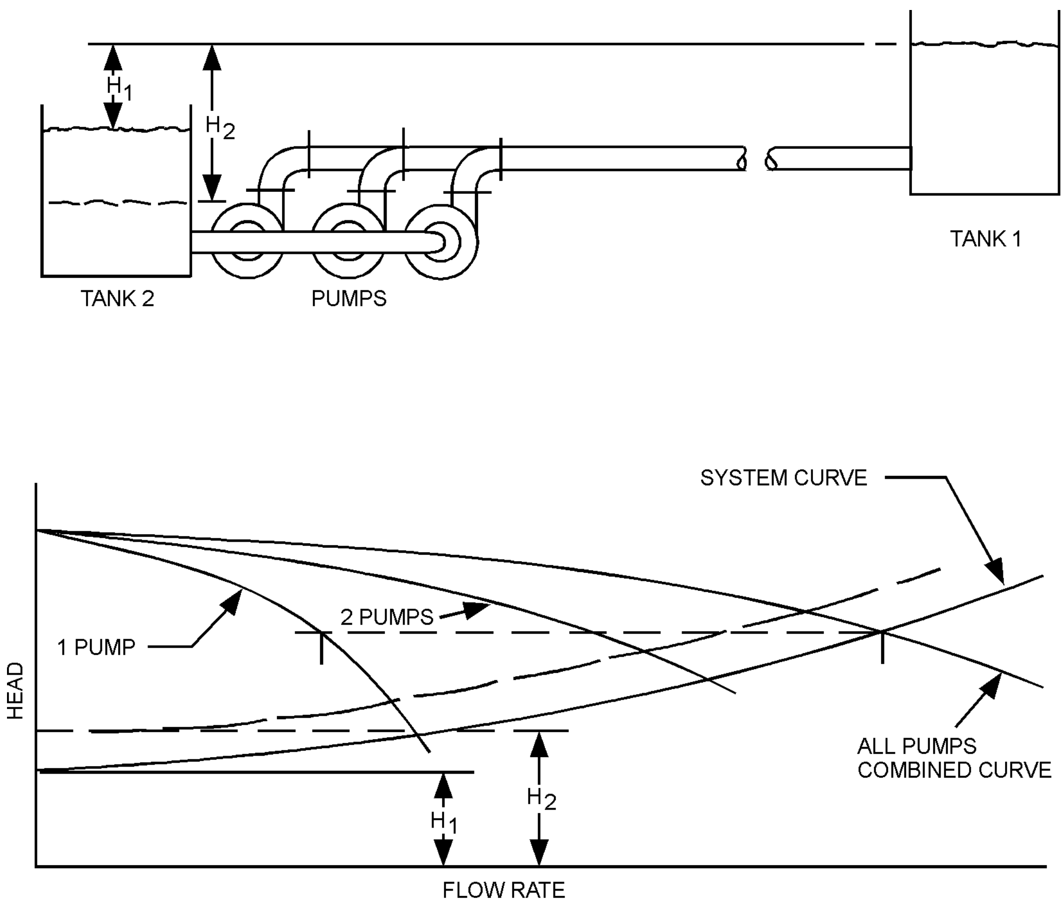

Figure 8 — Positive static head curves — pumps in parallel

A.10 Drum level oscillations

Under certain operating conditions, drum level oscillations in the form of wave action or standing waves in the drum can occur. This should not be confused with the shrink-and-swell phenomenon. On forced circulation units, combinations of pumps in service may also cause wave action. This oscillation can cause variations in drum level readings when they are taken at both ends of the drum. Boiler manufacturers should be consulted for recommendations on the expected magnitude of such oscillations.

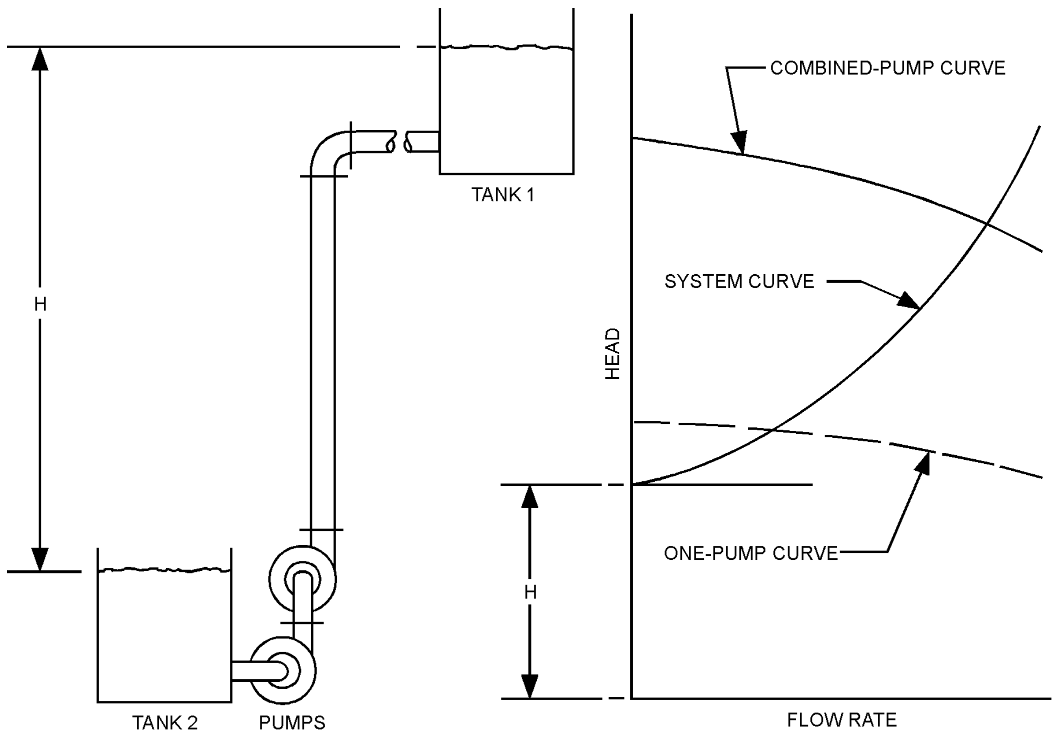

Figure 9 — Positive static head curves — pumps in series

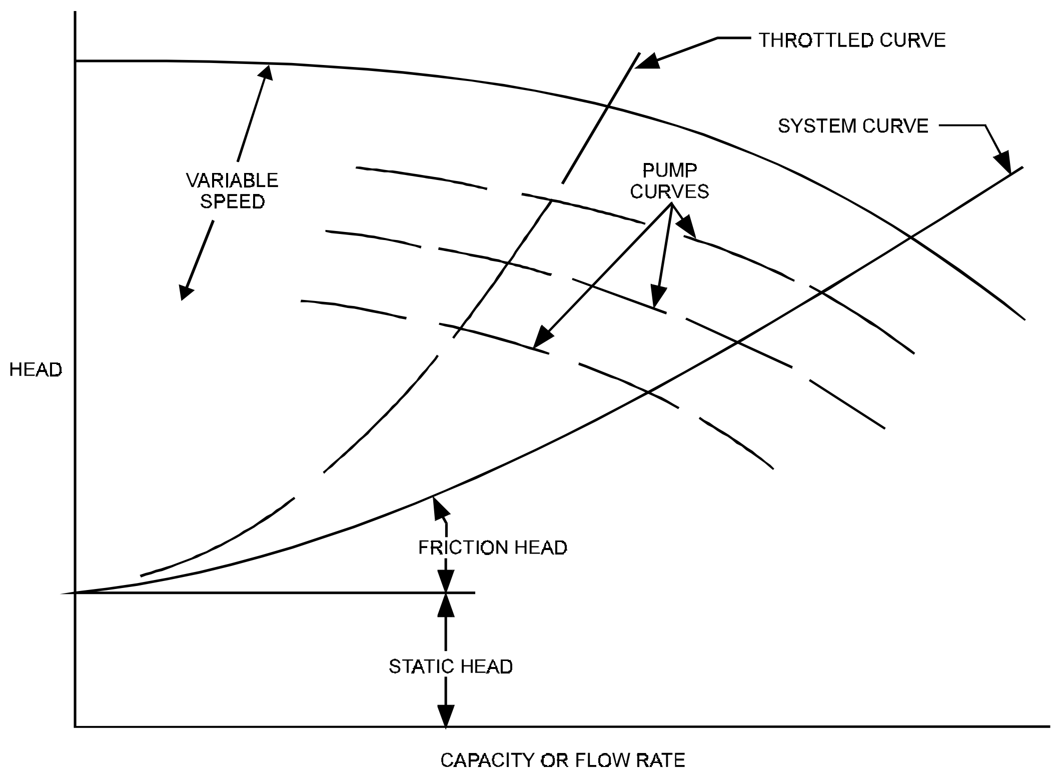

Figure 10 — Diagram depicting effects of throttling and speed reduction

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ISA
Attn: Standards Department
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709

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