ASME TDP-1–2023
(Revision of ASME TDP-1–2013)

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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CONTENTS

FOREWORD

In the late 1960s, the two major U.S. steam turbine manufacturers issued design recommendations to stem the increasing occurrence of water-induced damage to steam turbines. Consequently, utilities and designers began formulating their own design criteria because of the economic need to keep the generating units in service. Realizing the need for a uniform set of design criteria, the American Society of Mechanical Engineers (ASME) formed the Standards Committee on Turbine Water Damage Prevention (TWDP) to develop recommended practices for the electric-power-generating industry. The TWDP Committee, comprising representatives of utilities, equipment manufacturers, and design consultants, produced TDP-1, which was approved as an ASME standard by the ASME Standardization Committee and the ASME Policy Board, Codes and Standards, on July 26, 1972.

In 1979, the TDWP Committee proposed revising the Standard to include information on condenser steam and water dumps, direct-contact feedwater heaters, and steam generators. The revised Standard was approved by the ASME Standardization Committee on April 25, 1980. Another edition, ANSI/ASME TDP-1–1985, was approved as an American National Standard on September 13, 1985.

In 1994, the ASME Board on Standardization disbanded the TDWP Committee and withdrew ANSI/ASME TDP-1 due to a perceived lack of interest and use by the industry. However, subsequent interest in ANSI/ASME TDP-1 from previous and potential users convinced ASME to reconstitute the TDWP Committee under the Board on Pressure Technology Codes and Standards in June 1997. The re-formed committee revised ANSI/ASME TDP-1–1985, producing ASME TDP-1–1998, which was 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 TWDP Committee to again revise the Standard. The result was ASME TDP-1–2006, which was approved as an American National Standard on November 6, 2006.

Prompted by the broad acceptance of ASME TDP-1–2006, ASME reissued the Standard in 2013 with mandatory requirements rather than the recommended practices of the previous editions. ASME TDP-1–2013 was approved as an American National Standard on February 5, 2013.

ASME TDP-1–2023 clarifies the safety systems of the integrated control systems shown in the figures, clarifies and adds design guidance on plants with multiple steam drum systems, and adds guidance on selected level measurement devices. This edition also revises the design specifications of warm-up lines per current industry practice, clarifies the use of separate controllers for drain valves, addresses indirect level measurements, and adds definitions and device identification abbreviations. ASME TDP-1–2023 was approved as an American National Standard on November 20, 2023.

ASME TWDP COMMITTEE
Turbine Water Damage Prevention

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

CORRESPONDENCE WITH THE TWDP COMMITTEE

General. ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Standard should be sent to the staff secretary noted on the committee's web page, accessible at https://go.asme.org/TWDPcommittee.

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In addition, the committee may post errata on the committee web page. Errata become effective on the date posted. Users can register on the committee web page to receive e-mail notifications of posted errata.

This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph numbers, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Standard.

(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table numbers

(4) the editions of the Standard to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

Interpretations. Upon request, the committee will issue an interpretation of any requirement of this Standard. An interpretation can be issued only in response to a request submitted through the online Interpretation Submittal Form at https://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic e-mail confirming receipt.

ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers can track the status of their requests at https://go.asme.org/Interpretations.

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

1 SCOPE

This Standard includes required and 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 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 cycle: steam is produced by heating water in a steam generator and then expanded through a steam turbine to produce power. Also called *Rankine cycle*.

normal operation: operation of the power plant in any condition under which the plant has been designed to operate for extended periods. Normal operation excludes start-up and shutdown operations, which are transient, but includes partial load operations such as extended steam turbine bypass operation and major equipment-out-of-operation modes if such modes are included as design cases.

2.2.2 Systems

admission 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 called *dual extraction/admission*. Admission steam is also called *induction steam*.

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: 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. Also called *nonautomatic*, *uncontrolled*, or *bleed 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: a device for reducing steam temperature, usually by introducing water into a steam piping system. Also called a *desuperheater*.

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: 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. Also called *automatic extraction*.

deaerator: 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: 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. Also called a *flash tank*.

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

gas 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 to generate steam for use in a steam power cycle. Also called a *combustion turbine*.

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.

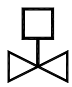
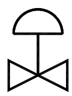
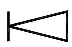
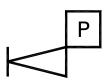
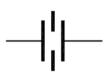
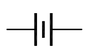
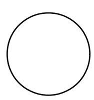
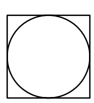
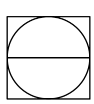
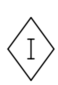
level element: a device used directly or indirectly to measure level and provide a corresponding output signal. A device used to provide a signal to indicate the presence of liquid is not a level element. See para. 3.10.3 for information on the use of a thermocouple as an alternative to a level element in high-design-temperature applications.

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.

Table 2.3-1
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

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 a heat recovery steam generator, 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 modules, and memory storage interconnected through a communication network and equipped with redundant power supplies. Normally, a distributed control system or redundant programmable logic controllers 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 2.3-1 for the symbol legend for the figures.

2.4 Device Identification Letters

See Table 2.4-1 for a list of device identification letters used in the figures.

2.5 References

The following is a list of publications referenced in this Standard. Unless otherwise noted, the latest edition shall apply.

Table 2.4-1
Device Identification

Device Identification Letters	Description
FI	Flow indicator
FT	Flow transmitter
HRSG	Heat recovery steam generator
HS	Hand switch
LAH	Level alarm high
LAHH	Level alarm high-high
LAHHH	Level alarm high-high-high
LC	Level control
LE	Level element
LSH	Level switch high
LSHH	Level switch high-high
LSHHH	Level switch high-high-high
LT	Level transmitter
PC	Pressure control
PT	Pressure transmitter
TC	Temperature control
TE	Thermocouple
XMTR select	Transmitter select [Note (1)]
ZI	Position indicator
ZS	Position switch

NOTE: (1) See para. 3.10.2.

ANSI/ISA-5.1. Instrumentation Symbols and Identification. International Society of Automation.

ASME Boiler and Pressure Vessel Code, Section I. Rules for Construction of Power Boilers — Part PHRSG, Requirements for Heat Recovery Steam Generators. The American Society of Mechanical Engineers.

EPRI CS-2251. Recommended Guidelines for the Admission of High-Energy Fluids to Steam Surface Condensers. Electric Power Research Institute.

Standards for Closed Feedwater Heaters. Heat Exchange Institute.

Standards for Steam Surface Condensers. Heat Exchange Institute.

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 attemperators, boiler start-up systems, high drum levels, undrained superheaters, and reheaters 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 entering the motive steam line. Therefore, at least two [(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.

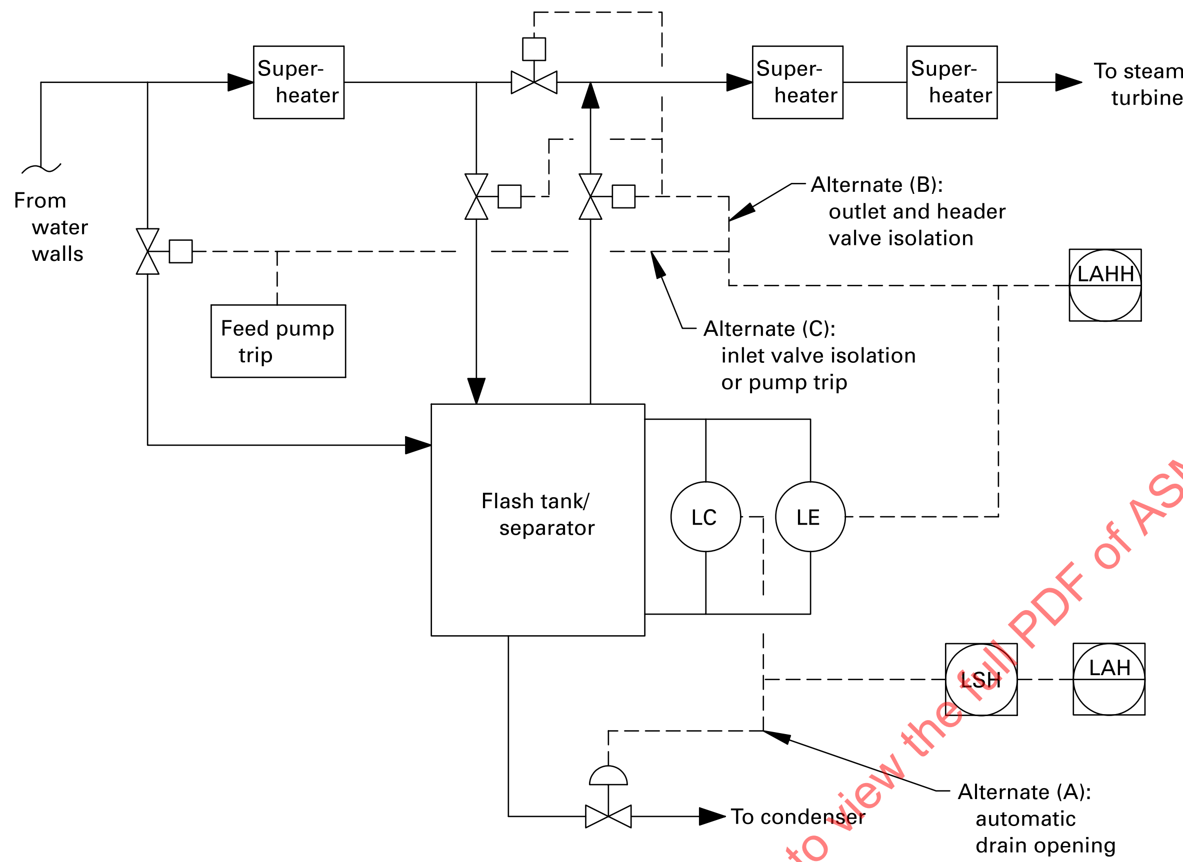
(c) automatic block of all sources of water entering the start-up system by either tripping all feed pumps or closing the feedwater block valve in the supply line to the flash tank, separator, or leveling vessel on detection of high-high level in the flash tank or separator.

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

Typical start-up systems for once-through boilers are shown in Figures 3.1.2-1 through 3.1.2-3. Figure 3.1.2-1 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 3.1.2-2 shows the same means of protection implemented using an 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

Figure 3.1.2-1
Typical Flash Tank/Separators Arrangement: Local Control System



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 ICS is shown in Figure 3.1.2-3.

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.

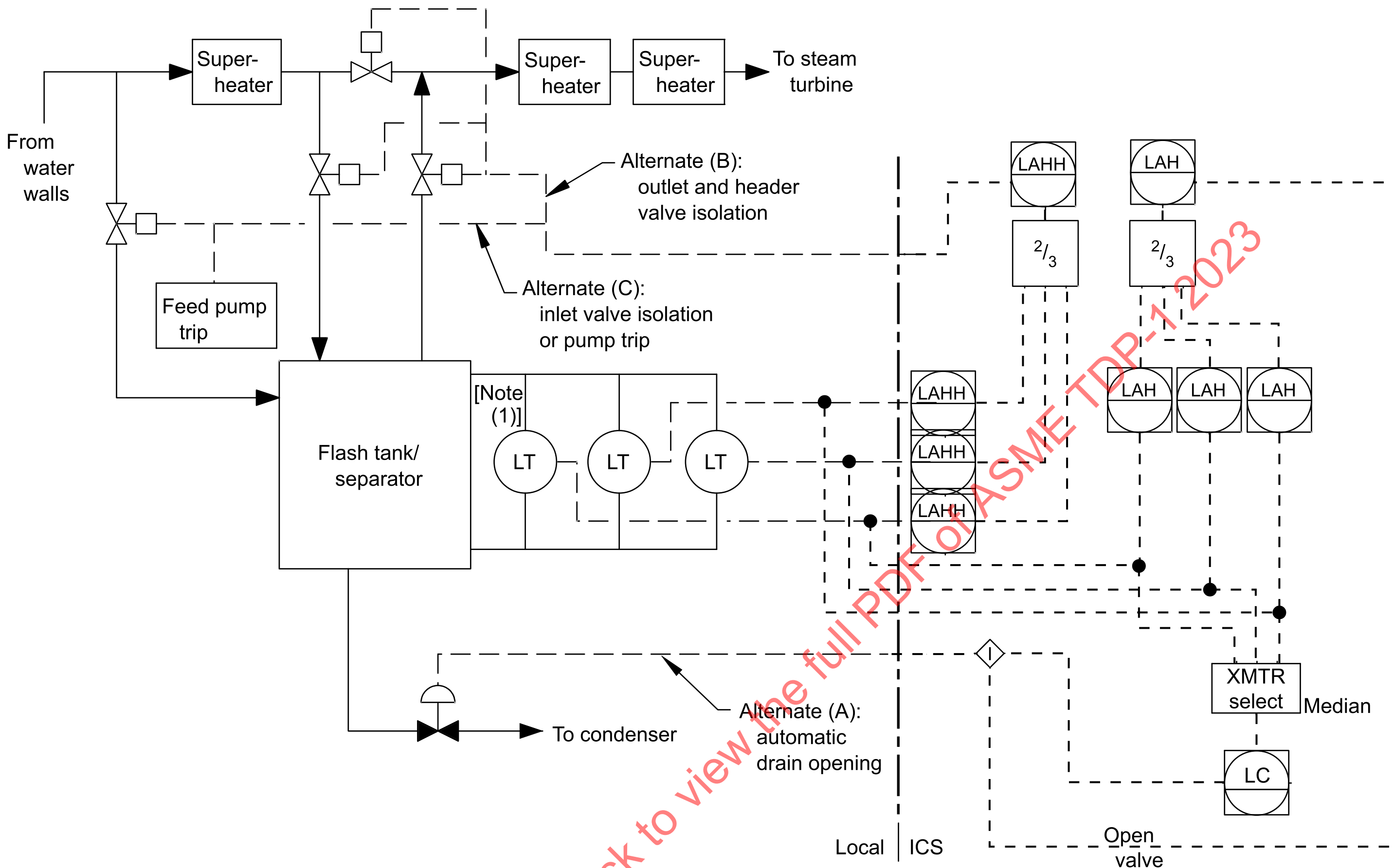
3.1.5 Heat recovery steam generator (HRSG) configurations typically include multiple steam drums at different operating pressures, each with independent water-level control. Some HRSG designs use a once-through high-pressure section. The same design requirements that apply to other steam generators shall apply to HRSGs.

3.1.6 If a single boiler or HRSG is supplying steam to a steam turbine, a high-high level alarm signal from any of the steam drums in that boiler or HRSG shall initiate a steam turbine trip.

3.1.7 When multiple boilers or HRSGs supply steam to a common motive steam line, a high-high level in any of the boiler or HRSG drums shall initiate a steam turbine trip if the boiler or HRSG is not already isolated from the motive steam line by at least one power-operated block valve and operating on the turbine bypass system.

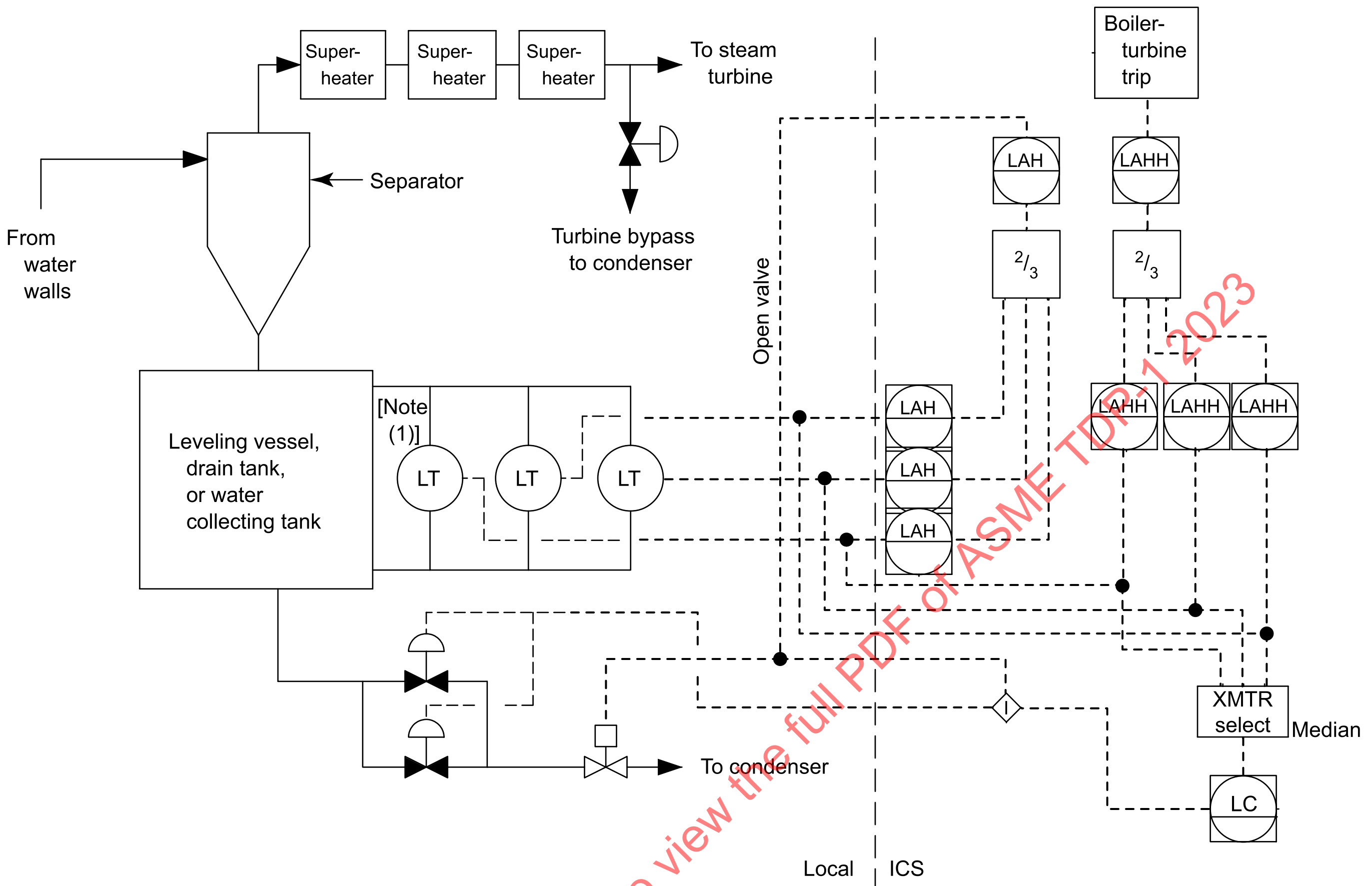
3.1.8 As an alternative to tripping the steam turbine as required in paras. 3.1.6 and 3.1.7, the steam turbine may remain operational if the steam generator controls are designed in accordance with the following requirements:

Figure 3.1.2-2
Typical Flash Tank/Separators Arrangement: ICS



NOTE: (1) The element may be a transmitter or a high-high level switch.

Figure 3.1.2-3
Typical Leveling System Arrangement: ICS



NOTE: (1) The element may be a transmitter or a high-high level switch.

(a) If the high level is reached in a steam generator, the boiler shall be isolated from the rest of the steam system by going back to turbine bypass.

(b) A power-operated block valve shall be installed between the steam generator and the steam turbine. The valve shall close to prevent water in the drum from filling the usable volume between the high level and the high-high level.

(c) A high-high level alarm shall trip the steam turbine if the steam generator is not already isolated from the motive steam line with at least one power-operated block valve.

3.1.9 HRSG superheater and reheater condensate removal connections and desuperheater spray water that is injected into the superheater or reheater piping shall be designed in accordance with the applicable portions of the ASME Boiler and Pressure Vessel Code, Section I, Part PHRSG.

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 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 shutdown 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.

(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.

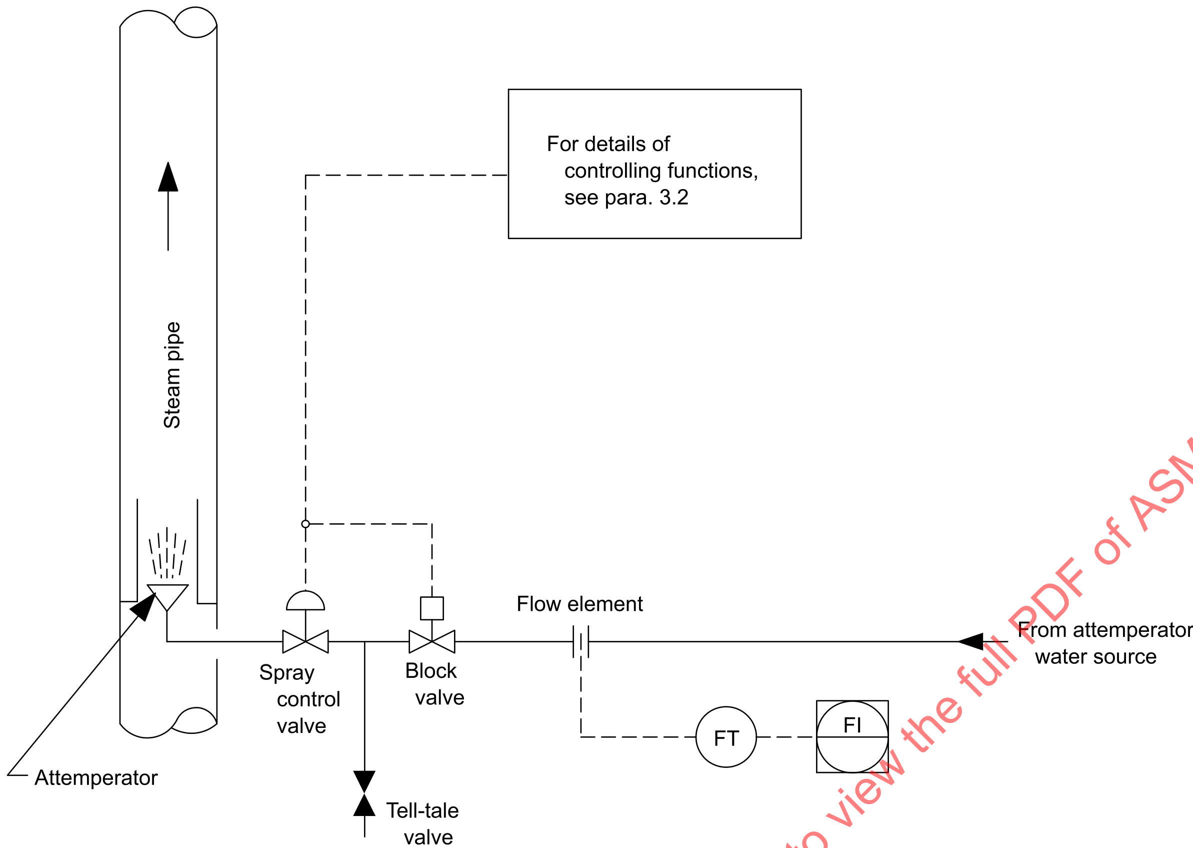
3.2.4 The use of motive steam attemperators shall prohibit activation or increase in spray when the steam conditions downstream of the attemperator are within 25°F (14°C) of saturation temperature.

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 Figure 3.2.5-1). 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.

Figure 3.2.5-1
Typical Attemperator System



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 Figure 3.2.5-1 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 Figures 3.3.3-1 and 3.3.3-2).

(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 Figures 3.3.3-1 and 3.3.3-2).

(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 Figures 3.3.3-1 and 3.3.3-2).

(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 drains.

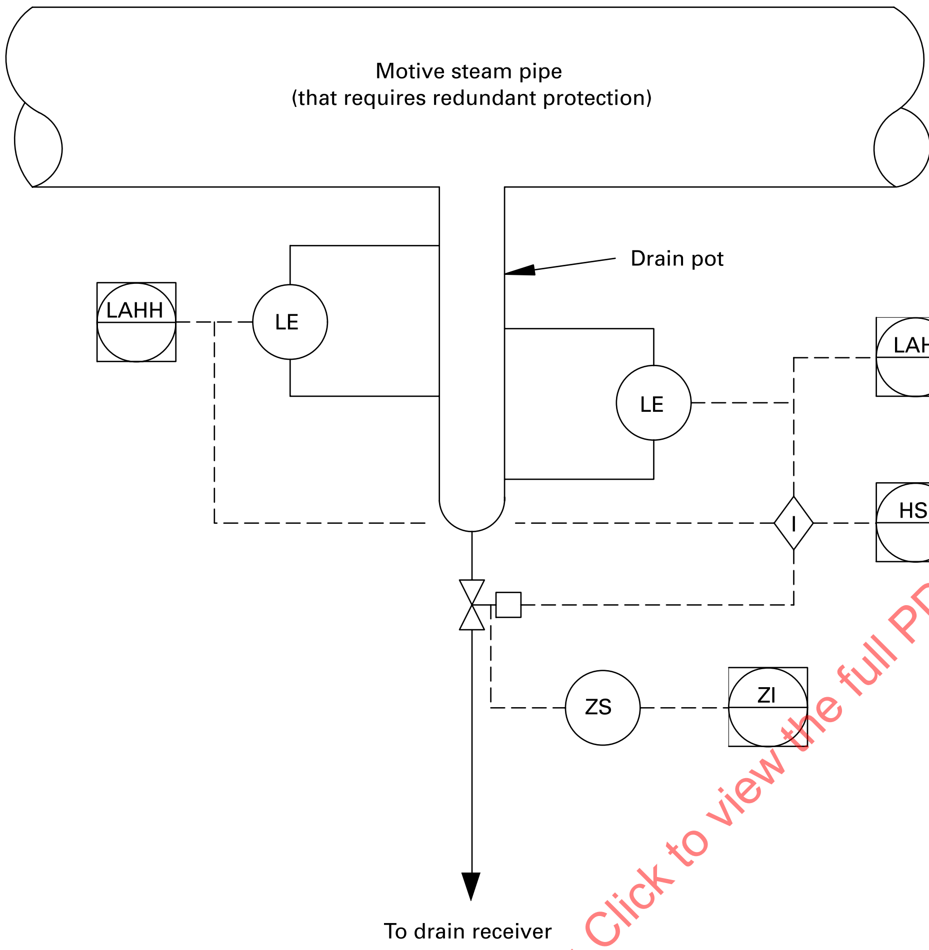
If the motive steam line is split into more than one branch going into the steam turbine, each branch, as well as the main header, shall be reviewed for low points. Motive steam piping drains shall not be manifolded with any other drains from the steam generator unless the manifold has been analyzed and designed so that the flow of each drain will not be impeded under any mode of operation. For additional information on drain-pot level control, see para. 3.10.

3.3.4 If the valve body is not self-draining, a before-seat drain or an equivalent connection shall be provided on each turbine stop valve to permit complete draining of any water that might accumulate at a low point. The before-seat drain on the turbine valve body, if provided, is for drainage of localized accumulation of water in the valve body. The before-seat drain may not be sized to handle drainage or warming of the main steam inlet piping leading up to the stop valve. A warming connection, either separate from 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 or an equivalent connection should be used with the drains in the system as a bleed-off point for warming the motive steam line before admitting steam to the turbine.

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

Figure 3.3.3-1
Typical Drain System With Redundant Level Elements

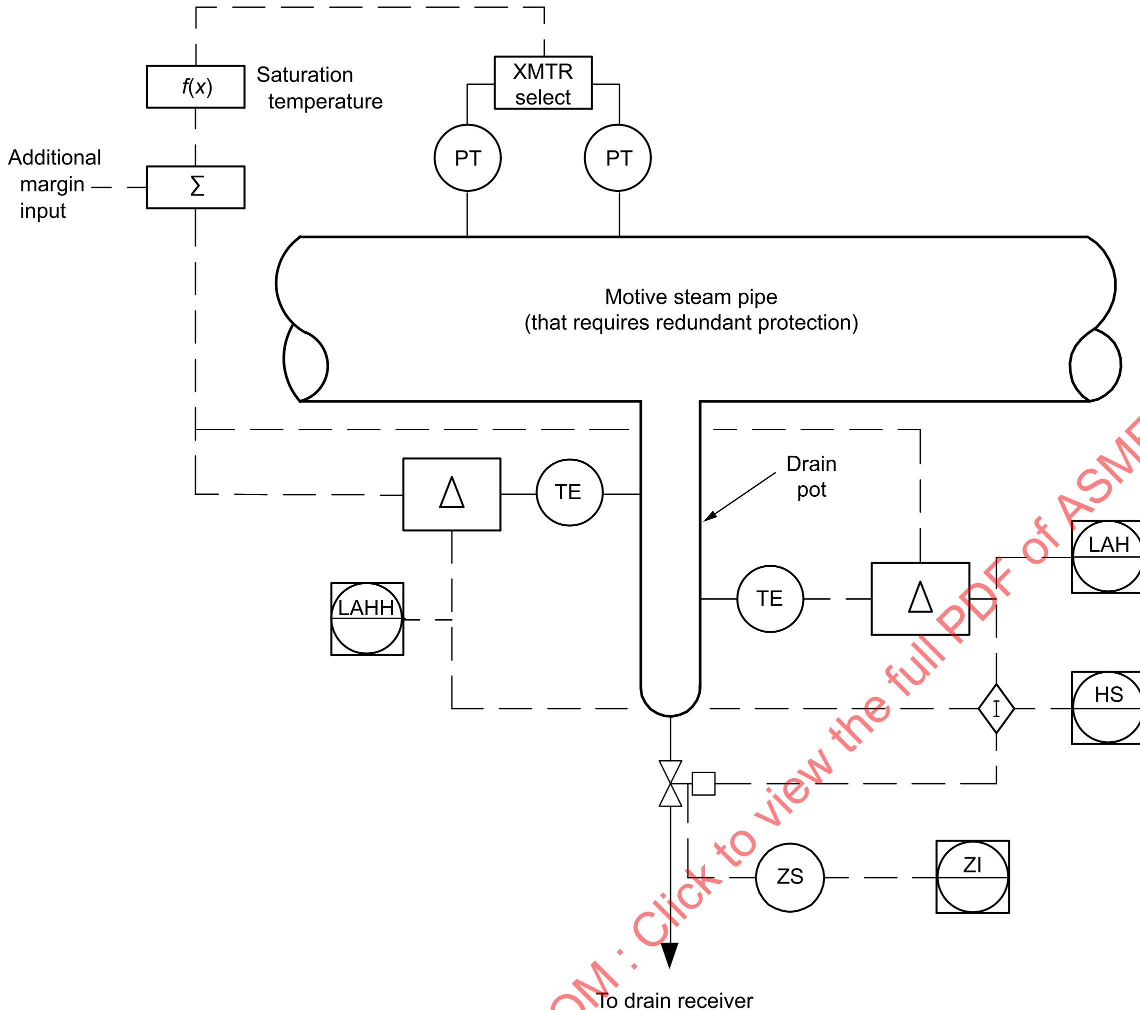


designed to prevent backup of water due to vessel or process steam line high water level. Attemperators in bypass systems that discharge to the cold reheat system (or any other line connected back to the steam turbine) shall be designed consistent with the requirements of para. 3.2 on attemperators.

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 valves may be power assisted according to the requirements of the main steam turbine manufacturer and actuated by a main steam turbine trip. The main steam turbine manufacture shall determine the number of nonreturn valves.

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 Figures 3.3.3-1 and 3.3.3-2), as well as the following:

Figure 3.3.3-2
Typical Drain System With Redundant Thermocouples



(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 valves may be power assisted according to the requirements of the main steam turbine and is actuated by a main steam turbine trip. The main steam turbine manufacture shall determine the number of nonreturn valves. 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 3.5.14 to minimize the possibility of water damage to the turbine.

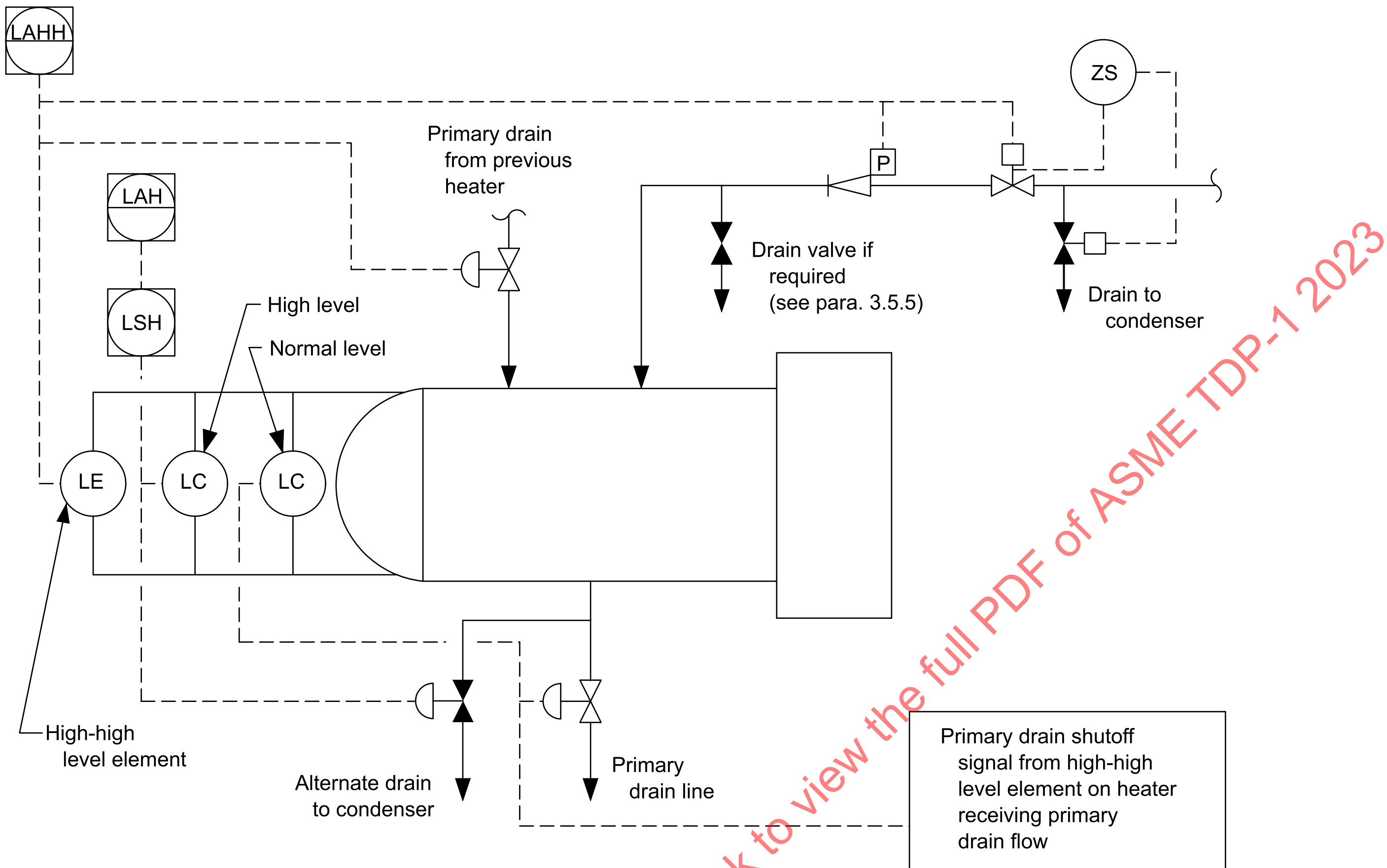
3.5.1 The system shall be designed so that no single failure of equipment results in water entering the turbine. Two independent means of automatically preventing water from entering the turbine from the extraction system shall be provided. In general, these independent means shall be a combination of 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 Figures 3.5.1-1 through 3.5.1-4)

(b) power-operated block valves between the feedwater heater and the turbine and power-operated block valves in cascading drain lines (see para. 3.5.1.2 and Figures 3.5.1-1 and 3.5.1-2)

(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 heater tubes (see para. 3.5.1.3 and Figures 3.5.1-3 and 3.5.1-4)

Figure 3.5.1-1
Typical Heater Steam-Side Isolation System: Local Control System



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 3.5.1-1 and 3.5.1-3 show the normal primary drain line with its associated level control and an automatically operated alternate drain and its level control system. Figures 3.5.1-2 and 3.5.1-4 depict the same control scheme using an ICS. 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.)

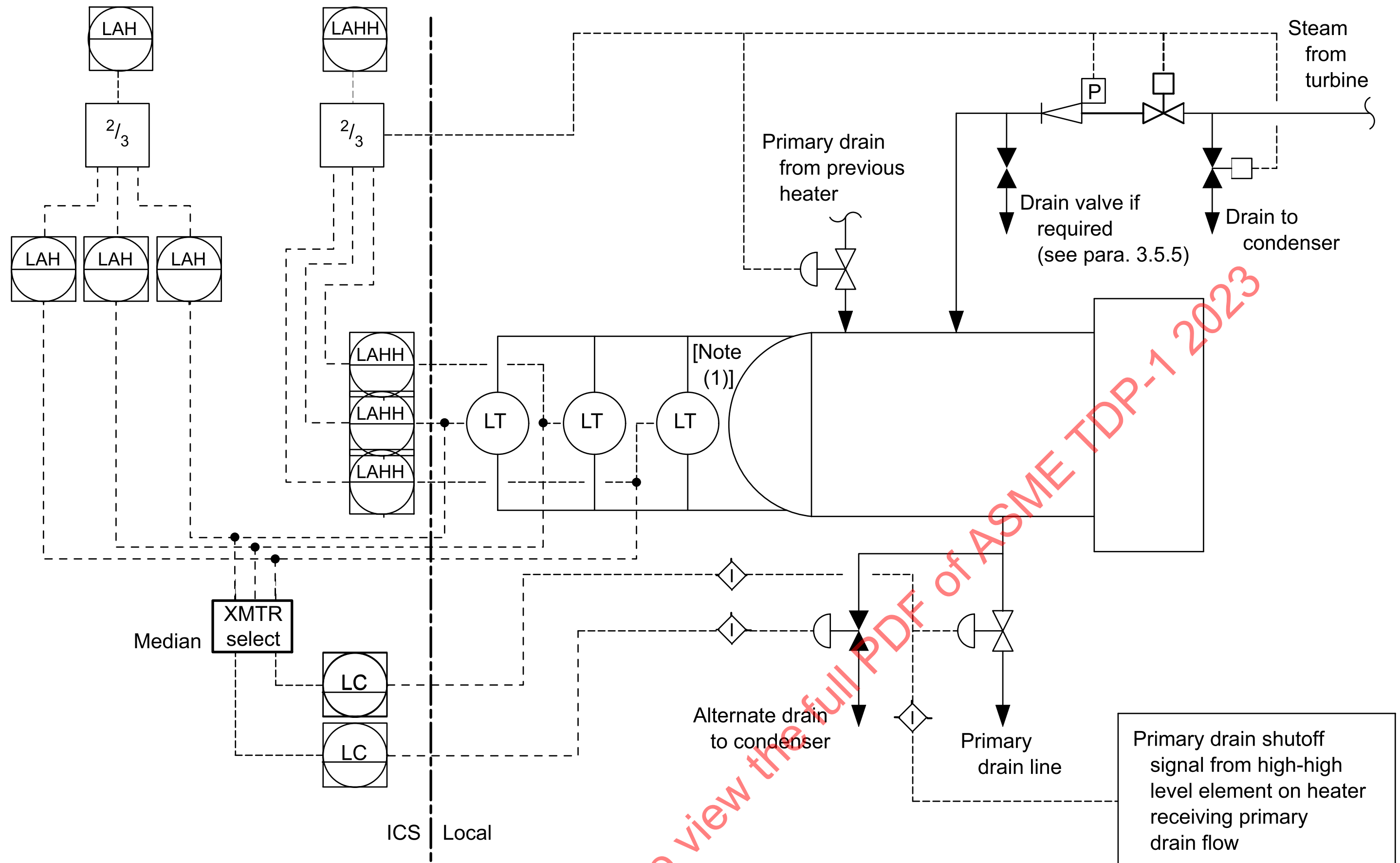
(c) In the case of low-pressure heaters with internal drain coolers, the alternate drain shall be connected directly to the heater shell ahead of the drain cooler to provide positive drainage (in case of damage of cooler).

(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.

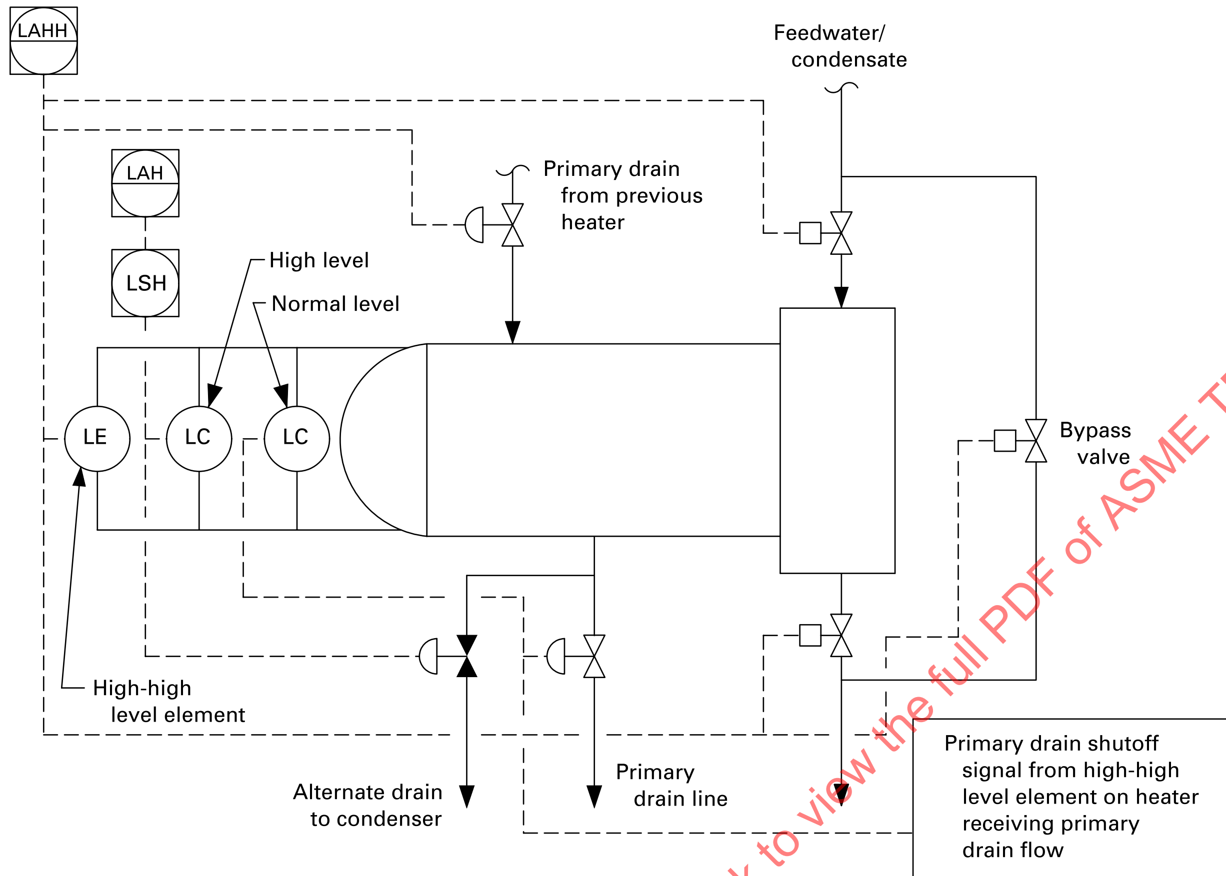
(f) The normal drain level control valve in drains cascading to a lower pressure feedwater heater shall be designed on loss of power, air, or ICS processor

Figure 3.5.1-2
Typical Heater Steam-Side Isolation System: ICS



NOTE: (1) The element may be a transmitter or a high-high level switch.

Figure 3.5.1-3
Typical Heater Tube-Side Isolation System: Local Control System



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 are shown in Figures 3.5.1-1 and 3.5.1-2. 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.

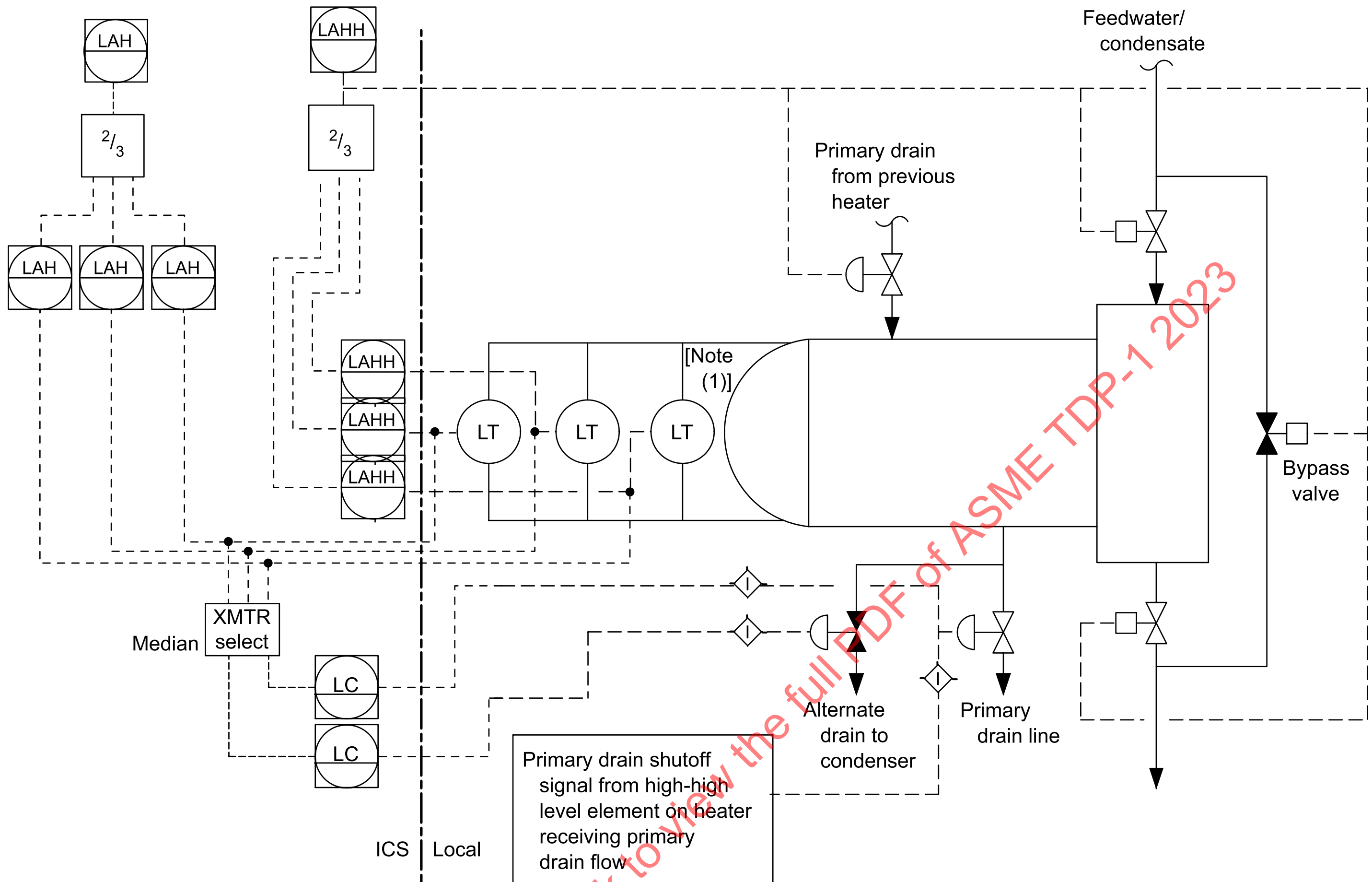
The required speed of operation of the power-operated block valves depends on the total amount of excess water flowing to the heater and the volume between the high-high level and the block valve. The total amount of excess water flowing to the heater for purposes of this calculation shall be the larger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

Figure 3.5.1-4
Typical Heater Tube-Side Isolation System: ICS



NOTE: (1) The element may be a transmitter or a high-high level switch.

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's Standards for Closed Feedwater Heaters (see para. 2.5).

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 Figures 3.5.1-1 and 3.5.1-2 for feedwater heaters in the condenser neck. Therefore, an acceptable alternative to the second line of defense shown in Figures 3.5.1-1 and 3.5.1-2 is to bypass the feedwater heaters as noted in Figures 3.5.1-3 and 3.5.1-4. 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. 3.5.1.2 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 Figures 3.5.1-3 and 3.5.1-4. 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 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 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.

Where an ICS 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 Figure 3.5.1-2 or Figure 3.5.1-4 shall be provided with two-out-of-three logic configuration.

(d) High level alarm, indicating opening of the alternate drain to the condenser per Figure 3.5.1-2 or Figure 3.5.1-4, shall be provided with two-out-of-three logic configuration.

(e) Separate logic controllers shall control the heater normal and alternate automatic valves. The control logic may use a transmitter select function, defined in para. 3.10.2, to interface with the redundant level measurements.

(f) The ICS shall be as defined in para. 3.10.1.

3.5.5 A drain shall be located at each low point 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.

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

3.5.7 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.

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

3.5.9 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.

3.5.10 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.

3.5.11 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.

3.5.12 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 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 Figure 3.5.1-2 or Figure 3.5.1-3.

3.5.13 Other arrangements of feedwater heaters and bypasses are satisfactory, provided they accomplish the same objective as the arrangement shown in Figures 3.5.1-3 and 3.5.1-4.

3.5.14 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.

3.5.15 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. One or more power-assisted check valves are 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 valves 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 Figures 3.6.1-1 through 3.6.1-4)

(b) an automatic emergency drain system from the DC heater storage tank or feed pump suction line (see para. 3.6.3 and Figures 3.6.1-1 and 3.6.1-2) typically to the condenser

(c) power-operated block valves on all sources of water entering the DC heater (see para. 3.6.4 and Figures 3.6.1-3 and 3.6.1-4)

Figure 3.6.1-1
Typical Deaerator Arrangement With Drain System: Local Control System

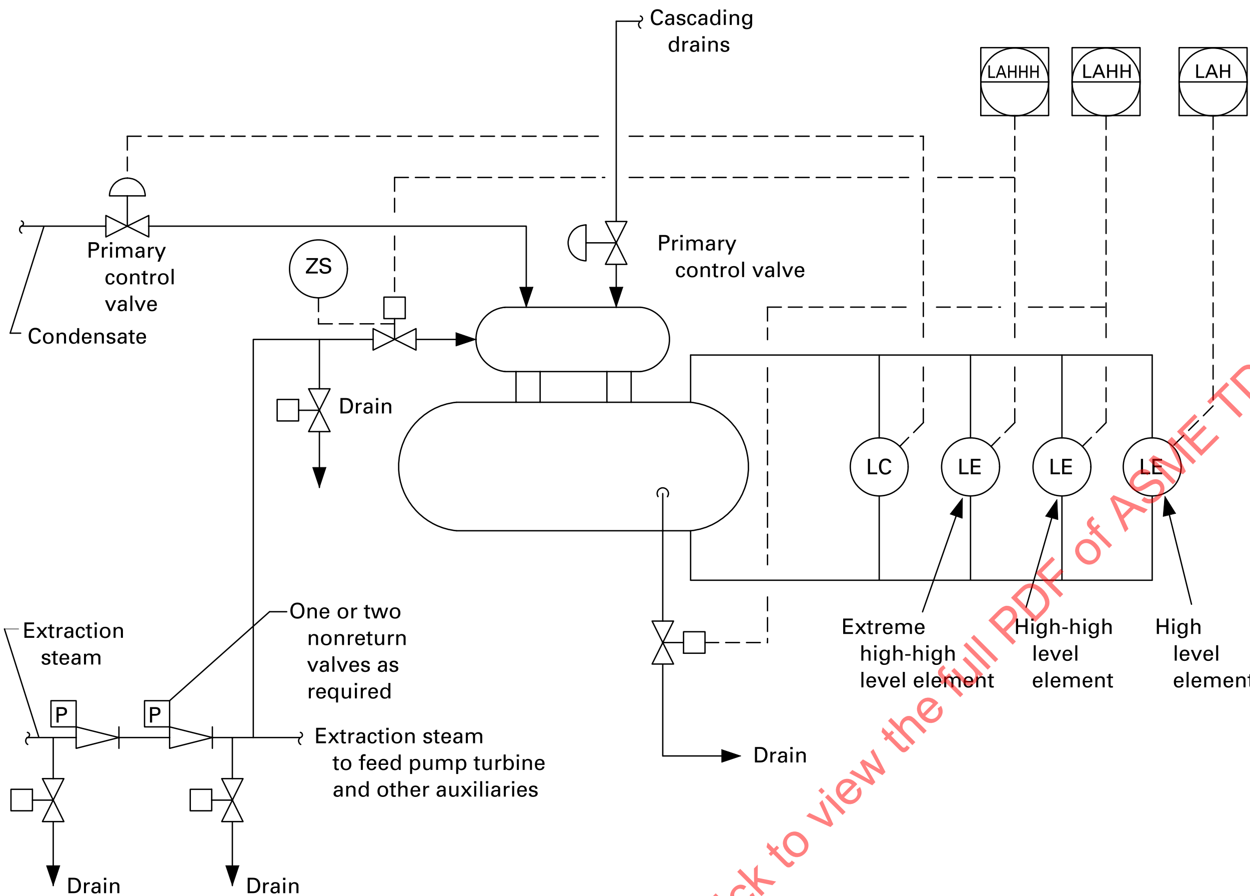


Figure 3.6.1-2
Typical Deaerator Arrangement With Drain System: ICS

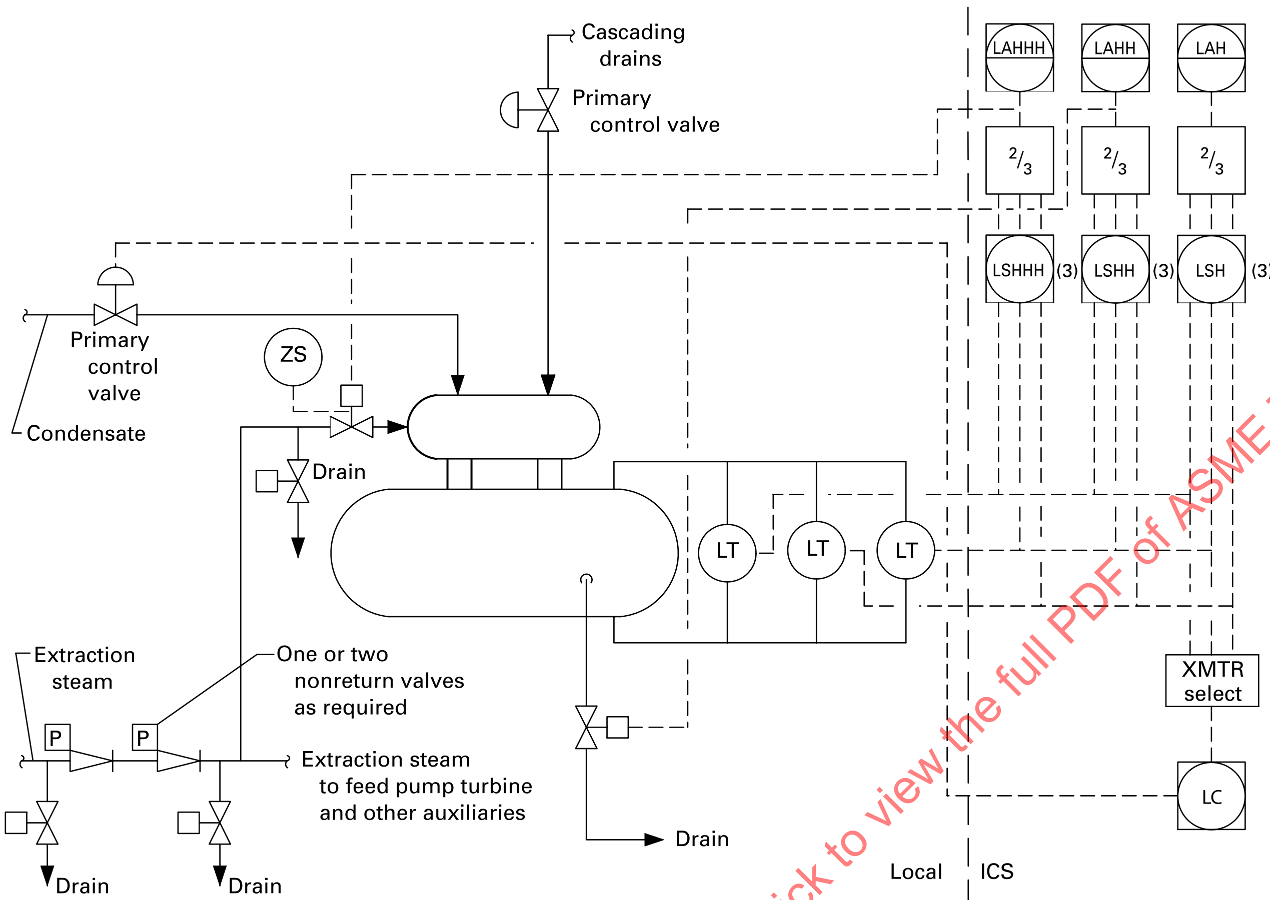


Figure 3.6.1-3
Typical Deaerator Arrangement With Inlet Isolation: Local Control System

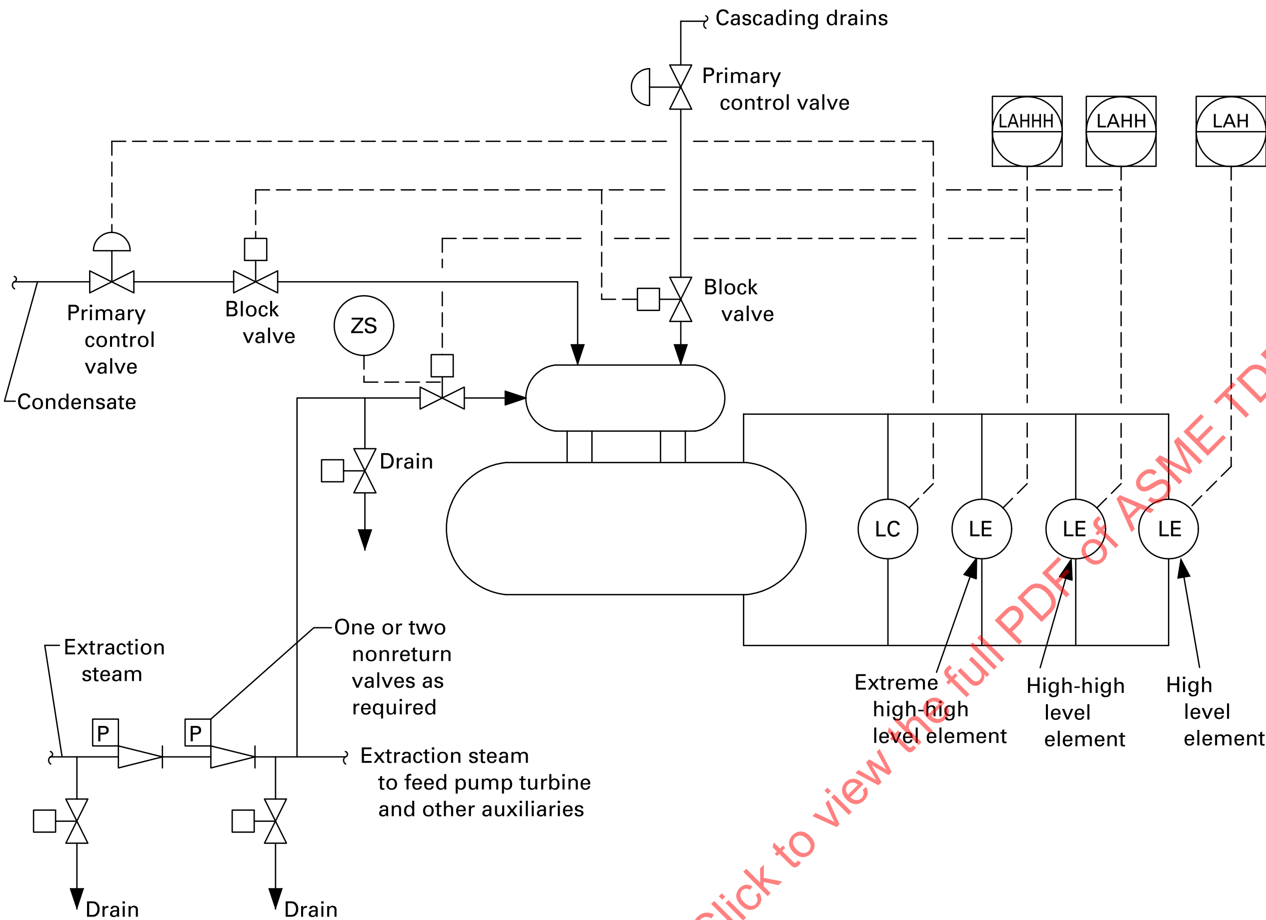
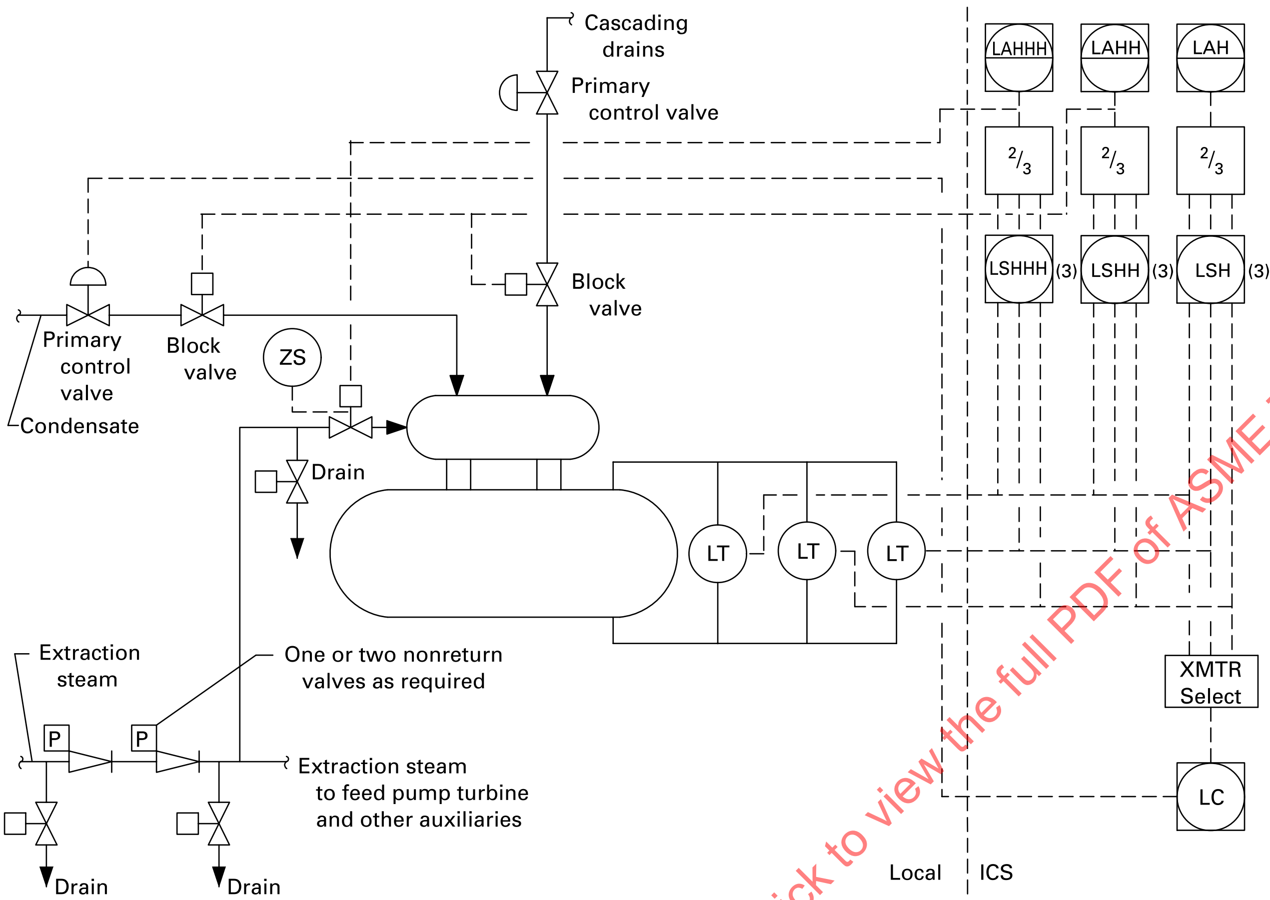


Figure 3.6.1-4
Typical Deaerator Arrangement With Inlet Isolation: ICS



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 3.6.1-1 and 3.6.1-2 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 Figures 3.6.1-1 and 3.6.1-2.

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 3.6.1-3 and 3.6.1-4 show a typical arrangement for these block valves.

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

3.6.5 Where an ICS 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 Figure 3.6.1-2 or Figure 3.6.1-4 shall be provided with two-out-of-three logic configuration.

(d) High-high alarm and isolation of the heater per Figure 3.6.1-2 or Figure 3.6.1-4 shall be provided with two-out-of-three logic configuration.

(e) High level alarm per Figure 3.6.1-2 or Figure 3.6.1-4 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 3.5.5.

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 DC 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 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 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) in 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 pipe 4 in. (100 mm) or larger in diameter 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. This requirement is not applicable to drain connections provided by the turbine manufacturer (see para. 3.7.5).

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 due to saturated conditions shall have a method (e.g., traps, flow orifices, or automatic drain valves) for draining water from the low points that is 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