ASME TDP-1–2013
(Revision of ASME TDP-1–2006)

Prevention of Water Damage to Steam Turbines Used for Electric Power Generation: Fossil-Fueled Plants

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

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The American Society of Mechanical Engineers
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FOREWORD

In the late 1960s, a substantial increase in the number of reported occurrences of steam turbine damage by water induction precipitated design recommendations from the two major U.S. steam turbine manufacturers in an attempt to reduce such incidents. Consequently, utilities and designers began formulating their own design criteria because of the economic need to keep the generating units in service. Realizing the common need for a uniform set of design criteria to alleviate this problem, an American Society of Mechanical Engineers (ASME) Standards Committee was formed, consisting of representatives of utilities, equipment manufacturers, and design consultants to develop recommended practices for use in the electric generating industry.

This Standard, resulting from the work and deliberation of the Turbine Water Damage Prevention Committee, was approved as a Standard of The American Society of Mechanical Engineers by the ASME Standardization Committee and the ASME Policy Board, Codes and Standards, on July 26, 1972.

In 1979, the Committee proposed a revision to this Standard to include information on condenser steam and water dumps, direct contact feedwater heaters, and steam generators. This proposed revision was approved by the ASME Standardization Committee on April 25, 1980.

The 1985 revision was approved as an American National Standard on September 13, 1985. In 1994, the ASME Board on Standardization approved the disbandment of the Committee on Turbine Water Damage Prevention along with the withdrawal of the standard TDP-1. This was due to perceived lack of interest and use by the industry.

Subsequent interest from users and potential users for TDP-1 convinced ASME to reconstitute the Committee under the Board on Pressure Technology Codes and Standards in June 1997. As a result of this committee's work, TDP-1–1985 was revised and approved as an American National Standard on June 17, 1998.

Advances in power plant technology, most notably combined cycle, multiple steam generators, cycling, cogeneration technology, and modern plant instrumentation and control systems, convinced the Committee to again revise the Standard. The result was TDP-1–2006. This revision was approved as an American National Standard on November 6, 2006.

The current Standard is a revision of TDP-1–2006. The broad acceptance that this Standard has received caused ASME to decide to reissue it in mandatory language rather than a recommended practice. In addition to the change to mandatory language, this revision also includes minor modifications and clarifications to the previous revision. This revision was approved as an American National Standard on February 5, 2013.

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Turbine Water Damage Prevention

(The following is the roster of the Committee at the time of approval of this Standard.)

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PREVENTION OF WATER DAMAGE TO STEAM TURBINES USED FOR ELECTRIC POWER GENERATION: FOSSIL-FUELED PLANTS

1 SCOPE

This Standard includes recommended practices concerned primarily with the prevention of water damage to steam turbines used for fossil-fuel-fired electric power generation. The practices address damage due to water, wet steam, and steam backflow into a steam turbine. The practices are applicable to conventional steam cycle, combined cycle, and cogeneration plants. The practices cover design, operation, inspection, testing, and maintenance of those aspects of the following power plant systems and equipment concerned with preventing the induction of water into steam turbines:

(a) motive steam systems
(b) steam attemperation systems
(c) turbine extraction/admission systems
(d) feedwater heaters
(e) turbine drain system
(f) turbine steam seal system
(g) start-up systems
(h) condenser steam and water dumps
(i) steam generator sources

Any connection to the turbine is a potential source of water either by induction from external equipment or by accumulation of condensed steam. The sources treated herein specifically are those found to be most frequently involved in causing damage to turbines. Although water induction into the high and intermediate pressure turbines has historically been recognized as the most damaging, experience has shown that water induction in low pressure turbines can cause significant damage and should also be taken seriously.

This Standard is not intended to impose new requirements retroactively for existing facilities.

2 CRITERIA

2.1 Basis

2.1.1 The normal practice to prevent turbine water induction is to

(a) identify systems that have a potential to allow water to enter the turbine

(b) design, control, maintain, test, and operate these systems in a manner that prevents accumulation of water

2.1.2 However, since malfunctions do occur, implement one or more of the following steps to prevent turbine damage due to water induction:

(a) detect the presence of water either in the turbine or, preferably, external to the turbine before the water has caused damage

(b) isolate the water by manual or, preferably, automatic means after it has been detected

(c) dispose of the water by either manual or, preferably, automatic means after it has been detected

2.1.3 No single failure of equipment, device, or signal, or loss of electrical power, shall result in water or cold steam entering the turbine.

2.1.4 Steam lines connecting to the steam turbine directly or indirectly shall be designed to ensure that any saturated steam or condensate that may have collected while the line or portion of the line was out of service is drained and warmed adequately prior to being returned to service.

2.1.5 Any automatic control system used to control steam line drain valves identified in these guidelines shall be designed so that the system has a means of initiating automatic valve actuation and a separate means of verifying the appropriateness of the automatic action. For example, if a drain valve is closed automatically based on a timer, something other than the timer, such as a level switch that would alarm if water were still present in the steam line, shall be used to verify that the timer initiation was appropriate. If an inappropriate action is taken, an alarm shall be provided.

2.1.6 An integrated control system (ICS) such as a distributed control system (DCS) can, by its inherent design, provide additional control and monitoring capability for power plant systems and equipment. Use of an ICS has been considered as an option for control and monitoring potential sources that might allow water to enter the turbine. If an ICS is available, the additional redundancy and availability of that system shall be used as indicated in this Standard. However, if no ICS is provided, following the non-ICS specific requirements is intended to still represent a conservative design for protection from water induction.

2.2 Definitions

2.2.1 General

cold steam: as a general rule, steam inducted into the steam turbine with the steam temperature more than 100°F (55°C) lower than the temperature expected for the operating condition of the turbine, or loss of measurable superheat. Temperature mismatches of more than 100°F (55°C) may be permissible on a case-by-case basis, if this has already been considered in the design of the turbine.

combined cycle: used in this Standard, a hybrid of the gas turbine (Brayton) and steam (Rankine) cycles. Waste heat contained in the gas turbine exhaust is fed through a heat recovery steam generator that produces steam that is expanded through a condensing steam turbine to produce power.

conventional steam (Rankine) cycle: steam is produced by heating water in a steam generator and then expanded through a steam turbine to produce power.

2.2.2 Systems

admission steam (induction steam): steam admitted to a steam turbine through an extraction/induction opening. During certain operating modes, the same turbine opening can supply extraction steam, depending on the pressure in the steam line compared to the prevailing steam turbine stage pressure. This dual mode of admission and extraction is termed "dual admission/extraction."

auxiliary steam: a steam system used outside of the main cycle systems for plant uses such as equipment power drives, air heating, building heating, start-up heating, etc.

condensate: the main cycle piping system that transports water from the condenser to the deaerator, feedwater system, or steam generator. Heating and purification of the water may be a part of this system.

extraction steam (nonautomatic, uncontrolled, or bleed steam): a steam turbine connection (opening) from which steam can be extracted at an uncontrolled pressure. This system may provide steam to feedwater heaters, other plant services, and process steam.

feedwater: a system that transports water from the condensate system, deaerator, or other storage vessel to the steam generator. Heating of the water may be included as part of this system.

gland steam (turbine steam seal): a steam system that provides steam at a pressure slightly above atmospheric conditions to connections at the steam turbine glands (seal areas at rotor shaft ends). This is done to prevent air leakage into turbines operating with steam conditions less than atmospheric pressure. The system normally includes piping to route high pressure turbine gland leakoff steam to the low pressure turbine glands.

heater drain: a system that removes condensate from feedwater heaters in the feedwater and condensate systems. The systems are generally designed to cascade the drains to the next lowest pressure heater, with the heaters in the feedwater system ultimately draining to the deaerator, and the drains from the heaters in the condensate system draining to the condenser. The drains may be pumped forward from the feedwater heater into the condensate line downstream of the heaters. The system also includes alternate drains to the condenser for start-up, shutdown, and emergency conditions.

motive steam: a steam system that supplies steam to a steam turbine for the primary purpose of power production or to an auxiliary turbine such as a boiler feed pump drive turbine. The term "motive steam" is intended to include steam lines typically referred to as main, hot and cold reheat, high pressure, intermediate pressure, low pressure, and admission. Motive steam lines as defined and used in this Standard do not include lines typically referred to as extraction steam and gland steam seal lines.

process extraction steam: a piping system that routes steam from connections on the turbine systems to other plant services and outside processes.

start-up: a system of piping, valves, and equipment used for starting the unit. This system may include a flash tank and the turbine bypass system. See also *turbine bypass.*

turbine bypass: a steam system designed to bypass steam around the steam turbine during start-up and shutdown operations. This system enables the steam generator to operate independently of the steam turbine for turbine warm-up, trip, and possibly sustained steam generator operation without the steam turbine being in operation.

2.2.3 Equipment

attemperator (desuperheater): a device for reducing steam temperature, usually by introducing water into a steam piping system.

automatic valve: a power-operated valve that receives a signal from a process controller or process switch to open or close. The valve may or may not be a block valve. Control valves, like attemperator spray valves, are considered automatic valves. See also *manual or remote manual valve* and *power-operated block (or drain) valve.*

auxiliary boiler: a secondary steam generator used in a generating plant to produce steam for use in auxiliary steam systems.

auxiliary turbine: a steam turbine used to drive mechanical equipment such as boiler feedwater pumps, fans, etc. This turbine is generally supplied with motive steam from the steam cycle. This turbine may exhaust into the steam cycle, to a process, or to a condenser.

block valve: an on-off valve that is used to start or stop the process flow. These valves are also referred to as isolation or shutoff valves.

boiler feedwater pump: a motor- or steam-turbine-driven pump that raises the feedwater water pressure to that required at the steam generator inlet.

bypass valve: a valve used in a bypass line that circumvents a primary valve or device.

closed feedwater heater: a shell-and-tube heat exchanger used to heat condensate and feedwater in the steam cycle. Water is pumped through the tube side and is heated by turbine extraction steam introduced on the shell side of the heater. Condensate on the shell side is removed by the heater drain system.

condenser: equipment that condenses low pressure turbine exhaust steam and thus provides the heat sink for the cycle. Normally, a condenser also serves to collect the condensate into a hotwell to supply the condensate system. Condensers may be of the following types:

air cooled: the turbine exhaust steam is routed to large heat exchangers arranged so that cooling air passes through them and steam is condensed directly. The condensate is collected in a drain tank that functions as the hotwell for condensate system supply.

auxiliary: a condenser is designated as auxiliary when it is supplied primarily for steam-turbine-driven auxiliary equipment or for steam dumps.

direct contact: condensate from the condenser is routed to a closed cooling heat exchanger and then returned, where it contacts the steam to continue the condensing process.

water cooled: this condenser, the most common type, is supplied with cooling water from a natural source or a cooling tower.

wet-dry: a cooling tower combination employs an evaporative cooling system (water-cooled) for a portion of the cooling and includes an air-cooled section for the remaining cooling.

continuous drain: a drain that does not contain a valve, trap, or other device to cycle and pass drains intermittently.

controlled extraction (automatic extraction): a steam turbine connection (opening) from which steam can be extracted at a substantially constant pressure. This can be achieved with an internal or external control valve holding substantially constant extraction pressure.

deaerator (open or direct contact heater): a feedwater heater that functions by mixing the steam with the condensate or feedwater. A contact heater that is especially designed to remove noncondensable gases is termed a deaerator. These heaters are often provided with a separate storage tank.

drain tank (flash tank): a tank into which relatively high temperature water and steam at a higher pressure enters and separates into steam and water at the lower tank pressure. The steam and water components can then be taken separately from the tank. This device is often used to reduce the temperature/pressure severity of water/steam entering high-energy drains before they are dumped into the condenser.

drain valve: a block valve used to isolate a steam line drain.

gas turbine (combustion turbine): a mechanical device that operates in the Brayton cycle converting chemical energy in a liquid or gaseous fuel into electrical power. When operating in combined cycle mode, the waste heat from the gas turbine is used in a heat recovery steam generator (HRSG) to generate steam for use in a steam power cycle.

gland steam condenser: a condenser used to recover the heat and condensate of the turbine steam leakoff from the seal steam system. It is a shell-and-tube heat exchanger typically located in the condensate system, with condensate flowing through the tubes. The leakoff steam condensate is drained to the condenser or other collection vessel, and the entrained air and other noncondensables are vented to the atmosphere.

level element: a device used directly or indirectly to measure level and provide a corresponding output signal.

main turbine: the entire steam turbine-generator machine, including all of its separate components. A typical large turbine unit may have a high pressure section, an intermediate pressure or reheat section, and one or more low pressure sections. A small turbine may include only one section.

manual or remote manual valve: a valve that requires operator action to open or close. The valve may have a power operator to allow remote actuation to be initiated by the operator in the control room. See also *automatic valve* and *power-operated block (or drain) valve.*

nonreturn/check valve: a valve that is designed to prevent a reverse flow in a pipeline. Flow in the desired direction keeps the valve open, while a reversal in flow closes the valve.

power-assisted nonreturn/check valve: a nonreturn/check valve that has an actuator that serves as a backup to close or partially close the valve and that assists in rapidly closing the valve, but is free-closing on reverse flow regardless of actuator status.

power-operated block (or drain) valve: a block or drain valve with a power operator, usually either a pneumatic or motor operator. The valve may be automatic or remote manual, with actuation initiated by the control system automatically (automatic valve) or by the operator manually from the control room.

steam generator: the equipment that provides heat to turn feedwater into motive steam and also reheats the steam in a reheat cycle. In a conventional steam generator, the heat is produced by the burning of fuel (usually coal, oil, or gas). In an HRSG, the heat comes from the exhaust of an external heat source such as a gas turbine, sometimes supplemented by the burning of additional fuel in the gas turbine exhaust. Drum-type steam generators employ a large drum to separate steam from the water as it boils in the tubes. The drum accommodates the increase in volume resulting from the water's conversion to steam, which is then taken from the drum through a section of superheating tubes to obtain the temperature needed at the main turbine. In the once-through type of steam generator, which does not use a drum, the feedwater is converted to motive steam conditions as it passes directly through the tubes.

2.2.4 Control System

integrated control system (ICS): a control system featuring multiple processors, input/output (I/O) modules, and memory storage interconnected through a communication network and equipped with redundant power supplies. Normally, a distributed control system (DCS) or redundant programmable logic controllers (PLCs) will meet this requirement.

local control system: a system that controls the final control element from a location in the vicinity of the primary element or the final control element.

2.3 Symbol Legend

See Table 1 for symbol legend to be used for reference to figures.

2.4 Device Identification Letters

See Table 2 for a list of device identification letters.

2.5 References

The following is a list of publications referenced in this Standard.

ANSI/ISA 5.1-2009, Instrument Symbols and Identification

Publisher: International Society of Automation (ISA), 67 T.W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709 (www.isa.org)

CS-2251, Recommended Guidelines for the Admission of High-Energy Fluids to Steam Surface Condensers

Publisher: Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304 (www.epri.com)

Standards for Closed Feedwater Heaters, Eighth Edition (2009)

Standards for Steam Surface Condensers, Tenth Edition (2006 or latest edition)

Publisher: Heat Exchange Institute (HEI), 1300 Summer Avenue, Cleveland, OH 44115-2815 (www.heatexchange.org)

3 DESIGN

This section outlines specific requirements for the design of the systems listed. These requirements are intended to represent a conservative design for protection from water induction. There is no intention to supersede any existing codes or governmental regulations.

3.1 Steam Generators

3.1.1 It is the plant designer's responsibility to review and understand the design features of the steam generator and the user's responsibility to adhere to the operating procedures of the steam generator manufacturer as a precaution against water induction. The majority of the incidents of turbine water damage caused by water entering the turbine from the steam generator system have occurred during start-up or shutdown of a unit. The steam generator manufacturer's design and operating instructions shall provide the measures required to prevent the induction of water into the motive steam piping. Such areas as superheater attemperators, boiler start-up systems, high drum levels, and undrained superheaters are potential sources of water.

3.1.2 Experience has shown that once-through flow units, because of their start-up system, hold a greater potential for water induction through the motive steam system during start-up and shutdown operating modes than do drum-type steam generators. The start-up system on once-through units shall be designed so that no single failure of equipment can result in water

Table 1 Symbol Legend

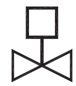
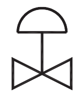
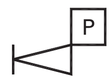
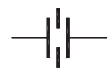
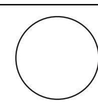
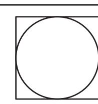
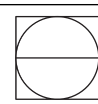
Symbol	Description
	Normally open valve
	Normally closed valve
	Open-shut power-operated valve
	Modulating control valve
	Check valve
	Power-assisted check valve
	Orifice
	Flow element
	Field mounted instrument
	Shared control, shared display function field mounted
	Shared control, shared display function normally accessible to the operator at primary panel (e.g., ICS)
	Hardware or software interlock

Table 2 Device Identification Letters

	First Letter	Succeeding Letters		
Letter	Measured or Initiating Variable	Readout or Passive Function	Output Function	Modifier
A	. . .	Alarm	. . .	. . .
C	. . .	. . .	Control	. . .
E	. . .	Sensor (primary element)	. . .	. . .
F	Flow rate	. . .	. . .	. . .
H	. . .	. . .	. . .	High
I	. . .	Indicate	. . .	. . .
L	Level	. . .	. . .	Low
P	Pressure	. . .	. . .	. . .
S	. . .	. . .	Switch	. . .
T	Temperature	. . .	Transmit	. . .
Z	Position	. . .	. . .	. . .

entering the motive steam line. Therefore, at least two [paras. 3.1.2(a) and (b), or (a) and (c)] of the following independent means of automatically preventing water from the start-up system from entering the motive steam lines shall be provided:

(a) automatic opening of the drain system to the condenser from the start-up system flash tank, separator, or leveling vessel on detection of high level.

(b) automatic closing of the block valve in the line from the start-up system (flash tank or separator) to the motive steam system on detection of high-high level in the flash tank or separator. The superheater division valve shall also be closed on high-high level.

(c) automatic block of all sources of water entering the start-up system by either tripping all feed pumps or closing the feedwater block valve in the supply line to the flash tank, separator, or leveling vessel on detection of high-high level in the flash tank or separator.

NOTE: These means of protection shall be activated prior to turbine steam admission.

Typical start-up systems for once-through boilers are shown in Figs. 1, 2, and 3. Figure 1 shows the implementation of the three independent means of protection listed above for a flash tank or separator start-up system using a local control system. Figure 2 shows the same means of protection implemented using an integrated control system (ICS).

3.1.2.1 In some once-through units, the start-up system design has evolved to separate the functions of steam/water separation using steam separators and separate leveling vessels, drain tanks, or water collecting tanks. These once-through units may also use sliding pressure start-up and may not include steam path block valves. In this situation, level control of the leveling vessel shall be maintained through controlled discharge to the condenser, which shall be forced open upon high level in the leveling vessel. Any additional valving in the line to the condenser shall also be forced open. If the level in the leveling vessel reaches a high-high level, a boiler-turbine trip shall be initiated. A typical system using a leveling vessel and an integrated control system is shown in Fig. 3.

3.1.2.2 When used for turbine water induction protection, the drain line block valve, the feedwater block valve, the superheater division valve, and the flash tank steam outlet block valve shall have indicators in the control room for the open and closed positions.

3.1.3 The start-up systems on other than once-through units (such as drum type) shall be designed so that no single failure of equipment can result in water entering the motive steam line. The design method to best accomplish this objective shall be determined by the designer.

3.1.4 Special consideration shall be given to drum level control, flash tank level control, and/or leveling vessel control design to realize a high degree of reliability such that no failure of instrumentation or equipment results in a release of water into the motive steam lines.

3.1.5 Heat recovery steam generator (HRSG) system configurations typically include as many as three steam drums, each with level controlled by feedwater valve modulation and condensate or feed pump recirculation or similar method of controlling inflows. The same plant design requirements that apply to other steam generators apply to HRSGs.

3.2 Steam Attemperators

This paragraph applies to all steam attemperators in or connected to motive steam and steam generator systems.

3.2.1 Spray water introduced into the steam generator ahead of the final superheat section is a means to control steam temperature at the superheater outlet. These sprays are generally not effective in controlling final superheat steam temperature at low loads or during

Fig. 1 Typical Flash Tank/Separators Arrangement: Local Control System

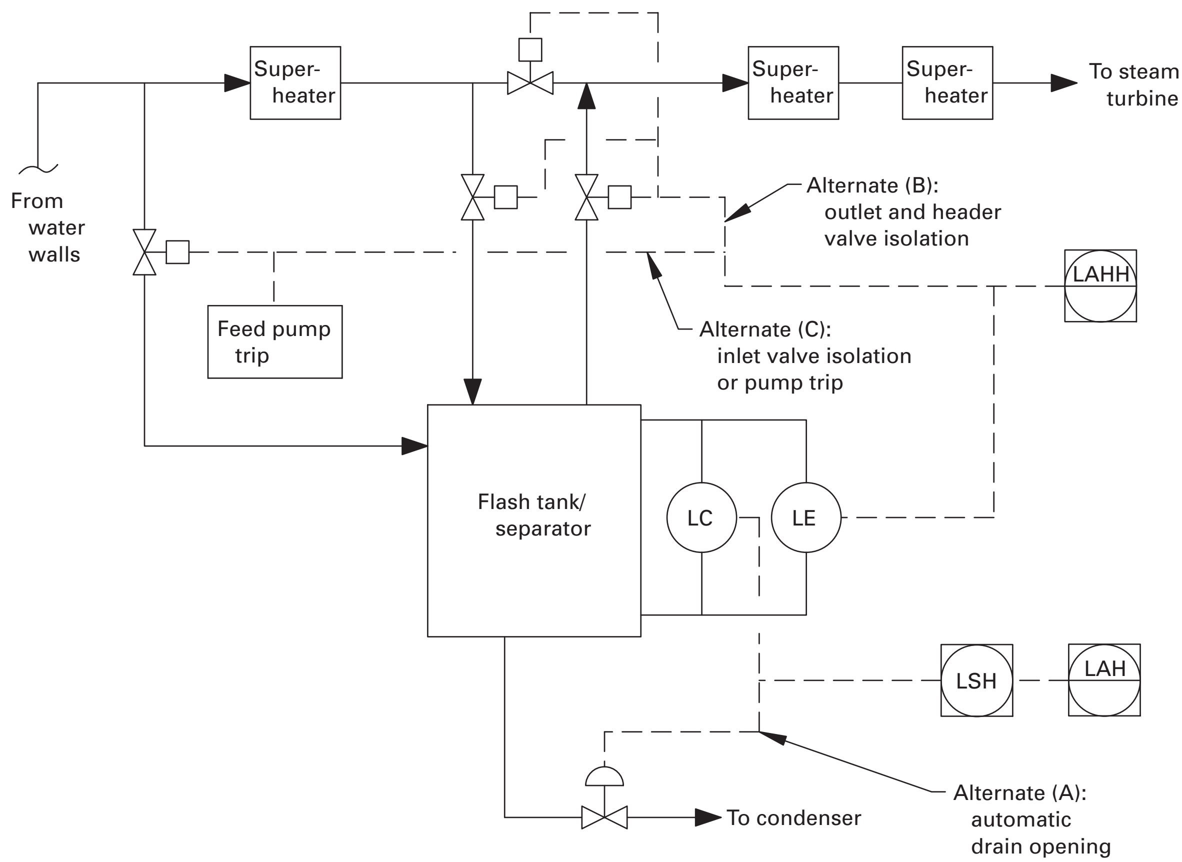
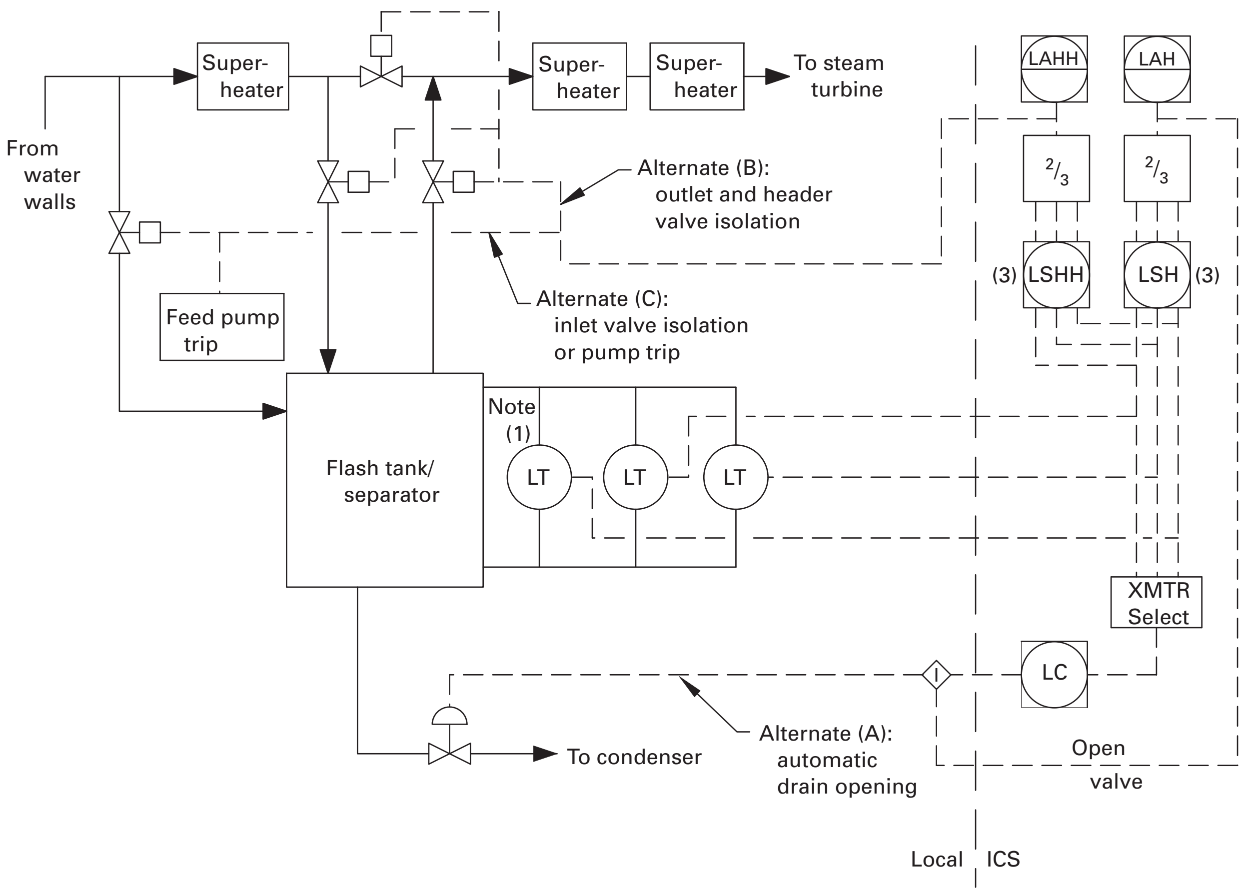
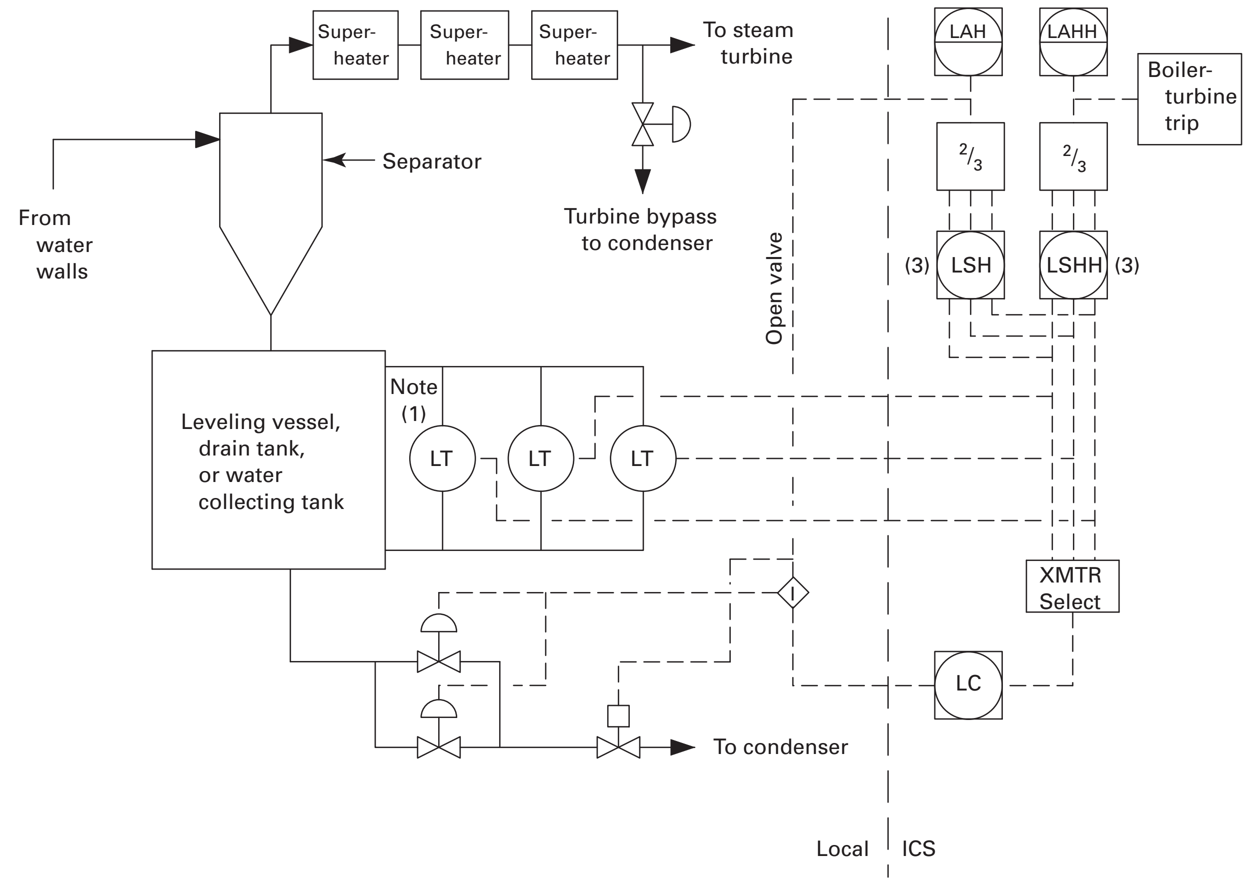


Fig. 2 Typical Flash Tank/Separators Arrangement: Integrated Control System



NOTE:
(1) Element may be transmitter or high-high level switch.

Fig. 3 Typical Leveling System Arrangement: Integrated Control System



NOTE:
(1) Element may be transmitter or high-high level switch.

turbine roll. The opportunity exists for water to accumulate in the pendant elements of the superheater during low load operation from either condensation or overspraying. Units that operate for extended periods of time with the spray header system charged to full pump discharge pressure (e.g., during start-up and shut-down conditions) are subject to possible leakage of the spray valves. Such leakage can result in water accumulating in the pendant superheater sections and may even flow over into the main steam system. When steam flow is increased rapidly, this accumulation of water can be injected into the turbine.

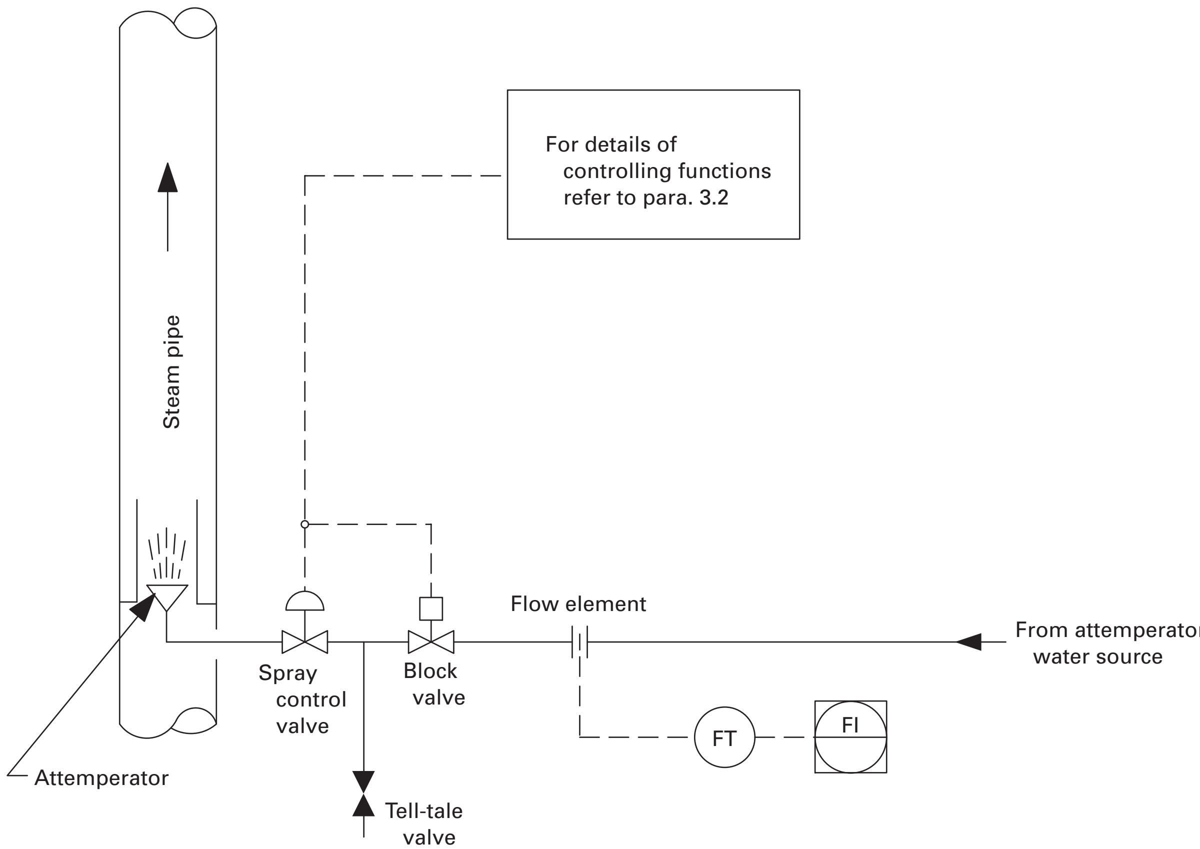
3.2.2 Spray water injection in the cold reheat line or between primary and final reheat sections is used as a means to control steam temperature at the reheater outlet. These sprays are not effective or normally required for reducing final reheat steam temperature when used at low loads or during turbine rolling. Most incidents of turbine water damage caused by attemperators have occurred during these periods as a result of overspraying. The water accumulates and flows back to the turbine, in most cases because of low steam velocity and the arrangement of the piping. Another potential source of water results when water accumulates from condensation in pendant elements of the reheater during a low load operation. This water can be injected into the turbine if flow is increased rapidly.

3.2.3 The use of attemperators external to the steam generator, downstream of the last superheating (or reheating) element, is discouraged; however, it is recognized that under some conditions it cannot be avoided. When this type of attemperator is required in the motive steam line to control the temperature of the steam entering a steam turbine, the following features shall be provided in addition to the other features listed in paras. 3.2.5 through 3.2.14:

(a) The attemperators shall not be allowed to operate when the steam exiting the attemperator will contain less than 50°F (28°C) of superheat unless a higher temperature is required by the turbine manufacturer.

(b) The attemperator shall be located as far from the steam turbine inlet as possible, but in no case closer than 50 pipe diameters.

Fig. 4 Typical Attemperator System



(c) The attemperator shall be located such that any associated water accumulation will drain in the direction of steam flow to a drain pot located at an elevation lower than the connection to the steam turbine. Thus, the piping shall be sloped toward the drain pot, and the drain pot shall be located between the attemperator and the steam turbine. This will result in the intentional creation of a low point to allow steam separation and water collection in the bottom of the pipe. An oversized drain pot shall be considered to enhance water collection at high steam velocity.

(d) The design of this type of attemperator system shall be coordinated with the steam turbine manufacturer.

3.2.4 The use of motive steam attemperators shall prohibit activation or increase in spray when the steam conditions downstream of the attemperator are within 25°F (14°C) of saturation temperature.

3.2.5 A power-operated block valve shall be installed upstream of the attemperator spray control valve. This valve provides tight shutoff to prevent water leaking past the spray control valve and provides a backup in the event that the spray control valve fails to close when required (see Fig. 4). The spray control and block valves constitute a double line of defense against the inadvertent introduction of spray water into the steam lines. Because spray control valves are susceptible to leakage, an additional block valve may be installed to provide additional protection.

3.2.6 The control system shall automatically close and override all manual and automatic settings of the spray control and block valves when the associated steam generator or the gas turbine trips.

3.2.7 The control valve shall be kept in the closed position until the block valve has reached the full open position. This will prevent wire drawing of the block valve seat and subsequent leakage through the block valve.

3.2.8 The block valve shall be automatically closed below a predetermined minimum boiler load and any time the demand signal to the control valves does not call for spray. Sprays shall not be released for automatic control at loads where it can be determined that it is relatively ineffective in reducing final steam temperature. The loads used shall be in accordance with the boiler/bypass valve manufacturer's recommendations. Manual control shall not prevent operation of the automatic protection features specified in para. 3.2.6. After a steam generator trip, operator intervention should be required to reset and reopen the attemperator block valves.

3.2.9 The attemperator shall be designed to achieve suitable atomization at the lowest and highest steam flow rates expected. Operation of the attemperator outside the range of suitable atomization is prohibited.

3.2.10 The control system for opening the spray control valve shall be designed to prevent the sudden injection of large quantities of water.

3.2.11 A manually operated drain valve shall be installed between the power-operated block valve and the spray control valve. This connection can be used as a telltale for periodically testing for block valve leakage.

3.2.12 If a bypass valve around spray control valves is used, it shall be power operated and actuated to close when the block valve is closed. Use of manual bypass valves around spray control valves is not recommended. If a manual bypass is used, a second power-operated block valve shall be provided as a second line of defense. If a manual bypass is used, the inherent possibilities of water induction shall be reduced through administrative control.

3.2.13 A bypass of the block valve shall not be provided under any circumstances.

3.2.14 Instrumentation shall be supplied as shown in Fig. 4 to indicate the flow rate of the spray water going to the attemperator.

3.3 Motive Steam Systems

Motive steam piping systems are defined in para. 2.2. Motive steam systems include systems traditionally referred to as Main Steam, Hot Reheat Steam, Cold Reheat Steam, and Boiler Feed Pump Turbine Steam Supplies for conventional steam cycles. Also included are systems referred to as High Pressure, Intermediate Pressure, Reheat, and Low Pressure Steam for combined cycle units. Generally, a motive steam system can be thought of as any steam line normally carrying steam to or from a steam turbine that is not an extraction line as covered in paras. 3.5 and 3.6. Steam seal lines are not considered to be motive steam lines and are covered in para. 3.9.

3.3.1 Because of the lack of detection instrumentation that will close steam turbine stop valves in time to prevent damage during steam turbine operation, no isolation recommendations are provided for the prevention of damage by water passing through the motive steam piping and into the steam turbine. If such devices are developed and marketed, consideration should be given to including this instrumentation. Rapid closure of steam turbine valves should not be considered as a method of preventing water induction into the steam turbine from a motive steam line.

3.3.2 Normal closure of the steam turbine admission stop and control valves with the opening of appropriate drains is considered a suitable method for isolating the steam turbine during start-up and other times when condensate might be present and the valves are already closed.

3.3.3 A drain shall be installed at each low point in motive steam piping. The review for low points shall consider all portions of the lines from the steam source outlet to the connection on the steam turbine, including any branches or dead legs (including those caused by valve closure). Each drain shall consist of a drain line connection or a drain pot connected directly to the bottom of the motive steam line. As a minimum, drain pots shall be used for the following lines (other lines do not require drain pots, but this Standard does not prohibit their use):

(a) motive steam lines that are prone to water accumulation during operation for which large drain collection areas and/or water detection devices are desired.

(b) cold reheat line at first low point downstream of the steam turbine exhaust (this application requires redundant level elements; see Fig. 5).

(c) motive steam lines that will be under vacuum during steam turbine start-up and shutdown.

(d) motive steam lines that operate (admit steam to the steam turbine continuously) with less than 100°F (56°C) superheat unless a continuous drain has been provided (this application requires redundant level elements; see Fig. 5).

(e) motive steam lines with attemperators. The drain pot shall be between the attemperator and the steam turbine (this application requires redundant level elements; see Fig. 5).

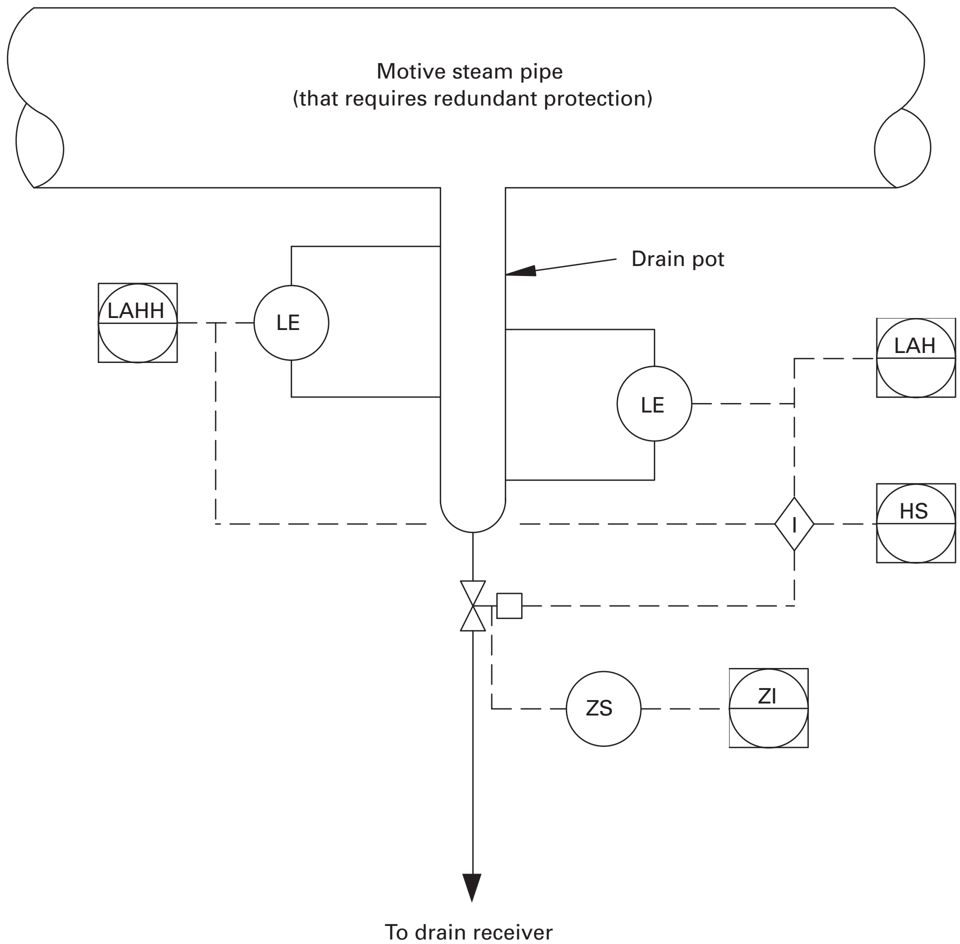
(f) branches and legs that will be stagnant during various operating modes, unless a continuous drain has been provided.

(g) at the steam turbine end of long horizontal runs [over 75 ft (23 m)].

When reviewing the location of low points, consideration shall be given to the installed position of the piping in both the cold and hot condition. Consideration shall also be given to sloping piping in the direction of flow to encourage drainage to the low point drain(s).

If the motive steam line is split into more than one branch going into the steam turbine, each branch, as well as the main header, shall be reviewed for low points. In addition, a warming connection, either separate or using existing drains, shall be located on each motive steam branch at the steam turbine inlet just before the steam turbine stop valve. This connection can be used with the drains in the system as a bleed-off point for warming the motive steam line during start-up. Motive

Fig. 5 Typical Drain System With Redundant Level Elements



steam piping drains shall not be manifolded with any other drains from the steam generator unless the manifold has been analyzed and designed so that the flow of each drain will not be impeded under any mode of operation.

3.3.4 Before-seat drains, or an equivalent connection, shall be provided on each turbine stop valve to permit complete draining of any water that may accumulate at a low point if the valve body is not self-draining. The before-seat drain on the turbine valve body, if provided, is for drainage of localized accumulation of water in the valve body. It should be noted that this drain might not be sized to handle drainage or warming of the main steam inlet piping leading up to the stop valve. Separate drains may be required to drain or warm up the main steam line.

3.3.5 Drains shall be provided between the steam turbine stop valve and first-stage nozzles to ensure removal of water. These would consist of after-seat drains on the steam turbine stop valve, before- and after-seat drains on the control or admission valves, and/or low point drains on any of the piping downstream of the stop valves.

3.3.6 Steam bypass systems shall be provided with the same level of protection as motive steam piping. The similarities shall include drains, drain pots (if applicable), and power-operated drain valves with control room indication. Bypass systems discharging to vessels or process steam systems other than cold reheat (or any other line connected back to the steam turbine) shall be designed to prevent backup of water due to vessel or process steam line high water level. Attemperators in bypass systems that discharge to the cold reheat system (or any other line connected back to the steam turbine) shall be designed consistent with the requirements of para. 3.2 on attemperators.

3.3.7 Nonreturn valves shall be provided in the cold reheat system to prevent the reverse flow of bypass steam into the steam turbine during start-up and during bypass system operation if the piping system design provides a source of cold reheat pressurization when the steam turbine is shut down. The nonreturn valve(s) may be power assisted according to the requirements of the main steam turbine manufacturer and actuated by a main steam turbine trip. The number of nonreturn valves is to be determined by the main steam turbine manufacturer.

3.3.8 Systems with a high potential to cause turbine water induction damage require the same protection as motive steam systems and additionally require the special design considerations outlined below. One such system is the cold reheat system, which has caused numerous instances of steam turbine water induction damage that have been attributed to the presence of water in the cold reheat line. This water is usually introduced into the system from the reheat attemperator spray station, the high pressure bypass attemperators, or the feedwater heaters, which extract steam from the cold reheat line. Designing a drainage system with sufficient capacity to remove all water that can be introduced into the cold reheat pipe from these sources is considered impractical because of the potentially high rate of flow into this piping from these sources. For this reason, the system shall be designed to stop the inflow of water automatically or to provide an alarm signal to permit operator action to stop water inflow. Systems with a high potential of causing turbine water induction damage require redundant level controls (see Fig. 5), as well as the following:

(a) The power-operated drain valve shall open automatically on high water level or high-high water level detected in the drain pot and shall not be capable of remote manual control to the closed position any time water is detected in the drain pot.

(b) The first level (high level) shall actuate to fully open the power-operated drain valve and shall initiate an alarm in the control room indicating that the valve has opened. The second level (high-high level) shall initiate a high-high level alarm in the control room.

3.3.9 When a gas turbine cooling steam or power augmentation steam pipe is connected to a motive steam line, this pipe shall not be connected at or near the low point of the motive steam pipe. If routing of this pipe creates a low point, a drain shall be provided from the pipe.

3.3.10 An auxiliary drive turbine, such as a boiler feed pump drive turbine, may receive throttle steam from different sources, and it is possible to have water in these piping systems. The following design guidelines are provided to assist designers in developing piping systems to prevent the induction of water into the main steam turbine through auxiliary drive turbine throttle steam supply lines. The protection of the auxiliary drive turbine itself shall follow the requirements for steam turbines as outlined in paras. 3.3.10.1 through 3.3.10.4.

3.3.10.1 Each auxiliary drive turbine throttle steam pipe connected to the motive steam piping or extraction piping shall contain not less than one nonreturn valve and block valve. The nonreturn valve(s) may be power assisted according to the requirements of the main steam turbine and is actuated by a main steam turbine trip. The number of nonreturn valves is to be determined by the main steam turbine manufacturer. The nonreturn valves shall be located so that they prevent steam bypass from one main steam turbine extraction zone to another.

3.3.10.2 All motive steam pipes connected to auxiliary drive turbines, including alternate sources, shall be heated whenever the units are operating so that they are available for immediate service. Power-operated drain valves, continuous orificed drains, and auxiliary drive turbine above-seat drain valves shall be considered typical. The power plant designer shall determine location of the warming orifices on the basis of the actual piping arrangement. When locating drains and warming lines, the designer shall consider the length of pipe both upstream and downstream of any valve that could cool down when that particular line is not flowing steam to the auxiliary drive turbine. Warming of only the upstream portion of stagnant piping systems may not be adequate if the downstream stagnant length is significant.

3.3.10.3 A drain with a power-operated drain valve on each side of the nonreturn valve station shall be provided. (A steam supply side drain may not be required if the pipe configuration is self-draining back to its source.) Each drain valve shall be bypassed with a line with a continuous orifice. The power-operated drains are used to heat the auxiliary drive turbine steam supply piping. The auxiliary drive turbine stop valve above-seat drains may be used for drainage if permitted by the manufacturer and of adequate capacity. Otherwise, a separate drain system shall be provided on the turbine side of the nonreturn valve station.

3.3.10.4 A connection on piping serving as a source of throttle steam for an auxiliary drive turbine (i.e., motive steam, cold reheat, or auxiliary source) shall be located on a vertical leg well above the low point in the source pipe or from the top of a horizontal run of piping.

3.4 Process Steam Lines

Process steam lines that are supplied from motive and extraction steam lines are a potential source of water induction. Motive and extraction steam lines shall be protected from process steam lines with the following features:

3.4.1 Two valves shall be provided to isolate the motive steam or extraction steam line from the process steam line. Acceptable combinations of the following items are (a) and (b), or (a) and (c):

(a) a power-operated block valve

(b) a pressure-reducing valve (control valve) with Fail-Closed capability against the maximum reverse differential pressure

(c) a power-assisted nonreturn valve

3.4.2 The designer should consider steam supply and process system upsets that may result in cold steam admission to the motive/extraction steam line.

3.4.3 Water detection and removal features between a motive steam line and the block valve shall be designed in accordance with this section and the requirements for motive steam lines. Water detection and removal features between an extraction steam line and the block valve shall be designed in accordance with this section and the requirements for extraction steam lines.

3.4.4 If an attemperator is required, it shall be located downstream of the valves required in para. 3.4.1.

3.4.5 If the piping downstream of the second isolation valve is not self-draining to a vessel (or other device) that will not allow water backup, and the piping is not terminated above the highest water level in that vessel, then water detection shall be provided in the form of a drain pot in the process steam line at the piping low point closest to the motive/extraction steam line. If water has accumulated downstream of the block valve, it shall be removed before the block valve is allowed to open. Detection of water downstream of the block valve during normal operation shall be alarmed in the control room. All other low points on the process steam line shall be provided with automatic drainage, but drain pots or automatic drain valves are not required.

3.5 Closed Feedwater Heaters and Extraction Systems

A major cause of turbine damage has been water induction from the extraction system, feedwater heaters, and associated drains. Therefore, it is important to pay considerable attention to the design of these areas. Extraction systems shall be designed in accordance with paras. 3.5.1 through 3.5.15 to minimize the possibility of water damage to the turbine.

3.5.1 The system shall be designed so that no single failure of equipment results in water entering the turbine. Two independent means of automatically preventing water from entering the turbine from the extraction system shall be provided. In general, these independent means shall be a combination of the following items (a) and (b), or (a) and (c):

(a) an automatic drain system from the heater shell (see para. 3.5.1.1 and Figs. 6 through 9)

(b) power-operated block valves between the feedwater heater and the turbine and power-operated block valves in cascading drain lines (see para. 3.5.1.2 and Figs. 6 and 7)

(c) power-operated block valves on all sources of water entering the heater shell and power-operated block valves on all sources of water entering the heater tubes (see para. 3.5.1.3 and Figs. 8 and 9)

Power-operated block valves shall not be interlocked with any permissive that would prevent closure and shall be activated on high or high-high level independent of control from that identified in para. 3.5.1.1.

3.5.1.1 The automatic drain system from the heater shall consist of a normal (primary) and an alternate (emergency) drain. An alternate drain shall be installed on each feedwater heater in addition to any drains cascading to another feedwater heater. This alternate drain shall include a power-operated drain valve. Figures 6 and 8 show the normal primary drain line with its associated level control and an automatically operated alternate drain and its level control system. Figures 7 and 9 depict the same control scheme using an integrated control system. The following features shall be incorporated into the automatic heater shell side drain system:

(a) The normal drain shall be sized for all normal operating conditions including operation with heater drains pumps out of service.

(b) The alternate drain shall be designed to discharge directly to the condenser. (A second normal drain or bypass does not constitute suitable alternate drain.)

(c) In the case of low-pressure heaters with internal drain coolers, the alternate drain shall be connected directly to the heater shell ahead of the drain cooler to provide positive drainage (in case of damage of cooler).

(d) The alternate drain shall activate on heater high level and shall be fully open when the heater level reaches high-high. The alternate drain line shall be sized to handle 100% of the cascading drain flow into the heater plus 100% of the extracted steam flow under all continuous operating conditions, including a lower pressure heater that is out of service.

(e) For heaters operating near condenser pressure, a loop seal may be used in the drain line in lieu of a control valve. Since a loop seal is a passive device, one properly sized drain line can be used as both a normal and an alternate drain.

(f) The normal drain level control valve in drains cascading to a lower pressure feedwater heater shall be designed on loss of power, air, or ICS processor communications, if applicable, to fail in the closed position (Fail-Closed).

(g) Normal and alternate drain valves in drains directed to the condenser shall be designed on loss of power, air, or ICS processor communications, if applicable, to fail to the open position (Fail-Open).

3.5.1.2 Power-operated block valves shall be included in the extraction line from the turbine to the feedwater heater. The valves and associated equipment

Fig. 6 Typical Heater Steam Side Isolation System: Local Control System

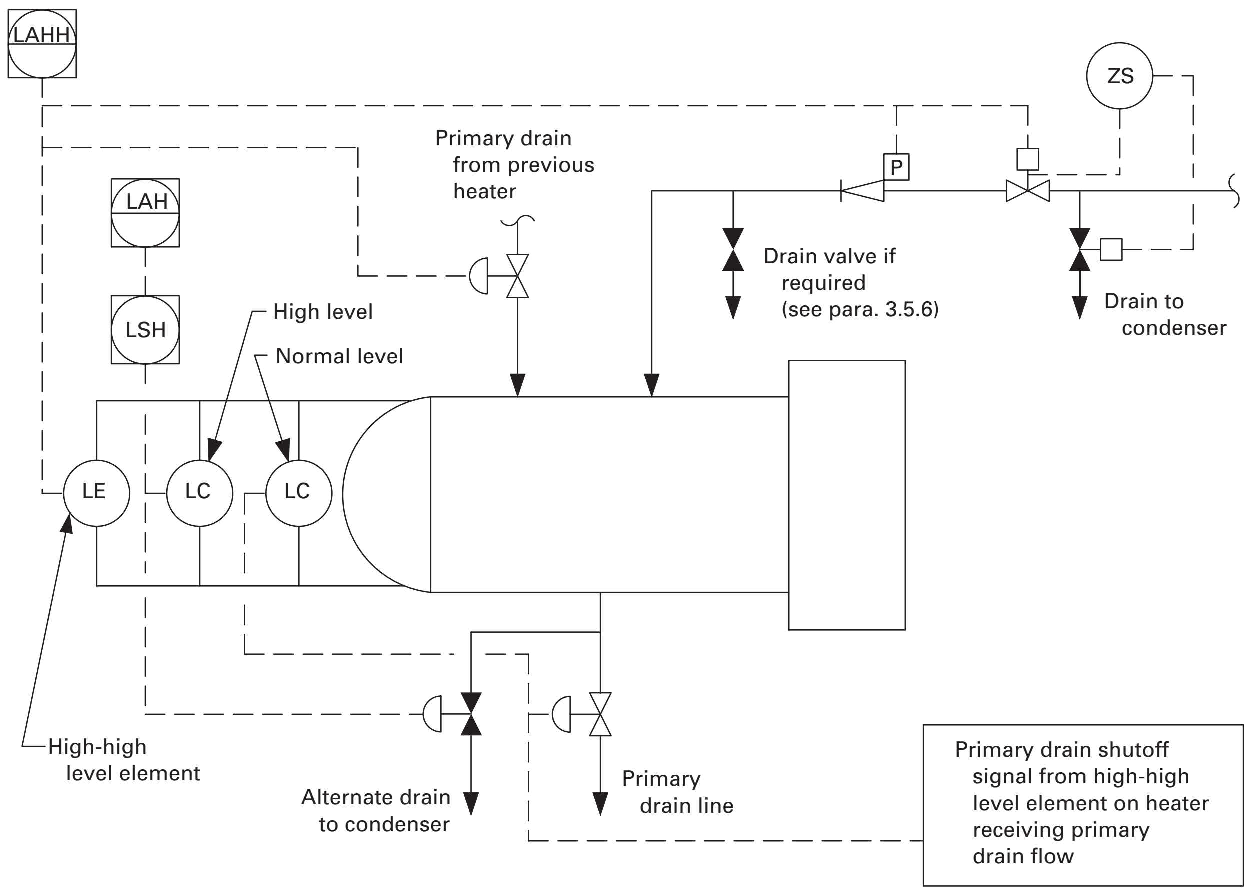
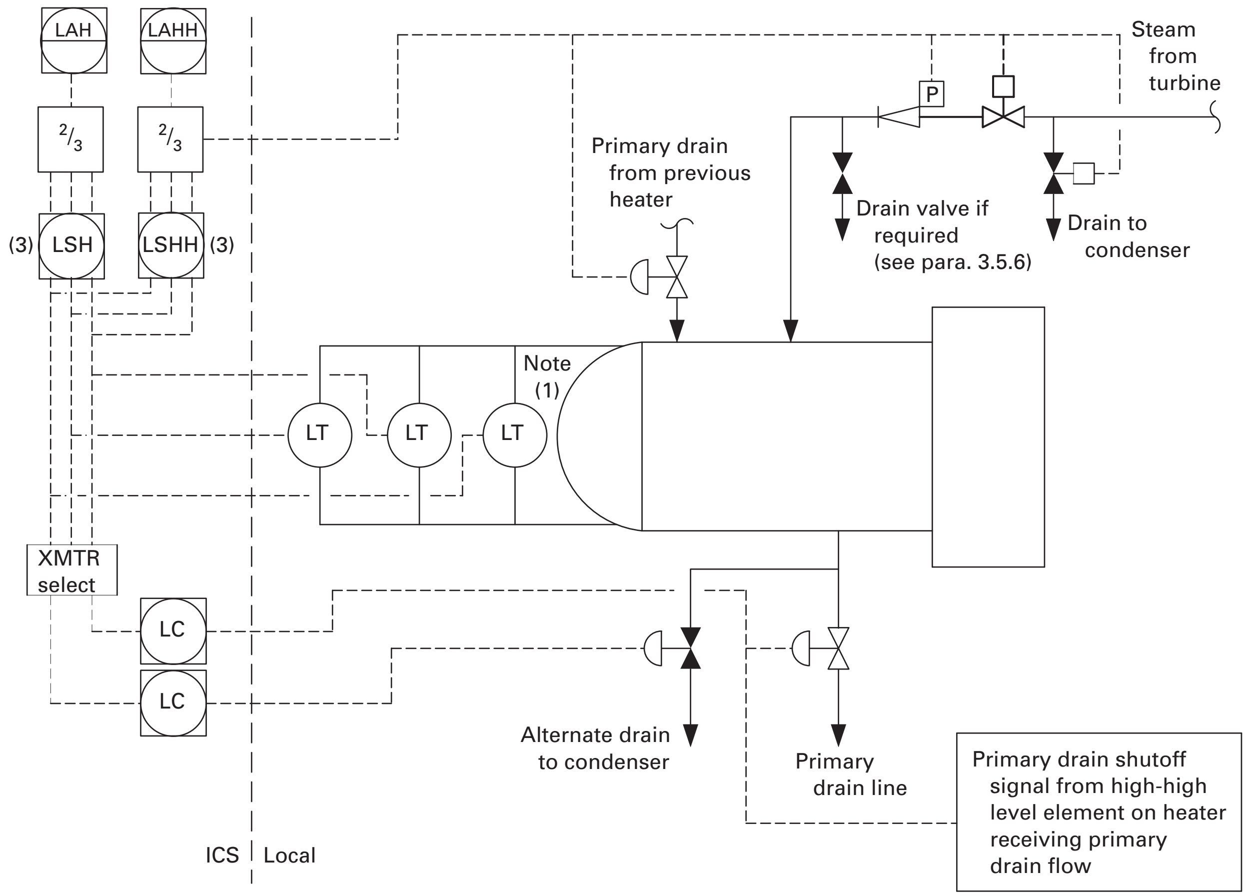


Fig. 7 Typical Heater Steam Side Isolation System: Integrated Control System



NOTE:
(1) Element may be transmitter or high-high level switch.

are shown in Figs. 6 and 7. These valves are actuated to close by a high-high level in the feedwater heater with a control independent from that described in para. 3.5.1.1.

Actuation of these valves indicates that the heater drainage system described in para. 3.5.1.1 is not keeping up with the draining of the heater. Therefore, cascaded drains to this feedwater heater shall be designed to automatically close on this heater's high-high level. This cascaded drain flow from the previous heater will then be bypassed to the condenser through its alternate drain.

The required speed of operation of the power-operated block valves depends on the total amount of excess water flowing to the heater and the volume between the high-high level and the block valve. The total amount of excess water flowing to the heater for purposes of this calculation shall be the larger of

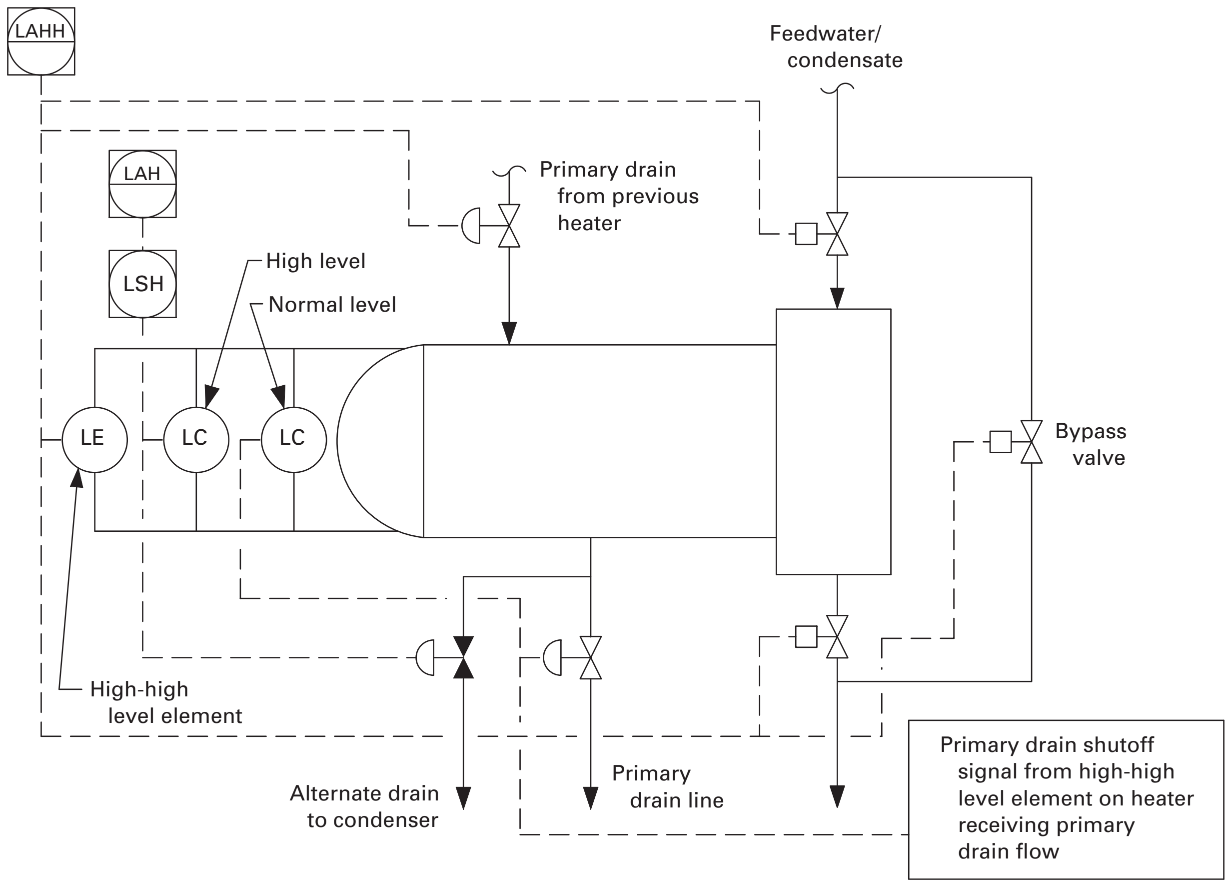
(a) water flowing from two ruptured tubes (four open ends)

(b) water equivalent to 10% of the tube side flow

For these two conditions, it is assumed that the normal heater drain or its alternate to the condenser is capable of draining the water that is cascaded to the heater from previous heaters and from the normal stage extraction flow for this heater (including lower pressure heater out-of-service scenarios). The maximum flow of water from conditions described in para. 3.5.1.2(a) or (b) is then considered to be contributing to a rising level in the heater. The required time of operation of the block valves is then calculated by using the larger flow rate of the above two conditions and the usable pipe and heater storage volume between the high-high level and the block valve. With some heater arrangements such as vertical heaters or heaters at or above the turbine, care shall be taken in determining usable storage volume, since water can begin to flow backward once the invert elevation in the piping is flooded. Additionally, the tube bundle occupies a large portion of the shell volume that cannot be counted in the storage volume.

More information regarding the calculation of tube rupture flow rates can be obtained from the Heat Exchange Institute (HEI), Standards for Closed Feedwater Heaters (see para. 2.5).

Fig. 8 Typical Heater Tube Side Isolation System: Local Control System



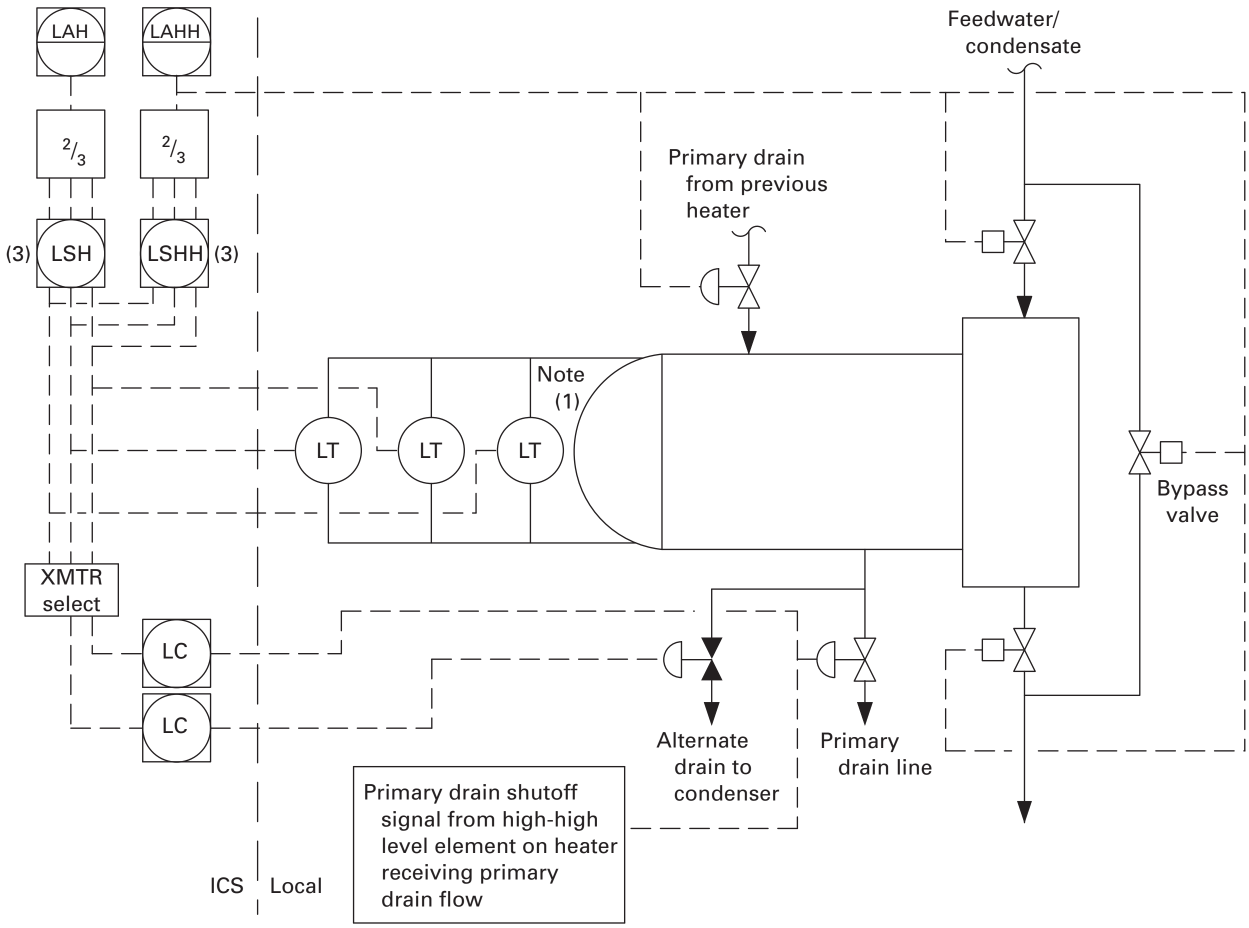
Check valves of either the free swing, power-assisted, or positive closing design are not considered a satisfactory block valve for this application because of possible seat and disk distortions. These check valves are normally provided for fast action to limit overspeed due to entrained energy in the extraction system. They can afford some protection from a water induction standpoint however, and should be closed automatically by the same signal that closes the associated block valve.

3.5.1.3 It may be impractical to install the block valves as shown in Figs. 6 and 7 for feedwater heaters in the condenser neck. Therefore, an acceptable alternative to the second line of defense shown in Figs. 6 and 7 is to bypass the feedwater heaters as noted in Figs. 8 and 9. This will remove the heater from service and cut off the source of water that results from tube leaks. The required speed of operation of these power-operated isolation and bypass valves shall be determined according to the method of para. 3.5.1.2 based on the time required to fill the heater to the top of the shell. These isolation valves shall only be opened with direct operator intervention, never by automatic preprogrammed control system action. The bypass valve shall be opened concurrent with closing the isolation valves and shall be sized to handle the full flow. The bypass operator speed shall be fast enough to avoid system upsets. The bypass valve closure may need to be independently operated to provide start-up flexibility. Drains cascaded into the heater shall also be automatically shut off based on the signal from the high-high level element.

3.5.1.4 If the feedwater heater bypass control method is used to protect more than one heater, separate level elements on each heater shall independently actuate the isolation system on high-high level in either heater. Occasionally, small bypass valves are installed around the tube side isolation valves shown in Figs. 8 and 9. These are generally used to equalize the pressure on each side of these large isolation valves to open them and to warm the tube sheets of high pressure heaters. Where such bypass valves are provided, they shall be power operated and close automatically on the same signal that closes the larger valves, or they shall be manual valves that are locked closed during normal operation.

3.5.2 Baffles placed above the water level in feedwater heaters are frequently required to control the rate of steam flow back into the turbine to limit the resulting

Fig. 9 Typical Heater Tube Side Isolation System: Integrated Control System



NOTE:
(1) Element may be transmitter or high-high level switch.

energy contribution to overspeed. These baffles can also be useful in minimizing the amount of water entrained with the steam flowing back into the turbine following a turbine trip.

3.5.3 Suitable alarms shall be provided for the benefit of the operator to indicate when the first and second lines of defense have been called into operation. This shall be accomplished through the use of separate high and high-high alarm annunciations in the control room. The high alarm shall be an indication that the heater level has risen to the point where the alternate drain system is required to function. The high-high alarm shall be an indication that the heater isolation system (second line of defense) has been called into operation. The high-high alarm is a warning to investigate and shut off the source of water. When a heater(s) is taken out of service automatically, it may be necessary to reduce load and/or steam temperature either automatically or manually in accordance with the turbine and boiler manufacturer's requirements.

3.5.4 Level alarms and indications shall be designed to reflect the actual level in the heater. The physical arrangement of instrumentation and heater drain piping shall preclude unnecessary actuation from level surges during start-up and normal operation. The physical arrangement shall minimize instrumentation interconnecting piping lengths to avoid inaccuracies in level indication. Sensing piping and valves for level controls and elements shall be designed so that failure or maloperation will not render all lines of water induction protection inoperative.

3.5.5 Where an integrated control system is used for plant control and monitoring functions, the following shall be considered to provide the minimum reliability and redundancy required by this Standard:

(a) Three transmitters shall be connected directly to the heater shell with individual isolation for maintenance, as required. The transmitters can be connected to the heater by a direct connection to the heater shell or via a standpipe that cannot be isolated from the shell.

A level switch may replace one of the transmitters to generate the third level signal.

(b) Each transmitter shall have its own input/output (I/O) channel on different I/O cards in the ICS.

(c) High-high alarm and isolation of the heater per Fig. 7 or 9 shall be provided with two-out-of-three logic configuration.

(d) High level alarm, indicating opening of the alternate drain to the condenser per Fig. 7 or 9, shall be provided with two-out-of-three logic configuration.

(e) Separate controllers shall control the heater normal and alternate drain valves. The controllers may use a transmitter select function to interface with the level transmitters.

3.5.6 A drain shall be located at the low point(s) in the extraction pipe between the turbine and the extraction steam block valve. The drain piping shall be sloped in the direction of flow away from the steam turbine. The drain shall be routed separately to the condenser or other receiver that is at condenser pressure. A power-operated drain valve shall be installed in this line and shall open automatically upon closure of the block valve in the extraction pipe.

Any other low points in the extraction piping between the block valve and the heater shall be similarly drained. A power-operated drain valve shall be installed in this line that opens automatically prior to opening of the block valve.

These drain valves shall have control room indication of open and closed positions. They shall also have a manual override to open in the control room for use during start-up. These drains are provided to dispose of steam condensing in the extraction line when the block valve is closed.

3.5.7 When there is more than one heater from a single extraction point, operation of the extraction line drain valve(s) depends on the design of the connecting extraction piping and the possibility for collection of water in the extraction line before the closed block valve(s).

3.5.8 All steam line drain valves from extraction steam lines shall be configured to Fail-Open on loss of power, air, or ICS processor communications as applicable.

3.5.9 Bypass lines around extraction line block or nonreturn valves are not acceptable.

3.5.10 Thermocouples may be installed in the turbine at locations determined by the turbine manufacturer or in the connecting steam piping to assist in locating sources of water that may enter the turbine.

3.5.11 The design of the feedwater heaters and extraction systems shall include features that permit periodic testing of the protective systems as required in section 5.

3.5.12 For heaters in the condenser neck, margins for preventing water induction are increased if subcooling zones are avoided and drains are not cascaded into these heaters.

3.5.13 Where a separate drain tank is employed with a low-pressure heater, adequately sized vents and drains are essential. To account for possible flow restriction in the interconnecting pipe, a separate level element shall be mounted on the heater and shall operate the heater's isolation system similar to the arrangement shown in Fig. 7 or 8.

3.5.14 Other arrangements of feedwater heaters and bypasses are satisfactory, provided they accomplish the same objective as the arrangement shown in Figs. 8 and 9.

3.5.15 Dual extraction/admission lines shall follow the steam turbine manufacturer's recommendations between the steam turbine casing and the stop/control valve. The steam lines up to the steam turbine stop/control valve shall meet the requirements outlined in the motive steam system description in para. 3.3.

3.5.16 Where the boiler start-up cycle pressurizes feedwater heaters, the block valves between the turbine and the pressurized feedwater heaters shall be interlocked closed during the start-up cycle to prevent any backflow from the heaters into the turbine. This is in addition to any possible check valve action. Once the pressure in the associated turbine stage is sufficient to prevent backflow from the feedwater heater, the feedwater heater block valve may be opened and the heater placed into service.

3.6 Direct Contact Feedwater Heaters and Extraction Systems

A direct contact (DC) feedwater heater (deaerator) can be a source of cold steam or water that can flow back to the turbine. A power-assisted check valve(s) is normally provided in the extraction line to the DC heater. For plant cycles in which the DC heater is supplied from the same extraction line as the feed pump turbine or other unit auxiliaries (air preheating, station heating, etc.), the power-assisted check valve(s) may be located in the common extraction header.

3.6.1 Two independent means of automatically preventing water from entering the turbine from the DC heater shall be provided. In general, the protection arrangement can be a combination of the following items (a) and (b), or (a) and (c):

(a) a power-operated block valve in the extraction line to the DC heater (see para. 3.6.2 and Figs. 10 through 13)

(b) an automatic emergency drain system from the DC heater storage tank or feed pump suction line (see para. 3.6.3 and Figs. 10 and 11) typically to the condenser

Fig. 10 Typical Deaerator Arrangement With Drain System: Local Control System

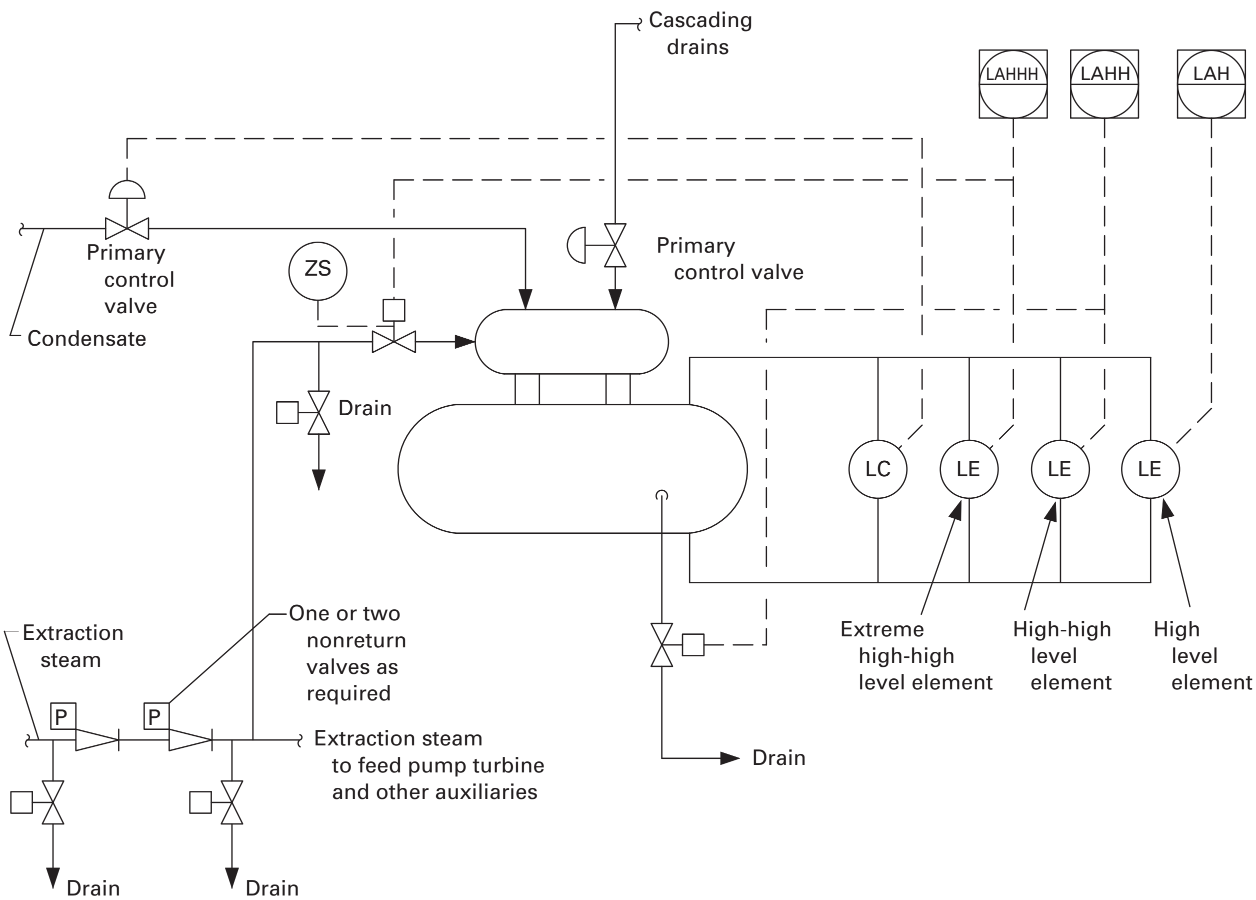


Fig. 11 Typical Deaerator Arrangement With Drain System: Integrated Control System

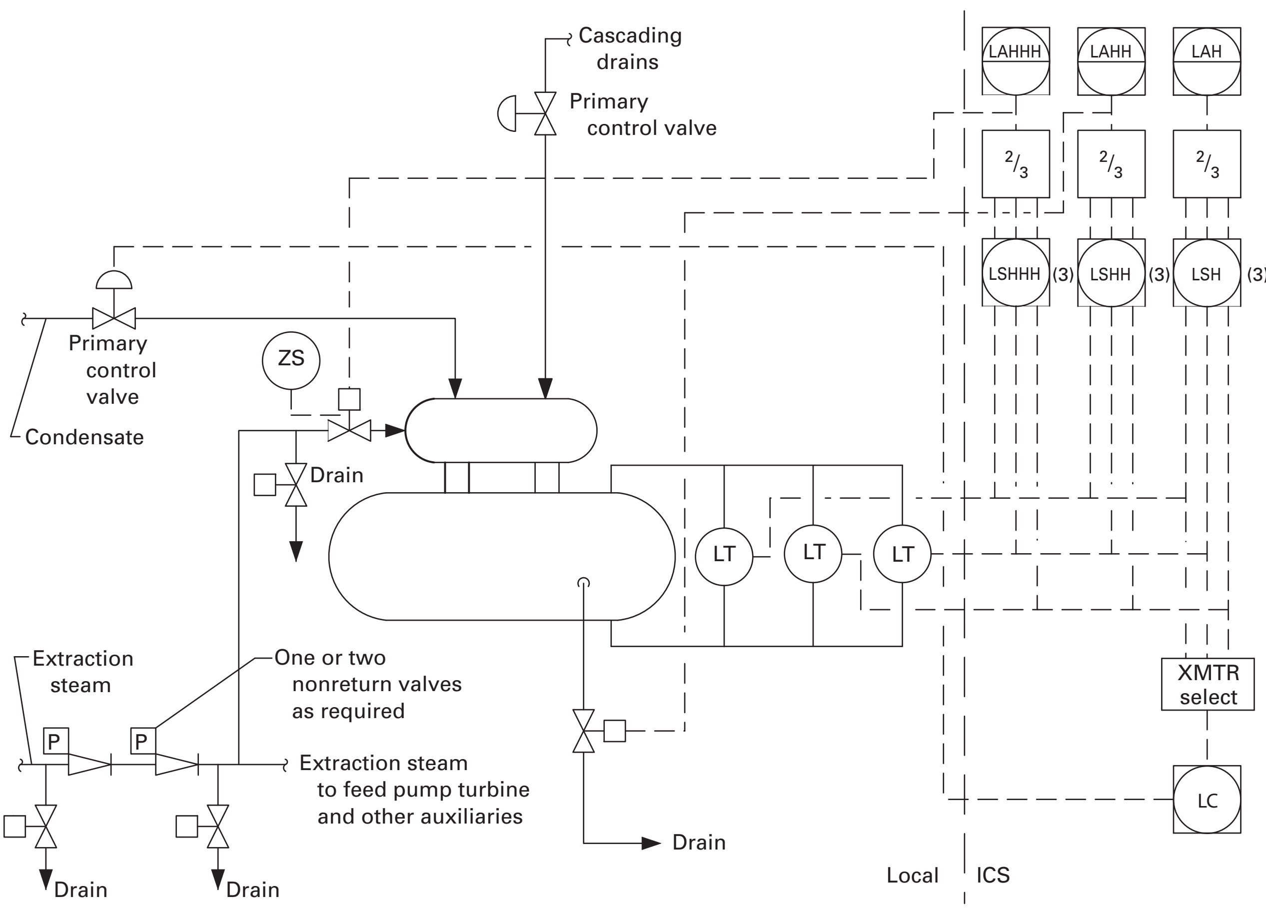
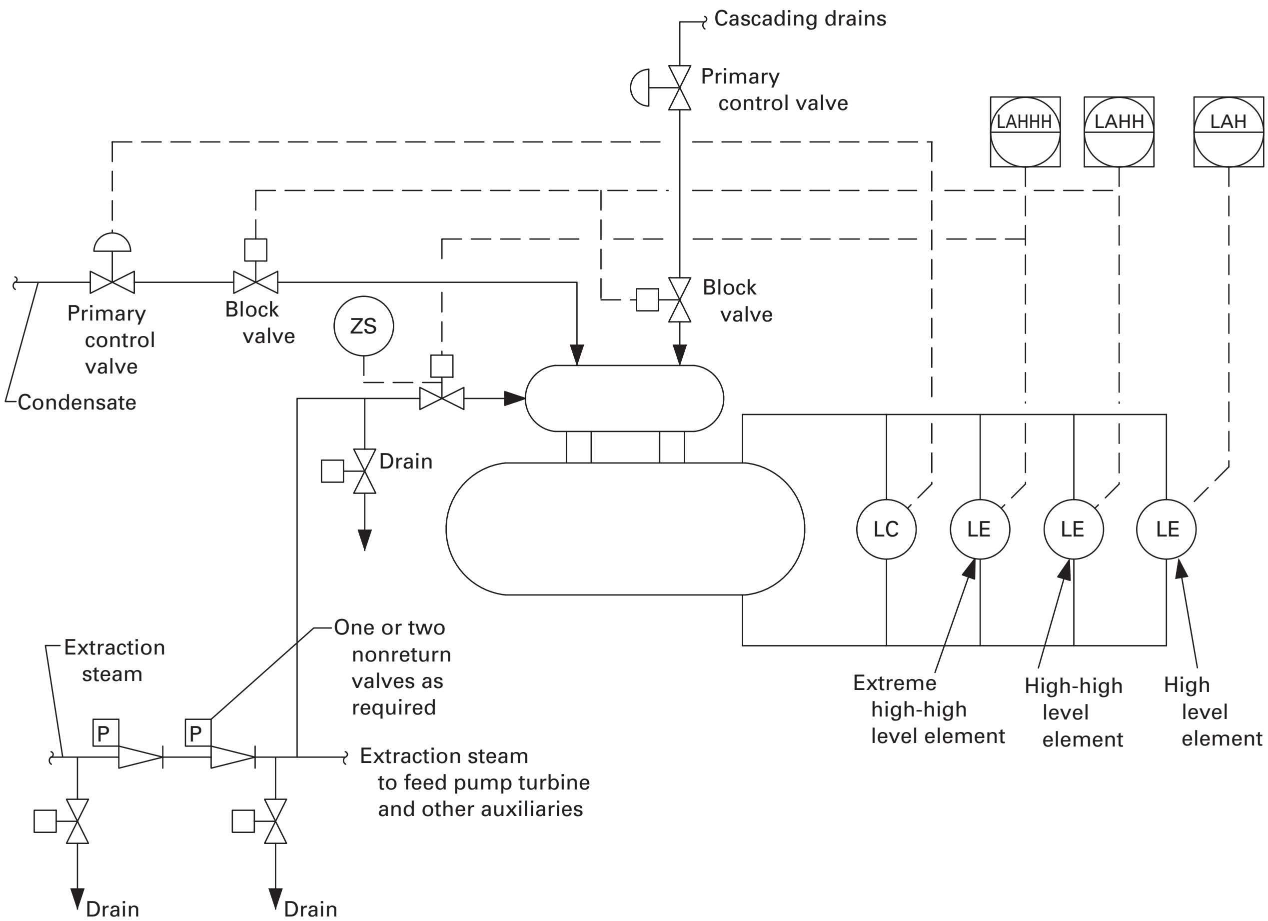


Fig. 12 Typical Deaerator Arrangement With Inlet Isolation: Local Control System



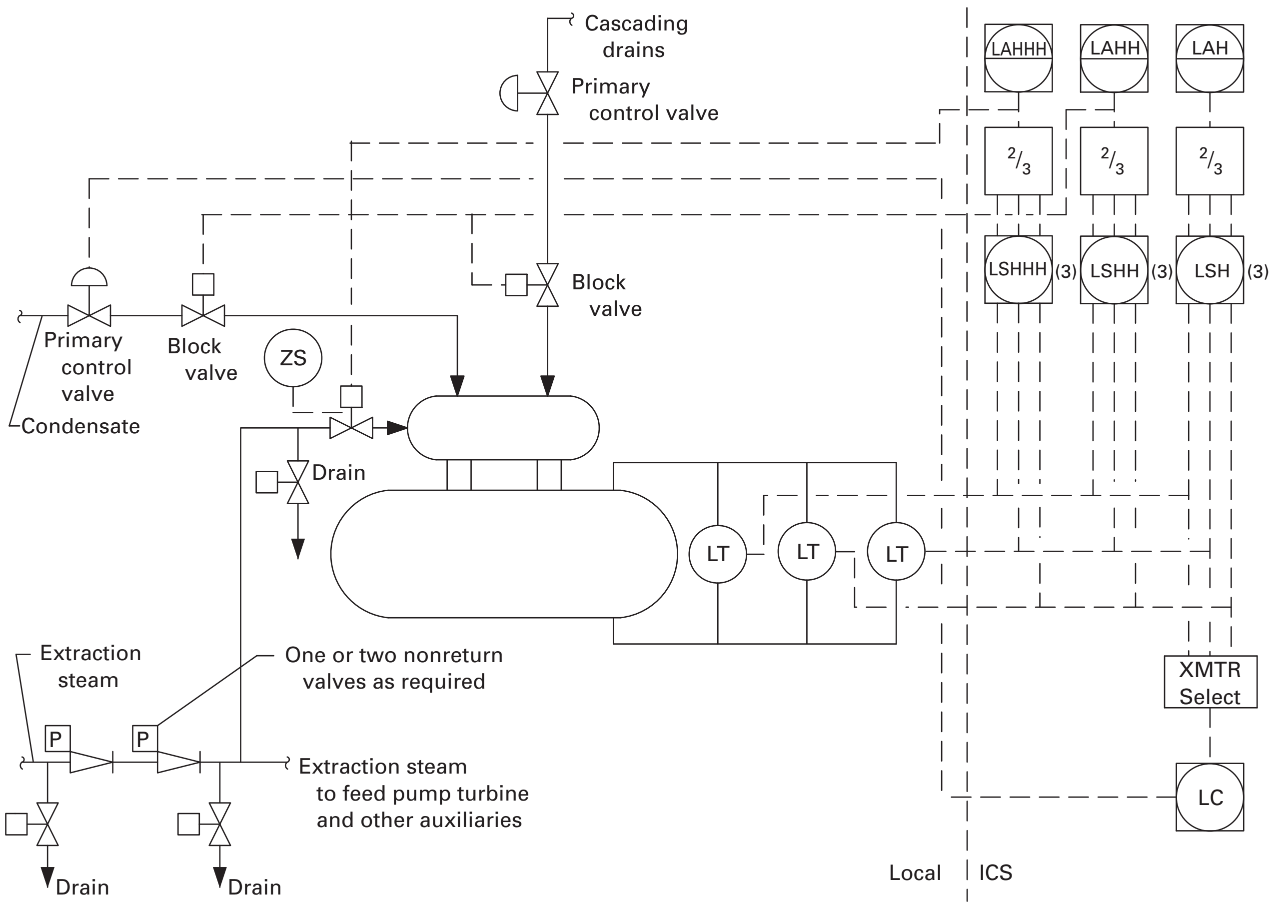
(*c*) power-operated block valves on all sources of water entering the DC heater (see para. 3.6.4 and Figs. 12 and 13)

3.6.2 In either protection arrangement, a power-operated block valve shall be provided in the extraction line to the DC heater and located so that it can isolate the heater from the extraction line but still permit extraction flow to the feed pump turbine (if included in the plant design). This valve shall operate at a speed fast enough that, during its travel time, the water inflow to the DC heater cannot fill the usable volume between the emergency high-high level and the bottom of the extraction connection on the heater. For this determination, the net inflow shall be considered to be the sum of the condensate flow from the low-pressure heaters plus the cascading drain flow from the high-pressure heaters. The available volume in a spray/tray heater is limited by the tray box and shall be taken into consideration. Care shall be taken not to include any volume of the extraction line in this determination.

3.6.3 If a drain from the DC heater storage tank or the feed pump suction line is provided as the second means of protection, it shall discharge to either the condenser, a flash tank, or an external storage tank and shall be activated on high-high level in the DC heater storage tank. Figures 10 and 11 show a typical arrangement of a drain from the DC heater storage tank and its associated level element. The drain connection at the storage tank shall be located high enough on the tank shell or configured with a standpipe so that the tank is not drained dry if the drain valve should fail open. For a drain connection from the feed pump suction line, low DC heater storage tank water level protection shall be provided for the feed pump in addition to the elements shown in Figs. 10 and 11.

3.6.4 If block valves are used as the second means of protection, they shall be power operated and installed in series with the normal control valves in all water lines entering the DC heater. Feed pump recirculation and leakoff lines are not considered to be sources of water entering the DC heater. The block valves shall be automatically closed on high-high level in the DC heater storage tank. Figures 12 and 13 show a typical arrangement for these block valves.

Fig. 13 Typical Deaerator Arrangement With Inlet Isolation: Integrated Control System



NOTE: Use of this alternative may result in unit trip or starvation of the boiler feed pumps.

3.6.5 Where an integrated control system is used for plant control and monitoring functions, the following shall be considered to provide the minimum reliability and redundancy required by this Standard:

(a) Three transmitters shall be connected directly to the heater shell with individual isolation for maintenance, as required. The transmitters shall be connected to the heater by a direct connection to the heater shell or via a standpipe that cannot be isolated from the shell.

(b) Each transmitter shall have its own I/O channel on different I/O cards in the ICS.

(c) Emergency high-high alarm and isolation of the heater per Fig. 11 or 13 shall be provided with two-out-of-three logic configuration.

(d) High-high alarm and isolation of the heater per Fig. 11 or 13 shall be provided with two-out-of-three logic configuration.

(e) High-level alarm per Fig. 11 or 13 shall be provided with two-out-of-three logic configuration.

3.6.6 The location of drains, valving, and the alarms provided shall be as previously mentioned in paras. 3.5.3 and 3.5.6.

3.6.7 All steam line drain valves from extraction steam lines shall be configured to Fail-Open on loss of power, air, or ICS processor communications as applicable.

3.6.8 The design of the direct contact feedwater heaters and extraction systems shall include features that permit periodic testing of the protective systems as required in section 5.

3.7 Drain Systems: Turbine and Cycle Steam Piping

General design rules for turbine and cycle steam piping drain systems are specified in paras. 3.7.1 through 3.7.25. They reflect past successful design practices and shall be used in conjunction with the specific drain recommendations made in the system-specific sections of this Standard and by the manufacturer(s) of the various equipment.

3.7.1 Drain lines shall be designed for both hot and cold conditions and shall slope in the direction of flow to the terminal point with no low points. Any loops required for flexibility shall be in the plane of the slope or in vertical runs.

3.7.2 Drains shall discharge to a receiver with a pressure always the same as or lower than that of the steam lines. Care shall be taken to ensure that, during trips, the vacuum created in some lines does not draw water back to the steam line because the discharge pressure is greater than the steam line pressure. Sections of the reheat system piping and piping between the turbine stop valve and the turbine casing are typically exposed to a vacuum condition during steam turbine start-up and trip.

3.7.3 Drain lines and drain valve ports shall be sized for the maximum amount of water to be handled under any operating condition. However, they shall never be less than $\frac{3}{4}$ in. (19 mm) internal diameter. Drain lines, including the connections for cold reheat and motive steam attemperator systems, shall have an inside diameter of not less than $1\frac{1}{2}$ in. (38 mm). Care shall be taken not to use nominal pipe or valve sizes without clearly determining that the inside diameter meets this minimum dimension.

3.7.4 Consideration shall be given to the pressure difference that exists during various operating modes, including start-up and shutdown, so that the drain line will be designed to handle the maximum expected flows under the minimum pressure differential conditions. Without sufficient line size, adequate drainage will not be obtained, particularly during the early stages of start-up when large amounts of water are produced in the motive steam lines and yet differential pressure is very low. When differential pressures are very low, the drain lines shall be designed to allow complete drainage by gravity flow.

3.7.5 Drain piping from the connections provided by the turbine manufacturer shall be large enough to ensure adequate flow area for the volume increase following critical pressure drop through the drain valve.

3.7.6 Drain pots are required to be used when level control of a drain line is required. Drain pots may also be used to assist gravity drainage for systems with low-pressure differentials. If used, drain pots shall be fabricated from 4 in. (100 mm) or larger diameter pipe for most steam lines except for cold reheat drain pots, which shall be 6 in. (150 mm) or larger in diameter. Drain pots shall be at least 9 in. (230 mm) long but shall not be longer than is required to install level detection equipment. Drain lines and valves shall be sized as discussed earlier in para. 3.7.

3.7.7 The pot and connecting piping shall be fully insulated.

3.7.8 A power-operated drain valve shall be located in each steam line drain. Determination of the failure mode for drain valves shall be made on the basis of the philosophy set forth in para. 2.1.3. If a drain valve is arranged to Fail-Open, attention shall be given to receiver (e.g., condenser) overpressure protection during plant power failures, since a large amount of steam will pass from each steam line to the receiver through the failed open drain valve.

3.7.9 Power-operated drain valves shall have control features that allow them to be remotely opened or closed by the operator in the control room at any time, except those from level-controlled drain pots, which shall be prevented from closing. Motive steam line power-operated drain valves shall not close until the main line superheat is in accordance with turbine manufacturer's requirements.

3.7.10 Drain valves are often located for ease of maintenance; however, it is suggested that the power-operated drain valve be located in the drain line as close to the source as is practicable. This will reduce the amount of water trapped upstream of the (closed) drain valve. Locating the power-operated drain valve close to the source can lead to problems with flashing in the piping downstream of the valve, and the piping shall be designed to take this into account.

3.7.11 Limit switches to indicate the full-open and full-closed positions of valves are adequate as remote position indication of drain valves.

3.7.12 Some users may require two or more valves in series in some of these drain lines. At least one of these valves shall be a power-operated drain valve. When the other drain valve(s) is a manual valve, it shall normally be kept open by locking or other acceptable procedures.

3.7.13 Drain valve fluid passages shall have an internal cross-sectional area of at least 85% of the internal cross-sectional area of the connecting piping.

3.7.14 Steam traps are not satisfactory as the only means of drainage of critical drain lines. They may be used in parallel with the power-operated drain valves.

3.7.15 Drains accumulating water during normal operation shall be provided with a method (such as traps or separate automatic drain valves) for draining water from the low points separate from the power-operated drain valve and associated level device.

3.7.16 All drain and manifold connections at the condenser shell shall be above the maximum hotwell level.

3.7.17 Drain lines may be routed separately to connections or to manifolds mounted on the condenser shell or to separate drain tanks. The following requirements apply to these drain manifolds:

(a) The cross-sectional area of each manifold shall be large enough to make certain that, under all operating

conditions, the manifold internal pressure with all simultaneous drains open will be lower than that of the lowest pressure drain into the manifold.

To allow a separation of water and steam, it is possible to have a vertical flash tank parallel to the condenser. This is connected to the hotwell and to the condenser shell. All drain manifolds shall be connected to this flash tank above the maximum hotwell level.

(b) If a baffle is used, the free area at the discharge of the manifold shall not be less than $1\frac{1}{2}$ times the internal cross-sectional area of the manifold. The baffle shall be arranged so that it does not interfere with proper functioning of adjacent baffles.

(c) Drain lines to the manifolds shall be mounted at 45 deg to the manifold axial centerline, with the drain line discharge pointing toward the condenser or other receiver. The drain lines shall be arranged in descending order of pressure, with the drain from the highest-pressure source farthest from the manifold opening at the condenser wall. Drain manifolds at the condenser shall be located in accordance with the condenser manufacturer's recommendation.

(d) The drains into the manifolds shall be grouped in approximately the same operating pressure ranges. Ideally, manifolds shall contain drains from the same area of the cycle or turbine. Care shall be taken in routing drains together from different sections of a pipe line that can experience extreme differences in pressure due to closing of isolation valves. The turbine manufacturer's requirements shall be considered for proper grouping of drains.

(e) Consideration shall be given to including a pressure test connection at the end of the manifold farthest from the receiving vessel to verify that the manifold is properly sized.

(f) Manifolds shall be self-draining.

3.7.18 On side or axial exhaust turbine condenser arrangements, it may be impossible to properly drain to the condenser. In this case, other provisions, such as a separate drain tank, shall be made.

3.7.19 When side or axial exhaust condensers are used, the hotwell level is closer to the turbine than with downward exhaust condensers. To avoid spraying water into the last-stage buckets, care shall be taken to avoid discharge of steam directly into the hotwell.

3.7.20 Drain lines shall be routed separately or connected to a manifold on a drain tank. The following design requirements apply to these drain tanks:

(a) The cross-sectional area of the drain tank vent shall be large enough to make certain that the tank internal pressure, with all simultaneous drains open, will be lower than that of the lowest pressure drain into the tank under all operating conditions, including start-up and shutdown.

(b) When the drain tank is connected to the condenser, the drain tank shall provide separation of entering condensate and steam from the drain source(s). The vent line to the condenser shall be large enough so that the tank pressure will be less than the source pressures of all drains connected to the tank under all conditions. Under start-up and shutdown conditions, some of the drains may be close to condenser pressure.

(c) The tank drain line shall be sized for the maximum service conditions. When a drain pump is required, it shall be actuated automatically based on drain tank level. If a drain pump is required and its failure could possibly lead to water entering the turbine, redundant drain pumps (supplied with power from separate power sources) shall be furnished, each controlled by an independent level controller actuated automatically based on drain tank level. Independent level signals indicating a high-high alarm condition in the tank shall be provided in the control room.

(d) Connections for incoming drains on the tank shall be located above the maximum water level in the tank.

3.7.21 Drain lines in exposed areas shall be protected from freezing.

3.7.22 Continuous drain orifices, when used, shall be located and designed so that they can be cleaned frequently and will not be susceptible to plugging. A drip pot or dirt catcher may be capped, flanged, or provided with a blowdown valve for occasionally cleaning out the pocket. Strainers may be used upstream of the orifice for additional protection.

3.7.23 Drainage from vessels such as feedwater heaters, condenser air removal equipment, and gland steam condensers that drain water continuously shall not be routed to drain manifolds.

3.7.24 Pipes discharging steam to the condenser from turbine (steam dump) valves that are automatically operated by the turbine control system (turbine bypass, ventilator valves, blowdown valves, equalizer valves, etc.) shall not be connected to turbine drain manifolds, but shall be routed separately to the condenser.

3.7.25 Thermocouples in drain lines, although not required, may be useful in verifying that drain lines are not plugged.

3.8 Condenser Steam and Water Dumps

3.8.1 The exhaust from main and auxiliary steam turbines is discharged into a condenser. Some of the many types of condensers are defined in para. 2.2. In the most common configuration, down exhaust steam turbines discharge into condensers located beneath the turbine. Some plants have used side exhaust or axial exhaust steam turbines, which discharge into steam surface condensers.

3.8.2 Side or axial exhaust or ducted turbine exhausts shall be configured to self-drain away from the turbine at elevations that do not allow water to overflow from the condenser to the turbine under start-up, normal shutdown, and emergency operating conditions. If the exhaust duct has low points, they shall be drained using a drain pot as described in para. 3.7.

3.8.3 Condenser neck high-energy diffusion headers are used by condenser designers under special operating conditions. This system may pose a risk for turbine water induction if incorrectly designed. The turbine manufacturer's design recommendations shall be considered when designing these components.

3.8.4 Improperly designed steam and water dumps to the condenser can cause turbine casing distortions and damage to stationary and rotating turbine parts comparable to that caused by water from extraction and from motive steam lines. The damage has consisted of low pressure inner casing distortion leading to severe packing rubs, permanent distortion of horizontal joints that cannot be closed, bucket/blade damage, and damage to the condenser itself. Dump flow shall be directed away from turbine components by properly designed spargers, baffles, and flow deflectors.

3.8.5 Because of axial and side exhaust steam condenser's relatively compact design and close proximity to the steam turbine exhaust, condenser designers should carefully consider the location, design, and orientation of large steam dumps (such as turbine bypasses) into the condenser. This is necessary to avoid or minimize injection of large, and potentially damaging, quantities of water into the steam turbine exhaust. The steam dump should be designed to disperse sufficient incoming steam energy to avoid backflow towards the turbine. Considerations should include, but not be limited to, desuperheater station placement, and placement and configuration of high-energy steam dumps to avoid velocity vectors toward the steam turbine and to achieve maximum possible steam dispersion. Criteria that should be considered include the following:

(a) avoid discharging high-energy bypass steam into the area between the condenser hotwell and the tube bundle

(b) locate the bypass sparger a safe distance from the condenser tube bundles to allow a sufficient reduction in kinetic energy so that high-energy steam does not reach areas above and below the tube bundles and cause a recirculation backflow with entrained water toward the turbine

(c) determine an incidence angle of high-energy steam jets that will avoid reflected velocity vectors toward the turbine exhaust

3.8.6 In some cases, flows from turbine bypass systems, relief valve dischargers, auxiliary steam turbine dumps, turbine auxiliary valve dumps, and feedwater heater alternate drains should be sent to separate equipment such as flash tanks and/or separate condensing equipment to safely dissipate the energy at a pressure somewhat higher than that in the condenser. Hot water drains from these flash tanks and/or separate condensing equipment could then be discharged by suitable valving to the main condenser. Atmospheric discharge of high volume, high energy flows that occur infrequently should also be considered, so as to reduce the duty on the condenser and to eliminate the need to handle these large flows at the low absolute pressures maintained in the condenser.

3.8.7 The injection points of continuous steam flow to the condenser, such as auxiliary turbine exhausts, shall be located where the incoming jet will not impinge at high velocity on turbine components or condenser tubes nor interfere with the high flow regions. A suggested location is in the region beneath heater shells or extraction piping, well below the turbine inner casing. Care shall be taken to orient the vanes of the grid to avoid an upward flow component. The connection shall normally be located in the condenser dome. Alternatively, this connection may be located on the condenser side wall if the steam lane is sufficiently wide to provide escape area. In this event, the tubes opposite the connections would be provided with appropriate deflection baffles to limit the impingement effect.

3.8.8 Additional information regarding the location and design of condenser connections may be obtained from the following (see para. 2.5):

(a) Standards for Steam Surface Condensers

(b) CS-2251, Recommended Guidelines for the Admission of High-Energy Fluids to Steam Surface Condensers

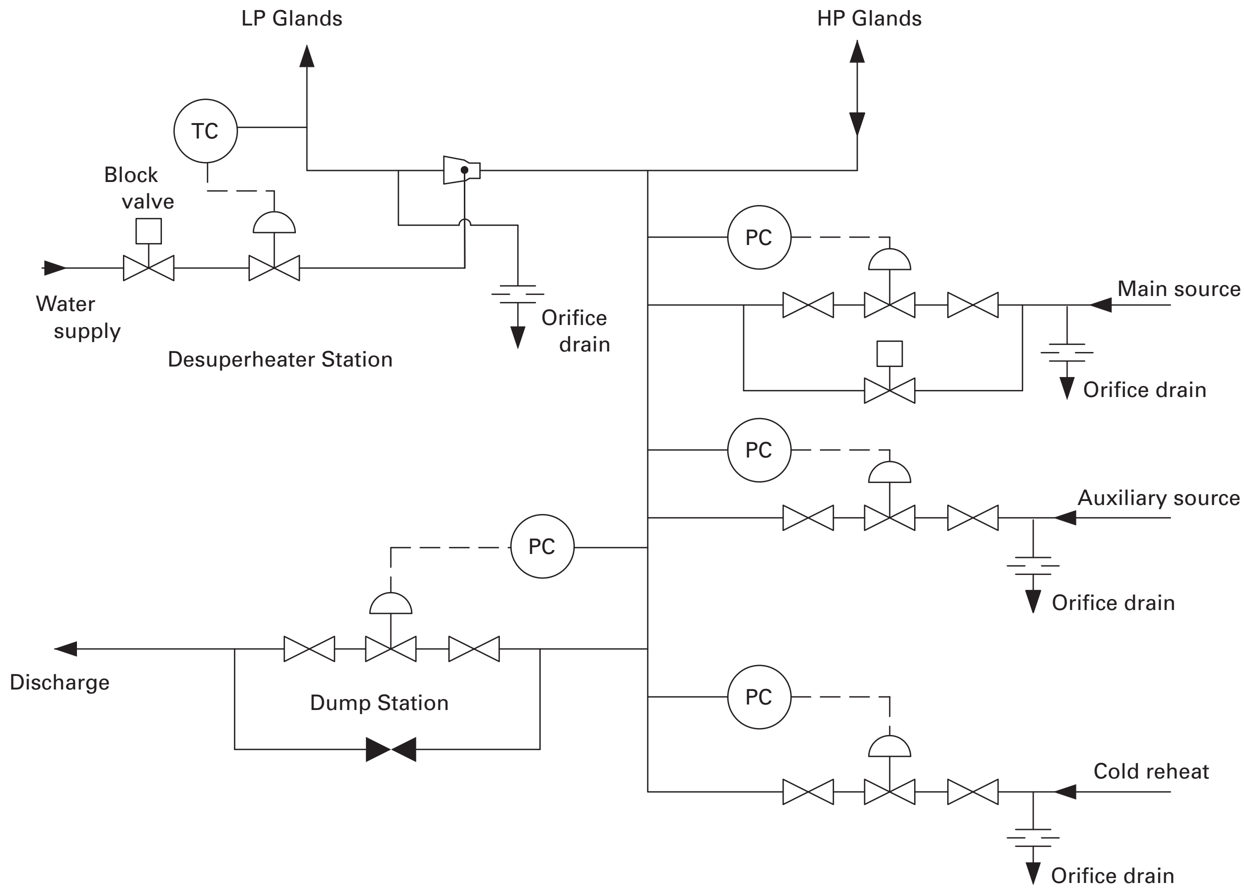
These standards and guidelines address the location of steam and water dumps as well as the baffle and manifold design considerations required to dissipate energy and distribute the steam and water appropriately.

3.9 Turbine Steam Seal Systems

Water induction through the steam seal system can cause serious damage to turbines, especially in the high or intermediate pressure elements having metal temperatures much greater than the temperature of water or saturated steam entering accidentally through the steam glands. Precautions shall be taken to prevent water or saturated steam from entering the steam seal system.

3.9.1 Pipes feeding steam to the steam seal supply systems upstream of the regulating valves shall be pitched (minimum of 2%) toward the source of steam (motive, auxiliary, or cold reheat steam). Refer to Fig. 14.

Fig. 14 Main Turbine: Typical Steam Seal Arrangement



If these pipes are not pitched to their sources, a drain shall be located on the inlet side of each regulating valve to avoid accumulation of water that can be injected into the seal system when a regulating valve opens. A drain with a continuous orifice shall be provided to keep the line warm.

3.9.2 Pipes of the steam seal supply system between the turbine and the gland steam header and between the regulating valves and the gland header shall be pitched (minimum of 2%) so that they self-drain to the header. Any low points in this piping system, including the header, shall be drained to the gland condenser or main condenser using continuous orifice drains.

3.9.3 Pipes of the steam seal leakoff system between the turbine and gland steam condenser shall be pitched (minimum of 2%) so they self-drain to the gland steam condenser. Any low points in this piping system shall be drained to the same pipe at a lower elevation or through a loop seal to a drain tank or atmosphere.

3.9.4 If an attemperator station is used, a power-operated block valve for remote manual operation shall be used to prevent water flow into the steam seal header when the steam seal system is out of service. Piping downstream of an attemperator station shall be configured to maximize mixing and evaporation of the attemperator spray. Refer to the turbine manufacturer's requirements.

3.9.5 A drain located downstream of the steam seal system attemperator shall be provided that is designed to handle all water that can be injected into the steam seal piping with the spray valve in the wide open position. This shall be a continuous drain routed to the gland steam condenser or main condenser. The piping configuration shall prevent spray water from entering the high pressure steam seal piping.

3.9.6 Any connection of a pipe serving as a source for seal steam (i.e., motive steam, cold reheat, or auxiliary source) shall be located on a vertical leg or from the top of a horizontal run of piping.

3.9.7 If an auxiliary boiler or other source is used to supply seal steam, the power plant designer shall consider the temperature flow characteristics of auxiliary boilers or other sources to make certain that the temperature of the seal steam satisfies the turbine manufacturer's requirements. Steam supplied at any gland shall be superheated in accordance with the manufacturer's requirements.

3.9.8 The possibility of water damage to the turbine through gland steam piping from a flooded gland steam condenser is relatively low; however, provisions shall be made to allow indication of condensate level in the gland steam condenser.

3.9.9 The gland steam condenser shell normal drain shall be routed to the main condenser or a liquid waste tank. The gland steam condenser drain shall be arranged to allow complete gravity drainage or shall have provisions for proper drainage of the shell at all times, with particular attention to periods before sufficient vacuum is established in the main condenser. As an additional measure of protection, an emergency drain or overflow connection shall be provided to prevent the water level in the gland steam condenser/leakoff system from reaching the turbine. The gland steam condenser normal drain shall be sized to handle the quantity of water formed when the maximum amount of steam entering the gland steam condenser (including margin, as determined by the manufacturer, for in-service increase in flow) from the glands, valve leakoffs, or other sources is condensed, while maintaining a normal level in the shell.

3.9.10 Excess steam from the steam seal header may be routed to a low pressure feedwater heater and/or the condenser. However, if this steam is routed to a low pressure heater, provisions shall be made (either automatically or by operator action) to divert the steam to the condenser if the heater becomes unavailable (due to low load operation, removal from service, or malfunction). The design of the seal steam and diverter system (including the piping system, control logic, or operating procedures, if applicable) shall be carefully considered to ensure that when the heater is restored to operation, and disposition of seal steam is reset back to the heater, that there is no accumulation of water in the seal steam piping that can enter the turbine through the heater extraction line.

3.10 Control Systems and Instrumentation

3.10.1 The minimum integrated control system (ICS) features required to meet the reliability and redundancy needs addressed in this Standard are as follows:

(a) dual processors

(b) uninterrupted power supply

(c) I/O associated with redundant plant equipment and instruments shall not be connected to the same I/O cards

(d) outputs that fail to known position during processor internal communication failure

3.10.2 The ICS programming shall be designed to handle instrument failures safely. The transmitter selection programming shall follow a safe progression of selection steps in the event of failure of each transmitter as shown below. A failed transmitter or switch shall produce a trip signal for the two-out-of three trip logic. The following examples illustrate this principle using high level conditions:

(a) Three-Transmitter Select (Example)

(1) zero transmitters failed (normal operation): median select of good signals

(2) one transmitter failed: high select of remaining good signals (one of three trip signals)

(3) two transmitters failed: select remaining transmitter and two out of three protective trips

(4) three transmitters failed: level controllers revert to manual and hold last good output

(b) Two Transmitter Select With One Level Switch for Two-Out-of-Three Logic (Example)

(1) zero transmitters failed (normal operation): high select of two good signals

(2) one transmitter failed: remaining good transmitter selected (one of three trip signals)

(3) one transmitter failed and high-level switch alarm: remaining good transmitter selected and two out of three protective trips

(4) two transmitters failed: level controllers revert to manual, hold last good controller output, and two out of three protective trips

3.10.3 Power-operated block or drain valves shall have remote position indication in the control room. Position indication at the full-open and full-closed position shall be to allow the operator to determine the position of each of these power-operated valves.

4 OPERATION

Station operators shall develop and conduct a training program for each installation to guide operators in handling start-up, shutdown, steady state, and varying load conditions; loss of steam generator fire; and trips and other situations that can involve water induction. These instructions shall cover the steps to take should there be any symptoms of water induction such as high level alarms, sharp drops in metal or steam temperature, or shaking steam pipes that result from water flashing to steam. In addition, training shall be tailored to each installation to the extent that special or unusual operating characteristics may make that unit or type of unit more susceptible to water induction (e.g., units that require extended condensate/feedwater system pressurization and operation for system cleanup or cooldown hold a greater potential for water induction). Damage can be minimized if prompt and decisive action is taken at the first warning of water induction into a turbine. An operator training review is recommended periodically to keep the specific instructions fresh in the operator's mind.

Many of this Standard's design requirements will provide indications and initiate automatic actions when water (or cold steam) is present in components that could lead to turbine damage. Operators need to give priority to investigating all actions of turbine-water-induction-influenced sensors and controls. Over-reliance on automatic features has resulted in turbine water induction incidences. Operators who can readily detect the presence of water can isolate the water from the turbine and dispose of it, thus preventing damage to the steam turbines.

Operating recommendations provided in this section are based on generic requirements because of the many variations in equipment and unit system designs and the varying needs of different system grids.

4.1 Motive Steam

Paragraphs 4.1.1 through 4.1.4 describe features that should be incorporated into plant operating procedures related to motive steam systems. The features may be programmed into the plant control system or may be operator procedures or a combination thereof.

4.1.1 Prior to starting the unit, the condenser shall be in operation and ready to accept drainage. The condenser should remain available to provide cooling for drains routed to the condenser prior to opening these drains during shutdown.

4.1.2 It is recommended that drain valves be opened (and remain open) during steam turbine shutdown and steam turbine trip. Under certain conditions, it is desirable to keep the motive steam lines pressurized. Under those conditions, provisions should be made to determine if water is present and, if so, to drain the line.

When a steam turbine is to be restarted shortly after a trip from load, the operator should decide whether the steam line drains need to be opened to eliminate water accumulations. Under certain conditions, opening these drain valves will allow the steam system to depressurize, which may produce quenching of the steam generator superheater and motive steam piping.

During the initial operation of the steam generator and steam turbine, operating procedures should be finalized that will balance the requirements for proper drainage against excessive depressurization. These procedures should be reviewed upon changes in generating unit use (i.e., from base load service to cycling service).

4.1.3 Prior to starting the steam turbine, it is recommended that all drain lines on the motive steam piping, as well as before-seat drains on the steam turbine stop valves, be opened to permit a flow of steam from the steam generator to warm the steam leads and steam turbine stop valve bodies at the desired rate. The process of heating will aid in clearing the superheater of water. During warming, a close check should be maintained on all thermocouples sensing steam and metal temperatures in the system.

Valves that are opened should be left in the open position until there is verification that adequate superheat in the steam line and/or complete drainage of all water has occurred. In lines containing drain valves that have remained closed, the operator should open the drain valves if a condition exists that could allow water to enter the turbine.

4.1.4 For turbines supplied by a header system that is fed by multiple steam sources, the motive steam drain system operation and control logic should ensure that motive steam lines from each steam source are adequately drained at all times, so that water or cold steam cannot enter the main header to the turbine under any operating condition, including transients, regardless of whether that steam source is in service. Caution should be exercised when bringing an additional steam source on line to ensure that steam lines are adequately warmed and drained and steam temperature meets the turbine manufacturer's requirements for superheat. Because it is recognized that induction of cold steam can also damage the turbine, the steam conditions should be such that the turbine manufacturer's recommendations for inlet steam temperature rate of change and/or instantaneous (step) change are not exceeded when the additional steam source is tied into the steam supply header. Proper operation of drain (or bypass) systems is needed to ensure that these recommendations are not exceeded.

4.2 Main Steam Turbine

4.2.1 In general, if water enters the turbine while operating at rated speed or while carrying load, the unit should not be tripped if the vibration and differential expansion are satisfactory and no other signs of distress are observed. Tripping the steam turbine causes the steam flow to be shut off and internal pressures in the turbine to quickly decay to condenser vacuum. The likelihood of flashing and drawing cool steam and/or water into the steam turbine is increased under these conditions, thus increasing the severity of the event.

4.2.2 Often, the best course of action is to search out and isolate the source of water immediately. Operation in this manner minimizes local thermal distortion by (heating) action of the mass flow of steam through the turbine.

4.2.3 If water enters the turbine while operating below rated speed, it should be shut down immediately and the source of water isolated, since rotor bowing caused by water induction may be aggravated below rated speed. Refer to the turbine manufacturer's turning gear operating instructions under these conditions.

4.2.4 If the turbine is on turning gear, the operator should not roll the turbine with steam if a water induction incident is in progress.

4.2.5 Once the unit has been placed on turning gear because of possible water induction, a restart should never be attempted until the shaft eccentricity is within normal limits, the various turbine shell temperature differences are within the allowable limits stated by the manufacturer, and the source of water has been identified and corrected with the assurance that it will not repeat on a subsequent start.

4.2.6 If a unit has been shut down because of indications of water induction, a restart should not be attempted in a time period less than that recommended by the turbine manufacturer and/or until turbine conditions (such as eccentricity, cylinder base-to-cover temperature differential, etc.) meet the turbine manufacturer's criteria for restart. When restarting a turbine after a distorted cylinder or bowed rotor has returned to acceptable conditions, the restart should be closely supervised following procedures recommended by the turbine manufacturer.

4.2.7 If the rotor is bowed or the shell distorted so the turning gear cannot turn the rotor, periodic attempts (once per hour) should be made to rotate the rotor and get the unit on turning gear. No attempt should be made to free a locked rotor by use of a crane or by the admission of steam to the turbine.

4.2.8 During start-up, all drains between the turbine stop valve and turbine casing should remain open until adequate superheat is achieved, water has completely drained, or as recommended by the turbine manufacturer.

4.3 Turbine Steam Seal System

4.3.1 When the turbine is hot and it is necessary to transfer to any auxiliary source of gland seal steam, the operator should assure that the piping is prewarmed, steam supplied to the gland is superheated, and the temperature is within manufacturer's limits.

4.3.2 If water is suspected in a steam pipe serving as a source of seal steam for the turbine gland system, and the turbine vibration and differential expansion are satisfactory, and there are no other signs of distress requiring that the unit be shut down, the operator should transfer either automatically or manually to another source of seal steam, then close the block valve in the line routed to the source pipe containing water. The water should be drained from the source pipe.

4.4 Attemperators

After a steam generator trip, both the turbine and the main fuel trip should be reset, and the attemperator spray control valve should be closed before the block valve is permitted to be opened (see para. 3.2).

4.5 Feedwater Heaters, Extraction Systems, and Process Steam Extractions

4.5.1 Operators should be instructed to investigate all high level alarms and isolate the source of water.

4.5.2 A feedwater heater should not be operated if some of the water induction protective devices are known to be faulty, unless special provisions are made to ensure equal protection.

4.5.3 If an alarm sounds and power-operated controls appear to isolate a source of water, the operator should follow up by actuating the remaining isolating and drain valves in the affected area of the cycle.

4.5.4 If any heater is taken out of service, drain valves in the associated extraction lines should be opened and the drain line from the drain valve checked to verify that it is not plugged. When returning the heater to service, the operator should check that the heater shell pressure is lower than the corresponding turbine stage pressure before opening the extraction line block valve.

4.5.5 Where the boiler start-up cycle pressurizes feedwater heaters, the feedwater heater block valve shall not be opened to place the heater in service until the pressure in the associated turbine stage is sufficient to prevent backflow from the feedwater heater. When placing these feedwater heaters in service, the operator should take proper care to control the rate of temperature change on the feedwater heater tubes and in the feedwater line to the boiler.

5 TESTING, INSPECTION, MAINTENANCE, AND MONITORING

All testing shall include complete control loop tests of normal and redundant systems from the initiating signal to the action the indicating signal is intended to perform.

Periodic time-based testing, inspection, and maintenance of turbine water damage prevention systems can be replaced by employing various predictive maintenance inspection techniques, provided that such techniques result in a reliability equal to or better than that afforded by time-based testing.

5.1 Quarterly Testing and Inspection

5.1.1 Feedwater heater extreme high level controls, elements, alarms, transmitters, and interlocks shall be tested. Operation of level control instrumentation shall be verified during this test. Testing shall be done in a manner that approximates as closely as possible the actual flooding of a heater without endangering the turbine or other station equipment and without tripping the unit (deaerator testing will cause a unit trip if the extraction block valve is allowed to go closed). All annunciators shall be checked for alarm indications. Bypassing of interlocking devices should be avoided, but when this is necessary for testing critical water prevention equipment (such as extraction nonreturn valves, drain lines, and feedwater heater level controls), the equipment shall be verified to have been restored to the original operating condition.

5.1.2 The mechanical and electrical operation of all drain valves shall be tested. Where applicable, the valves shall be operated from the control room and determined to open and close properly by observing control room indicating lights. At least once a year, this inspection shall include verification that control room indication of valve position is working as intended by physical checks of the actual valve movement.

5.1.3 Mechanical operation of all power-assisted check valves shall be tested, including all solenoid valves, air filters, air supply, air sets, etc. The turbine air trip relay need not be actuated.

5.1.4 A visual check of the turbine supervisory instruments shall be made to ensure that instruments showing differential expansion, casing expansion, eccentricity, vibration, rotor position, and metal temperature are in working order.

5.1.5 The isolation function of all attemperation block valves shall be tested by operating the telltale drains installed between block and control valves in attemperation lines.

5.1.6 All turbine and steam pipe drain lines shall be inspected by using contact pyrometers, infrared thermography, or thermocouples to determine by temperature difference that the line is clear.

5.1.7 All continuous drains from the steam seal system shall be periodically checked to be sure that they are not plugged. During turbine operation, contact pyrometers, thermocouples, or other temperature sensors may be used for this check.

5.1.8 All traps and orifices in drain lines shall be inspected by using contact pyrometers, infrared thermography, or thermocouples to determine that they are functioning properly.

5.2 Inspection and Maintenance During Planned Unit Outages

5.2.1 All valves essential to water induction prevention (such as heater level valves, automatic and remote manual drain valves, attemperator spray valves, and power-operated block valves) shall be functionally tested in a manner that closely approximates the control actions that protect the turbine.

5.2.2 Drain pots, traps, and orifices for all drains shall be cleaned.

5.2.3 Where the tests of para. 5.2.1 indicate inoperative drain lines, the drain valves shall be disassembled and inspected internally to verify that they will operate properly. Connecting piping shall also be inspected or tested to verify that the flow path is clear.

5.3 Monitoring

Monitoring techniques that can be used to detect conditions that have subsequently been associated with water damage to steam turbines include, but are not limited to, the following:

(a) acoustic/ultrasonic detection of feedwater heater tube leaks

(b) fast-acting and/or heated-differential-type thermocouples for detection of water in steam lines

(c) acoustic monitoring of valves

(d) electrical-resistance-based water level elements in steam lines

(e) thermography cameras for detection of clogged drain lines

(f) conductivity-based water level elements

(g) paired temperature elements on the top and bottom of pipes, shells, and vessels

6 CONCLUSION

These recommendations by the Committee are not to be considered all-inclusive as a means of eliminating water damage. Design, operating, and maintenance instructions shall be tailored to suit specific conditions of each installation to provide reliable protection. The recommendations are not intended to relieve designers, operators, and manufacturers of the responsibility to continue their efforts to improve unit safety and reliability.

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