ASME TDP-2–2012
(Revision of ANSI/ASME TDP-2–1985)

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

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Three Park Avenue • New York, NY • 10016 USA

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The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

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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 as 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 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.

ASME TDP-1, resulting from the work and deliberation of the Turbine Water Damage Prevention Committee, was approved as a standard of ASME 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.

In 1985, it was decided to issue separate documents for fossil-fueled and nuclear-fueled plants. TDP-1, covering fossil-fueled plants, was approved as an American National Standard on September 13, 1985.

ASME TDP-2, written by the same ASME committee, is a comparable document to cover turbines used with light water nuclear-fueled steam supply systems that produce nominally dry-and-saturated steam. This Standard, resulting from the work and deliberation of the Turbine Water Damage Prevention Committee, was approved by the American National Standards Institute on October 15, 1985.

In 1994, the ASME Board on Standardization approved the disbandment of the Committee on Turbine Water Damage Prevention and the withdrawal of TDP-1. This was due to perceived lack of interest/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 of 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.

The 2006 version of TDP-1 was issued to incorporate combined cycle, multiple steam generators, cycling, and cogeneration technology and to incorporate the capabilities of modern plant instrumentation and control systems. TDP-1 was approved as an American National Standard on November 6, 2006.

Based on the renewed interest in light water nuclear-fueled steam supply systems, the Committee began work on a revision of TDP-2–1985. This Standard was approved as an American National Standard on March 7, 2012.

ASME TWDP COMMITTEE
Turbine Water Damage Prevention

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

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Secretary, TWDP Standards Committee
The American Society of Mechanical Engineers
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Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued for the purpose of providing alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee Web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard, the paragraph, figure or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the TWDP Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the TWDP Standards Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The TWDP Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the Secretary of the TWDP Standards Committee.

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

1 SCOPE

This Standard includes practices that are concerned primarily with the prevention of water damage to steam turbines used for water-cooled nuclear reactor power generation. The practices cover design, operation, inspection, testing, and maintenance of those aspects of the following power plant systems and equipment concerned with the prevention of water induction into steam turbines and the safe removal of water from steam turbines and the following associated systems and equipment:

(a) main steam and bypass systems, piping, and drains
(b) turbine extraction systems, piping, and drains
(c) turbine steam seal systems, piping, and drains
(d) feedwater heaters, piping, and drains
(e) turbine drain systems
(f) condenser steam and water dumps
(g) start-up systems

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 for existing facilities retroactively.

2 CRITERIA

2.1 Basis

2.1.1 The normal practice for the prevention of turbine water damage shall be 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 Because of the lower main steam temperature from these types of steam supply systems, much of the steam path of the turbine contains wet steam. The turbine manufacturer designs for continuous removal of a part of this water at various stages in the turbine. This Standard indicates means of removing water from the turbine and preventing its reintroduction once it is in the external piping. It also indicates means of preventing induction of water into the turbine from external sources, such as the main steam system and feedwater heaters. The methods for preventing turbine water damage due to water induction or accumulation include one or more of the following basic procedures for design where appropriate:

(a) detection of the accumulation of water either in the turbine or preferably external to the turbine before that water has caused damage
(b) isolation of the water by manual or preferably automatic means after it has been detected
(c) disposal of water either by manual or preferably automatic means after it has been detected

2.1.3 No single failure of equipment shall result in water entering the turbine. The failure mode of the various devices used to prevent water induction shall be considered so that a single failure of the signals (loss of air or electrical signal) will not result in water 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 that was out of service is adequately warmed and drained prior to being returned to service.

2.1.5 Any automatic control system used to control steam line drain valves identified in this Standard shall be designed so that the system has a means for initiating valve actuation and a separate means to verify the appropriateness of the automatic action. 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 Definition of Terms

2.2.1 Systems

auxiliary steam: a steam system that is 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 part of this system.

condenser: equipment that condenses low-pressure turbine exhaust steam and thus provides a 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, condenser: 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, condenser: a condenser is designated as auxiliary when it is supplied primarily for steam-turbine-driven auxiliary equipment or for steam dumps.

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

wet-dry, condenser: 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.

cross-around: a generic term for cross-over or cross-under piping located between the high-pressure turbine exhaust and the moisture separator, or moisture separator/reheater (MS or MS/R) or between the moisture separator, or moisture separator/reheater (MS or MS/R) and the low-pressure turbine inlets as defined above. Cross-around piping could also refer to the piping between the HP turbine exhaust and the LP turbine inlet that is routed alongside the turbine.

cross-over: piping from the high-pressure/intermediate pressure turbine to the low-pressure turbine that is above the turbine deck.

cross-under: piping from the high-pressure/intermediate pressure turbine to the low-pressure turbine that is below the turbine deck.

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

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: the 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 area 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 gland leakoff steam to the low-pressure turbine glands.

heater drain: this system 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 drains from the heaters in the condensate system to the condenser. The drains may be pumped forward from the feedwater heater to the condensate line downstream of the heaters. The system includes alternate drains to the condenser for start-up, shutdown, and emergency conditions.

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

main steam: the steam system that connects the nuclear steam supply to the high-pressure turbine.

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* in para. 2.2.2 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 should close the valve.

power-assisted nonreturn/check valve: a nonreturn/check valve with an actuator that serves as a backup to close or partially close the valve and that assists in rapidly closing the valve. The nonreturn/check portion of the valve shall always be free to close when reverse flow occurs, regardless of actuator status.

power-operated block (or drain) valve: a block or drain valve with a power operator. For this Standard, a power-operated block valve shall have open and closed position indication and shall be operable in the control room. 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.

2.2.2 Equipment

attemperator (desuperheater): a device for reducing steam temperature, usually by the introduction of 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 utilized to drive mechanical equipment, such as reactor feedpumps, fans, etc. This turbine is generally supplied with 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 valves" or "shutoff valves."

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

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

feedwater pump: motor or steam turbine driven pumps that convey the feedwater from the deaerator or other feedwater storage vessel to the steam generator through the feedwater piping system and that also raise the water pressure to that required at the steam generator inlet. On systems without a deaerator, they would convey the water directly from the condenser.

2.2.3 Control Systems

integrated control system (ICS): a control system featuring multiple processors, input/output 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.

The minimum ICS features to meet the reliability and redundancy needs for use in this Standard are as follows:

(a) dual processors
(b) uninterruptible power supply
(c) input/output (I/O) associated with redundant plant equipment and instruments, which shall not be connected to the same I/O cards
(d) outputs that fail to known position during processor or internal communication failure

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

transmitter select: 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:

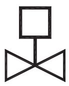
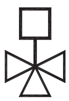
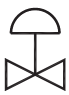
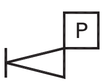
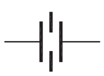
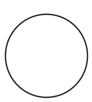
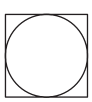
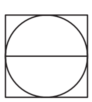
(a) Three Transmitter Select (Example)
(1) zero transmitters failed (normal operation): median select of good signals.
(2) one transmitter failed: high select of remaining good signals (one of three trip signals).
(3) two transmitters failed: select of remaining transmitter and two out of three protective trips.
(4) three transmitters failed: reverting of level controllers 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: select of remaining good transmitter (one of three trip signals).
(3) one transmitter failed and high-level switch alarm: select of remaining good transmitter and two out of three protective trips.
(4) two transmitters failed: reverting of level controllers to manual, hold last good controller output, and two out of three protective trips.

2.3 Symbol Legend

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

Table 1 Symbol Legend

Symbol	Description
	Normally open valve
	Normally closed valve
	Open–shut power-driven valve
	Power-operated three-way 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 normal accessible to the operator at primary panel (e.g., ICS)
	Hardware or software interlock

2.4 References

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

ANSI/ISA-5.1-2009, Instrumentation Symbols and Identification

Publisher: The International Society of Automation (ISA), 67 T.W. Alexander Drive, 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, Seventh Edition (2004)

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

Publisher: Heat Exchange Institute (HEI), 1300 Sumner Avenue, Cleveland, OH 44115 (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 intent to supersede any existing design code or government regulation.

3.1 Main Steam and Bypass Systems

3.1.1 Consideration will be given to the main steam and bypass systems only from the reactor or steam generator outlet connections to the turbine casing. However, a potential for significant water carryover to the main steam lines exists under all load conditions in steam systems producing saturated or low superheat steam. Prevention of water carryover is dependent upon the protective systems of the steam-generating equipment. These controls shall be designed so that no single failure of equipment can permit excessive water carryover to the main steam headers. Two independent means of preventing water carryover beyond specified limits shall be provided. This includes water level control on recirculated steam generators and start-up and control systems for once-through steam generators. It is the responsibility of the plant designer to review and understand the design features of the steam-generating equipment and of the owner/operator to adhere to the manufacturer's operating procedures as a precaution against water induction from these sources.

3.1.2 The major portion of past incidents of turbine water damage caused by water entering the turbine from the main steam system has primarily occurred during start-up or shortly after shutdown of a unit. There are no recommendations included pertaining to the prevention of damage by water passing through the main steam piping and into the turbine because of lack of detection instrumentation that will close the turbine stop valves in time to prevent damage. If such devices are developed and marketed, consideration shall be given to include this instrumentation.

3.1.3 A drain shall be installed at each low point in the main steam piping in which water could collect during the start-up, shutdown, or normal operation of a unit. When reviewing the location of low points, consideration shall be given to the position of the piping in both the cold and hot positions. This is necessary due to the possible extreme difference in pipe position between the cold and hot conditions. When there is no specific low point (where there are long runs of horizontal piping), install a low point drain at the turbine end of the section. If the main steam line is split into more than one branch going to the turbine, each of these individual branches, as well as the main header, shall be reviewed for low points. Sections of the main steam lines and manifolds that can be isolated by closed valves must have adequate drains, with particular attention to valves that are routinely tested, such as containment isolation valves. In addition to the low point drains, which have been covered above, a connection shall be located on each main steam branch at the turbine inlet just before the turbine stop valve. This connection can be used with the drains in the system as a bleed-off point for warming the main steam line during start-up conditions.

3.1.4 All of the drain lines and drain valve ports, including the connections on the main steam pipes just upstream of the turbine stop valves, shall have an inside diameter of no less than 1 in. to minimize risk of plugging by foreign material. Care shall be taken not to use nominal pipe sizes without clearly determining that the ID will meet this minimum dimension. Without sufficient line size in each of these areas, adequate drainage will not be obtained, particularly during the early stages of start-up when large quantities of water are present in these lines.

3.1.5 A power-operated valve shall be located in each of the drains noted in this section. Many users will require two valves in series in each of these drain lines. At least one of these two valves shall be power operated by controls located in the main control room. In addition, position indication shall be provided in the main control room to permit the operator to determine the position of each of the power-operated drain valves. Where the second of these two valves is a manual valve, it shall normally be kept open by locking or other acceptable means or procedures.

3.1.6 Before-seat drains, or an equivalent connection, shall be provided on the turbine stop valve to permit clearing of any moisture and to permit a steam flow in the valve prior to start-up. This drain shall be installed in the valve to permit complete draining of any water if this area is not self-draining. It shall be designed basically in accordance with the criteria set forth earlier in this section for drain lines. This similarity shall include the installation of power-operated valves, control room indication of valve position, and control room operation of the valves. The drain line, connection, and valve port shall, however, be a minimum of $\frac{3}{4}$ in. inside diameter.

3.1.7 Drains shall be provided between the main steam stop valve and first stage nozzles to ensure removal of water. These would consist of after-seat drains on the main steam stop valve, before-seat and after-seat drains on the control or admission valves, and low point drains on any of the main steam piping downstream of the control valves. These drains shall be designed basically in accordance with the criteria set forth earlier in this section for drain lines. This similarity shall include the installation of power-operated valves, control room indication of valve position, and control room operation of the valves. The drain lines, connections, and valve ports shall, however, be a minimum of $\frac{3}{4}$ in. inside diameter.

3.1.8 If the main steam system incorporates a turbine bypass, the bypass piping shall either include drains similar to those for main steam piping or be pitched away from the bypass valve so they are self-draining. The drains shall be of the continuously operating type with an orifice. As an alternative, a level-actuated automatic drain valve may be used. Care shall be taken to drain the downstream section of piping continuously.

3.2 Crossaround Piping: Moisture Separator/Reheater

3.2.1 Nuclear units may be either of the reheat or nonreheat design. Reheat units have a moisture separator and a one- or two-stage reheater in the piping between the high-pressure turbine exhaust and the low-pressure turbine inlets. The piping from the high-pressure turbine exhaust to the moisture separator or moisture separator/reheater (MS or MS/R) is frequently called cold reheat or cross-under piping, and the piping from the reheater to the low-pressure turbine inlets is frequently called hot reheat or cross-over piping, as on fossil units. For nonreheat nuclear units, there is a moisture separator in the piping from the high-pressure turbine exhaust to the low-pressure turbine inlet. For simplification in the discussion, all of this piping will be referred to as cross-around piping, unless specifically stated otherwise.

3.2.2 The cross-around piping is normally specified by the turbine manufacturer. Considering the wide range of variations in the physical arrangement of this piping combined with the quantity of water that can be separated from the flow stream in this area, the drainage system for the cross-around pipe shall meet the requirements provided by the turbine manufacturer.

3.2.3 The MS or MS/R is normally supplied/specified by the turbine manufacturer. These vessels are points of water accumulation, and therefore, the drainage system shall be designed in accordance with the manufacturer's requirements. The drainage system usually directs the water into a feedwater heater or other point in the cycle for additional heat recovery. With such an arrangement, an alternate or emergency automatic drain shall be provided to direct these drains to the condenser if the normal drain system cannot remove the water. Instrumentation including normal level indication, dump/emergency level indication, high-level alarms, and high-high-level alarms and trips shall be provided as recommended by the turbine manufacturer. Cross-under piping represents a definite low point in the piping and is especially susceptible to water accumulation, and appropriate means to protect this piping should be provided.

3.2.4 Drain lines shall have sufficient slope and differential pressure to ensure drainage during normal operating and transient conditions when there are sudden pressure reductions in the MS or MS/R. The tube side of the reheater section does not present the same potential of water damage to the turbine. The drainage system, however, shall be thoroughly analyzed and designed to consider potential tube leaks.

3.2.5 If extraction steam is provided from the cross-around pipe, it shall be connected at a high elevation, close to the high-pressure turbine. This will minimize the amount of water normally handled by the drains of the associated feedwater heater and the amount of water handled by the drains of the extraction pipe when the heater is out of service. The point of connection will also depend on where the extraction point is with respect to the MS or MS/R. Avoid connecting the extraction pipe to the side or bottom of a horizontal section of the cross-around pipe. If routing of the extraction steam piping has a low point, continuous drains shall be provided in accordance with the rules under para. 3.3.6.

3.3 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. Requirements for the design of the extraction systems to minimize the possibility of water damage to the turbines are specified in paras. 3.3.1 through 3.3.13.

3.3.1 Because of the severity of damage that can occur when water enters the turbine from an extraction point, the system shall be designed so that no single failure of equipment shall result 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 can 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. 3.3.1.1 and Figs. 1 through 4)

(b) power-operated block valves between the feedwater heater and the turbine and power-operated block valves in cascading drain lines (see para. 3.3.1.2 and Figs. 1 and 2)

(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 tubes (see para. 3.3.1.3 and Figs. 3 and 4)

3.3.1.1 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 1 and 3 show the normal primary drain line with its associated level control and an automatically operated alternate drain and its level control system. Figures 2 and 4 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 drains shall be sized for all normal operating conditions.

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

(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 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 in the open position (fail-open).

3.3.1.2 Power-operated block valves shall be included in the extraction line from the turbine to the feedwater heaters. The valves and associated equipment are shown in Figs. 1 and 2. These valves are actuated to close by a high-high level in the feedwater heater

Fig. 1 Typical Heater Steam Side Isolation System: Local Control System

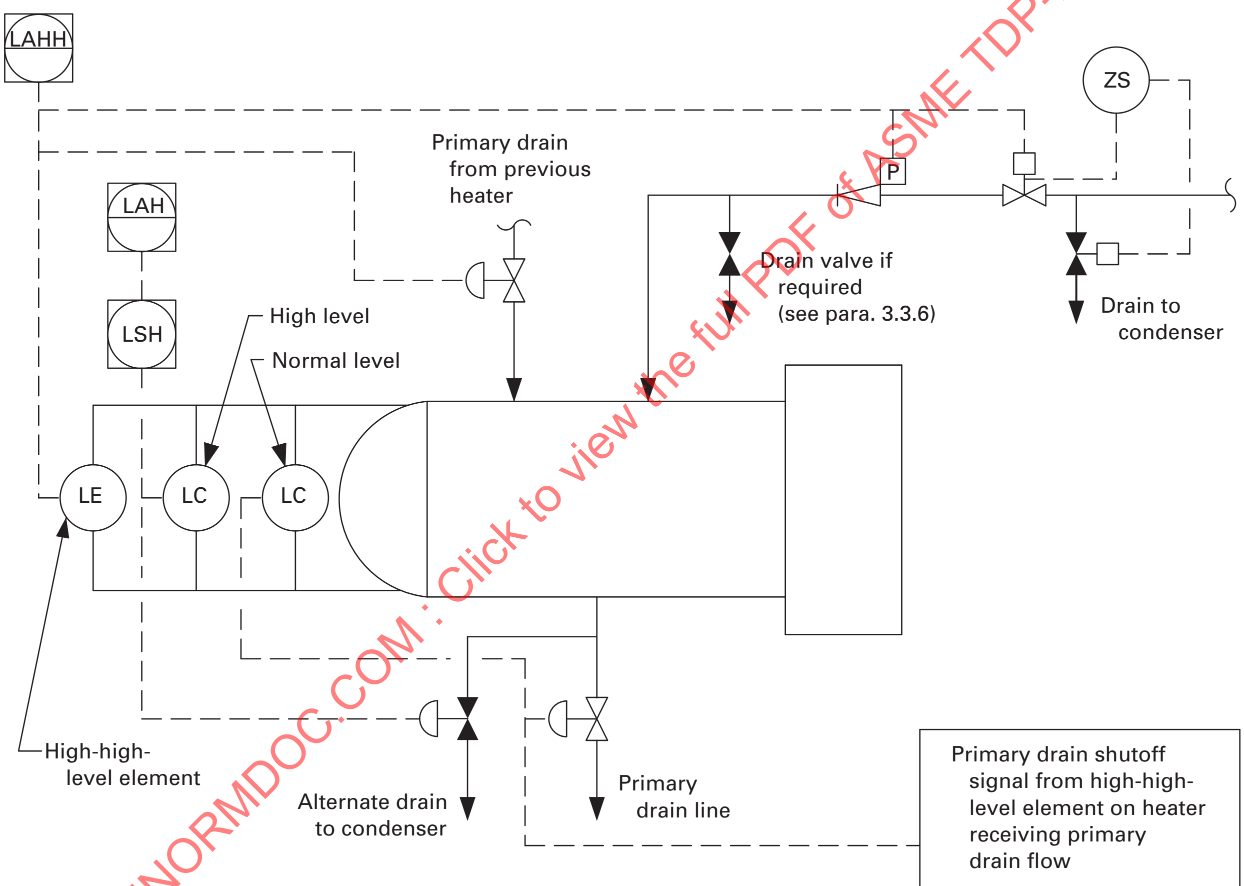
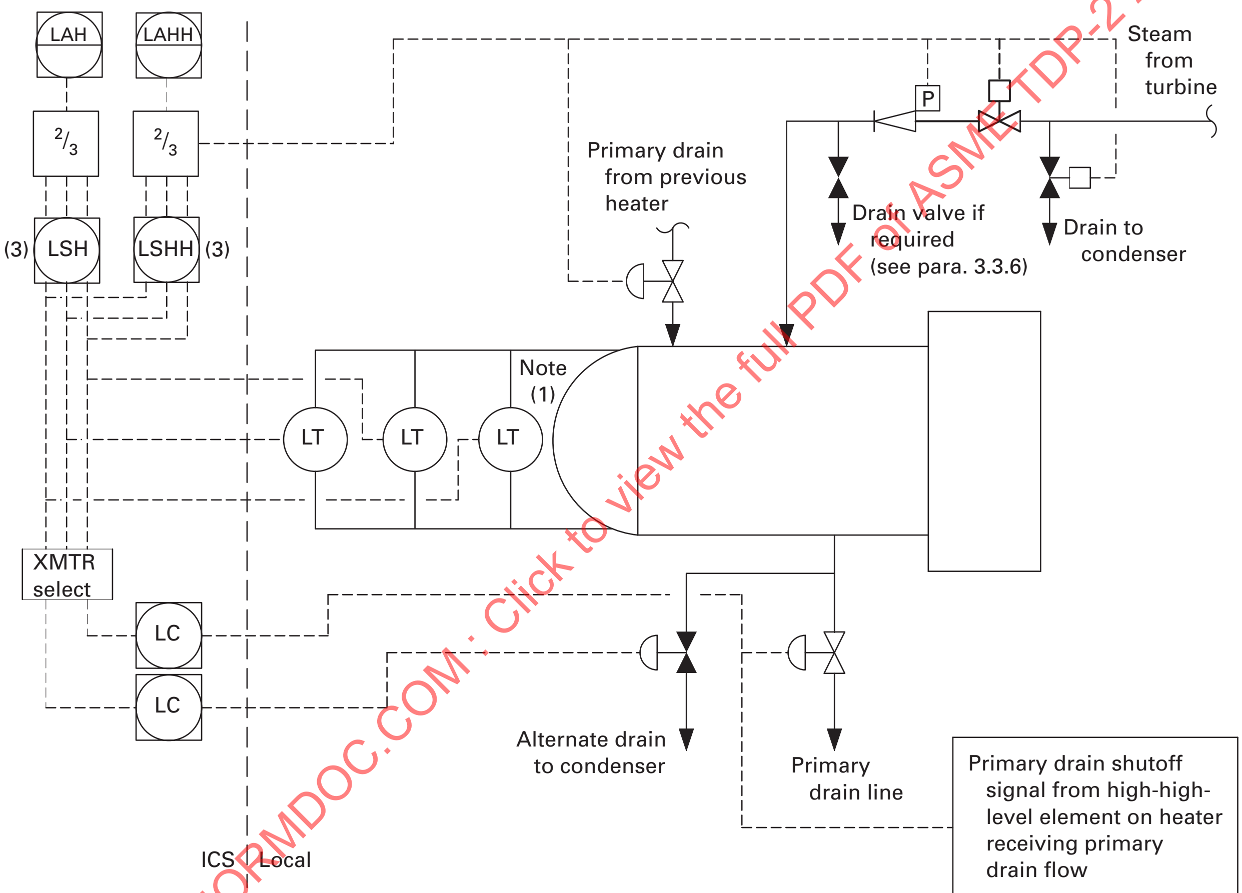


Fig. 2 Typical Heater Steam Side Isolation System: Integrated Control System



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

Fig. 3 Typical Heater Tube Side Isolation System: Local Control System

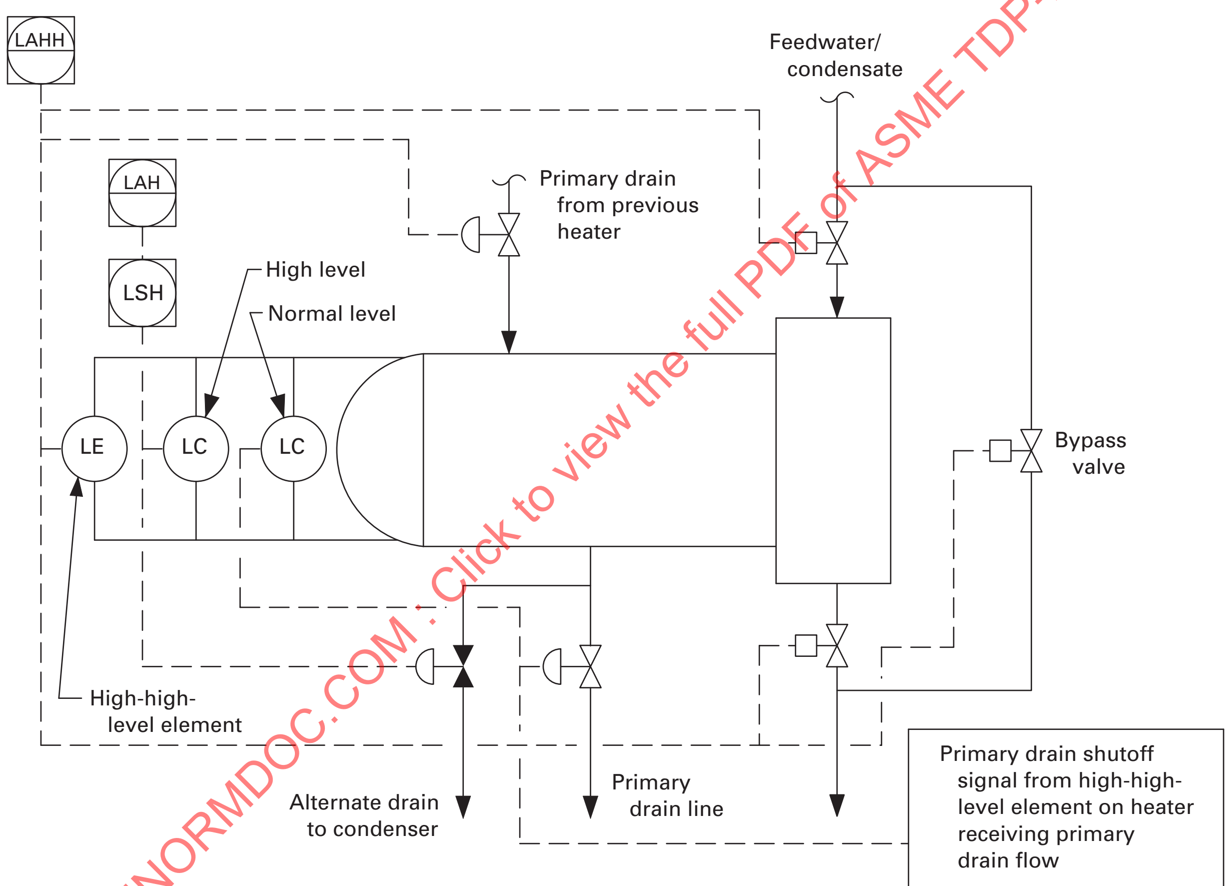
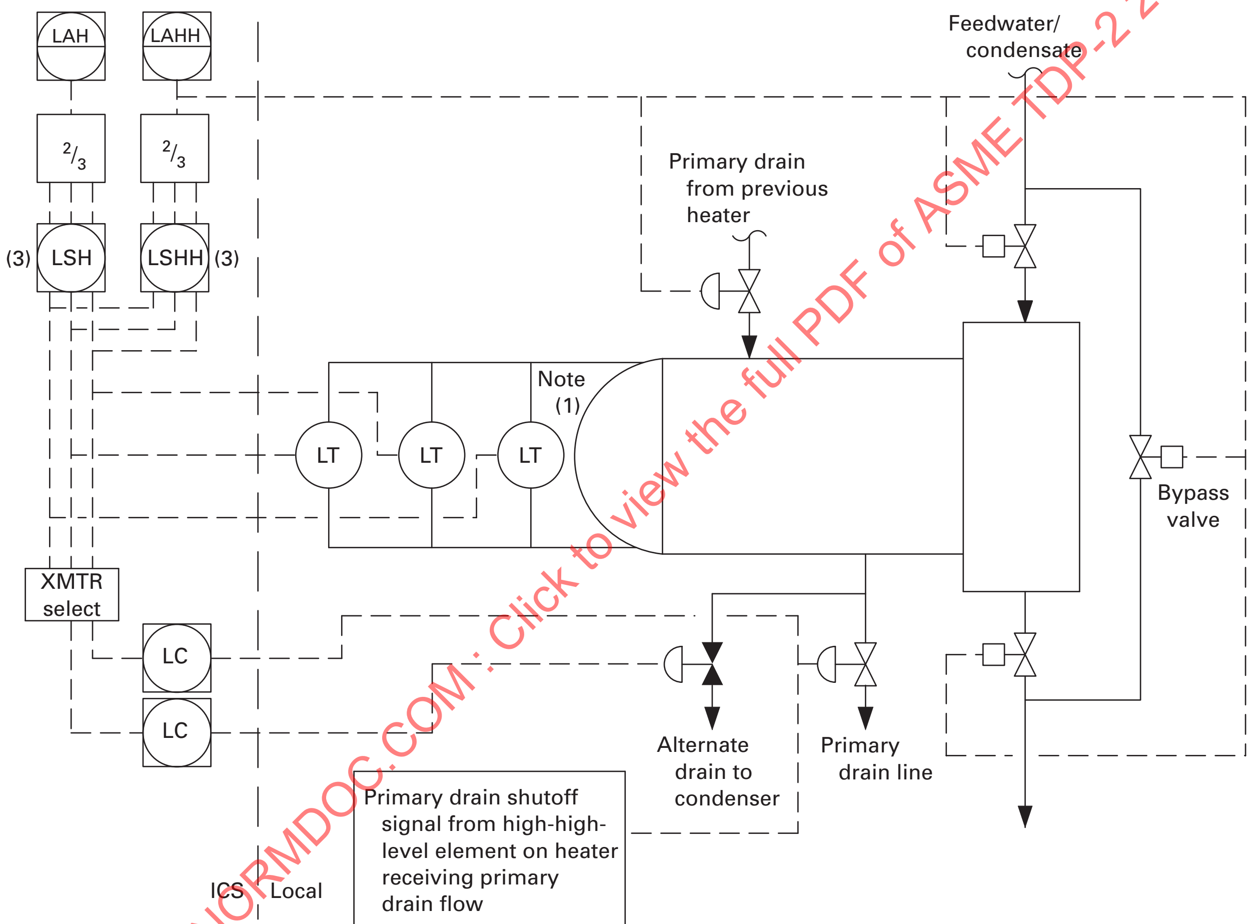


Fig. 4 Typical Heater Tube Side Isolation System: Integrated Control System



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

with a control independent from that described in para. 3.3.1.1.

Actuations of these valves indicate that the heater drainage system described in para. 3.3.1.1 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 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 the conditions described in para. 3.3.1.2(a) or (b) is then considered to be contributing to a rising level in the heater. The required time of operation of the block valve 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 block valve. With some heater arrangements, such as vertical heaters or heaters 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. 2.4).

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, they shall be closed automatically by the same signal that closes the block valve. They may be located on either side of the block valve. The nonreturn/check portion of the valve shall always be free to close when reverse flow occurs, regardless of actuator status.

3.3.1.3 It may be impractical to install the block valves as shown in Figs. 1 and 2 for feedwater heaters in the condenser neck. Therefore, an acceptable alternative to the second line of defense shown in Figs. 1 and 2 is to bypass the feedwater heaters as noted in Figs. 3 and 4. 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. 3.3.1.2 based on the time required to fill the heater to the top of the shell. Isolation valves shall not be interlocked with any permissive that would prevent closure and shall be activated on high-high level, independent of control from that identified in para. 3.3.1.1. 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 element.

3.3.1.4 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. 3 and 4. These are generally used to equalize the pressure on each side of these large isolation valves to open them and warm the tubesheets 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 kept closed by locking or other acceptable procedures.

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

3.3.3 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 annunciation 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 reactor manufacturer's requirements.

3.3.4 Level alarms and indications shall be designed to reflect the actual level in the heater. The physical arrangement of the instrumentation and heater drain piping shall preclude unnecessary actuation from level surges during start-up and normal operation. The physical arrangement shall minimize instrumentation interconnection piping lengths to avoid inaccuracies in level indication. Sensing pipes 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.

3.3.5 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. 2 or 4 shall be provided with two-out-of-three logic configuration.

(d) High-level alarms, indication opening of the alternate drain to the condenser per Fig. 2 or 4, 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.

3.3.6 A drain shall be located at the low point(s) in the extraction pipe between the turbine and extraction steam block valve. These drain valves are provided on nuclear units to open automatically when a feedwater heater is removed from service by closing the extraction block valve. These drain valves are necessary for start-up and continuous drainage of moisture injected into the extraction line from the wet steam path of the turbine when the block valve is closed. 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 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. They do not constitute a line of defense as covered in para. 3.3.1.

3.3.7 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).

3.3.8 All steam line drain valves in the extraction steam lines between the turbine and block valve shall be configured to fail-open on loss of power, air, or ICS processor communications as applicable.

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

3.3.10 The design of these protective systems shall include provision for periodic testing (see section 5 for testing).

3.3.11 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.

3.3.12 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 piping, a separate level element shall be mounted on the heater and shall operate the heater's isolation system similar to the arrangement shown in Figs. 3 and 4.

3.3.13 Other arrangements of feedwater heaters and bypasses are satisfactory, provided they accomplish the same objective as the arrangement shown in Figs. 3 and 4.

3.4 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, the power-assisted check valve(s) may be located in the common extraction header. The nonreturn/check portion of the valve shall always be free to close when reverse flow occurs, regardless of actuator status.

3.4.1 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. 3.4.2 and Figs. 5 through 8)

(b) an automatic emergency drain system from the DC heater storage tank or feed pump suction line (see para. 3.4.3 and Figs. 5 and 6)

(c) power-operated block valves on all sources of water entering the DC heater (see para. 3.4.4 and Figs. 7 and 8)

3.4.2 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 bottom of the extraction connection to 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.

3.4.3 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 5 and 6 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 shall 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. 5 and 6.

3.4.4 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 leak-off 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 7 and 8 show a typical arrangement for these block valves.

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

3.4.5 Turbine water induction prevention systems for DC heaters involve extraction steam isolation, plus a choice of a drain to the condenser or isolation of all incoming sources of water. Part of the latter was discussed in para. 3.3.1 concerning failure mode of the control valves in the incoming high-pressure heater drains. The other source of water is the condensate inlet. If the control valve in this line is arranged to be fail-closed, the action will result in a feedwater pump and unit trip, as the DC heater level will fall rapidly. A fail-open arrangement could easily result in high level with the potential for turbine water induction. While one solution is to provide for fail-in-place operation of the condensate valve, the designer is urged to recommend a power-operated drain valve from the DC heater to the condenser to ensure positive turbine water induction prevention design.

3.4.6 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.

(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. 6 or 8 shall be provided with two-out-of-three logic configuration.

(d) High-high alarm and isolation of the heater per Fig. 6 or 8 shall be provided with two-out-of-three logic configuration.

(e) High-level alarm per Fig. 6 or 8 shall be provided with two-out-of-three logic configuration.

3.4.7 The location of drains, valving, and the alarms provided shall be as previously mentioned in paras. 3.3.3 and 3.3.6.

3.4.8 All steam line drain valves from extraction steam lines shall be arranged for fail-open operation.

3.5 Turbine Steam Seal Systems

Water induction through the steam seal system can cause damage when steam seal casing or rotor metal temperatures are greater than the temperature of wet steam entering the steam seals.

Fig. 5 Typical Deaerator Arrangement With Drain System: Local Control System

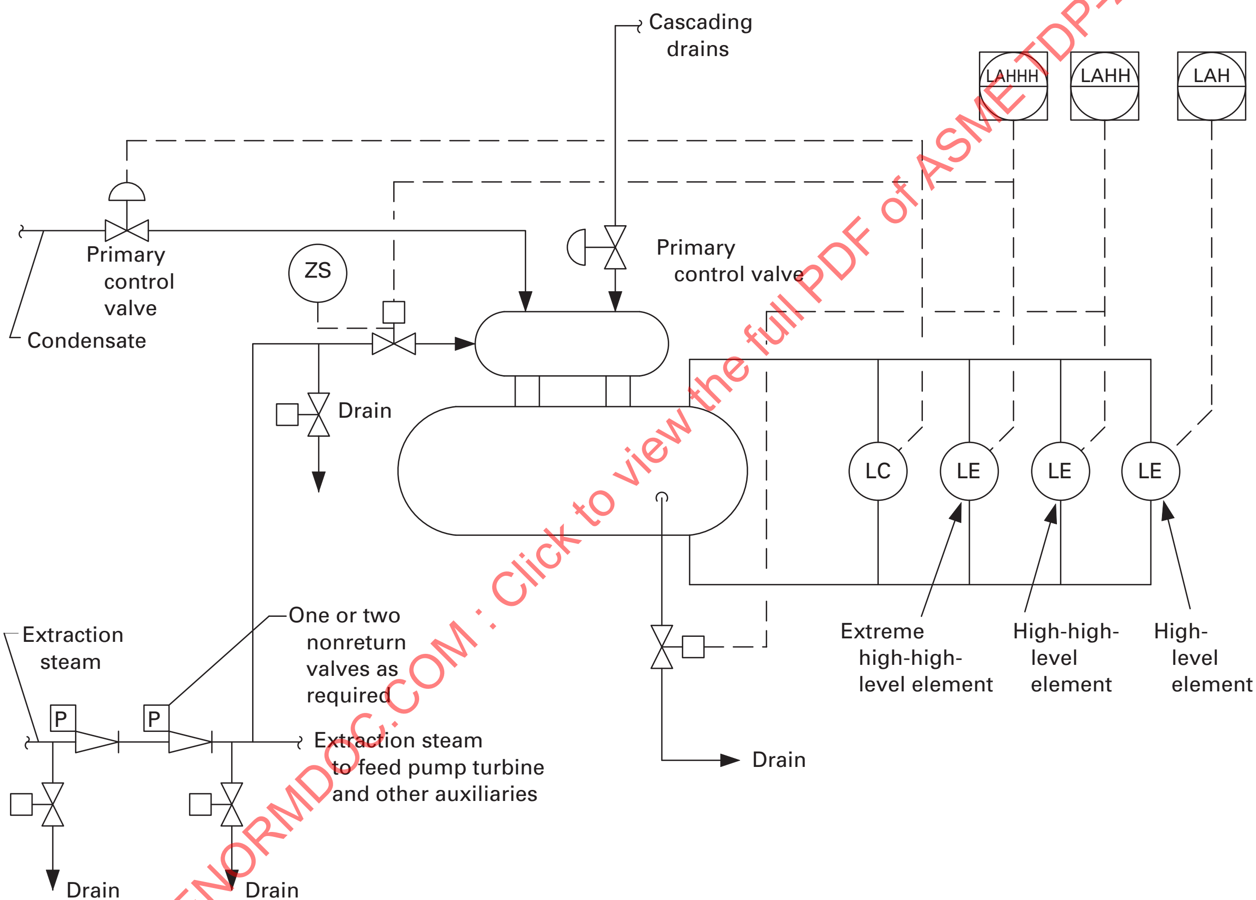


Fig. 6 Typical Deaerator Arrangement With Drain System: Integrated Control System

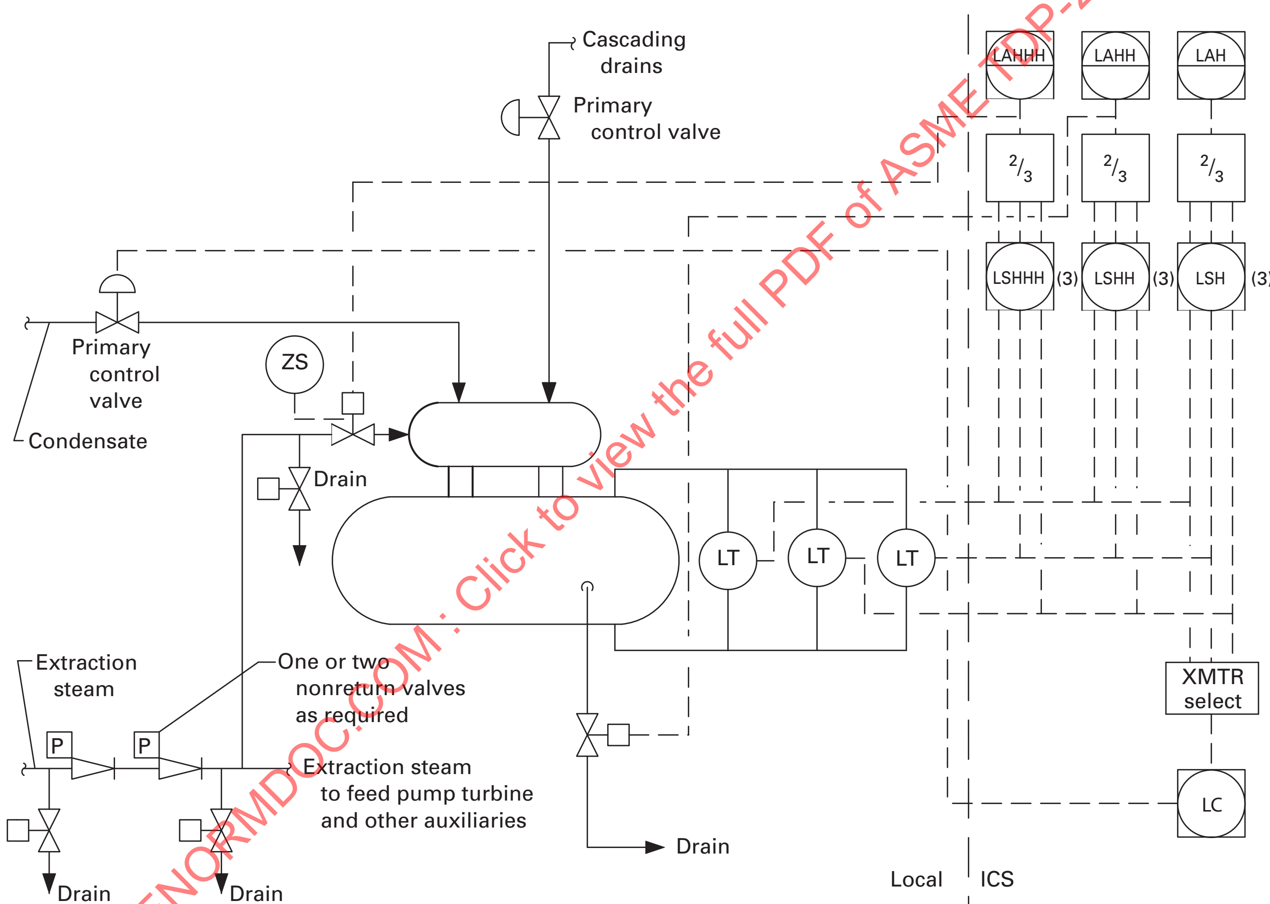


Fig. 7 Typical Deaerator Arrangement With Inlet Isolation: Local Control System

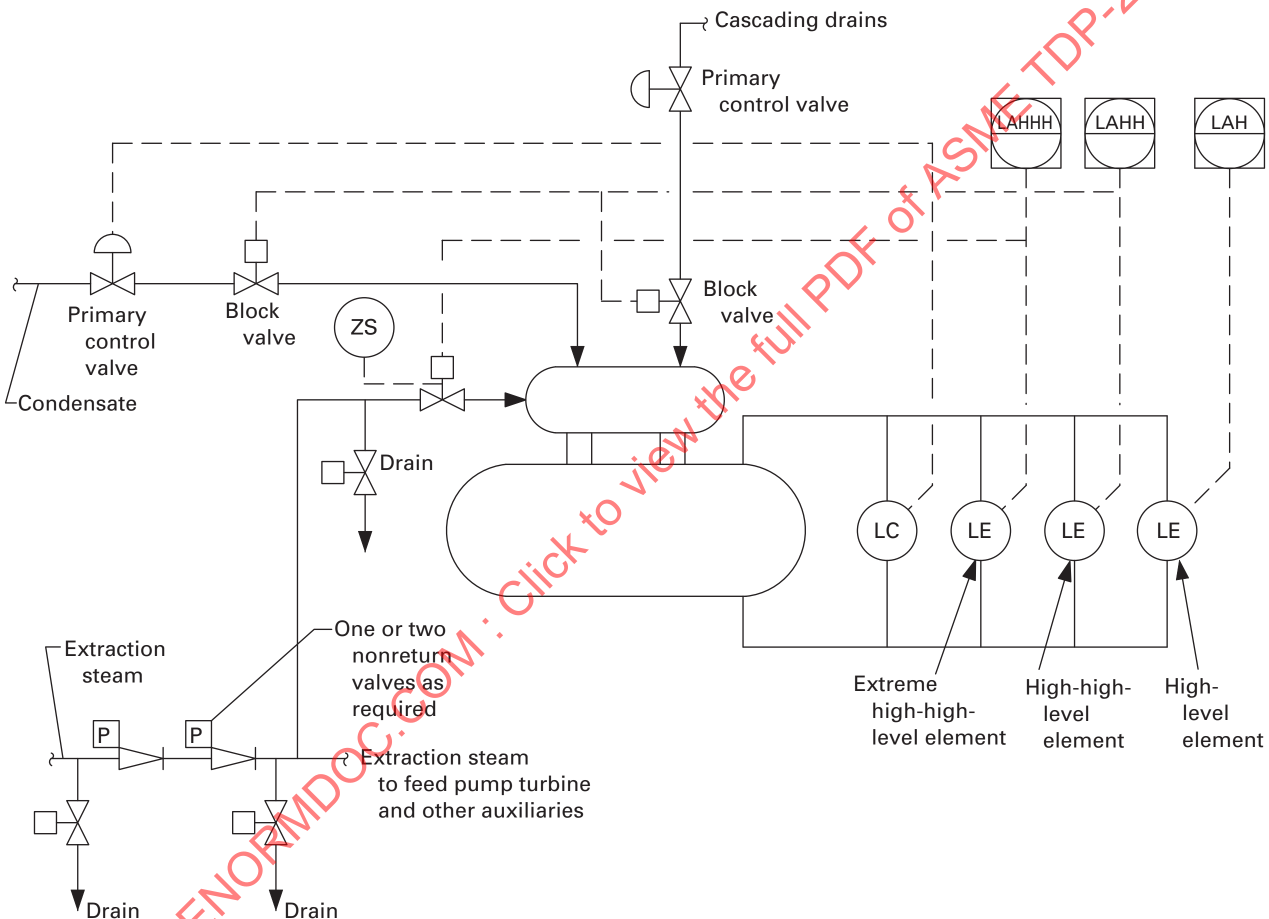


Fig. 8 Typical Deaerator Arrangement With Inlet Isolation: Integrated Control System

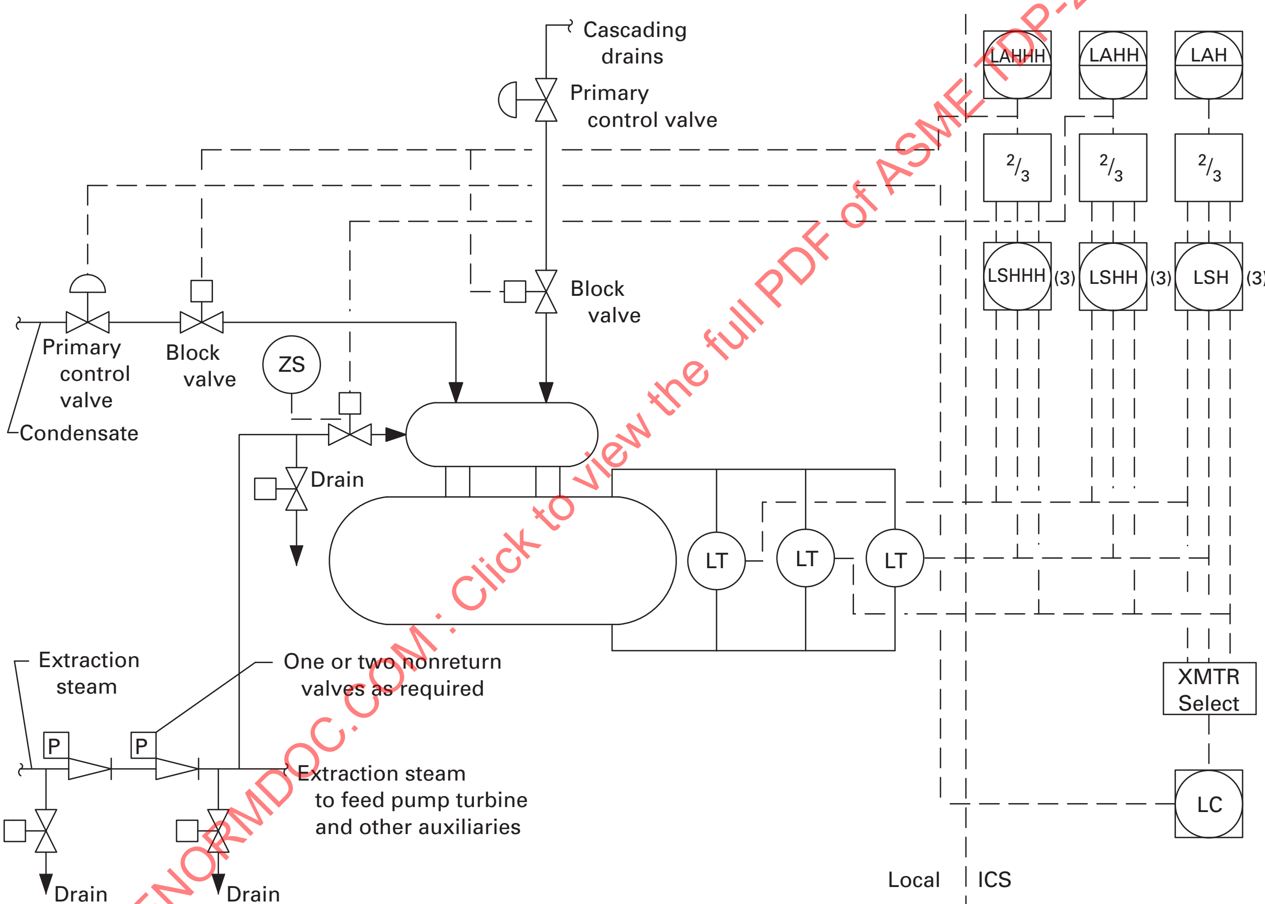
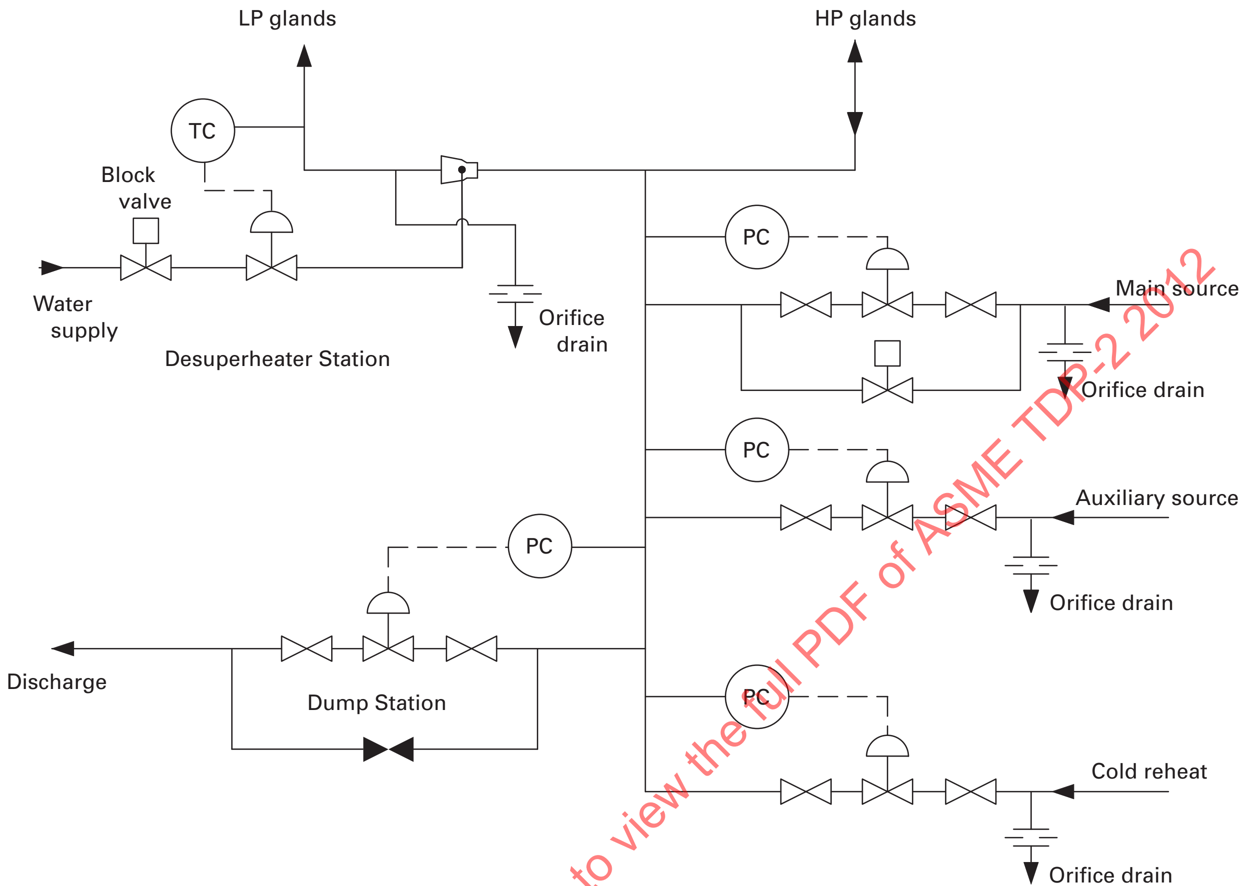


Fig. 9 Main Turbine: Typical Steam Seal Arrangement



3.5.1 Refer to Fig. 9. Pipes feeding steam to steam seal systems shall be pitched (2% minimum) toward the source of steam (main or auxiliary steam). If these lines are not pitched to their sources, there must be a drain on the inlet side of each 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.

3.5.2 Pitch the lines of the seal steam system (2% minimum) between the turbine and seal steam header so that they are self-draining to the steam seal header. If there are low points in the piping system, they shall be drained to the gland condenser or main condenser using continuous, orifice drains. Drain pipe bore and shutoff valve ports shall not be less than 3 in.

3.5.3 Pitch the lines between the turbine and gland condenser (2% minimum) so that they are self-draining to the gland condenser. If there are low points in this piping system, they shall be drained to the same pipe at a lower elevation or through a loop seal to a drip tank or atmosphere.

3.5.4 If an attemperator spray 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 in such a manner as to maximize mixing and evaporation of the attemperator spray. Refer to the turbine manufacturer's requirements.

3.5.5 A drain located downstream of the seal steam attemperator shall be provided that is designed to handle all the water that can be injected into the steam seal system 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.

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

3.5.7 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 are often 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, there is no accumulation of water in the seal steam piping that can enter the turbine through the heater extraction line.

3.5.8 If an auxiliary boiler or other source is used to supply seal steam, the power plant designer must consider the temperature–flow characteristics of auxiliary boilers or other sources to ensure that the temperature of the seal steam satisfies the turbine manufacturer's requirements.

3.5.9 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.

3.5.10 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 that allow 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 means 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 increases in flow) from the glands, valve leakoffs, or other sources is condensed, while maintaining a normal level in the shell.

3.5.11 Separate steam seal systems for turbines used with boiling water reactor may require provisions in addition to those listed above for preventing turbine water damage. Consult the turbine manufacturer for these additional requirements.

3.6 Feed Pump Turbine Steam Supply

A feed pump turbine (FPT) may receive throttle steam from different sources, typically low- and high-pressure steam. 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 turbine and FPT through throttle (low-pressure) steam supply lines.

3.6.1 Refer to Fig. 10. Each FPT throttle (low-pressure) steam pipe connected to the main turbine piping (i.e., extraction and/or MS/R) shall contain not less than one nonreturn valve and shutoff valve. The nonreturn valve(s) may be power assisted according to the requirements of the main turbine and actuated by a main turbine trip. The number of nonreturn valves is to be determined by the main turbine manufacturer. The nonreturn valves shall be located so that they prevent steam bypassing from one main extraction zone to another.

3.6.2 All throttle steam pipes to FPTs shall be heated so that they are available for immediate service. Remote power-operated drains shown in Fig. 10 shall be considered typical. The power plant designer shall determine the location of the warming orifices on the basis of the actual piping arrangement. Valve position indicators shall be located in the control room.

3.6.3 Provide a drain with a power-operated valve on each side of the nonreturn valve station. (The second drain may not be required if the pipe configuration is self-draining.) Bypass each drain valve with a continuous, orificed drain as shown in Fig. 11. The power-operated drains are used to heat the FPT throttle steam pipes. Use the FPT stop valve above-seat drains if permitted by the manufacturer and if of adequate capacity. Otherwise, provide a separate drain system on the turbine side of the nonreturn valve station.

3.6.4 Connections of the throttle steam for the FP turbine to the steam source(s) (i.e., main or auxiliary steam) shall be located on a vertical leg well above the low point or from the top of a horizontal run of piping in the source piping.

3.7 Drain Systems: Turbine and Cycle Piping

General design rules for turbine and cycle steam piping drain systems are specified in paras. 3.7.1 through 3.7.23. Also see Fig. 12. They reflect past successful design practices and shall be used in conjunction with the specific drain requirements made in the system-specific sections of this Standard and by the manufacturers 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 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

Fig. 10 Typical Arrangement for a Feed Pump Turbine Steam Supply With Dual Admission

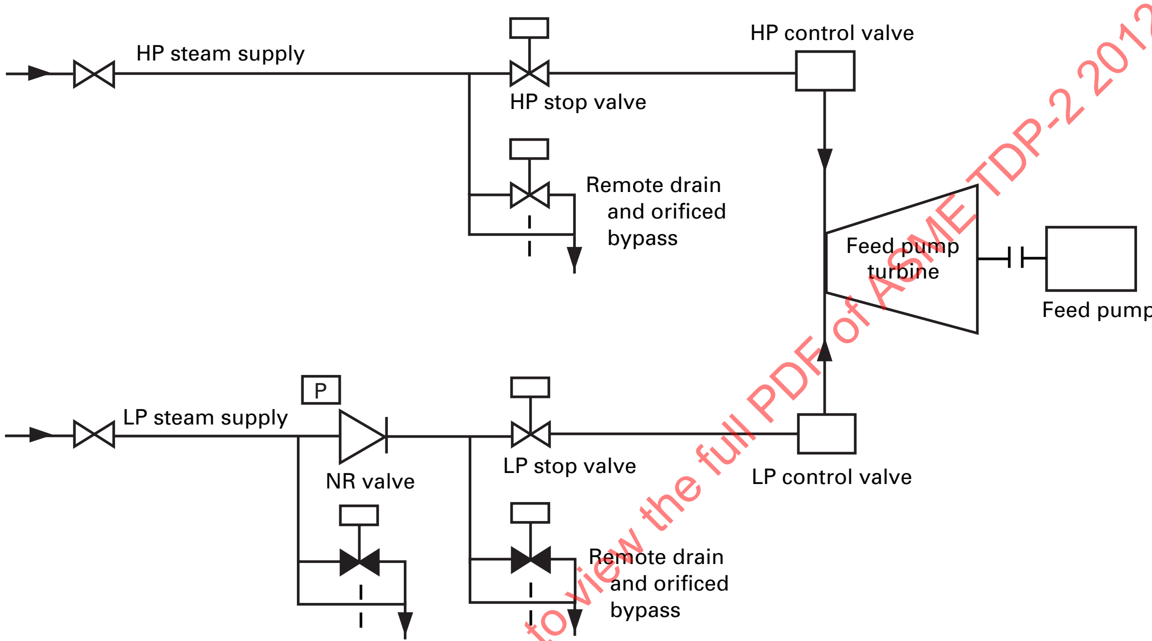


Fig. 11 Typical Continuous Drain Orifice

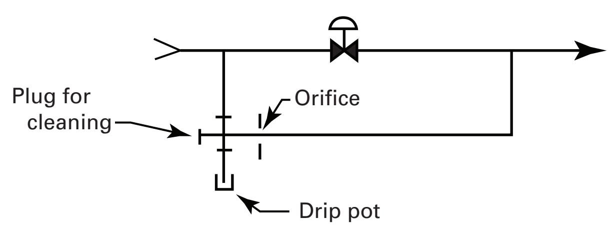
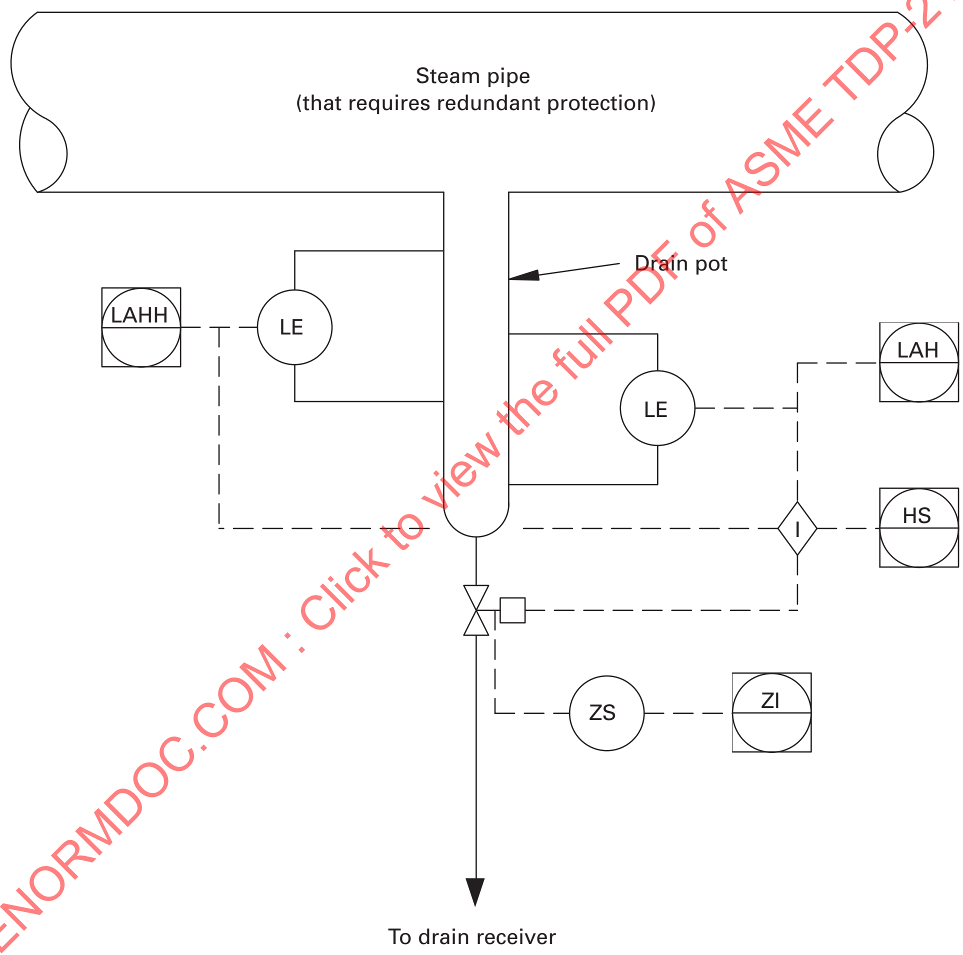


Fig. 12 Typical Drain System With Redundant Level Elements



is greater than the steam line pressure. Sections of the steam cycle downstream of the turbine stop valves are typically exposed to a vacuum 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, to minimize the risk of plugging by foreign materials, they shall never be less than $\frac{3}{4}$ in. internal diameter. Care shall be taken not to use nominal pipe or valve sizes without clearly determining that the inside diameter will meet 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 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. or larger pipe. Drain pots shall be at least 9 in. 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 To help ensure that the drain pot remains dry during normal unit operation, the pot and connecting piping shall be fully insulated.

3.7.8 A power-operated drain valve shall be located in each steam line. Position indication at the full-open and full-closed position shall be provided in the control room to allow the operator to determine the position of each of the power-operated drain valves. 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, adequate receiver overpressure protection during power plant failures must be provided, 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-controlling drain pots, which shall be prevented from closing.

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 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 pipe 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 a 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 drain lines installed for water induction protection. 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 water induction drain valve and associated piping.

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

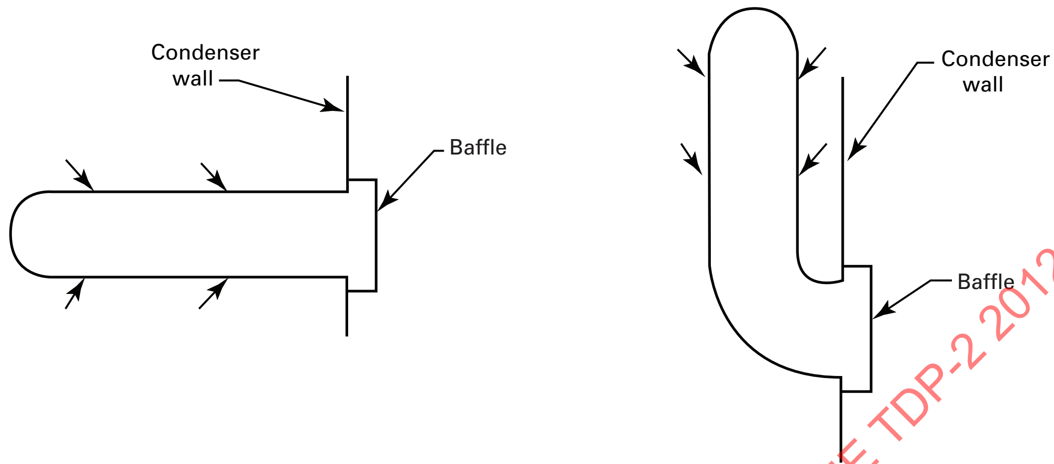
3.7.17 Drain lines may be routed separately to connections or manifolds mounted on the condenser shell or to separate drain tanks. The following requirements apply to these drain manifolds:

(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. Straight or L-shaped manifolds, as shown in Fig. 13, are acceptable.

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 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

Fig. 13 Typical Condenser Drain Manifolds



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 axis 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 the closing of isolation valves. The turbine manufacturer's requirements shall be considered for proper grouping of drains.

(e) Consideration shall be given to include 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 Drain lines may be routed separately or connected to a manifold on a drain tank. The following 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 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 tank drain level. If a tank 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.

3.7.19 Drain lines shall be protected from freezing.

3.7.20 Continuous drain orifices, where 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 occasional cleaning out the pocket. Strainers may be used upstream of the orifice for additional protection.

3.7.21 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.

3.7.22 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.

Pipes shall be pitched to the condenser, so that there are no low points to collect water. Spray attemperators introducing water into these discharge lines to the condenser shall be arranged to shut off whenever there is no steam flow. This is to prevent possible backflow of water into the turbine when the vacuum is broken in the condenser.

3.7.23 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 Improperly designed steam and water dumps to the condenser can cause turbine casing distortions and damage to stationary and rotating parts comparable with that caused by water from extraction, main steam, and reheat 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 flows should be directed away from turbine components by properly designed spargers, baffles, and flow deflectors.

3.8.2 The primary contributors to condenser-related turbine problems include inadequate condenser volume, incorrect location, improper design or design modification, control device failure, or misoperation involving the admission of high-energy fluids. Design-related problems can involve tube and shell erosion from jet impingement, baffle failures, and thermal distortion of turbine casings. Exhaust hoods that are sensitive to uneven temperature distributions and the last stage of turbine blades should not be exposed to any water impingement. Condenser problems are typically mitigated via proper fluid admission location, internal distribution, and effective dissipation of high-energy fluids.

3.8.3 To mitigate turbine damage potential, plant designers and condenser manufacturers shall ensure that sufficient space in terms of both volume and surface area are provided. These design features prevent crowding conditions that

(a) diminish energy dispersion capacity

(b) decrease preferred connection injection locations' flexibility for different types of fluids and fluid energy levels

The plant designer shall provide accurate fluid flow data, and the condenser manufacturer shall select the proper condenser connection type, size, and location based on that data.

3.8.4 In the initial specifications for the condenser, consideration is given to many factors, such as flow and heat load from the turbine exhaust, the economics of water temperature, fuel costs, turbine and plant cycle efficiencies, and condenser space requirements. The condenser manufacturer is required to meet these design parameters within the space limitations of the foundation opening. The required major steam and water dumps to the condenser must be known during the initial design stages and included with calculations of design margins and flow areas. It is very important to include provisions for flow from the main steam bypass system in the original specification of the condenser since this may actually have the most significant effect on the condenser sizing. Consideration should be given to abnormal as well as normal operation of steam and water dumps at various load conditions on the turbine. Examples are turbine bypass systems, relief valve discharges, auxiliary steam turbine dumps, turbine auxiliary valve dumps, and feedwater and moisture separator/reheater (MS/R) alternate drains. In some cases, separate equipment, such as flash tanks and/or separate condensing equipment, should be considered for receiving these flows to safely dissipate the energy at a pressure somewhat higher than in the main condenser. Water drains from these flash tanks and/or separate condensing equipment would then be discharged by suitable valving to the condenser.

3.8.5 *Recommended Location.* Condenser steam and water dumps shall be located on the condenser such that the resulting flows have the least possible chance of affecting the turbine. More detailed information regarding the location and design of condenser connections may be obtained from the Heat Exchange Institute (HEI), Standards for Steam Surface Condensers (latest edition) and from the Electric Power Research Institute (EPRI), Recommended Guidelines for the Admission of High-Energy Fluids to Steam Surface Condensers (CS-2251).

3.8.5.1 The HEI connection guidelines provide recommendations for different types of equipment and system drains, condenser make-up water, and steam and water dumps at different energy levels. It also includes guidelines for maximum steam enthalpy, steam superheat, fluid temperatures, and steam velocity, along with design recommendations on steam-flashing drains system's minimum pressures and circulation water flow availability.

3.8.5.2 The EPRI document presents both condenser design criteria and design guides for high-energy water and steam flow distributions of either a continuous or intermittent nature to the condenser. This document addresses various types of power plant fluids, including cold, saturated, or superheated water; flashing mixtures; and saturated or superheated steam, and provides recommendations for their dissipation in the condenser based on research and input from various manufacturers. It also identifies design requirements for deaeration, as well as desuperheating spray limitations. The EPRI document addresses kinetic energy dissipation limitations and associated design considerations for the