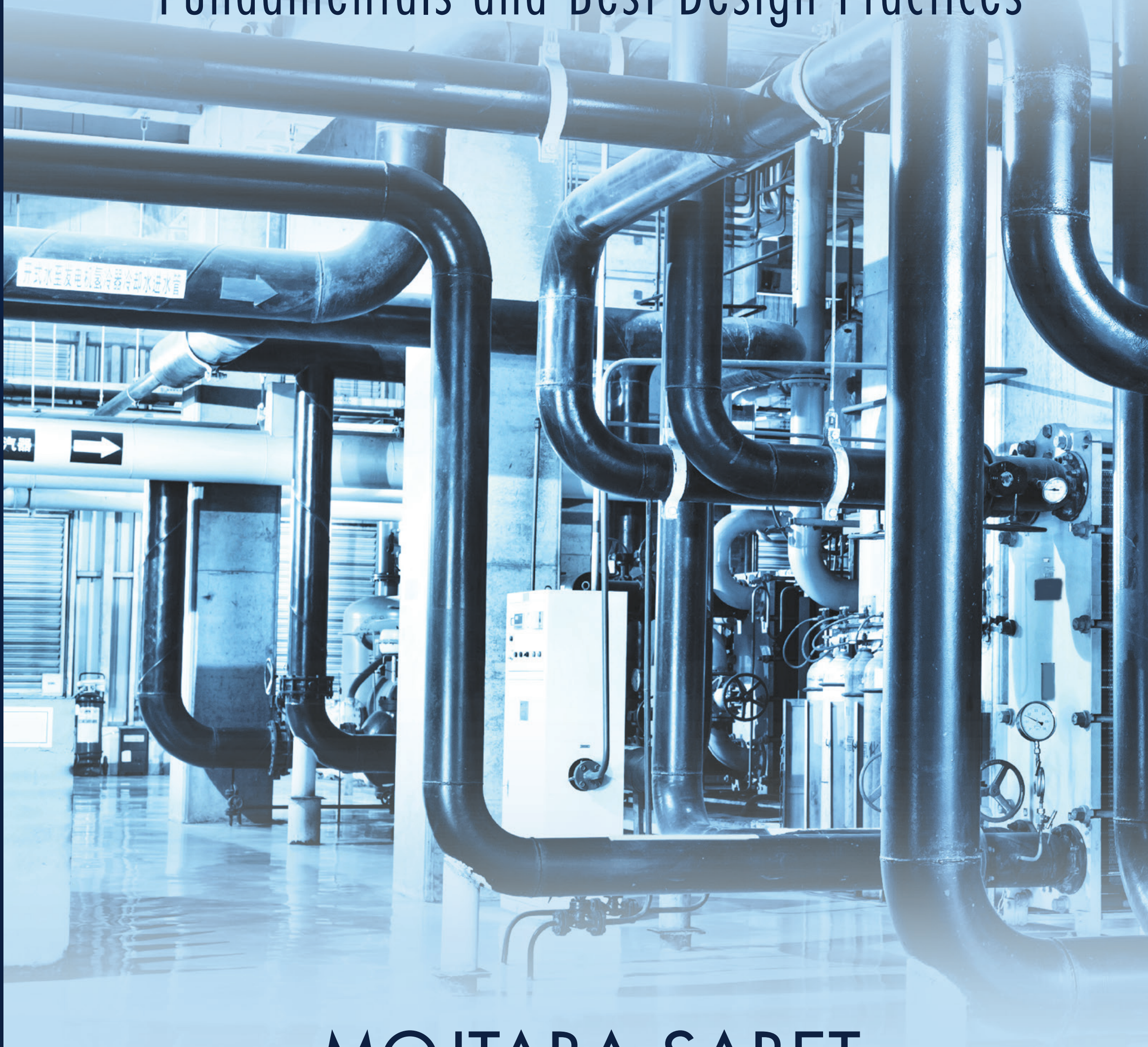
INDUSTRIAL STEAM SYSTEMS

Fundamentals and Best Design Practices



MOJTABA SABET

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Dedication

For my parents, Tahere and Ibrahim, they taught me how to live.

For my children, Yasmin and Sina, they taught me how to be.

And dedicated to humanity and world peace.

And to all who advance our lives by believing

in the power of thoughts and intention.

Thoughts Are Things

I hold it true that thoughts are things;
They're endowed with bodies and breath and wings;
And that we send them forth to fill
The world with good results, or ill.
That which we call our secret thought
Speeds forth to earth's remotest spot,
Leaving its blessings or its woes
Like tracks behind it as it goes.
We build our future, thought by thought,
For good or ill, yet know it not.
Yet so the universe was wrought.
Thought is another name for fate;
Choose, then, thy destiny and wait,
For love brings love and hate brings hate.

—Henry Van Dyke

Contents

Disclaimer

Although the author has made a strong effort and compiled this book with a lot of care to make sure that the information is accurate, safe, complies with applicable codes and regulations, is efficient, and is cost-effective, the author does not guarantee that all of the information is always correct, complete, complies with all applicable codes and regulations, applies to all systems, is efficient, is cost-effective, and is up to date. Moreover, the material included in the book does not constitute endorsement, warranty, and guaranty by the author for any products, services, and the like. The user is assumed to take the entire risk of using any information from this book.

Preface

The fundamental principles of industrial steam systems in conjunction with applicable codes and regulations constitute the all-important building blocks of proper and safe design and setup for this type of system. The primary purpose of this book is to help engineers and operators to obtain, without too much expenditure of effort and time, a complete and thorough understanding of these systems for more safety and efficiency.

The guiding and teaching principle followed in preparing the book rests on the firm belief that a sample project, executed in detail, is the ultimate means and effective way of explaining such a complex system. The sample project drawings and the detail drawings are available for download from the website (https://www.crcpress.com/Industrial-Steam-Systems-Fundamentals-and-Best-Design-Practices/Sabet/9781498724685) at a larger scale and size for better clarity. These drawings can be a very effective tool to follow for real projects. Additionally, the book includes examples for individual subject matter throughout different chapters to help faster learning.

The topics covered in the book range from elementary to advanced to provide within a single volume most of the important information needed by the reader regardless of his level of attainment.

I am certain that this book will assist those who are just beginning to understand the design, installation, and operation of industrial steam systems as well as those who have been involved with these systems for many years.

Mojtaba Sabet

About the Author

Mojtaba Sabet has been working as a mechanical engineer for more than 30 years.

He earned a master's degree in mechanical engineering, is certified as a Leadership in Energy and Environmental Design Accredited Professional (LEED AP), and is registered as a professional engineer in several states in the United States.

He is a member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Sabet's areas of expertise include detail design and engineering of utility, HVAC, industrial ventilation, dust control, and plumbing systems. He has worked as a lead engineer on projects for a variety of industries including pharmaceuticals and biotechnologies, chemicals, consumer products, food and beverage, and semiconductors.

Sabet sincerely believes that this book will be highly beneficial to all practicing engineers, technicians, and others who are involved with industrial steam systems.

> All of us who provide services and stand ready for sacrifice are the torch bearers. We run with the torches until we fall, content if we can pass them to the hands of the other runners.
>
> **Theodore Roosevelt**

Symbols and Abbreviations

≈	Approximately equal to
°C	Degrees Celsius
°F	Degrees Fahrenheit
>, <	Greater than, less than
%	Percent
abs	Absolute
atm	Atmosphere
bar	Unit of pressure in SI
btu	British thermal unit
C	Hazen Williams roughness
cal	Calorie
CC	Cubic centimeter
cfm	Cubic feet per minute
cm	Centimeter (equal to 0.01 meter)
E	Energy
fpm	Feet per minute
ft	Feet or foot
ft^3	Cubic feet
g	Grams (equal to 0.001 kilogram)
gal	Gallon
gpm	Gallons per minute
H	Enthalpy
h	Hour
HVAC	Heating, Ventilation and Air Conditioning
in.	Inch
in.^{3}	Cubic inch
kcal	Kilocalorie (1,000 calories)
kg	Kilogram
kPa	Kilopascal (1,000 pascal)
kPaa	Kilopascal absolute
kPag	Kilopascal gauge
kW	Kilowatt
kW-h	Kilowatt-hour
lb	Pound
lb/h	Pounds per hour
L	Length
L	Liter
L_e	Equivalent length
m	Meter
m^2	Square meters
m^3	Cubic meters
min	Minute
mm	Millimeter (equal to 0.001 meter)
NPT	National Pipe Thread Taper
υ	Specific volume
P	Pressure
Pa	Local absolute pressure
P_a	Pascal
P_b	Boiler pressure relief valve pressure set point
P_c	Water column at pump inlet
P_d	Deaerator or condensate receiver pressure
P_i	Inlet pressure
P_l	Water level control valve pressure drop
P_o	Outlet pressure
P_p	Piping pressure drop
ppm	Parts per million
P_r	Condensate return line pressure
P_s	Static lift
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
P_v	Vapor pressure
q	Heat transfer rate
Q	Volumetric flow rate
RPM	Round per minute revolution
S	Second
T	Temperature
T-x	Steam trap-tag no.
typ.	Typical
V	Velocity
W	Mass flow rate

1

General

What Is Steam?

Steam is water in the vapor phase. It is generated when the water is heated, causing its molecules to vibrate at a faster speed and forcing it to change its state from liquid to vapor.

Steam can exist in two different states: saturated state and superheated state.

Saturated steam occurs when water is in equilibrium with its vapor at a certain pressure corresponding to a certain temperature. Most industries use steam in the saturated state.

Water starts turning into steam if it is heated in a closed container to above 212°F (100°C). If the heating continues, the pressure and the temperature of the media inside the container (water and steam mixture) rise. The increases in pressure and temperature are related, always maintaining the vapor (steam) and the liquid (water) inside the container in equilibrium. This is called saturation state. Adding more heat to the container does not result in all water turning into steam, but rather the container pressure and temperature rise, still maintaining water and steam at the equilibrium/saturation state at higher pressure and higher temperature. The pressure increase is due to the evaporation of some of the water in the container.

Increasing the container pressure by external means at constant temperature forces some of the steam to condense back to water. This is to compensate for added pressure by reducing the steam volume to maintain the container pressure to match the saturation temperature. Since the temperature stays unchanged, the added external pressure does not cause the container pressure to increase.

Lowering the container pressure at constant temperature by external means forces some water to vaporize. This is to add to the steam volume to maintain the container pressure.

With no more water in the container, if its pressure is lowered externally at constant temperature, the steam state changes from saturate steam to superheated steam. This is due to the steam temperature that is higher than its saturation temperature for the lowered pressure. This higher than saturation steam temperature for superheated steam results in steam being dry and behaving like a perfect gas.

TABLE 1.1

Steam Properties at Different Pressures and Temperatures

P_s^a	50	100	150	200	300	400
T_{st}^b	298	338	366	388	422	448
H_{st}^c	1,180	1,190	1,196	1,200	1,204	1,205
v_{st}^d	6.68	3.89	2.76	2.13	1.47	1.12
T_{sp}^e	598	638	666	688	722	748
H_{sp}^f	1,331	1,348	1,359	1,367	1,380	1,388
v_{sp}^g	9.63	5.61	3.99	3.1	2.16	1.67

Note: For SI units: 1°C = (1°F × 1.8) + 32, 1 kPa = 0.145 psi, 1 kg = 2.2 lb, 1 kcal = 3.97 btu.

[a] Steam pressure (psig).
[b] Saturation temperature (°F).
[c] Saturation enthalpy (btu/lb).
[d] Saturation specific volume (ft^3/lb).
[e] Superheated temperature, $T_{sp} = T_{st} + 300$ (°F).
[f] Superheat enthalpy (btu/lb).
[g] Superheated specific volume (ft^3/lb).

Steam at superheated state is defined in terms of degrees of superheat above the saturation temperature at that pressure. For example, steam at 150 psig (1,034 kPag) and 450°F (232°C) is referred to as being 84°F (29°C) superheated since its saturation temperature is about 366°F (186°C), 84°F (29°C) lower.

Table 1.1 shows some examples of steam properties such as enthalpy and specific volume at the saturation and the superheated states.

How to Desuperheat Steam

To desuperheat steam the energy must be extracted from it to lower its enthalpy from superheat level to saturation level at that pressure. Usually water is injected into the superheated steam through a desuperheater device to make the state change. This type of desuperheater is called mechanical atomization type. The process causes the injected water to evaporate after absorbing superheated steam energy and turn into steam. The superheated steam, now at lower enthalpy level, turns to saturated steam and the total steam flow rate increases. The increase in steam flow rate is equal to the injected water mass flow rate.

Usually steam condensate is used as the desuperheating water to ensure that the steam quality remains the same. The process, in its simplest setup, uses a modulating water flow control valve, a water spray device, a temperature transmitter, and a controller. The valve modulates to adjust the spray water flow rate to maintain saturation temperature at the temperature transmitter location. The desuperheater must be installed per manufacturer guideline with proper straight run of pipe at its downstream and upstream to ensure a uniform and complete process. The temperature transmitter location and the temperature set point are crucial and must be per manufacturer guideline. The flow control valve must have appropriate turndown to maintain its effectiveness at the lowest and highest steam flow rates.

Assuming water specific weight of 8 lb/gal for condensate at 212°F, the approximate water flow rate for desuperheating is calculated by the following formula:

$$Q_w = 0.0021 \times W_{sp} \times [(H_{sp} - H_{st}) \div (H_{st} - H_w)] \quad (1.1)$$

where
- Q_w = Water flow rate (gpm)
- W_{sp} = Superheated steam flow rate (lb/h)
- H_{sp} = Superheated steam enthalpy (btu/lb)
- H_{st} = Saturated steam enthalpy (btu/lb)
- H_w = Water enthalpy at 212°F (btu/lb)

For example, to desuperheat 10,000 lb/h of steam at 200 psig pressure and 1,000°F (approximately 612°F superheated) using steam condensate at 212°F, the approximate injected condensate flow rate is calculated as follows.

$$W_{sp} = 10{,}000 \text{ lb/h}$$

$$H_{sp} = 1{,}529 \text{ btu/lb (from superheated steam table at 200 psig and 1,000°F)}$$

$$H_{st} = 1{,}200 \text{ btu/lb (from saturated steam table at 200 psig)}$$

$$H_w = 180 \text{ btu/lb (from saturated water table at 212°F)}$$

$$Q_w = 0.0021 \times 10{,}000 \times [(1{,}529 - 1{,}200) \div (1{,}200 - 180)] = 6.8 \text{ gpm}$$

Assuming 8 lb/gal for condensate at 212°F, the injected condensate into the superheated steam will increase the saturated steam flow rate approximately $6.8 \times 8 \times 60 = 3{,}264$ lb/h, from 10,000 lb/h to 13,264 lb/h.

For SI units, assuming water specific weight of 1 kg/L, the formula is as follows:

$$Q_w = 0.017 \times W_{sp} \times [(H_{sp} - H_{st}) \div (H_w - \mathrm{H_{st}})] \quad (1.2)$$

where
- Q_w = Water flow rate (L/min)
- W_{sp} = Superheated steam flow rate (kg/h)
- H_{sp} = Superheated steam enthalpy (kcal/kg)
- H_{st} = Saturated steam enthalpy (kcal/kg)
- H_w = Water enthalpy at 100°C (kcal/kg)

Other types of steam desuperheater include steam atomization type and surface absorption type.

What Is an Industrial Steam System?

An industrial steam system is a system that generates steam at the quality and quantity required by process and mechanical systems for a manufacturing facility. Due to the safety issues and system complexity, an industrial steam generating system is installed inside a protected area referred to as a steam plant. A steam plant can be a room or a fenced area with controlled access, only accessible to authorized personnel. Major steam generating equipment like boilers, deaerators, and pumps are housed inside the steam plant. In most facilities the steam plant is a dedicated room called a boiler room.

Industrial steam systems design and operation must be in compliance with ASME codes, applicable local and national codes, owner insurance underwriter requirements, utility companies' regulations, and good engineering practices.

Boiler rooms are designed, constructed, and operated in accordance with applicable local and national codes and owner's requirements. This includes boiler room enclosure fire rating, structural requirement for piping and equipment support, underground and aboveground plumbing needs, containments for collection and disposal of chemicals, room heating and ventilation system, combustion and dilution air supply for boilers, room lighting, and emergency shower and eye wash for personnel protection. Refer to Chapter 2 for boiler room combustion air, dilution air, and ventilation requirements.

The operation of boilers above certain size in some states requires continuous attendance of a certified boiler operator. For example, it is mandatory for a high-pressure steam boiler operation in the State of Ohio to be supervised by a certified boiler operator if the boiler heating surface is greater than 358 ft^2 (33.3 m^2).

Some examples of steam applications in a manufacturing facility include air heating, products heating, water heating, and cleaning and sterilization.

How Is Industrial Steam Generated?

Industrial steam is usually generated inside a pressurized vessel by applying heat to the water or allowing high-pressure hot water to flash by reducing its pressure in a drum.

Presently, steam is generated either through a steam boiler or a steam generator. Both systems generate steam using different approaches. A more detailed description for each type is provided in Chapter 4.

What Is the Pressure Rating of a Boiler or a Steam Generator?

Steam systems are referred to as being either high-pressure or low-pressure systems. A steam system with a maximum design pressure of 15 psig (103 kPag) is considered a low-pressure steam system. If the design pressure of the steam system exceeds 15 psig (103 kPag) it is considered a high-pressure steam system.

The steam system design pressure is the pressure set point of the boiler or steam generator pressure relief valve at which the pressure relief valve opens to relieve the overpressurized steam. Usually the operating pressure of a high pressure steam system is set to 10 psi (69 kPa) or 10%, whichever is higher, less than the boiler pressure relief valve set point. For example, a steam boiler with a pressure relief valve set point of 250 psi (1,724 kPa) will normally generate steam at 200 psig (1,379 kPag) or lower.

What Is a Boiler Capacity Test Connection and How Is It Designed?

A boiler capacity test connection is a piping set up for measuring the boiler or the steam generator maximum capacity in place inside the facility in its actual working condition. It is a takeoff connection from the steam distribution header, piped and routed to the outside to a safe place. The setup allows the boiler or the steam generator operation at its maximum capacity by discharging the steam to the atmosphere.

What Is Equivalent Length of Pipe?

Equivalent length of pipe for a valve or a fitting in a piping distribution system, is defined as the straight run of pipe with the same inside diameter that will have a total pressure drop equal to the valve or the fitting.

When a large number of fittings and valves are installed in a piping distribution, additional pressure drop can be accounted for by the use of the equivalent length method. This is a fairly accurate and simple method to determine not only the pressure drop through the straight run of piping sections, but also the pressure drop through fittings and valves.

Refer to Table A.1 in Appendix A for the approximate equivalent length of a pipe for different fittings and valves.

What Is Valve Flow Coefficient, C_v?

The valve flow coefficient, C_v, is the flow rate of water through the valve in gallons per minute (gpm) at 60°F (15.5°C) temperature that results in a pressure drop of 1 psi (6.9 kPa). For example, a valve with C_v of 45 has 1 psi (6.9 kPa) pressure drop at a water flow rate of 45 gpm (170 L/min).

With the C_v known for a valve, the following formula is used to calculate the valve pressure drop (ΔP) in psi at other flow rates:

$$\Delta P = (\text{gpm}/C_v)^2 \tag{1.3}$$

For SI units:

$$1 \text{ psi} = 6.895 \text{ kPa}$$

$$1 \text{ gpm} = 3.785 \text{ L/min}$$

What Is Net Positive Suction Head (NPSH) in a Pumping System?

Net positive suction head (NPSH) is a term used to evaluate a pump inlet pressure to prevent cavitation.

Water boils and turns to vapor at a certain temperature and pressure. At atmospheric pressure at sea level (14.69 psia or 101.3 kPaa), water starts to boil at 212°F (100°C). This is due to the water vapor pressure that equals the atmospheric pressure at 212°F (100°C). At lower atmospheric pressure (like high elevation above the sea level), water starts to boil at lower temperature. This is due to its vapor needing less pressure to overcome the surrounding ambient pressure to release.

The pressure at which water starts to boil is called water flash point at that temperature.

A pump will cavitate if the water vaporizes inside its housing. The water flow profile becomes turbulent as it enters the pump suction port and goes through the impeller inside its housing. It goes through stages of pressure drop and high-velocity phases. With insufficient pump inlet water pressure the pressure drop can cause the water pressure inside the pump housing to drop to a pressure, low enough to cause the water to boil and vaporize.

To prevent pump cavitation, there must be enough water pressure at the pump inlet port to keep it above its flash point as it travels inside the pump housing through different stages. This inlet pressure is referred to as the net positive suction head (NPSH) and is indicated in units of pressure, either psi, feet of water column, or kilopascal in SI units.

If cavitation is not prevented, it will generate water vapor in bubble form inside the pump housing that will in turn make the pump operation noisy, inefficient, and incontrollable. It will damage the pump internal parts, especially the impeller.

There are two types of net positive suction heads (NPSH) for every pumping system that must be considered and analyzed to determine the requirements for preventing pump cavitation:

$NPSH_r$: This is the required NPSH, a unique minimum inlet suction pressure required at the pump inlet port to prevent cavitation. The required NPSH is determined by the pump manufacturer through tests and experiments. It is available as part of each pump performance's published data.

$NPSH_a$: This is the available NPSH, the calculated water pressure at the pump inlet port. Available NPSH depends on the type of system, piping setup, water temperature, local elevation above sea level, open or closed type pumping system, etc. It is calculated for each pumping system.

For a cavitation-free pumping system, the available NPSH must be at least 2 ft (600 mm) of water column higher than the required NPSH.

What Is Culinary Steam?

Culinary steam is steam with acceptable quality for direct contact with or injection into milk and milk products. The steam must be dry, free of entrained contaminants, and come from a source that uses acceptable quality water and chemicals used for steam system water treatment. Culinary steam production must comply with the 3-A Accepted Practices and 3-A Sanitary Standards.

3-A Accepted Practices include the requirements and criteria for design, fabrication, and installation of the systems, such as high-temperature short-time (HTST) pasteurizers, clean-in-place (CIP) systems, compressed air and steam systems, etc., where the media (like steam) comes in direct contact with the food during the food processing.

3-A Sanitary Standards include the requirements and criteria for design and fabrication of equipment and components, such as pumps, mixers, vessels, filters, conveyers, instrumentation devices, etc., that come in contact with food during the food processing operation.

Recommended installation and piping setup for culinary steam include the following in the order they are listed. The setup starts from the tie-in point to a high-pressure nonculinary steam source and ends at the culinary steam use point.

1. Manual valve.
2. Separator capable of removing water and particles 10 microns and larger. Separator will have condensate drain arrangement using steam trap.
3. A pressure reducing station to reduce the steam high pressure to desired culinary steam pressure. This pressure reduction will further help to dry the steam.
4. Modulating valve to control the culinary steam flow rate based on the user's requirements, manual or automatic, based on culinary steam user controls.
5. Steam filter to remove at least 95% of particles 2 microns or larger. Filter will have pressure gauges at its downstream and upstream to indicate dirty filter condition. Filter will have condensate drain arrangement using steam trap.
6. All piping, fittings, valves, etc., downstream of the filter will be acceptable type stainless steel material.
7. A sample connection with valve for culinary steam quality test.
8. Connection to process equipment with manual valve and spring-loaded acceptable sanitary check valve to prevent any backflow from the users into the culinary steam station.

Refer to Appendix B for culinary steam station components and setup detail.

What Are Applicable Codes and Standards for Industrial Steam Systems?

Some applicable codes, standards, and guidelines follow:

ASME: American Society of Mechanical Engineers (ASME) provides standards and guidelines for fabrication, installation, and operation of steam boilers.

ASME B31.1 ("Power Piping") provides requirements for high-pressure piping, including piping around the high-pressure boilers.

ASME Boiler and Pressure Vessel Code (BPVC) is a standard for fabrication of safe boilers and pressure vessels. The standard also covers boiler inspection, tests, and operation.

ASTM International: ASTM International used to be called American Society for Testing and Materials (ASTM), provides standards that are used worldwide to improve product quality, operation safety, production efficiency, and to establish testing methods and measurable ratings. Established in 1898, it serves many kinds of industries such as metals, consumer products, oil and gas, construction, etc. The ASTM standards as a minimum, include the following categories: standard specification, standard practice, standard guide, standard classification, and terminology standard.

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) develops high-quality standards and guidelines for heating ventilation and air conditioning systems, including indoor air quality and energy conservation.

ASHRAE Standard 90.1-2013 ("Energy Standard for Buildings Except Low-Rise Residential Building") provides requirements for piping insulation (Table 6.8.3-1) and mandates the minimum efficiency for boilers (Table 6.8.1-6).

ASHRAE Standard 62.1-2013 ("Ventilation for Acceptable Indoor Air Quality") provides requirements for ventilation and indoor air quality (Table 5.5.1: Air Intake Minimum Separation Distance).

ICC: International Code Council (ICC) is an association dedicated to developing codes and standards used to construct safe, economical, sustainable, and efficient structures. The international codes published by ICC have been adopted and used by 50 states and the District of Columbia in the United States. They are also acceptable to many global markets.

International Fuel Gas Code (IFGC) 2012 has been prepared to cover the minimum requirements for fuel gas systems and gas-fired appliances.

USGBC: United States Green Building Council (USGBC) developed a set of rating systems in connection with Leadership in Energy and Environmental Design (LEED) for design, construction, commissioning, operation and maintenance of energy efficient and environmentally friendlily (Green) homes and commercial, industrial, schools, etc. buildings. The Green Building Certification Institute (GBCI) is a part of USGBC. The Green Building Certification Institute provides certifications to the qualified professionals who are involved in certification procedure for Green Buildings.

2

Boiler Room Combustion and Ventilation Air

Every boiler room requires air for combustion, dilution of the flue gases, and boiler room ventilation and cooling.

The combustion air is the theoretical air needed for the burner for complete combustion of the fuel. It is needed whenever the boilers are operating.

The dilution air is the excess air needed to dilute the combustion product before it discharges to the atmosphere. This usually takes place through the draft hood on the boiler stack. The dilution air is needed whenever the boilers are running.

The ventilation air is the required air from outside and the treated recirculation air for maintaining the boiler room indoor air quality. This is to provide breathing air for operators, to maintain space humidity level, and to reduce the possible contaminant concentration inside the room. The ventilation air is needed year-round.

The boiler room cooling air is for space cooling in order to maintain the maximum allowable temperature, especially during hot season. The cooling air is only needed seasonally whenever the space temperature exceeds the maximum temperature allowed.

The combustion air discussed in this chapter also includes the required dilution air.

The combustion air (combustion and dilution air) is regulated by applicable codes and local regulations for the boiler rooms. For boilers burning oil, the National Fire Protection Association Standard 31 (NFPA 31), "Standard for the Installation of Oil-Burning Equipment," is a recommended source for defining the requirements for design criteria. The combustion air discussed in this chapter only applies to the boilers that use natural gas for their fuel. The recommended source for gas-fired boiler combustion air is the International Fuel Gas Code (IFGC) publication.

This chapter describes the setup and requirements for the boilers that draw combustion air from the boiler room. This chapter does not apply to the boilers directly ducted to the outside for their combustion air.

Heating is needed for a boiler room to prevent freezing of the water piping and for personnel comfort during maintenance in cold climate. Boiler room heating is done by installing unit heaters inside the room or through makeup air units that supply heated air to the space. Makeup air units, when used, can be set up to provide combustion air, ventilation air and boiler room cooling very efficiently.

Boiler Room Combustion Air

The combustion air, as described above, can be provided all from inside air or all from outdoor air, or a combination of inside air and outdoor air. The requirements are as follows.

Combustion Air from Inside

The combustion air is allowed to be from the inside air if the building that provides the air is not tight and has adequate volume. It can be from the boiler room only or a combination of the boiler room and other spaces communicating with the boiler room through acceptable permanent openings. The required minimum volume is determined as follows:

1. For a building with the outside air infiltration rate through its envelope known, or if the infiltration rate is less than 0.4 air changes per hour (ACH), the minimum building volume is calculated as follows.
   a. For boilers equipped with a blower for combustion air:

$$\text{Volume (in ft}^3\text{)} \geq (15 \div ACH) \times (E \div 1{,}000) \tag{2.1}$$

   b. For boilers without a blower for combustion air:

$$\text{Volume (in ft}^3\text{)} \geq (21 \div ACH) \times (E \div 1{,}000) \tag{2.2}$$

   where
   ACH = Air changes per hour
   E = The sum of all the boilers input energy (btu/h)

   For SI units:

$$1 \text{ ft}^3 = 0.0284 \text{ m}^3$$

$$1 \text{ btu/h} = 0.0003 \text{ kW}$$

2. For a building where the outside air infiltration rate is not known but is equal to or greater than 0.4 ACH, the required minimum volume for the boiler room or a combination of communicating rooms must be equal to 50 ft^3/1,000 btu/h (4.8 m^3/kW) of the total boilers' input energy.

   To comply with the volume requirement, the boiler room can be connected to adjacent spaces through permanent personnel access openings without door or openings as specified below.

a. For spaces on the same floor, the connections shall be through two wall openings, each sized to have a net free area of at least 1 $in.^2$/1,000 btu/h (2,201 mm^2/kW) of total boiler's input energy. Each opening shall not have a net free area less than 100 $in.^2$ (0.06 m^2) with a minimum dimension of 3 in. (76 mm). The opening's locations must be one within 1 ft (305 mm) of the ceiling or roof and one within 1 ft (305 mm) of the finished floor.
b. For spaces on different floors, the openings shall be one or several through doors or floors having a total net free area of at least 2 $in.^2$/1,000 btu/h (4,402 mm^2/kW) of total boilers' input energy.

The net free area of an opening covered with louver, grill or screen is equal to the total opening area minus the obstructed area by the covering device(s). This is provided by the covering devices' manufacturer.

In case the louvers are the motor-operated type or equipped with an automatic damper (open-closed) for volume control, smoke control, fire control, etc., an end switch and interlocking are required to positively prove the louver open position before any boiler can start. The boilers shall shut down in case the combustion air to the boiler room is interrupted.

Combustion Air from Outside

Combustion air can be provided from outside either by gravity through direct openings or by force using mechanical systems like a supply fan. Both of these methods are acceptable to authorities having jurisdiction and to the boiler manufacturers.

The outside air openings must be located far enough from any hazardous or noxious contaminant, but never less than 10 ft (3,048 mm) from these harmful sources. The separation distance must increase for sources with more hazardous contamination. Consult ASHRAE Standard 62.1, "Ventilation for Acceptable Indoor Air Quality," for recommended separation distances from different types of hazardous sources.

The outside openings must be protected with corrosion-resistant screens to stop birds entry into the building. The screen mesh size should be between 1 in. (25 mm) and 1/4 in. (7 mm). The openings must be protected from weather, rain, and snow through weatherproof louvers, rain hoods, or similar devices.

In case louvers are motor operated or equipped with an automatic damper (open-closed), an end switch and interlocking are required to positively prove the louver open position before any boiler can start. The boilers shall shut down in case the combustion air to the boiler room is interrupted.

Combustion Air from Outside by Gravity

To supply combustion air from outside by gravity, the boiler room must communicate with the outside through permanent wall or roof openings. These openings will communicate either directly with the outside or through other spaces with direct outside openings.

The combustion air can be provided through either two permanent openings or one permanent opening, described below.

1. The two openings setup requires two permanent openings, one at a high level, within 1 ft (305 mm) of the ceiling or roof, and one at a low level, within 1 ft (305 mm) of the finished floor. Each direct opening must have a net free area equal to 1 in.^{2}/4,000 btu/h (550 mm^2/kW) of the total boiler's input energy. For cases where the openings are connected with ductwork, each opening size is determined as follows:
   a. Openings connected through horizontal ductwork shall be at least 1 in.^{2}/2,000 btu/h (1,100 mm/kW) of the total boiler's input energy. The ductwork cross section area shall be equal to or larger than the required opening size.
   b. Openings connected through vertical ductwork shall be similar to the direct opening sizes, each 1 in.^{2}/4,000 btu/h (550 mm^2/kW) of the total boiler's input energy. The ductwork cross-section area shall be equal to or larger than the required opening size.
2. The one opening setup requires one opening directly connected or ducted to outside at a high level. The opening shall be within 1 ft (305 mm) of the roof or ceiling. The boilers must have clearances of at least 1 in. (25 mm) from the sides and back and 6 in. (152 mm) from the front to the opening. The opening net free area shall be at least 1 in.^{2}/3,000 btu/h (734 mm^2/kW) of the total boiler's input energy. The opening free area shall not be less than the sum of the boiler's stack cross section area connected to the boilers.

Supplying combustion air by gravity is not practical for large boilers due to the required large openings sizes. For example, a boiler room with one 500 hp boiler (approximately 21,500,000 btu/h or 6,305 kW input energy) with direct wall openings to the outside needs two openings, each with a net free area of 38 ft^2 (3.5 m^2). Protecting these openings from rain and bird entry with wall louvers and bird screens increases each opening size to maintain the required net free area. The net free area for most wall louvers with a ½ in. (13 mm) bird screen is reduced to 50% of its total area. Therefore, each opening size increases to 76 ft^2 (7 m^2). These are considered large outside wall openings. The large openings are not desirable, especially in cold climate areas.

Combustion Air from Outside through Forced Air

The forced combustion air systems use mechanical equipment such as fans and makeup air units to provide the required combustion air. Similar to the gravity systems, proof of supply air is required for these systems before any boiler can start. This is usually accomplished through airflow switches located in the supply airstream (ductwork) and through interlocking.

For installations where the forced air mechanical system is used to provide both combustion air and ventilation air for the boiler room, the forced air mechanical system shall be sized and designed to provide the required combustion air in addition to the required ventilation air.

The forced air combustion air shall provide at least 0.35 cfm of outside air per 1,000 btu/h (0.034 m^3/min/kW) of total boiler's input energy.

For example, a 200 hp boiler (6,695,000 btu/h or 1,962 kW boiler output) with 82% efficiency needs:

$$\text{Boiler input energy} = 6{,}695{,}000 \div 0.82 = 8{,}164{,}634 \text{ btu/h or } 2{,}393 \text{ kW}$$

In PI units:

$$(8{,}164{,}634 \div 1{,}000) \times 0.35 = 2{,}857 \text{ cfm}$$

This is approximately equal to 14 cfm/boiler hp.

In SI units:

$$2{,}393 \text{ (kW)} \times 0.034 = 81.36 \text{ m}^3\text{/min}$$

This is approximately equal to 0.41 m^3/min/boiler hp.

Combustion Air from Combination of Inside and Outside Air by Gravity

The combustion air can be set up to be provided through a combination of inside air and outside air. This setup can be used if the boiler room and its communicating spaces does not satisfy the indoor volume requirements.

The directly connected opening(s) to the outside shall comply with the requirements explained above for gravity-supplied combustion air through direct outside openings.

The net free area of the direct opening(s) to the outside for this case shall be calculated as follows:

1. Calculate the ratio of the available space volume (R_v) by dividing the available space volume by the required space volume that provides all combustion air from inside.
2. Calculate the opening area reduction factor (R_f) as follows:

$$R_f = 1 - R_v \tag{2.3}$$

   And the opening(s) net free area is calculated as follows:

$$\text{Opening(s) net free area} = \text{opening(s) full size for all combustion air from outside} \times R_f \tag{2.4}$$

Boiler Room Ventilation Air for Cooling

There is a need for cooling the boiler room, especially during the hot season, to maintain the room space temperature below 104°F (40°C). This maximum temperature is based on the boiler room equipment and instrument and controller's requirements. This is done by supplementing the boiler room's combustion air with additional outside air to offset the inside generated heat. The additional supplied air to the boiler room that is not drawn by the burner must be exhausted through an exhaust fan or a gravity relief louver. The supply air and exhaust air locations must be carefully determined to prevent short-circuiting and to provide a uniform temperature inside the boiler room.

Mechanical cooling (cooling with media like refrigerant) is recommended for boiler rooms requiring cooling air flow rate greater than 40 air changes per hour. The cooling effect of the air significantly reduces for airflow rates above 40 air changes per hour.

To determine the required cooling air for a boiler room, the dissipated heat from equipment like pumps and boilers, from hot surfaces like tanks and piping, from electrical devices, from lighting, and from the building envelope must be calculated. Having the maximum generated heart rate inside the boiler room, the following formula is used to determine the required maximum cooling air flow rate.

In PI units:

$$Q_c = q \div (1.08 \times \Delta T) \tag{2.5}$$

where

Q_c = Cooling airflow rate (cfm)
q = Generated maximum heat rate inside the boiler room (btu/h)
ΔT = (Boiler room inside temperature – outside maximum ambient temperature) (°F)

In SI units:

$$Q_c = q \div (0.02014 \times \Delta T) \tag{2.6}$$

where

Q_c = Cooling airflow rate (m^3/min)
q = Generated maximum heat rate inside the boiler room (kW)
ΔT = (Boiler room inside temperature – outside maximum ambient temperature) (°C)

The maximum boiler room inside temperature should not exceed 104°F (40°C).

3

Industrial Steam System Operation

Refer to piping and instrumentation diagram, PID drawings, in Chapter 7 for an example of an industrial steam system setup. The drawings show equipment arrangements and layout, piping setup, and controls and instrumentations for a typical system.

Steam is generated in a boiler using water and heat. Its pressure and temperature is controlled and maintained to satisfy the steam users. For a single steam system common to different users with different pressure and temperature requirements, the system operating pressure and temperature (if superheated) are set based on the user with the highest need. The steam pressure and temperature are then regulated down (desuperheating for temperature and pressure reducing for pressure) for users with lower needs. For example, for a system to provide saturated steam at 120 psig (827 kPag) for process and 30 psig (207 kPag) for HVAC system, the boiler operating pressure is set to 125 psig (861 kPag). This will allow for a 5 psi pressure drop through distribution piping and 120 psig (827 kPag) steam will be available at the process users. The steam pressure is then regulated through a steam pressure reducing station to 30 psig (207 kPag), close to the use point, for the HVAC users. The 30 psig (207 kPag) steam right after the pressure reducing station will be superheated. The superheated steam will change state to saturated steam quickly in a short piping distance using the condensed steam inside the pipe and through piping heat loss to the surrounding.

Steam is distributed through piping to users, mainly HVAC coils, humidifiers, process heat exchangers, steam spargers, and mixing values hose stations. It uses its pressure as motive force to flow through the piping. The distribution piping is usually installed overhead and is well insulated for energy conservation and personnel protection. No matter how much insulation is used, there is always some heat loss through the piping, causing some steam to condense inside it. To prevent water hammering and other undesirable effects, the formed condensate inside the piping is removed from piping through drip legs. Drip legs are pipe drops from the steam distribution piping for collecting and removing the condensate. A drip leg is assembled with isolation valve, strainer, steam trap, check valve (if required), test valve, and unions or flanges to allow disassembly for maintenance. The condensate is separated and removed by a device called a steam trap. A steam trap, as described in Chapter 4, allows only the condensate to pass but prevents the live steam to escape. The removed condensate through the drip legs is either returned to the boiler room for reuse as boiler feed water or drained.

Most of the heat exchangers are designed to extract the latent heat from steam. Steam turns into liquid condensate inside the heat exchanger, maintaining its saturation temperature after its latent heat is transfered. Some heat exchangers are designed to provide additional sensible heat exchange by extracting heat from hot condensate. This additional sensible heat extraction causes the condensate temperature to drop below its saturation temperature. This overcooked condensate is referred to as subcooled condensate. The formed condensate is drained through a steam trap from the heat exchanger and returned to the boiler room for reuse.

Depending on the supply steam pressure and controls the supply stream control setup, the discharged condensate from a heat exchanger is either directly piped to a central condensate collection tank or collected locally and pumped to the tank.

A local condensate collection and pumping system is required if there is not enough steam pressure to act as motive force to push the condensate through piping back to the central condensate collection tank. An example for this case is a heat exchanger with steam supply equipped with a modulating temperature control valve. At low heating demand, the control valve can be almost closed, supplying steam to the heat exchanger at a negligible pressure. Unless the condensate can be drained by gravity, the heat exchanger will fill up with condensate due to inadequate pressure. The flooded heat exchange will lose its efficiency and temperature controllability. To operate properly the heat exchanger condensate must drain by gravity to a condensate collector with no back pressure, meaning a vented storage tank at atmospheric pressure. This locally collected condensate will then be pumped to the central condensate collection tank.

Returned condensate to the boiler room is collected in a vented tank called a condensate receiver. The tank vent is sized to allow flash steam discharge to outside with minimal pressure drop to maintain the tank pressure close to atmospheric pressure. Any high temperature returned condensate above boiling temperature releases flash steam as it enters the atmospheric condensate receiver tank, causing its temperature to drop to boiling temperature. Flash steam discharges through the vent to atmosphere. To conserve energy steam systems are often set to return high temperature condensate to the deaerator instead of the condensate receiver tank. This set up uses the high temperature condensate energy to deaerate and heat the boiler makeup water.

Collected condensate in the condensate receiver is continuously pumped to the boiler feed water package called the deaerator.

The deaerator package includes the deaerating tank, boiler feed water pumps, and other required accessories and controls. It receives different types of streams, such as pumped condensate from the condensate receiver tank, high-temperature condensate from heat exchangers and distribution piping drip legs, and fresh makeup water. As described in Chapter 4, a deaerator is used to separate water-entrained oxygen and carbon dioxide and heat the boiler feed water for boiler protection.

The boiler feed water pump, part of the deaerator package, pumps the feed water from the deaerator to the boiler. If the boiler flue gas stack is fitted with a stack economizer, usually the boiler feed water is routed through it for waste heat recovery and further heating.

Evaporated water inside the boiler is pure water leaving behind water impurities and solids. These impurities, referred to as dissolved solids, are continuously added to the boiler water, increasing its hardness. To control the level of hardness, water is drained from the boiler and is replaced with freshwater. The process uses two types of water discharge, referred to as blowdown water and blowoff water.

The blowoff water is the intermittent water dump from the bottom of the boiler drum. This is usually done manually. This is referred to as bottom blowoff. Depending on the makeup water quality the manual blowoff is normally done up to once per day.

The blowdown water is the water taken from the boiler drum at a high water level. This is referred to as surface blowdown. Surface blowdown is continuous either manually set or automatically controlled. The automatic set up is through a modulating flow control valve that controls the flow rate based on the measured and monitored conductivity level of the boiler water.

The source of the dissolved solids in the boiler water comes from makeup water impurities and the added chemicals used for the purpose of precipitation of hardness inside the boiler. Usually there is a water treatment program for each steam plant to monitor and control the water and steam quality. The treatment program is established based on the desirable steam quality, level of equipment protection, water conservation requirement, and makeup water quality.

Adverse conditions such as foaming, priming, and water carryover can happen inside the boiler in the event the boiler water treatment and quality control are not in place and the dissolved solids' concentration exceeds the manufacturer recommended limits.

Boiler blowdown and blowoff water is cooled by mixing with cold water and then drained. Cooling is done inside a device called a blowdown separator.

Some steam systems use a water-to-water heat exchanger to recover heat from the blowdown and blowoff water before it is drained. The added heat exchanger not only recovers heat from blowdown and blowoff water, but also reduces the mixing cooling water need. Refer to Chapter 4 for a more detailed description of the blowdown separator.

All industrial steam systems require makeup water to compensate for water and steam losses. Main losses include flash steam discharges through the vents (e.g., condensate receiver tank) and water discharges through the boiler blowdown and blowoff operations. Some processes may consume steam or drain the condensate if it can contaminate the steam system.

Unless fresh makeup water is in an acceptable quality for the steam system, the water, as a minimum, must be softened. Water is softened by running it through a water softener.

A backflow preventer is installed upstream of the water softener to prevent water backflow to the water source. This is to avoid contaminating the water source with the added chemicals to the water in the steam system.

4

Industrial Steam System Equipment

This chapter describes the industrial steam system equipment needed to generate steam, distribute it, and collect and return the steam condensate for reuse. The chapter also describes the boiler feed water equipment and the required water and steam treatment systems.

Boilers and steam generators are the main part of an industrial steam system. They are considered fired pressure vessels. Their safe operation is the key to a safe system. To be acceptable as being safe these equipment must bear the American Society of Mechanical Engineers (ASME) stamp. Their fabrication, tests, installation, operation, maintenance, etc., must comply with ASME codes. Other steam system equipment, like a deaerator, blowdown separator, flash steam separator, etc., are considered unfired pressure vessels. They must also comply with ASME codes and bear an ASME stamp.

The following is the most common equipment and accessories in an industrial steam system:

1. Steam generators
2. Steam boilers
3. Boiler fittings and accessories
4. Condensate receiver package
5. Deaerator and boiler feed water package
6. Water softener
7. Pressure relief valves
8. Steam pressure control valves
9. Steam traps
10. Condensate return pumps
11. Strainers
12. Miscellaneous equipment

Steam Generators

Steam generators are commonly used in industry to generate steam. They are available in different shapes and setups. They hold less water than steam boilers with the same output capacity and, as a result, are considered to be safer than boilers. They are available in two different configurations. Either type uses the same heating method of running the water inside tubes located inside the heating chamber of the unit.

In the first configuration, the water is fed to the steam generator at high pressure. The water travels inside helically shaped tubes while it is continuously heated. The high-temperature high-pressure water is then forced into a drum through a pressure-reducing device. This causes the water to flash and generate steam. The steam generators in this configuration are available on one or two prepiped and prewired skids. The second skid, when used, is to house the drum section. The two-skid unit is popular in some states in the United Stated where its operation is exempt from needing a certified boiler operator for any steam generation size. Note that the operation of steam boilers above a certain size in those states requires continuous certified boiler operator attendance.

In the second configuration of the steam generator, the water tube helices start in small diameter and progressively increase in flow direction. The water is fed to the tube at high pressure at the small diameter end and is heated as it travels, causing its temperature to rise. Gradual tube diameter increase provides additional volume for the high temperature water to evaporate and flash into steam as it travels. In this version, the steam-generating drum is replaced by variable diameter helical tubes. The steam outlet is from the final tube turn that also has the largest diameter. This type of steam generator is prepiped and prewired on a single skid.

In either case, the outlet steam, approximately 90% steam by mass, passes through a water separator to separate the residual water before it enters the steam distribution piping.

Comparing steam generators to steam boilers, the steam generators are

1. Considered to be safer to operate
2. Quicker to respond to steam demand changes
3. Considered safer operation due to the small-diameter tubes with a higher pressure rating and less water content
4. Very sensitive to water quality due to the tubes fouling
5. Available for high-pressure steam applications with capacities up to 1,000 boiler hp (34,500 lb/h or 15,660 kg/h of steam)

The steam generator's principle of operation, code compliance, type of fuel, capacity rating, etc., are the same as those of steam boilers, with minor differences. See the next section for more information.

Steam Boilers

Steam boilers are the first choice for generating industrial steam. Except for the large units, the boilers are usually packaged (prepiped, prewired) and tested at the factory before being shipped to the plant.

In addition to the local and national code requirements, boilers' design, fabrication, testing, and operation must comply with ASME 31.1 and ASME Boiler and Pressure Vessel Codes (BPVC).

A boiler capacity is indicated by either boiler horsepower (hp), pounds per hour, or kilograms per hour of steam it can generate from and at 212°F (100°C) water at sea level. This is the boiler capacity when it is fed with 212°F (100°C) water and generate steam at the atmospheric pressure at sea level. One boiler hp is equivalent to 34.5 lb/h (15.66 kg/h) of steam from and at 212°F (100°C) at sea level.

The source of heat for boilers is provided by burning any one of the several available fuels, such as wood, coal, oil, or natural gas. Electric steam boilers are available using resistance or an immersion type of electric heating elements. Nuclear fission is also used as a heat source for large systems especially in steam generators.

This book only discusses the high-pressure industrial steam systems that use natural gas fired factory-packaged boilers. The design conditions and approaches are applicable to other type boilers using different fuels.

The part of a boiler that generates heat is called the burner. Burners can be atmospheric, drawing required combustion air at atmospheric pressure, or forced draft type, drawing the combustion air into the burner using a blower.

The newer burners provide some turndown capability. The term *burner turndown* is an indication of the burner operation flexibility for matching with the steam demand. For example, a burner with a turndown ratio of 10 to 1 (10:1) is capable of modulating its firing rate (output heating capacity) between 100 and 10% of its maximum capacity based on the steam demand. If the maximum capacity of the burner is 100,000 btu/h (29.31 kW), the burner will modulate between 100,000 btu/h (29.31 kW) and 10,000 btu/h (2.931 kW) to match the steam demand without cycling on and off. Below its 10% capacity, the burner will shut down.

Boilers are available in two different heating configurations: fire tube boilers and water tube boilers.

Fire Tube Boilers

The fire tube boilers are the most popular ones, internally set up for hot flue gases to pass through inside the tubes located in the boiler drum or chamber and surrounded with water. The water in the chamber is heated and boils, generating steam. The fire tube boilers are mainly used to generate saturated steam. They are available in three-pass and four-pass configurations. A pass means the number of flue gas travel times inside the boiler tube length before it is discharged into the boiler flue stack to atmosphere. The fire tube boilers are usually referred to as scotch marine boilers. They are available in either dry back units or wet back units. The dry back fire tube boiler is the oldest manufactured boiler. Dry back refers to the refractory section at the back of the boiler opposite the burner end. The term dry back fire tube boilers are available with capacities up to approximately 1,000 boiler hp (approximately 35,000 lb/h or 15,890 kg/h of steam).

The wet back fire tube boiler is similar to the dry back unit except its dry end refractory is eliminated. The wet back fire tube boilers are available with capacities up to approximately 2,000 boiler hp (approximately 70,000 lb/h or 31,780 kg/h of steam).

Comparing similar size dry back and wet back fire tube boilers, the dry back boilers are usually heavier and require more electric power input. This is not always true and can be different for some boiler manufacturers.

Water Tube Boilers

In this type of boiler, the water passes through inside the tubes and the combustion takes place inside the boiler chamber. Water vaporizes as it travels in heated tubes toward the steam nozzle.

The water tube boilers are either packaged for small and low-pressure steam systems or field erected for large, high-pressure, and superheated steam systems.

The large industrial type water tube boilers are available in different tube shapes like A type, D type, and O type, meaning the boiler tubes are shaped like the letter A, D, or O.

Similar to steam generators, the water tube boilers are sensitive to makeup water quality and require additional water treatment to prevent tube fouling.

The water tube boilers are especially used if the application requires superheated steam.

The water tube boilers can operate at high-pressure steam, up to 3,500 psig (24,132 kPag) with unlimited steam generation capacity.

Design Considerations for Boilers and Steam Generators

Consider the following criteria when designing industrial steam systems with steam boilers or steam generators:

1. Size and select boiler(s) and steam generator(s) per manufacturer's recommendations. Verify the unit's efficiency at maximum, average, and minimum steam generation capacities to be acceptable for energy conservation and efficiency per applicable energy codes and to satisfy the owner's requirements.
2. Comply with plant insurance underwriter requirements.
3. Include adequate standby equipment for critical operations.
4. Verify that the selected boiler(s) complies with emission allowance dictated by the Environmental Protection Agency (EPA) and other authorities having jurisdiction.

5. Verify that the boiler(s) operation noise level is acceptable to the plant's standard and complies with Occupational Safety and Health Administration (OSHA) and other applicable codes.
6. Include controls for setting the boiler surface blowdown and the boiler manual bottom blowoff to maintain the boiler water conductivity (dissolved solids) to the level required by the boiler manufacturer. Some manufacturers recommend conductivity to be below 7,000 microsiemens/cm.
7. Include controls for setting the boiler surface blowdown and the boiler manual bottom blowoff to maintain the boiler water silica content to below 150 ppm and the water alkalinity to below 700 ppm.
8. Verify that the number of boilers are optimized based on the operation needs and steam demand. Using more smaller-capacity boilers, compared to fewer larger-capacity boilers, increases:
   a. System efficiency
   b. Capital cost
   c. System reliability
   d. Maintenance cost
   e. Boiler room footprint
   f. System and controls complexity
   g. Boiler's life expectancy
9. Verify the boiler steam discharge nozzle size to be suitable for the intended operating pressure to minimize water carryover.
10. When possible, use a boiler with a high turndown capability. Boilers equipped with high turndown burners have a better efficiency at partial loads, quicker response to demand changes, and longer life due to less on-off cycling.
11. Verify the boiler stop check (nonreturn) valve size and the required reducing spool piece size at the boiler steam discharge nozzle are suitable for the boiler capacity and its turndown capability. Boilers with high turndown must be fitted with smaller stop check valves.
12. Provide adequate combustion air for boiler(s) and steam generator(s) per applicable codes and as recommended by the unit manufacturer. Include heating and temperature control for freeze protection and personnel comfort and interlocking for boiler(s) combustion air control.
13. Provide trench drain or floor drain around the boilers to capture any water discharge. Trench drains can also provide a convenient location for installing piping around the boilers that will eliminate trip hazard.

14. Provide adequate maintenance space, not less than 4 ft (1.22 m), around each boiler and steam generator.
15. Provide access platforms or chain-operated valves for steam discharge valves that are not easily accessible.
16. Arrange boilers with adequate space for their tube pull-out for maintenance.
17. Arrange boilers and other related equipment with adequate space to allow the replacement of any equipment without disturbing other units.
18. Insulate hot piping, valves, etc., for energy conservation and personnel protection.
19. Comply with seismic requirements.

Boiler Fittings and Accessories

The following lists boiler fittings and accessories, referred to as boiler trim. Boiler trim is the fittings and devices required for a boiler's safe and efficient operation. They also provide operational monitoring capability for boiler maintenance and troubleshooting.

Pressure Relief Valve

The pressure relief valve is a mechanically operated device used to relieve pressure and prevent possible explosion of a boiler due to overpressurization. The ASME standard requires at least two pressure relief valves for boilers with 500 ft^2 (46 m^2) of heating surface and above. Smaller boilers can have one pressure relief valve.

Water Level Indicator

The water level indicator, also known as sight glass, is external to the boiler chamber for visual indication of the chamber water level. It is made of transparent material connected with valves to the top and bottom of the boiler chamber. They are provided with a blowoff valve for cleaning and maintenance.

Bottom Blowoff

The bottom blowoffs are connections with valves at the bottom of the boiler chamber, usually one at each end. These are for manual boiler water blowoff. They provide a means for controlling boiler water suspended solids and dissolved solids as well as removing solids that lie on the bottom of the boiler.

Surface Blowdown

This connection allows a small quantity of boiler water from its surface to drain continuously either manually set or automatically controlled based on monitored and measured boiler water conductivity level. Its purpose is to prevent the boiler water from becoming saturated with dissolved salts, as well as to skim off oil from the water surface. Saturation with salt can lead to boiler water foaming that can cause water droplets to be carried over with the steam into the distribution piping.

A surface blowdown connection is also used to manually draw a water sample from the boiler for monitoring the chemistry of the boiler water.

Manholes

The manholes are openings on the boiler chamber, covered with bolted plates for allowing inspection and access to the boiler internal parts and sections.

Low-Water Cutout

The low-water cutout is a mechanical device (usually a float switch) that is used to turn off the burner or shut off the fuel to the boiler if the boiler water level drops to below a low-level set point. This is for the boiler protection to prevent it from running dry. The low-water cutout is external to the boiler chamber to eliminate the chamber water turbulence effect.

Water Column

The water column, similar to a sight glass, is a vertical piping connected to the top and bottom of the boiler chamber. The water column is used for installing instrumentation and control components external to the boiler chamber. The water column has a blowoff valve for draining its water when needed. Installing instrumentation on this external piping column eliminates false sensing that could happen due to the boiler chamber water turbulences.

Pressure Gauge

The pressure gauge is installed on the boiler chamber to indicate the steam pressure. This is a monitoring device for maintenance and troubleshooting.

Boiler Operation Control

The boiler operation control is a sensing device that monitors the steam pressure and starts and stops the burner on steam differential pressure set points. The burner starts as the plant high steam usage causes the steam pressure to drop below the lower limit. The burner shuts down as the plant low steam usage causes the steam pressure to rise above the high limit.

High Limit Control

The high limit control is a second sensor similar to the boiler operating controller set at higher pressure (cut-out pressure) to shut down the burner in case of boiler operating controls failure. This is a safety device to prevent the boiler chamber overpressurization.

Modulating Control

The modulating control is a pressure sensor that controls the burner modulation between its firing ranges (turn down limits) to match the plant steam demand.

Feed Water Connection

The boiler feed water connections are on the boiler chamber, usually available at both sides of the boiler. The connections are located either at the side of the boiler chamber just below the high-water-level switch, or at the top of the boiler chamber.

Chemical Injection Connection

The chemical injection connection is a connection on the boiler shell for adding chemicals to the water in the boiler chamber. In some installations the chemical is injected into the boiler feed water line downstream of the feed water check valve.

Natural Gas Train

The natural gas train includes a piping and valves arrangement for natural gas supply to the burner. The gas train must comply with the plant insurance underwriter requirements. Mostly used gas train setups in the United States complies with either Factory Mutual (FM) or Industrial Risk Insurers (IRI), owner requirements and the applicable local regulations. The gas train includes all required pressure regulators, on-off valves, modulating control valves, vents, etc., for the burner main and pilot gas lines.

Gas Pressure Switches

The gas pressure switches are the relays for shutting down the burner and initiating alarm in case the natural gas supply pressure goes out of the acceptable pressure range.

Stack Thermometer

The stack thermometer is a temperature indicator for indicating the boiler flue gas temperature. This is a monitoring device for checking the boiler efficiency.

For boilers with a stack economizer, two thermometers are required to indicate the flue gas temperatures upstream and downstream of the economizer.

Control Panel

The control panel is a panel that houses the boiler's control devices and distributes power and controls to panel-mounted and equipment-mounted devices. The control panel receives the main power supply for the boiler in a single feed and distributes it to all components requiring power. All required controls for boiler operation, safety controls, burner supervisory controls, local alarms, remote alarm signals, etc., are located in the boiler control panel.

Condensate Receiver Package

Large steam plants with several pumped condensate returns from steam heat exchangers require a central condensate receiver package. The condensate receiver package provides storage capability for storing the high-flow-rate condensate that could come from different condensate pumps at the same time. This happens because of the condensate pump's operation setup. Typically, a condensate pump is located close to a heat exchanger that needs its condensate to drain by gravity. The condensate pump collects the condensate in a storage tank and pumps it at two to three times of its inflow rate as soon as the stored condensate level rises to the pumping level. Without a central condensate receiver package, the pumped condensate from several heat exchangers can cause overflow in the boiler feed water (deaerator) package.

A condensate receiver package includes the following components.

Surge Tank

The surge tank is an atmospheric storage tank that receives pumped and nonpumped condensate from heat exchangers. The tank is vented to the atmosphere, allowing any incoming high temperature condensate to flash and cool to boiling temperature.

The tank is sized to store, as a minimum, equivalent to 10 to 20 min of incoming condensate flow rate. For example, a surge tank that accepts 12,000 lb/h (5,448 kg/h) of combined pumped and nonpumped condensate should have a minimum storage capacity for 4,000 lb (1,816 kg) of condensate. The upper range of 20 min of storage is for situations where the returned condensate coming from several pumps can happen simultaneously. Knowing that every 500 lb/h (227 kg/h) of condensate is approximately equivalent to 1 gpm (3.78 L/min) of water flow rate, the storage capacity should be 480 gal (1,815 L).

The tank should be insulated to conserve heat and internally lined to minimize corrosion.

The surge tank is usually set up to receive only returned condensate rather than the fresh makeup water in order to minimize corrosion in its internally exposed components. The required makeup freshwater for the steam system is provided through the deaerator, where it is scrubbed off of O_2 and CO_2 before it is fed to the boiler.

Transfer Pump

The transfer pump is used to pump condensate from the surge tank to the boiler feed water tank or the deaerator. The deaerator storage tank water level control must be set to accept 100% of the pumped condensate from the surge tank whenever the transfer pump is running.

The transfer pump is sized for the maximum incoming condensate flow rate plus 50%. The 50% extra capacity is to account for future wear, aging, and a safety factor. The maximum incoming flow rate is the sum of condensate discharge from all heat exchangers discharging directly or indirectly into the surge tank.

The transfer pump discharge pressure is calculated as follows:

$$P = P_d + P_s + P_p \tag{4.1}$$

where

P = Transfer pump discharge pressure
P_d = Deaerator pressure
P_s = Static lift
P_p = Piping, valves, etc., pressure drop

For example, the transfer pump for a condensate receiver package with the following requirements is sized as follows:

1. Maximum incoming flow rate = 10,000 lb/h (4,540 kg/h) of condensate
2. Deaerator operating pressure = p_d = 5 psig (34.5 kPag)
3. Deaerator tank inlet connection height = P_s = 22 ft (6.7 m) above transfer pump inlet centerline that is equal to (22 ft ÷ 2.31 ft/psi) = 9.6 psi (66 kPa)
4. Estimated piping, valves, and fittings pressure drop = P_p 10 psi (69 kPa)

Transfer pump flow rate = 10,000 × 1.5
= 15,000 lb/h (6,810 kg/h), or assuming 1 gpm
= 500 lb/h of condensate, the pump flow rate
= 30 gpm (113.6 L/min)

Transfer pump head pressure = 5 + 9.6 +10 = 24.6 psi (169.5 kPa)

In this example, the column of water at the pump suction side is neglected in the calculation as a safety factor. Depending on the surge tank stand height and water pressure drop through the suction piping section, the pump suction pressure can be positive. This is due to the column of water (static height) created by the stand height. The actual pump head pressure is the pump total discharge pressure (calculated before) minus the pump positive inlet pressure.

The condensate receiver package controls are set for the transfer pump to start running when the surge tank water level rises to above 70% of its storage capacity. The pump runs continuously until the water level drops to below 20% of its storage capacity.

The controls include safety features to protect the pump. For example, the transfer pump is disabled and an alarm signal is initiated if the surge tank water level drops to below 10% of its storage capacity. This is to protect the transfer pump from running dry. A high-water-level alarm is initiated if the surge tank water level rises to above 85% of the tank storage capacity. The reset for alarm conditions is manual to provide the opportunity for correcting the causes.

The transfer pumps are selected with proper required net positive suction head ($NPSH_r$) based on the system available net positive suction head ($NPSH_a$) to prevent pump cavitation. For example, assuming sea level elevation with an atmospheric pressure of 14.7 psia (101 kPaa), a condensate temperature at 212°F (100°C) with a vapor pressure of 14.7 psia (101 kPaa), a minimum water column at the pump suction side of 10 ft (3.05 m), and a pump suction side piping and fitting pressure drop of 6 ft (1.83 m) of the water column, the available net positive suction head is

14.7 psi = 14.7 × 2.31 = 34 ft (10.4 m) of water column

$NPSH_a$ = [34 ft (atmospheric) – 34 ft (vapor pressure)] + 10 ft (static head) – 6 ft (piping pressure drop)
= 4 ft (1.22 m) of water column

Therefore, the selected transfer pump required $NPSH_r$, assuming no safety factor, must be less than 4 ft (1.22 m) of water column. The surge tank stand height must be increased or the pump suction side piping must be oversized to increase the available $NPSH_a$ in case the required $NPSH_r$ causes the selected pump to be special and expensive.

Control Panel

The condensate receiver package control panel houses the power and control devices for its operation. The panel, as a minimum, houses the following components and devices. Additional control capabilities such as system monitoring, data recording, and operation control from a central plant control system are also available.

1. Selector switch, hand–off–auto, one per transfer pump
2. Status lights for off, running conditions for each transfer pump
3. Disconnect switches, one for each transfer pump
4. Visual and audible alarm with remote alarm contact and test and reset push button for all fault/alarm conditions
5. Transformer for low-voltage control power
6. Low-water-level cut-out switch
7. High-water-level switch
8. Pump inlet and outlet panel-mounted pressure gauges
9. Panel-mounted water temperature indicator
10. Lead lag and alternation controls for packages with standby pump
11. Pump discharge line pressure transmitter for proving pump operation
12. Pump failure automatic switchover with local alarm and alarm signal for packages with standby pump
13. Motor starters or variable-frequency drive for each pump

Design Considerations for the Condensate Receiver Package

Consider the following for sizing and selecting a condensate receiver package:

1. Size the surge tank vent to allow flash steam discharge without building pressure in the tank. A tank pressure higher than atmospheric results in high water temperature above boiling (212°F or 100°C) that can cause pump cavitation and damage to its seals.
2. Run surge tank vent pipe to a safe location.
3. Include adequate redundancy for critical operations.
4. Size the surge tank stand height to provide adequate static head and a minimum of a 2 ft (0.61 m) safety factor for the transfer pump available $NPSH_a$.

5. Provide an overflow trap or water seal, minimum of 18 in. (0.46 m) deep, for the surge tank overflow to eliminate steaming into the boiler room.
6. Insulate surge tank and hot piping for personnel protection and energy conservation.
7. Provide trench drain or floor drain close to the package to capture possible overflow, water leakage, and pipe breaks and water discharge.
8. Verify that the transfer pumps have appropriate seals and materials suitable for high-temperature condensate up to 212°F (100°C).
9. Specify the package to include redundant feed water pump.

Boiler Feed Water Package

All steam-generating devices, steam boilers, or steam generator, need a feed water package. The package may provide all or some of the following operations.

1. Steam condensate collection
2. Water deaeration
3. Water heating
4. Feed water supply to the boiler or steam generator

The boiler feed water packages are available in two different forms:

1. Heating tank feed water package
2. Deaerator package

Heating Tank Feed Water Package

This type of boiler feed water is popular for small steam systems operating at low pressure. There is no need for a separate condensate receiver package when this type of boiler feed water package is used. A large tank can be used with no significant cost increase. The oxygen removal capability of this type of feed water system is limited.

Minimizing the feed water oxygen level is crucial for the boiler and distribution piping life cycle. At its best performance and if the water temperature is maintained at 212°F (100°C), this type of feed water system can accomplish oxygen removal down to 0.03 CC/L. In most operations, oxygen scavenger chemicals are added to the tank to further reduce the oxygen level. Of course, the added chemicals settle inside the boiler chamber and require additional boiler blowoff that in turn increases the boiler makeup water.

A heating tank feed water package is simple and inexpensive, but it has the following disadvantages:

1. Inadequate removal of CO_2 and O_2 to prevent boiler internal corrosion.
2. Heat and water losses due to the tank atmospheric pressure (vented), especially if there is a high-temperature condensate return that flashes to steam and discharges through the vent.
3. Lack of ability to control the water temperature evenly inside the tank. This can cause feeding the boiler with water that is not hot enough to minimize boiler thermal shock. Boiler thermal shock can compromise its integrity and shorten its life cycle.

A heating tank feed water package includes the following components.

Storage Tank

An atmospheric tank sized for a minimum of 10 min of water storage based on the boiler output steam flow rate plus a 25% safety factor. The safety factor is to account for the possible simultaneous pumped condensate returns. The tank is elevated and installed on a structural stand to provide adequate suction head for the boiler feed water pump to prevent cavitation. The tank is insulated to conserve heat and internally lined to minimize corrosion. There are connections on the tank for maintaining tank atmospheric pressure by venting, receiving condensate, steam feed for water heating (if steam is used), makeup water supply, drain, overflow, boiler feed water pump outlet, and installing instrumentations and control devices.

Water Heater

Usually a steam sparger is used for heating the water inside the storage tank. A temperature control valve on the steam supply line maintains the water temperature at approximately 212°F (100°C). Baffles are installed around the heater inside the storage tank to prevent the sparged steam to be drawn into the feed water pump suction lines. If not prevented, the pump could cavitate. Other types of heating, like the electric coil, are also available. No matter what type of heating is used, the heater must be designed to provide uniform water temperature inside the storage tank.

Boiler Feed Water Pump

Unless the boiler gaseous, liquid, or solid fuel burning has safety measures to shut down the boiler prior to the boiler water level dropping below a permissible low level, the ASME codes require two means of feed water for steam boilers with more than 500 ft^2 (46.5 m^2) of heating surface.

New boiler packages mostly include the ASME required safety features eliminating the need for two boiler feed water sources.

According to ASME codes, boiler feed water pump must provide a pressure at least 3% higher than the boiler pressure relief valve pressure set point at the boiler feed water connection.

For example, the feed water pump for a boiler with the pressure relief valve set at 150 psi (1,034 kPa) must be able to deliver the required boiler water flow rate (explained below) at 155 psi (1,069 kPa) at the boiler feed water connection. Assuming an equivalent static lift of 5 psi (34.5 kPa) for feed water and piping pressure drop of 10 psi (69 kPa), the water pump head pressure, as a minimum, must be 170 psi (1,172 kPa).

The selected feed water pump must be verified for its required net positive suction head and material of construction to be suitable for the system it is serving.

Depending on the type of boiler feed water control, the pump required flow rate is calculated as described below.

On–Off Boiler Feed Water Control

This type of control cycles the feed water pump to maintain the boiler chamber water in preset levels. The pump cycles on and starts pumping when the boiler chamber water drops below a low level. The pump cycles off when the boiler water rises to above a high level. The feed water pump for systems with this type of controls should be sized for a flow rate of two to three times the boiler maximum steam output flow rate. For example, the feed water pump flow rate for a 500 boiler hp with approximately 17,300 lb/h (7,854 kg/h) of steam output with on-off control should be between 35,000 lb/h (15,890 kg/h) and 52,000 lb/h (23,608 kg/h). Knowing that 500 lb/h (227 kg/h) of steam is approximately equal to 1 gpm (3.79 L/min), the pump flow rate should be between 70 gpm (265 L/min) and 104 gpm (393 L/min).

Modulating Boiler Feed Water Control

For this type of setup, the feed water pump runs continuously and maintains the boiler water at a preset level. This type of control requires a bypass water line with an orifice from the pump discharge pipe back to the feed water tank. This is to maintain the pump minimum pumping flow rate when no water supply is needed to the boiler, for pump protection. The boiler chamber water level is maintained through a modulating level control valve. For boilers with a modulating feed water control, the pump should be sized for a flow rate of approximately 1.25 times the boiler maximum steam output rate. This is for a safety factor and to provide for the pump continuous bypass water. For example, the feed water pump flow rate for a 500 boiler hp with approximately 17,300 lb/h (7,854 kg/h) of steam output with modulating control should be 21,625 lb/h (9,818 kg/h). Knowing that 500 lb/h (227 kg/h) of steam is approximately equal to 1 gpm (3.79 L/min), the pump flow rate should be approximately 45 gpm (170 L/min).

Control Panel

The heating tank feed water package control panel houses the power and control components for its operation. Controls and instrumentation for this package, as a minimum, include:

1. Selector switch, hand-off-auto, one per feed water pump
2. Status lights for off, running conditions for each feed water pump
3. Disconnect switch for each feed water pump
4. Transformer for low-voltage control power
5. Visual and audible alarm with remote alarm contact and test and reset push button for all alarm/fault conditions
6. Low-water-level cut-out switch
7. High-water-level switch
8. Pump inlet and outlet panel-mounted pressure gauges
9. Water temperature indicator
10. Lead lag and alternation controls for packages with standby pump
11. Pump discharge line pressure transmitter for proving pump operation
12. Pump failure automatic switchover for packages with standby pump
13. Motor starters or variable-frequency drive for each pump
14. Feed water tank water level controller, modulating or on-off type, for makeup water
15. Feed water temperature control for the storage tank through the steam modulating control valve or electric stepped or modulating controls, or other means of water heating. Additional control capabilities such as system monitoring, data recording, and control and monitoring from the plant central control system are also available.

Design Considerations for Heating Tank Feed Water Package

1. Specify the feed water pump to be suitable for temperatures up to 250°F (121°C), including seals and pump materials.
2. See additional design considerations described in the condensate receiver package section.

Deaerator Package

As the name implies, the deaerator boiler feed water package removes most of the entrained CO_2 and O_2 from the water before feeding it to the boiler. The deaeration process takes place inside the deaerator tank. The package also heats the water to a uniform temperature of about 227°F (108°C) to minimize the boiler thermal shock.

A deaerator is a pressurized tank operating at approximately 5 psig (35 kPag). Properly designed, selected, and operated, the deaerator will remove all CO_2 and most of the O_2 from the water down to 0.005 CC/L. The remainder of the oxygen is removed by chemical treatment, by injecting oxygen scavenger into the deaerator tank.

The deaeration process takes place when the water is fed to the deaerator in a specific way, causing water to release its entrained gases. The released gases are discharged through the deaerator vent to the outside. The vent is sized and provided with a restriction like an orifice to maintain the tank pressure at approximately 5 psig (35 kPag).

More and more owners and plant operators are now convinced they should use a deaerator for boiler feed water, even for small steam plants, rather than the heating tank feed water package to get a better protection and a longer life cycle for the equipment.

Except for the deaerator tank and its internal parts, the rest of a deaerator feed water package is similar to a heating tank feed water package, as described above.

The same approaches as explained in the "Heating Tank Feed Water Package" section are applicable for sizing and selection of the boiler feed water pumps in a deaerator package.

Note that the deaerator tank 5 psig (35kPag) pressure does not add to the system available net positive suction head ($NPSH_a$). The deaerator pressure cancels out with the water vapor pressure at 227°F (108°C).

$$\text{Deaerator tank pressure} = 5 \text{ psig} = 19.7 \text{ psia} = 135.8 \text{ kPaa}$$

$$\text{Water vapor pressure at } 227°\text{F } (108°\text{C}) = 19.7 \text{ psia} = 135.8 \text{ kPaa}$$

The available $NPSH_a$ for the boiler feed water pump is only equal to the water column above its suction connection centerline minus the pump suction piping and fittings water pressure drop.

Since the deaerator receives water from different sources, like makeup water, pumped condensate from the condensate receiver package, hot condensate directly from drip legs, etc., usually the makeup water level is controlled to provide enough storage capacity for all other inflows. For example, it is not uncommon for a system with high condensate transfer flow rate to set the makeup water level controller to fill the deaerator tank only to 70% of its storage capacity, leaving the remaining 30% storage for other inflows to prevent tank overflow.

Some of the differences between a deaerator packge and a heating tank feed water package are

1. The deaerator is fitted with a pressure relief valve, usually set at 50 psi (345 kPa).
2. The deaerator uses a special trap called overflow trap on its overflow connection, instead of a U trap formed by piping usually installed for the heating tank feed water package.
3. The deaerator uses steam for water heating.

Deaerators are divided into two types: spray type deaerators and tray type deaerators.

Spray-Type Deaerator

This type of deaerator uses water spray to atomize the water as the first stage of deaeration. Atomization is done using a spray valve that sprays water in a specific profile. The process causes the release of gases entrained in water and creates a lower local pressure due to the relatively colder environment around the spray zone. All of the CO_2 and most of the O_2 gases are released from the atomized water. Released gases and other noncondensed gases flow toward this low-pressure zone and discharge through the deaerator vent to outside.

The spray valve is capable of maintaining the water spray profile from 100% of its flow rate capacity to 1%, making this phase of the deaeration process effective in a large water flow rate range.

The second stage of deaeration takes place in an internal section called scrubber. The scrubber is where supplied steam to the deaerator, usually at 5 psig (35 kPag), vaporizes some of the makeup water, resulting in more oxygen release. This process also heats the water. By the time the water leaves the scrubber section, it is heated to the deaerator saturation temperature of approximately 227°F (108°C) at 5 psig (35 kPag).

Compared to a tray type deaerator, the spray type deaerator is

1. Cheaper in equipment cost
2. Shorter in height
3. Simpler in design
4. Less affected by water quality
5. Less efficient in responding to the sudden load changes

Tray-Type Deaerator

Similar to spray type, the tray type deaerator uses water spray as the first stage of deaeration. The process is as explained above for the spray type deaerator.

The second stage of deaeration, similar to a spray type deaerator, exposes the water to steam to force more oxygen release. A stack of trays are used to force the water to expand as it is exposed to the steam. This provides a result similar to that of the scrubber section of a spray type unit. The water fills the tray and overflows to the tray below, while steam surrounds the tray stack as it flows upward toward the low-pressure spray zone. Steam comes from the supplied live steam as well as high-temperature condensate returns flash steam, when available. Exposed water to steam is scrubbed, releasing more oxygen. As the water overflows downward from trays, its temperature rises, approaching the deaerator saturation temperature of approximately 227°F (108°C) at 5 psig (35 kPag).

Compared to a spray type deaerator, a tray type deaerator is

1. More efficient, needing less steam to heat the water
2. Faster responding to the rapid load changes
3. More sensitive to water quality
4. Sensitive to installation to maintain proper level to achieve a full tray's water level and uniform overflow
5. More expensive in equipment cost
6. Taller in height, needing more headroom

Design Considerations for Deaerator Feed Water Package

Consider the following when sizing and selecting a deaerator package:

1. See design considerations for the condensate receiver package.
2. Specify the boiler feed water pump to be suitable for temperature up to 250°F (121°C), including seals and pump materials. Provide external water cooling or other means as recommended by the manufacturer for temperatures above 250°F (121°C).
3. Study the actual operation and use a tray type deaerator if the steam demand changes are rapid and significant.
4. Pipe deaerator pressure relief valve to a safe place.
5. Verify that the high-temperature condensate return will not cause the deaerator water temperature to exceed the design temperature used to select the feed water pumps. Install a flash tank upstream of the deaerator if needed to control the high temperature condensate return temperature.

Water Treatment Systems

Different boiler systems require different feed water quality. A competent water treatment company or person is required to study and recommend the necessary water treatments. The primary concerns for a boiler system include protecting the system from corrosion, preventing scale buildup inside the boiler, and reducing the boiler blowdown and blowoff water. The corrosion concern is treated through the deaeration process and chemical treatments. Other water treatments are available and are used to minimize the other concerns. Some basic nonchemical water treatments widely used for protecting the steam systems and increasing the boiler efficiency are described below.

Reverse Osmosis Water Filtration

The reverse osmosis filtration is perhaps the simplest method for controlling the boiler scale buildup and minimizing the boiler blowdown and blowoff water. It is done by forcing the water through membrane type filters. The process generates high-purity water by eliminating or reducing the water hardness, total solids, alkalinity, and silica. Using reverse osmosis-treated water, the boiler scaling will be reduced to a high degree and the boiler blowdown and blowoff water will be reduced tremendously.

Dionized Water Treatment

Similar to the reverse osmosis water filtration, the pure water generated through the deionization process will reduce the scale buildup and boiler blowdown and blowoff water.

Deionization is done through ion exchange using synthetic resins. The most common configurations for ion exchanges are the two-bed system (using two separate beds/tanks) and the mixed-bed system (single column/tank). The mixed-bed system is used when smaller capacity with higher system quality water is required.

Water Softening

The water softening is the main subject of this water treatment section and will be discussed in detail. It is the most common water treatment used for the boiler feed water.

Softening boiler feed water will reduce the scale buildup and minimize the boiler blowoff and blowdown water to less than 3% of the boiler evaporation rate.

The blowdown is done through the boiler surface blowdown continuously either manually set or automatically controlled based on the measured water conductivity level. This is to maintain the water hardness level below a high limit. The blow off is done through the boiler bottom blowoff valves. This is a manual operation to discharge solids collected at the bottom of the boiler.

Water softener is used to remove the water-dissolved minerals such as salts (mainly calcium and magnesium bicarbonates), commonly referred to as water hardness. Boiler feed water, as a minimum, must be softened. Without a soft water supply, scale and buildup form inside the boiler rapidly, causing loss of boiler efficiency and eventually boiler burnout. The scaling can be slowed by more frequent boiler blowoffs. This in turn will increase the water consumption and will further reduce the boiler efficiency due to the increased makeup water, the water heating, and the energy loss through the blowoff water.

The water softening process uses ion exchange through a media of bead size resin. This medium has the capability to exchange the ions that replace the hardness (calcium and magnesium) of the water with sodium ions of regular salt.

The following description of the water softening process assumes the water source is potable, similar to city water quality. In cases where the water source is different, like surface water or well water, more complex water treatments are needed.

The water softening process is as follows.

Exchange Process

This is the exchange phase to make soft water. The exchange process is done when the hard water flows through precharged sodium ion resin in a pressurized tank column. The resin beads replace the hard water calcium and magnesium ions with sodium ions, removing the water hardness.

The water is sprayed in a uniform profile at the top of the tank over the column of resin. Ion exchange takes place as the water flows downward through the column in a uniform distribution exposing to all resin beads. The water then passes through a layer of gravel and discharges from the bottom of the resin column as soft water.

Saturation Condition

This is when the resin beads have exchanged all the calcium and magnesium ions they are capable of accepting. The resin column is now saturated. The resin column cannot generate any more soft water.

Backwash Process

This is to prepare the saturated resin column for recharge. Freshwater is forced to flow through the saturated resin column in the reverse direction. Water flows from the bottom of the tank upward through a gravel layer and resin beads, loosening all dirt and foreign materials. It washes all internals and discharges from the top of the resin column out of the tank to the drain.

Regeneration Process

This is to recharge the resin column. The column is subjected to salt water (brine), causing its resin to replace the calcium and magnesium ions with regular salt sodium ions.

Salt water is generated in a separate tank called a brine tank. This is done by adding freshwater to the salt inside the brine tank at the end of every regeneration cycle to make the salt water for the next regeneration.

Salt water is drawn from the brine tank to the top of the resin column through an eductor. Salt water is sprayed over the resin column and flows downward through the column. The brine volume used is controlled by a float valve inside the brine tank to be in a quantity sufficient to saturate the resin column.

Rinse Cycle

This is to rinse the regenerated resin column to remove excess salt. Rinsing is done by flowing freshwater downward, in the normal water direction, through the resin column for a set time period. The resin column is ready to generate soft water after the rinse cycle is over.

Water softeners are available in a single resin column (simplex), two resin column (twin type or duplex), or more columns. In processes where soft water is continuously needed, a twin type or more resin columns are required. Multiple resin columns allow making soft water through some resin columns while regenerating the other ones. Switching from one column to another to provide a continuous supply of soft water is done automatically using on-off solenoid valves controlled by either a timer or a water meter. The changeover based on the water metering is called demand control and is considered a more efficient operation.

Design Considerations for Water Softeners

Consider the following for sizing and selection of a water softener:

1. Select and size water softener based on the maximum and minimum soft water flow rates for the application.
2. Do not oversize water softener or the water will channel through the resin column. Channeling will cause water to expose to a limited number of resin beads only. The exposed beads will quickly saturate and will not remove the water hardness anymore. The unused resin beads will remain unused.

3. Provide a duplex water softener for applications where soft water is needed continuously. The duplex package allows one softener column to regenerate while the second column is in service.
4. Size water softener to regenerate at an interval not to exceed 3 times per day. It takes approximately 2 hours for the resin column to regenerate and approximately 3 hours for saturated salt water to be ready.
5. Provide water softener and other required treatments to minimize the makeup water hardness to less than 1 ppm.
6. Provide a properly sized hub drain next to the water softener to prevent water splash during its backwash and rinsing.
7. Using a water meter instead of a timer for resin column regeneration saves water and salt.
8. Provide a 3/4 in. connection downstream of the water softener for soft water sampling.
9. Provide space for storing salt pellets and bags close to the water softener salt tank.
10. Provide easy access to the salt tank for salt charging.

Pressure Relief Valves

Pressure relief valves (PRVs) are used to relieve excess pressure from pressure vessels like boilers, deaerators, and steam distribution lines where the steam pressure is reduced. This is often needed to satisfy the users' pressure requirements.

Usually, the boiler, the deaerator, and most other equipment pressure relief valves are sized, selected, and installed in accordance with the ASME applicable codes by their manufacturers. They are included in the factory-packaged equipment.

This section discusses the pressure relief valve used in the steam distribution piping where the steam pressure is reduced through a pressure reducing station. This pressure reduction is required either due to the application need or for protecting the steam users with lower pressure rating than the plant steam.

The steam pressure reduction is done through what is commonly referred to as a steam pressure reducing station. The station usually includes isolation valves, strainer, and steam pressure control valve. Often a bypass with a globe valve around the steam pressure control valve is installed to allow temporary service if the steam pressure control valve needs maintenance. The bypass globe valve provides some degree of pressure adjustability.

The steam pressure control valves accept steam at higher pressure and reduce it to the desired lower pressure. To ensure that the maximum acceptable lower-pressure set point is maintained during variable steam flow rate, during inlet steam pressure swings, and if the steam pressure control valve fails, a pressure relief valve is installed downstream of the pressure reducing station. Its pressure relieving set point is usually either 10 psi (69 kPa) or 10%, whichever is higher above the lowered steam pressure set point.

The pressure relief valve pressure set point must be verified to be lower than its downstream steam users' pressure rating.

The pressure relief valve is sized for the highest possible steam flow rate either through the steam pressure control valve and/or through the bypass line. It is installed downstream of the pressure control valve with proper fittings and support. It requires venting to a safe location.

Refer to the "Drip Pan Elbow" section in this chapter for recommended pressure relief valve installation.

The following formulas are used to determine the maximum steam flow rate through the steam pressure control valve and through the bypass line. The highest calculated flow rate, through the pressure control valve or the bypass line, is used to size and select the pressure relief valve for the application.

Steam Pressure Control Valve Maximum Steam Flow Rate

The following formula is used to determine the maximum possible steam flow rate through a steam pressure control valve:

$$W = (1/3) \times (O) \times (A) \tag{4.2}$$

where

W = Steam flow rate (lb/h)

O = Pressure control valve orifice flow rate capacity (lb/h.in.^{2}) from Table A.2 in Appendix A

A = Pressure control valve pipe size cross section area (in.^{2}) from Table A.3 in Appendix A

For SI units:

$$1 \text{ lb/h} = 0.454 \text{ kg/h}$$

$$1 \text{ in.}^2 = 645 \text{ mm}^2$$

The critical stream flow rate provided by the steam pressure control valve manufacturer is acceptable to be used instead of the above formula to size and select the pressure relief valve.

Note that in using Table A.2, the pressure control valve inlet pressure is the lowest set pressure of any pressure relief valve on its high-pressure side. For example, if the boiler pressure relief valve is the only one on the high-pressure side of the steam pressure control valve, then its set pressure must be used in Table A.2.

Bypass Line Maximum Steam Flow Rate

The following formula is used to calculate the maximum possible steam flow rate through a pressure reducing station bypass line.

The bypass line must have a globe valve for setting the approximate outlet steam pressure.

$$W = (1/2) \times (O) \times (A) \tag{4.3}$$

where

W = Steam flow rate (lb/h)

O = Globe valve orifice flow rate capacity (lb/h.in.^{2}) from Table A.2 in Appendix A

A = Bypass valve pipe size cross section area (in.^{2}) from Table A.3 in Appendix A

For SI units:

$$1 \text{ lb/h} = 0.454 \text{ kg/h}$$

$$1 \text{ in.}^2 = 645 \text{ mm}^2$$

Design Considerations for Pressure Relief Valves

Consider the following for sizing, selection, and installation of pressure relief valves:

1. Pipe pressure relief valve discharge to a safe place.
2. Use drip pan elbow to indirectly (connection with air gap) discharge the pressure relief valve into an exhaust vent. Refer to the “Drip Pan Elbow” section in this chapter for more details.
3. Size and select pressure relief valve per manufacturer recommended procedures.
4. Minimize the length of the piping and avoid beads between the pressure relief valve and the drip pan elbow.
5. Provide drain for the pressure relief valve to separate and drain formed condensate during relieving to prevent interruption to steam discharge.

Steam Pressure Control Valves

As described above, a steam pressure control valve is used to reduce the steam pressure where required for the operation. The pressure reduction takes place as the steam passes through an adjustable orifice like the passage inside a pressure control valve, causing the steam pressure to drop.

This section discusses different types of steam pressure control valves presently popular in the market, together with design considerations for their applications.

Steam pressure control valves are available in different types, configurations, and materials of construction. The three most popular types are as follows.

Direct Acting Steam Pressure Control Valves

These steam pressure control valves are a compact design with self-contain pressure control features such as an internal diaphragm or bellows. These valves are the simplest and the cheapest if they can satisfy the application requirements.

The normal pressure reduction for this type of valve is approximately 3 to 1 with 10% accuracy. For example, it can reduce steam pressure from 150 psig (1,034 kPag) to a minimum of 50 psig (345 kPag) with 10% accuracy. The accuracy will drop for pressure changes beyond this range. Its normal flow turndown ratio is 4 to 1, meaning a pressure control valve with a maximum capacity of 4,000 lb/h (1,816 kg/h) of steam flow rate will only operate properly for the steam flow rates down to 1,000 lb/h (454 kg/h).

Pilot-Operated Steam Pressure Control Valves

This type of pressure control valve is equipped with a pressure sensing tube that controls the pilot section of the valve by sending the pressure signal. The pilot, in turn, is set up to modulate the valve main regulator to maintain the pressure set point downstream of the valve at the sensing tube location. Any pressure variation from the set point at the sensing tube location is transferred to the pilot device that will force the valve regulator to readjust.

The pressure sensing line must be installed to sense the steam pressure at least 10 pipe diameters downstream of the pressure control valve outlet. The sensing line must be installed with proper slope to gravity drain any formed steam condensate inside the tube.

The normal pressure reduction for this type of valve is approximately 4 to 1 with 3% accuracy. It can handle steam flow rate with a turndown ratio of 10 to 1, going from 100% capacity to 10% while maintaining its accuracy.

Externally Controlled Steam Pressure Control Valves

These steam pressure control valves are equipped with an electric or pneumatic actuator and are controlled by an external controller. A pressure sensing line that continuously measures the downstream steam pressure sends the pressure signal to the controller. The controller then modulates the valve actuator to maintain the pressure at the pressure sensing location. Similar to the pilot-operated pressure control valves, the sensing line for this type valve must connect to the steam line at least 10 pipe diameters downstream of the valve outlet with proper slope for steam condensate gravity drain. This type of valve is the most expensive one, but provides accurate control with the largest turndown range.

Normal pressure reduction for this type of pressure control valve is approximately 10 to 1 with better than 1% accuracy. It can handle a flow rate with a turndown ratio of 30 to 1. For example, a valve with a maximum flow rate capacity of 30,000 lb/h (13,620 kg/h) of steam at 150 psig (1,034 kPag) can within 1% accruacy reduce the pressure down to 15 psig (103 kPag) at a reduced flow rate down to 1,000 lb/h (454 kg/h).

Design Considerations for Pressure Control Valves

Consider the following when designing a steam pressure reducing station:

1. Always consult with the manufacturer for sizing and selection of a steam pressure control valve. Software is also available on the manufacturers' website to help with valve selection.
2. Always consult with the manufacturer for valve installation requirements. Some installation may require a long space to provide a straight run of piping upstream and downstream of the valve for noise reduction and proper operation.
3. Never oversize a steam pressure control valve or the minimum acceptable flow rate for accurate operation for the valve will increase, the operation will be noisy, the pressure control accuracy will go down, and the valve life cycle will be reduced.
4. Size piping around the steam pressure control valve for a steam inlet velocity less than 9,000 fpm (46 m/s) and an outlet steam velocity of less than 6,000 fpm (31 m/s).
5. Select the valve for acceptable noise, usually less than 85 dB at 5 ft (1.5 m). If the noise is unavoidable, use thicker insulation and heavier pipe, i.e., schedule 80 carbon steel pipes instead of schedule 40 pipe. Mufflers and orifice plates are available from the valve manufacturers for reducing the operating noise.
6. Use two-stage pressure reductions (two pressure control valves in series) if a single-stage pressure reduction is not satisfactory. For example, instead of a one-stage pressure reduction from 300 psig (2,069 kPag) to 50 psig (345 kPag), use two-stage pressure reduction; the first valve reduces the pressure from 300 psig (2,069 kPag) to 150 psig (1,034 kPag), and the second valve reduced the pressure from 150 psig (1,024 kPag) to 50 psig (345 kPag).

7. Use two parallel steam pressure control valves if the flow rate is too high for a single valve or the steam demand change is significant. This is usually set up in a two-valve arrangement sized for 1/3 and 2/3 of the maximum steam flow rate. The small valve pressure is set at 1 psi (6.9 kPa) higher than the required low steam pressure set point. The larger valve pressure is set at 1 psi (6.9 kPa) lower than the required low steam pressure set point.
8. For steam pressure up to 150 psig (1,034 kPag), use cast iron valves with a stainless steel seat. For steam pressure above 150 psig (1,034 kPag), use cast steel valves with a stainless steel seat. Use stainless steel material for clean steam applications.

Steam Traps

Steam traps are automatic devices used in steam systems to remove condensate and noncondensable gases from the distribution piping and heat exchangers without passing live steam.

The formed condensate due to the heat loss in steam distribution piping must be removed to prevent piping erosion, water hammering, noisy operation, and wet steam delivery.

The heat exchanger's condensate must be removed to maintain its heat transfer efficiency and temperature controllability.

Without a steam trap, live steam will pass into the condensate collection system, resulting in a significant loss of energy. The escaped steam will increase the condensate temperature, which will in turn upset the deaeration process and the boiler feed water pumps' operation.

Based on their principle of operation, steam traps are divided into three different types.

Mechanical Steam Traps

The mechanical steam traps use a lever and floating device to mechanically open their discharge port to drain the condensate. A liquid seal prevents the live steam from passing through the trap, preserving it from being wasted. The floating part moves up as the collected condensate level inside the trap rises and eventually opens the trap discharge port. The steam pressure or the gravity force pushes the condensate out of the trap causing the float to drop and close the discharge port.

This family of steam traps is the most common ones in industrial steam systems application. The two mostly used mechanical steam traps are the inverted bucket traps and the float and thermostatic traps.

Inverted Bucket Steam Trap

The inverted bucket steam trap uses an inverted bucket placed over the condensate inlet port as its floating part. The trap discharges intermittently and does not subcool the condensate unless it is oversized. The noncondensable gases are discharged through a small vent at the top of the inverted bucket. The inverted bucket traps are available with a wide selection of outlet port orifices for matching precisely with the application differential pressure and the condensate load.

Do not use an inverted bucket trap if the source of the condensate is not continuous or the trap can lose its water seal. Without the water seal the steam trap will pass live steam.

Float and Thermostatic Steam Trap

The float and thermostatic steam trap uses its float to open its mechanical discharge port. The trap has a separate thermostatic valve for releasing noncondensable gases. The trap drains the condensate as quickly as it receives it. It also discharges air and other non-ondensable gases at the same time.

Thermostatic Steam Traps

These steam traps are controlled thermostatically based on the sensed temperatures of the condensate and the steam. They use a temperature sensing element to open the discharge port when the condensate temperature drops to below the steam temperature. They discharge the condensate intermittently.

Two common types of temperature sensing elements used for these steam traps are the balance bellows and the bimetallic. Both sensors respond to the temperature difference between the steam and the condensate.

The flexible bellows uses expansion and contraction of the charged volatile liquid (i.e., alcohol) to open the discharge port. They respond also to the pressure to adjust in their move.

The bimetallic elements uses the thermal expansion of dissimilar metals to open the discharge port. They are not sensitive to the pressure; therefore, they must be calibrated for the operating pressure for each application.

Both sensing elements respond as soon as the collected condensate cools inside the steam trap shell by a few degrees.

The thermostatic traps are not suitable for the superheated steam applications.

Thermodynamic Steam Traps

The thermodynamic steam traps operation is driven by the steam kinetic energy (steam velocity) by moving a flat disc that closes the trap discharge port. As the condensate enters the trap, the flat disc is lifted, allowing the condensate to pass through. As the condensate temperature goes up (e.g., after start-up), the hot condensate flashes, releasing flash steam above the flat disc. The steam high velocity, on the other hand, creates a low-pressure zone under the flat disc. The flash steam pressure above the flat disc, together with the low-pressure zone underneath it, pushes the flat disc down, closing the discharge port. As the trap cools down the flash steam condenses and loses its pressure. The flat disc is lifted, opening the discharge port and allowing the condensate to pass through.

The thermodynamic traps have only one moving part, the stainless steel flat disc. They easily withstand water hammer and freezing conditions.

The thermodynamic traps are suitable for the superheated steam application.

The thermodynamic traps are not recommended for common applications and the normal saturated steam systems since they are not efficient and do not effectively discharge noncondensable gases.

Recommended Steam Trap Type for Different Applications

1. Use the inverted bucket trap as the first choice and the float and thermostatic trap as the second choice for the constant steam pressure applications and where the steam supply to the heat exchanger is not modulated, i.e., the steam supply is either on or off.
2. Use the inverted bucket trap with standard material suitable for application pressure for the steam distribution piping drip legs that are not subjected to freezing. Use the stainless steel inverted bucket trap where the application is subjected to freezing.
3. Use the float and thermostatic trap as the first choice and the inverted bucket trap as the second choice for applications with modulating steam, where the supply steam pressure to the heat exchanger changes, due to the modulation of a temperature control valve.

Design Considerations for Steam Traps

Consider the following design considerations for sizing and selection of the steam traps for different applications:

1. Consult with the steam trap manufacturer for recommended trap application and sizing, including trap type, safety factor for trap sizing, and the required differential pressure across the trap. Computer software is available on the manufacturer's website for sizing and selection of the steam trap for common applications.
2. As a minimum, the condensate load, steam supply pressure, condensate back pressure, application type, and steam supply control type (on-off or modulating) are required for selecting and sizing a steam trap.

3. Avoid bypassing around the steam trap line. Add a second full-capacity condensate line with its own steam trap, strainer, and valves if a sensitive process application requires more reliability. The second condensate line stays closed until opened manually.
4. Include a vacuum breaker between a steam coil and its steam supply control valve to prevent vacuum inside the coil. This allows the coil condensate to drain properly. Without a vacuum breaker the coil can accumulate condensate due to the vacuum caused by the high-volume steam turning into condensate.
5. Provide a minimum 6 in. (152 mm) long full size dirt leg on the steam coil condensate outlet line. Refer to the details in Appendix B.
6. Provide a minimum of 2 ft (0.61 m) drop from the steam coil condensate discharge centerline to the steam trap inlet centerline for applications using a modulating steam control valve. The recommended trap type for these applications is the float and thermostatic. The 2 ft (0.61 m) is the minimum required pressure (in water column) for proper condensate drain for a float and thermostatic steam trap.
7. Do not lift the steam condensate after the steam trap for applications with modulating steam supply to a steam coil. An example is a steam coil with a modulating temperature control valve on its steam supply. The condensate must be gravity drained to an atmospheric tank and pumped to the central collection system.
8. Provide a ½ in. (15 mm) test connection with a valve downstream of each steam trap for trap testing. The test is to ensure no live steam passes through the steam trap.

Condensate Return Pumps

A condensate return pump unit is a package that collects the steam condensate from the heat exchangers and pumps it to the central condensate receiver tank. The package includes, as a minimum, a vented storage tank or receiver, a pump, piping, and controls and instrumentations. The pumps included in the package are available in electric-powered type and pressure-powered type. Either type collects the condensate in the receiver and pumps it out when the stored condensate level rises to the pumping level.

Electric-Powered Condensate Pump Package

The pumps in this package are driven by electric motor. This package is the preferred type in most industrial steam systems applications. The package is prepiped and prewired and includes a storage tank, one or more pump(s), control panel, piping, valves, and controls and instrumentations.

The pumps are usually the closed coupled type with cast iron casing, bronze impeller, and stainless steel shaft.

The cast iron storage tank is standard and is good for up to 120 gal (454 L) storage capacity. The carbon steel, copper, and stainless steel materials are recommended for larger size storage tanks.

The controls, as a minimum, for electrical pumps include a manual on-off switch for each pump, a disconnect switch for each pump, a starter for each pump, a level controller to automatically start and stop the pump based on the storage tank liquid level, and a high liquid level alarm switch. Sight glass, thermometer, and pressure gauges are recommended for the package for monitoring and troubleshooting.

The recommended sizing criteria for this type condensate return pump package is as follows:

$$\text{Pumping flow rate} = \text{2 to 3 times the normal incoming condensate flow rate} \tag{4.4}$$

$$\text{Pump discharge pressure} = P = P_p + P_s + P_d \tag{4.5}$$

where

P_p = Discharge piping, fittings, and valves pressure drop

P_s = Static lift to lift condensate from pump inlet centerline to the receiver tank inlet centerline

P_d = Condensate receiving tank pressure if not atmospheric or the deaerator pressure

A safety factor of 10 to 20% is recommended for the pump discharge pressure to account for aging and pump component wear.

The storage tank capacity is 1 to 2 min of storage based on its discharge flow rate, where practical, mainly to allow the condensate to flash and cool. Larger storage capacity causes fewer pumps cycling and a longer life cycle for the pump and its motor. However, the condensate must be returned to the boiler as soon as possible to eliminate unnecessary makeup water and to reduce the water heating.

For example, a condensate return pump package for 10,000 lb/h (4,540 kg/h) of incoming condensate requiring a 5 psi (34.5 kPa) pressure drop through piping, 20 ft of water static lift (8.7 psi or 59.7 kPa), and a deaerator receiver tank pressure of 5 psig (34.5 kPag) is sized and selected for

Flow rate = 2 × 10,000 = 20,000 lb/h (9,080 kg/h) or knowing that 500 lb/h of condensate is approximately equal to 1 gpm, the flow rate is 40 gpm (151 L/min)

$$\text{Discharge pressure} = (5\text{ psi} + 8.7\text{ psi} + 5\text{ psi}) \times (1.2\text{ safety factor})$$
$$= 22.5\text{ psi (155 kPa)}$$

$$\text{Storage tank capacity} = (2\text{ min}) \times (40\text{ gpm}) = 80\text{ gal (303 L)}$$

A duplex package is recommended for applications where the condensate return is critical. A duplex condensate return pump package includes two pumps, set up for one pump to run and the second one to stay in standby. The package comes with controls to automatically switch to the standby pump in case the running pump fails. This is usually set up based on the storage tank liquid level. Alarming capabilities, local and remote, must be included in the package to announce the pump failure. An alternating controller can be added to the package to alternate the pumps' operation based on their actual run time for equal wear.

Pressure-Powered Condensate Pump Package

A pressure-powered condensate package includes a vented condensate receiver and one or more pumps, prepiped, on one skid. The pumps are driven by either steam or compressed air. Their principle of operation is similar to an inverted bucket steam trap. They have internal float assembly housed inside the pump body and inlet and outlet check valves. The pump body is sized to store a certain amount of condensate.

The condensate is received in the vented receiver. The pumps are vented either directly or through the condensate receiver to the outside. Except for the time period when a pump is pumping, the receiver condensate drains continuously into the pump section by gravity through the pump inlet check valve. The condensate drains to the pump as soon as it is received in the receiver.

As the condensate level rises inside the pump, the pump internal float moves up, closing its vent and opening its motive media, steam or compressed air, port. The motive media pressure then closes the pump inlet check valve and opens the pump discharge check valve, forcing the condensate out of the pump body. The pump float valve drops, opening its vent and closing its motive media port after the condensate is pumped out. The pump inlet check valve opens and the pump discharge check valve closes.

The pumping time period is short, usually less than a minute. The incoming condensate during the pumping period, when the pump inlet check valve is closed, is stored inside the condensate receiver.

The pressure-powered condensate pump packages are good candidates for installation inside classified areas requiring explosion-proof motors. They can pump the condensate at high temperatures not acceptable for electric driven pumps. They are also suitable for applications where the electrical power is not readily available or is remote.

To size a pressure-powered condensate pump, the back pressure (piping and fittings pressure drop, static lift, and receiver tank pressure), the motive media (steam or compressed air) pressure, the amount of flash steam, and the incoming condensate flow rate are needed. The package is sized based on the incoming condensate flow rate at a motive media pressure. Unless required otherwise by the manufacturer, the recommended motive media pressure is approximately 20 psi (138 kPa) higher than the system back pressure. The pump package can be selected using selection software available on the manufacturer's website.

The pressure-powered condensate pump packages are available with cast iron or carbon steel condensate receiver and cast iron or carbon steel pump body with stainless steel internals and stainless steel inlet and outlet check valves.

Design Considerations for Condensate Return Pumps

Consider the following when sizing and selecting condensate return pumps:

1. Provide a water seal trap for the storage tank overflow to stop steaming through the overflow. The water seal trap is recommended to be a minimum of 18 in. (46 cm) deep and the same size as the unit overflow connection.
2. Install a flash tank upstream of the electric driven condensate return pump package to flash and cool the condensate if the incoming condensate is high temperature. The condensate temperature should be below 210°F (99°C) for efficient and trouble-free pumping.
3. Size the vent for the storage tank or the condensate receiver for the maximum anticipated flash steam discharge to maintain the tank pressure close to atmospheric pressure.
4. Use motive media with at least 30 psi (207 kPa) higher pressure than the calculated discharge pressure for pressure-powered condensate pumps.
5. Do not use motive media with too high pressure for the pressure-powered pump packages. It can cause water hammering and noisy operation. It will reduce the life cycle of the pump check valves.
6. The electric driven pump(s) seals are recommended to have carbon/tungsten carbide for stationary and rotating parts with a Viton O-ring and stainless steel components for better durability.

Strainers

This section describes Y-type strainers in sizes up to 12 in. (300 mm) used in industrial steam systems. Strainers are in-line devices with filtering media for limiting solid particles of larger than a certain size to pass through. As the name implies, this type of strainers are shaped like a Y.

The filter section is either a perforated sheet or a wire mesh usually sized to filter out all particles larger than about 100 mesh, approximately 0.005 in. (0.13 mm) round. The strainers come with a blowoff port for their filter media cleaning without having to remove it, even though the media is removable.

Strainer materials of construction include ductile iron, cast iron, bronze, carbon steel, and stainless steel. Carbon steel is the suitable material for high-pressure steam applications. Stainless steel strainers are used for clean steam applications.

Design Considerations for Strainers

Consider the following for strainers when designing steam systems:

1. Install strainer upstream of 2 in. (50 mm) and smaller control valves. Control valves larger than 2½ in. (65 mm), especially the butterfly type, are self-cleaned by allowing the particles to pass through.
2. Install strainer upstream of all steam traps.
3. Provide full port valve at the strainer blowoff connection. Strainer cleaning is done by opening the blowoff valve. The fluid pressure and velocity loosen particles inside the filter media and blow them out through the blowoff valve.
4. Use screen perforation size of 1/32 in. (1 mm) for piping up to 2 in. (50 mm) and 3/64 in. (2 mm) for piping 2.5 to 12 in. (65 to 300 mm).
5. Provide adequate maintenance space for strainers to allow the removal of the filter media.
6. Provide trench drain or floor drain close to the strainers to collect the blowoff water when they are cleaned.

Blowdown Separators

A blowdown separator is a simple water cooler that receives the hot boiler blowoff and blowdown streams in a single inlet, allows them to flash, vents the flash steam to outside, cools the remaining hot water by mixing it with cold water, and drains it.

Flashing, as the first cooling stage, takes place by allowing the high-temperature blowoff and blowdown water from the boiler to expand inside the blowdown separator. The flash steam discharges through the blowdown separator vent to the outside. The remaining hot water, now at about boiling temperature, mixes with the cold water that is supplied through a temperature control valve in a mixing section, and then discharges to the drain. The drain water temperature control is through a self-contained temperature control valve using a capillary tube. It has a temperature sensor bulb on the drainpipe that reads the mixed water temperature. The temperature control valve modulates to adjust the cooling water flow rate to maintain the mixed water temperature set point.

In most locations, the discharged water temperature, if it is connected to the public sewer, is regulated by the local authorities having jurisdiction to be below a high temperature limit, for example, 140°F (60°C).

The blowdown separator and hot piping around it should be insulated for personnel protection.

Design Considerations for Blowdown Separator

Consider the following for the blowdown separator when designing steam systems:

1. Verify the underground piping material to be suitable for blowdown and blowoff water temperature.
2. Verify the acceptable drained water temperature if the blowdown and blowoff water is discharged into the public waste.
3. Verify if heat recovery from the blowdown and blowoff water is feasible. The surface blowdown flow rate is usually low. The bottom blowoff is intermittent and can contain sludge that will cause the heat recovery equipment to be hard to maintain.
4. If heat recovery is used, provide appropriate material for heat recovery equipment to withstand erosion. Set the boiler surface blowdown at a proper continuous flow rate to maintain the suspended and dissolved solids at an acceptable level. The most common uses for recovered heat are generating flash steam through a flash tank for deaerator use and preheating the boiler makeup water.

Miscellaneous Equipment

Chemical Treatment Package

A chemical treatment system is required to supplement mechanical water treatments and deaeration to generate pure steam, to maintain the boiler efficiency by preventing scale buildup, and to eliminate or slow down equipment and piping internal corrosion.

The most common chemical treatments are

1. Injection of chemicals such as sulfate (SO_3) as oxygen scavenger into the deaerator to remove water-entrained leftover oxygen from the deaeration process.
2. Injection of chemicals such as phosphate (PO_4) into the boiler chamber to remove the deposits and buffer the water pH level when the caustic is released.
3. Injection of antifoam agents into the boiler chamber to prevent foaming.

Chemical feed packages include a tank with an agitator, one or more injection pumps, and piping and controls. These are usually mounted on a single skid, prepiped and prewired. Chemical feed systems are controlled either manually (run continuously) or automatically. The automatic cycling can be based on water (pH level, conductivity level), preset time periods using a timer, or boiler cycling.

Every manufacturing plant, especially those sensitive to the water quality, has its own water treatment specialist on site who determines the specific treatments needed based on the source water and the desired steam qualities.

The treatment process, as a minimum, maintains a preset level for the following:

1. pH (acidity-alkalinity)
2. Hardness (calcium and magnesium salts)
3. Total dissolved solids (minerals)
4. Silica (SiO_2)
5. Turbidity (floating solids not solved)

Design Considerations for Chemical Treatment Systems

Consider the following in the design for chemical treatment systems:

1. Provide a containment area for chemical treatment packages and stored chemicals to contain any possible leakages.
2. Provide an emergency safety shower and eye wash with tepid water, potable water quality between 60 and 100°F (16 and 37°C), per ANSI Z358.1. Install the safety shower and eye wash in a location easily accessible and close to chemical treatment packages.
3. Provide a hand sink with hot and cold water and proper waste disposal for chemical treatment tests and samplings.

Sample Cooler

A sample cooler is a heat exchanger for cooling the steam, the condensate, and the boiler feed water samples. It is a shell and tube type heat exchanger with stainless steel material. It can be freestanding, mounted on the floor, or installed on the wall. City water is often used for cooling the samples.

In an industrial steam system, samples are taken and tested on a regular basis to ensure the water treatment is generating the expected results.

Boiler Stack

The boiler stack is a type of chimney, mostly a vertical pipe, through which the combustion gases from the boiler are exhausted to outside. The boiler stacks are double-wall and positive-pressure type vents. The gap between the walls is either left as an air gap or filled with insulation as needed to maintain the stack surface temperature below the limit for personnel protection. Boiler stacks are available with aluminum or stainless steel materials.

Design Considerations for Boiler Stack

Consider the following when designing a boiler stack:

1. Comply with wind and seismic requirements for supporting the boiler stack.
2. Support stack to accept its expansion and contraction due to the temperature changes without damaging itself, the building structure, or the boiler.
3. Provide proper roof penetration in compliance with applicable codes for the boiler stack with required clearance to the combustible or noncombustible materials.
4. Support the boiler stack on the roof to withstand the local wind.
5. Terminate the boiler stack high enough above the roof to adequately disperse the flue gases with no possibility of adverse effect on building HVAC systems. Verify the applicable codes for minimum allowed termination height.
6. Verify that the boiler connection for stack, usually a flange type, has adequate load-bearing capacity to support and handle the stack weight.
7. Verify if there are any possible constraints in the boiler stack and breeching layout that can affect the flow of gases through it. Constraints will cause additional pressure drop through the boiler stack, will affect the boiler combustion, and will reduce the boiler efficiency.
8. Verify, if due to the temperature limitations, a boiler stack with a higher insulation rating is required.

Stack Economizer

To increase the boiler efficiency, a gas-to-water heat exchanger is used to recover heat from the boiler flue gases. The heat exchanger is installed in the boiler stack section usually under the roof. This is called a stack economizer. Stack economizers are available in condensing and non-condensing forms. The condensing stack economizer is more efficient but must be corrosion resistant. The recovered heat through the stack economizer is usually used to further heat the boiler feed water, but it can be used for other applications also.

Depending on the steam system setup, the system operating pressure, the boiler efficiency, and the flue gas CO_2 concentration level, the boiler flue gas temperature can be as high as 500°F (260°C). In a typical boiler operation, up to 20% of the boiler input energy can be lost through the boiler stack. A significant amount of this lost heat can be recovered through the stack economizer. The recovered heat, if used to heat the boiler feed water, will improve the steam system efficiency up to 3%.

Stack economizers are becoming more popular in industrial steam systems to improve energy efficiency.

Design Considerations for Stack Economizers

1. Verify if the stack economizer is appropriate for the application. Usually steam systems requiring more than 50% make up water are good candidates to have stack economizers for heating the makeup water.
2. Follow the manufacturer's recommendations for the type of economizer (condensing, noncondensing), piping setup, and for support.
3. Verify with the boiler manufacturer that the combustion air blower is capable of handling the flue gas pressure drop through the stack economizer.
4. Set up the system to feed the stack economizer with deaerated hot water at a minimum of 220°F (105°C) to prevent corrosion. The water flow through the stack economizer must be continuous.
5. Insulate hot piping, including drain lines around the stack economizer, for personnel protection.
6. Size boiler feed water pumps to include water pressure drop through the stack economizer.
7. Provide adequate instrumentation, pressure gauges, temperature indicators, etc., for piping around the stack economizer for monitoring and troubleshooting.
8. Verify if the boiler flue gas outlet flange can handle the stack economizer weight. Some boilers can handle weights as high as 2,500 lb (1,135 kg).

Boiler Control Panel

Every boiler is equipped with a control panel that houses controls and electrical devices. It is set up to control the boiler and monitor and reset the set points to make the boiler operation safe and efficient.

Newer boilers are controlled by programmable processor-based controllers. In addition to controlling the operation, monitoring the equipment status, and displaying and recording the data, the controller is capable of communicating with the plant central control system. This communication, as a minimum, provides the following data exchange between the boiler control panel and the plant central control system:

1. Equipment operational status
2. System operating data like steam pressure and flow rates
3. Equipment on-off control
4. Failures announcement through a general alarm signal

Boilers are controlled through a supervisory program with set time periods between sequences to safely start the boiler. If an expected event is not proven complete, the supervisory program disables the boiler start-up control and initiates an alarm.

Common events for safe start-up for a natural gas burning boiler, controlled automatically by its controller, are as follows:

1. Enable boiler controls by commanding it to start.
2. Start boiler room ventilation air system to provide combustion air.
3. Prove boiler room ventilation air system is running.
4. Check boiler water is at the proper level.
5. Check natural gas pressure is in an acceptable range.
6. Enable boiler feed water system control.
7. Enable boiler and deaerator chemical feed systems.
8. Purge the burner for possible natural gas presence.
9. Initiate the burner low-fire procedure.
10. Ignite the burner pilot.
11. Prove the burner pilot is on.
12. Start the burner on low fire.
13. Control the firing rate based on the steam demand.

Once the boiler starts safely, the controller starts to control makeup water, surface blowdown, chemical feed addition, and modulates the burner heat to maintain the steam pressure.

Flash Tank

A flash tank or flash steam recovery is a vessel that receives a mixture of flash steam and high-temperature condensate and allows the condensate to expand and flash. It is used to recover the energy that is usually wasted through the condensate receiver vent to the atmosphere. The process also helps to reduce the condensate temperature to closer to the boiling temperature. Without a flash tank the high temperature condensate can cause pump cavitation and pump seal failure.

The generated flash steam is separated inside the flash tank and piped out of the tank for applications using steam at lower pressure.

The amount of generated flash steam depends on the supply steam pressure and the flash steam pressure.

The flash steam discharges from the top of the flash tank to a low-pressure steam distribution system. The condensate drops to the bottom of the flash tank and discharges through a float and thermostatic steam trap to a condensate collection line.

The flash tanks are only economical for applications that use high-pressure steam with continuous maximum demand. Their operation will fail if they are used for applications with modulating steam supply pressure.

To size a flash tank, the supply steam pressure, the flash steam pressure, and the total condensate flow rate are required.

The flash tank and the hot piping must be insulated for energy conservation and personnel protection.

When designing a flash tank, as a minimum, include a pressure relief valve and a pressure gauge on the flash tank for safety and monitoring.

Backflow Preventer

As the name implies, a backflow preventer is a device that prevents the backflow of water from the water user to the water supply source. This is required for the makeup water supply line to the steam plant. Without a backflow preventer, the chemically treated boiler water can backflow and contaminate the water source.

The backflow preventer is not needed if the water source in a plant is set up for similar services through a dedicated and protected water distribution system with no backflow potential to other water sources and distributions.

Backflow preventers are available in different types suitable for applications with a higher or lower degree of contamination risk.

Makeup water for industrial steam systems must be protected by reduced pressure type backflow preventers. This type of backflow preventer has the highest degree of protection.

Design Considerations for Backflow Preventers

Consider the following when designing a backflow preventer:

1. Provide proper drain with air gap for the backflow preventer. A direct drain connection without an air gap is not allowed.
2. Pipe the drain to a hub drain to prevent water splash.
3. Install backflow preventers in an easily accessed place for required testing and inspection. They need to be tested and certified at least once per year.
4. Insulate water piping if it can sweat and drip.

Drip Pan Elbow

A drip pan elbow is a special pipe fitting that is installed at the discharge side of a pressure relief valve. It is either steel or cast iron with a companion flange or treaded connection to match the pressure relief valve discharge connection size and type. Common applications for the drip pan elbows are the boiler pressure relief valve, the steam pressure reducing station pressure relief valve, and the deaerator pressure relief valve.

The drip pan elbow provides an indirect connection from its discharge pipe to the exhaust vent pipe. This indirect connection allows the exhaust vent pipe to expand and contract and move freely.

As a steam pressure relief valve opens to relieve extra pressure, a large quantity of steam is discharged into the atmosphere. Some of the discharged steam will quickly turn into condensation. With no drip pan elbow in place, the steam discharge will fill the area around the pressure relief valve, causing the area to be unsafe and hard to reach.

The drip pan elbow provides the following benefits:

1. It collects the hot condensate and discharges it at a single connection that can be piped to a safe place to drain.
2. It prevents the pressure relief valve discharge vent from flooding.
3. It prevents the transfer of discharge vent piping strain and movement to the pressure relief valve.
4. It provides personnel protection by properly controlling the steam and condensate discharges by piping them to safe locations.

Design Considerations for Drip Pan Elbows

Consider the following in the design for the drip pan elbows:

1. Pipe the drip pan elbow drain connection to a safe place.
2. Support the exhaust vent pipe independent of the boiler pressure relief valve.

3. Provide proper roof opening for the exhaust vent with the required clearance and flashing for hot vent penetration through the roof. Consult applicable codes for minimum clearance and support requirements.
4. Terminate the exhaust vent above the roof at a height required by applicable codes, but not less than 8 ft (2.45 m).
5. Insulate the hot piping/vent for personnel protection.
6. Run the drip pan elbow discharge pipe/vent as short and as straight as possible.
7. Run the piping between the pressure relief valve and the drip pan elbow as short and as straight as possible.

Exhaust Silencer

An exhaust silencer is recommended to reduce the noise when discharging the steam to the atmosphere to perform boiler capacity and efficiency tests.

The exhaust silencer is installed at the end of the boiler capacity test pipe above the roof. The exhaust silencer is similar to a muffler, reducing the noise to a lower level. It also captures most of the formed condensate in the test pipe and directs it to a drain port. The drain port must be piped to a proper disposal place that accepts hot condensate.

5

Design Requirements for Piping around the Steam Boiler

This chapter briefly describes the design requirements for piping around a high pressure steam boiler as required by ASME Boiler and Pressure Vessel Code (BPVC). The requirements for miniature boilers, as described in ASME BPVC Section I, are not included.

The pipings around a high pressure steam boiler are categorized in two groups; Boiler External Piping and Joint (BEP) and Nonboiler External Piping and Joint (NBEP).

The boiler external piping and joint are the piping that connects directly to the boiler. The piping section starts from the boiler connection and extends and includes the valve(s) required by the ASME Codes on this line, as described below. The boiler external piping and joint sections must comply with the ASME Code B31.1, Power Piping. These piping sections must be provided with stamping, inspection and Data Reports. Except for the pressure relief valves, the valves included in these boiler external piping and joint sections do not require stamping and inspection, but they must comply with the valve requirements described in ASME B31.1 Code. The boiler external piping and joint sections include; steam discharge lines, feedwater lines, blowoff and blowdown lines and drain lines.

The nonboiler external piping and joint (NBEP) include the piping around the boiler beyond the boiler external piping and joint sections. These sections must comply with the ASME Pressure Piping B31 Code but do not need stamping and or inspection. The steam system design engineers and the owner must ensure the compliance with the code requirements for these sections.

The pressure used for designing the piping around the boiler must be sufficient to exceed all expected operating conditions to prevent the operation of pressure relief devices. The design temperature must include the maximum temperature tolerance used by the boiler manufacturer.

Piping design must include provisions for piping movement due to the changes in temperature. Any transfer of piping movement and strain to the boiler must be eliminated by proper piping supports and anchorage. Storage capability must be added to the steam header for applications with steam usage pulsations that can cause vibration in piping.

Every boiler has a stamp indicating its maximum allowable working pressure (MAWP), as defined in the ASME Boiler and Pressure Vessel Code, Sections I and VIII. The boiler maximum allowable working pressure indicates the maximum pressure at the coincident temperature that the boiler can safely operate at.

Refer to ASME Boiler and Pressure Vessel Code (BPVC) and ASME B31.1, Power Piping, for additional requirements and information for the piping around the high pressure steam boiler.

Steam Piping and Valves

Per ASME code B31.3, Power Piping, each boiler must have a stop valve on its steam discharge line, installed as close to its steam nozzle as possible. The valve must be easily accessible from the floor level, from a platform, or it must be chain operated allowing remote operation. The stop valve must be of the rising stem style, or if not, it must be equipped with an indicator to indicate its open or closed position from a distance. Refer to ASME Code B31.1, Power Piping, for requirements for the valve. For example the valve seat must be metallic for applications with working pressure higher than 150 psig (1035 kPag) or design temperature higher than 360°F (186°C).

For installations with more than one boiler connected to a common steam header and each boiler connection has a manhole opening, a second stop valve with a drain line in between the valves is required. The drain line must have a stop valve properly capped. It is recommended to use a nonreturn/stop check valve type for the first stop valve. The stop check valve is recommended to be installed closer to the boiler. The second stop valve will be installed immediately downstream of the stop check valve.

The steam discharge line from the boiler nozzle to and including the required valves and the drain line is considered boiler external piping and joint. The internal design pressure for the steam piping up to the first valve must be at least equal to the lowest boiler pressure relief valve pressure set point but never less than 100 psig (690 kPag). The design temperature will be equal to the saturated steam temperature at that pressure.

The piping between the first and the second stop valves, where required, will have an internal design pressure at least equal to the expected pressure and temperature of the steam or 85% of the lowest boiler pressure relief valve pressure set point, whichever is higher.

The design temperature for this section will be equal to the expected maximum steam temperature.

The valves and fittings must have pressure and temperature ratings, as a minimum, equal to the piping at the higher pressure side but never less than 100 psig (690 kPag).

The operation of the stop check valve is critical when two or more boilers with standby setup and lead lag control are discharging into a common header. The stop check valve will stay closed, preventing the continuously formed steam condensate in the steam line to enter the standby/off boiler. Without a stop check valve, the water level in the standby boiler can rise to a high level, causing a high-water-level alarm. The high water level will prevent the standby boiler to start automatically until the high water level alarm is corrected.

The boiler manufacturer must be consulted when selecting a stop check valve. The valve size is critical for noise-free and proper operation, especially for boilers with high turndown capability. Often the valve size is smaller than the boiler steam discharge nozzle and requires a reducing spool piece to connect. The smaller stop check valve is to ensure that the valve will open even at partial load when boiler steam generation rate is low.

Attention must be given to the pipe connection to each boiler from the steam header to have proper anchor and guide supports to prevent transferring piping movements and strain to the boilers.

The piping connections and the steam header must have proper slope for formed condensate and carried over water collection and removal.

Boiler Feed Water Piping and Valves

The boiler feed water piping, from the feed water pump to the boiler connection, must be equipped, as a minimum, with a check valve and a stop valve. The stop valve must be installed between the boiler connection and the required check valve. The piping section from the boiler connection to the check valve, and including the check valve, is considered the boiler external piping and joint.

For applications where the boiler feed water includes a flow regulating valve with or without a bypass line around the regulating valve, the assembly must be installed upstream of the required check valve. The boiler external piping and joint when a regulating valve is included will include the piping and valves from the boiler connection to and including the valve(s) located immediately upstream of the required check valve.

The boiler feed water external piping and joint must have an internal design pressure exceeding the boiler maximum allowable working pressure by 25% or 225 psi (1,551 kPa), whichever is less, but never less than 100 psig (690 kPag). The design pressure must also satisfy the maximum water pressure that the boiler feed water pump can generate.

The design temperature for the boiler feed water external piping and joint section will be the saturated steam temperature at the boiler maximum allowable working pressure.

The nonboiler external piping and joint of the feed water line, including fittings and valves, shall have an internal design pressure at least equal to the maximum water pressure that the boiler feed water pump can generate but never less than 100 psig (690 kPag).

The size of the feed water piping to the boiler between the boiler connection and the required stop valve or the boiler branch feed line (for installations where one source water supply is feeding several boilers) shall be at least equal to the boiler feed water connection size.

The above requirements will apply to the piping upstream of the economizer for boiler systems with an integral economizer with no valve between the economizer and the boiler connection.

Boiler Blowdown and Blowoff Piping and Valves

According to ASME B31.1, Power Piping, the blowoff and blowdown piping are considered to be boiler external piping and joint. The blowoff and blowdown piping are used to drain the boiler when it is under pressure for various reasons.

The ASME code defines the blowoff operation as intermittent draining and the blowdown as continuous draining. Blowoff operation is usually manual, for lowering the boiler water level or purging the sediments out of the boiler and piping. Blowdown operation is continuous either through an automatically controlled modulating valve or through a hand valve, manually set. This book assumes the drain from the bottom of the boiler to be the blowoff type, operated manually and intermittently. The discharge from the top of the boiler, surface drain, is assumed to be the blowdown type, draining continuously.

The boiler blowoff piping, fittings and valves from the boiler connections to and including the required valves are considered boiler external piping and joint. The piping internal design pressure must be equal to the boiler maximum allowable working pressure plus 25% or 225 psi (1,551 kPa), whichever is less, but never less than 100 psig (690 kPag).

The design temperature for blowoff piping must be equal to the saturated steam temperature at boiler maximum allowable working pressure.

Two blowoff valves, installed in series, are required for boilers with maximum allowable working pressure exceeding 100 psig (690 kPag). One quick-open valve (lever operated) is installed close to the boiler blowoff connection. A second valve, slow-open type (wheel operated), is installed downstream of the quick-open valve.

For boilers with maximum allowable working pressure less than or equal to 100 psig (690 kPag), only one blowoff valve is required. The valve can be either a slow-open or quick- open type.

The boiler blowdown piping requires one valve. The blowdown piping, fittings and valve from the boiler connection to and including the required valve is considered boiler external piping and joint. The piping internal design pressure must be at least equal to the lowest boiler pressure relief valve pressure set point.

The design temperature for blowdown piping must be equal to the saturated steam temperature at boiler maximum allowable working pressure.

The valves and fittings for blowoff and blowdown sections must have at least the same pressure and temperature ratings as the piping at their high pressure side but never less than 100 psig (690 kPag). For blowoff valves for pressure not exceeding 100 psig (690 kPag) the valves and fittings must have ratings at least equal to Class 125 cast iron or bronze, or Class 150 steel or bronze valves per ASME standards.

The piping sections downstream of the required blowoff and blowdown valves, from the valve discharge to the blowdown separator or any other point of discharge, are considered to be nonboiler external piping and joint, provided the terminal discharge pressure is approximately atmospheric with no restriction or pressure increase possibility (for example, there is no valve on the line). With restriction and possibility of higher pressures, the internal design pressure for these sections will be the same as the blowoff and blowdown piping for boiler external piping and joint. These piping sections must have an internal design pressure as indicated in ASME B31.1-2012, Power Piping Code, 122.2, or later issues. The design temperature must be equal to the saturated steam temperature at the design pressure. Some examples for internal design pressure for these sections are as follows:

For boilers with maximum allowable working pressure below 250 psig (1,724 kPag): The piping section design pressure shall be at least equal to the boiler pressure relief valve pressure set point.

For boilers with maximum allowable working pressure of 250 to 600 psig (4,137 kPag): The piping section design pressure shall be 250 psig (1,724 kPag).

For boilers with maximum allowable working pressure of 601 to 900 psig (4,143 to 6,205 kPag): The piping section design pressure shall be 400 psig (2,758 kPag).

For applications where the pressure in these piping sections can exceed that of ASME B31.1-2012, 122.2, their internal design pressure will be similar to the blowoff and blowdown boiler external piping and joint.

Blowdown and blowoff piping should be designed with proper slope for gravity drain without water pockets in the drain lines. Additional valved drains must be provided at the low points if a complete gravity drain is not possible.

The size of the blowoff and blowdown piping for boiler external piping and joint and nonboiler external piping and joint sections must be at least equal to the boiler connection size. The pipe size will not reduce after the required valves.

Recommended piping material for blowoff and blowdown services is steel pipe. Schedule 80 steel piping and fitting must be used for application with internal design pressure exceeding 100 psig (690kPag). Galvanized steel piping and fittings are not allowed.

Boiler Drain Piping and Valves

Boiler drain is required for system complete drainage. Drain piping from the boiler is considered boiler external piping and joint.

All requirements of boiler blowoff is applicable if the boiler drain line is used for boiler blowoff operation.

For installations where the drain is only used when the boiler is under no pressure, the drain line must have two valves. However, a one valve installation is acceptable, provided one of the following is in place:

1. The valve is lockable in closed position.
2. An acceptable bolter flange is installed at the valve discharge connection.

The drain line from the boiler connection to and including the required two valves or the single valve with its flange must have the same pressure and temperature ratings as the drain connection. Piping downstream of the valve(s) must be designed for the maximum pressure and temperature expected, but never less than 100 psig (690 kPag) and 220°F (105°C).

Drain line size, as a minimum, must be equal to the boiler drain connection size.

Miscellaneous Piping and Valves

Miscellaneous devices like pressure gauges, water columns, sight glasses, etc., must be properly installed with valve type and set up as required by ASME Boiler and Pressure Vessel Code Section I. These piping sections are considered boiler external piping and joint. They must be designed based on internal design pressure and temperature at least equal to the boiler maximum allowable working pressure and its coincident saturated steam temperature.

Boiler Pressure Relief Valve

Each boiler must have at least one pressure relief valve. Boilers with more than 500 ft^2 (46.5 m^2) of heating surface must have two or more pressure relief valves.

The boiler pressure relief valve piping from the boiler connection to and including the pressure relief valve is considered boiler external piping and joint. The Internal design pressure and temperature for this section is the same as the boiler steam discharge piping, described above.

Installation of intervening stop valve is not allowed on the pressure relief valve boiler external piping and joint.

The pressure relief valve discharge piping is considered nonboiler external piping and joint. This section must be designed for the maximum expected pressure but not less than 100 psig (690 kPag). The pressure relief valve discharge piping must be installed with sufficient flexibility and proper support so that it does not cause any strain on the pressure relief valve body during pressure relieving. No stop valve of any type is allowed downstream of the pressure relief valve.

A drain line must be installed to drain any collected water in the pressure relief valve discharge piping so it can maintain its full relieving capability during its operation.

The pressure relief valve discharge pipe must be routed to a safe place, preferably to outside and away from personnel, equipment, walkways, etc. A drip pan elbow with a drain line is recommended to be installed for each pressure relief valve to provide a safer condition. Refer to the Drip Pan Elbow Section in Chapter 4.

For applications with the drip pan elbows, each pressure relief valve must have its own drip pan elbow. The common exhaust vent, if the drip pan elbow exhaust vents are combined, must have a cross-section area at least equal to the sum of the individual exhaust vents' cross-section areas.

The pressure relief valve pressure set point must be at or below the boiler maximum allowable working pressure. The pressure relief valve relieving capacity must be at least equal to the boiler maximum generating capacity without allowing the boiler pressure to rise 6% above the pressure relief valve set point.

6

Steam Plant Pipe Sizing and Design Considerations

This chapter describes how to size piping in a steam plant for different services such as water, steam, steam condensate, natural gas, vents, and drains. The chapter also describes helpful design recommendations for each piping category.

Proper pipe sizing is crucial for efficient operation and optimal capital cost investment. Oversized piping results in high capital expense for piping, fittings, and valves. It also increases the heat loss to the surroundings due to the larger pipe diameter and larger heat transfer surface area. Undersized piping results in operational problems, inefficiency, and excess erosion in the piping, fitting, and valves due to the increased velocity. It can also result in noisy operation.

Follow the procedures and the formulas described below to size piping. Comply with ASHRAE Standard 90.1 , Energy Standard for Buildings Except Low-Rise Residential Buildings, for piping insulation requirements (for example Table 6.8.3-1 of ASHRAE 90.1-2013) and pipe sizes where applicable.

Water Pipe Sizing

Water piping is sized based on the water velocity or the water pressure drop inside the pipe. The two sizing criteria are interrelated. A higher water velocity inside the pipe will result in a higher pressure drop and vice versa.

An approximate average water velocity through a pipe is computed by the following formula:

$$V = (0.408 \times Q) \div d^2 \tag{6.1}$$

An approximate water pressure drop in a pipe is computed by Hazen Williams's formula as follows:

$$P_p = 302.2 \times (V \div C)^{1.852} \times (1 \div d)^{1.167} \tag{6.2}$$

where

V = Velocity (ft/s)
Q = Flow rate (gpm)
d = Pipe inside diameter (in.)
P_p = Piping pressure drop (ft of water/100 ft of pipe)
C = Hazen Williams roughness (constant)

For SI units: 1 ft/s = 0.305 m/s, 1 gpm = 3.785 L/min, 1 in. = 25 mm, 1 ft of water = 2.98 kPa.

The Hazen Williams roughness constant C differs for different piping materials as follows:

C = 140 for new steel pipe

C = 150 for copper tubing and plastic pipe

C = 100 for concrete pipe

Recommended criteria for sizing water piping for different line sizes and applications are as follows.

Pump Discharge Piping

Use the criteria in Table 6.1 for preliminary sizing of the pump discharge piping.

Resize piping to minimize the total line pressure drop to less than 10% of the pump discharge pressure if it is higher.

TABLE 6.1

Recommended Criteria for Sizing Pump Discharge Water Piping

Pipe Inside Diameter (in.)	V[a]	P_p[b]
2	7.5	5
3	8	5
4	8	5
6	8	4
8	8	3
10	8	2
12	8.5	2
14	8.5	2
16	8.5	2

Note: For SI units: 1 ft/s = 0.305 m/s, 1 in. = 25 mm, 1 ft of water = 2.98 kPa.

[a] Maximum velocity (ft/s).

[b] Maximum pressure drop (ft of water column/100 ft of pipe).

Pump Suction Piping

Size the pump suction piping for water velocity not to exceed 5 ft/s (1.5 m/s) and the pressure drop not to exceed 0.4 psi (2.8 kPa)/100 ft (30.5 m) of pipe for nonboiling water.

For boiling water, size the pump suction line for a pressure drop of less than 0.25 psi (1.7 kPa)/100 ft (30.5 m) of pipe.

Drain Lines

For drain lines from the equipment, that drain under pressure, size the lines for velocity in the range of 4 to 7 ft/s (1.2 to 2.14 m/s) but never less than the equipment outlet connection size. Verify the drain water pressure to be adequate for the entire line pressure losses including any static lift, from the equipment discharge connection to the drain line discharge end.

Verify if applicable codes require waste treatment before the drain can discharge to the public sewer system.

Verify if the drain requires air gap and indirect connection to the waste system.

City Water

City water piping should be sized for velocities in the range of 3 to 7 ft/s (0.92 to 2.14 m/s). Verify that the supplied water pressure is adequate to overcome the distribution piping, fittings, and valves (e.g., backflow preventer) pressure drop and provides adequate pressure at the users.

High-Pressure Steam Pipe Sizing

Use the steam pipe sizing charts, figures, and tables available in the 2013 *ASHRAE Handbook—Fundamentals*, Chapter 22 (i.e., figure 13), or a later edition, to determine the pipe sizes based on the following criteria:

Steam velocity of 5,000 to 10,000 fpm (1,525 to 3,050 m/min). Note that higher velocities will result in noisy operation and higher pressure drop.

Set the steam velocity based on the allowed pressure drop based on the initial steam pressure and the required steam pressure at the user as described below.

1. Maximum total steam pressure drop of 30% of the initial steam pressure for systems operating at pressure below 100 psig (690 kPag).
2. Maximum total steam pressure drop of 20% of the initial steam pressure for systems operating at pressure between 100 psig (690 kPag) and 150 psig (1,034 kPag).
3. Maximum steam pressure drop of 2 psi (13.8 kPa)/100 ft (30.5 m) of pipe for steam systems operating at pressure up to 30 psig (206 kPag) pressure.
4. Maximum steam pressure drop of 5 psi (34.5 kPa)/100 ft (30.5 m) of pipe for steam systems operating at pressure between 30 and 100 psig (206 and 690 kPag) pressure.
5. Maximum steam pressure drop of 10 psi (69 kPa)/100 ft (30.5 m) of pipe for steam systems operating at pressure between 100 and 150 psig (690 and 1,034 kPag) pressure.

The following approximate formulas can be used to determine pipe sizes based on the steam velocity and steam pressure drop through the pipe.

Approximate steam velocity through a pipe can be computed based on the steam velocity inside the pipe by the following formula:

$$V = 3.057 \times [(W \times \upsilon) \div d^2] \tag{6.3}$$

Approximate inside pipe diameter can be computed based on the steam velocity inside the pipe by the following formula:

$$d = [(3.057 \times W \times \upsilon) \div V]^2 \tag{6.4}$$

where

V = Velocity (fpm)
W = Steam flow rate (lb/h)
υ = Steam specific volume (ft^3/lb)
d = Pipe inside diameter (in.)

For SI units: 1 fpm = 0.305 m/min, 1 in. = 25 mm, 1 lb/h = 0.454 kg/h, 1 ft^3/lb = 0.0623 m^3/kg.

The steam specific volume for 100 psig (690 kPag) saturated steam is approximately 3.9 ft^3/lb (0.243 m^3/kg). Its approximate value at other steam pressures can be estimated by the following formula using the steam gauge pressure.

$$\upsilon = 449 \div (P + 15) \tag{6.5}$$

where
υ = Steam specific volume at the gauge pressure (ft^3/lb)
P = Steam gauge pressure (psig)

For example, the specific volume of saturated steam at 50 psig (345 kPag) is

$$\upsilon = 449 \div (50 + 15) = 6.9\ ft^3/lb$$

Approximate steam pressure drop through a pipe can be computed by the following formula:

$$P_p = 0.01306 \times \upsilon \times W^2 \times [(1 + (3.6 \div d)) \div (3{,}600 \times d^5)] \quad (6.6)$$

where piping
P_p = Pressure drop (psi/100 ft of pipe)
W = Steam flow rate (lb/h)
d = Pipe inside diameter (in.)
υ = Steam specific volume at the gauge pressure (ft^3/lb)

For SI units: 1 psi = 6.895 kPa, 1 foot = 0.305 m, 1 in. = 25 mm, 1 lb/h = 0.454 kg/h, 1 lb/ft^3 = 16.05 kg/m^3.

Steam piping must be properly designed to accommodate the piping movement due to the temperature changes. Anchor supports and guide supports must be located based on actual piping run as required by piping stress analysis. Steam piping must be sloped not less than 1% in flow direction to drain the generated condensate to the collection points. A recommended piping interval between condensate collections (drip legs) for steam main lines is 100 ft (31 m). Condensate must be collected at all locations where the piping rises. Refer to the details for drip legs in Appendix B.

Steam Condensate Pipe Sizing

The discussion below is based on two pipe steam systems where the steam distribution and the steam condensate collection are designed to have separate piping distributions.

The sizing criteria in this section are a simplified extract from the 2013 *ASHRAE Handbook—Fundamentals*, Chapter 22.

The collected condensate comes from different sources such as

1. Drip legs: The collected condensate from the drip legs has the full steam pressure as motive force to flow to a main collection tank. With adequate steam pressure the condensate can be lifted.

2. Steam coil with on-off steam control valve: Similar to drip legs, a steam coil with on-off steam control valve has the full steam pressure (inlet steam pressure to the steam coil) as the motive force for condensate discharge when the valve is open. No condensate is formed when the control valve is closed.
3. Steam coil with modulating steam control valve: Some steam coils are equipped with a steam modulating control valve for controlling the process side temperature. As the control valve modulates its downstream steam pressure (the inlet pressure to the steam coil) changes. The steam full pressure is not always available, especially when the modulating control valve is partially open, to be used as motive force to move the condensate out of the coil. Unless the application is properly designed, the steam coil will flood, the process side temperature controllability will be lost, and the operation will be noisy. The steam coil may even subject to water hammering.

   To ensure proper operation for the type setups, the following two conditions are required:

   a. A vacuum breaker must be installed, preferably, on the steam supply line to the coil, downstream of the control valve. This will ensure a minimum atmospheric pressure plus a column of condensate and liquid leg is available at the coil steam trap inlet.
   b. The condensate collection for the steam coil must be designed with no back pressure. This is to provide adequate pressure differential across the coil steam trap for condensate gravity drain.

Without these conditions in place, the steam coil condensate will not drain completely and will flood the coil.

The condensate return systems are divided into two types: wet systems and dry systems.

In a wet condensate return system, the piping contains liquid only. There is no flash steam in the piping. An example of this type system is when the condensate is subcooled before it enters the steam trap or when the condensate is allowed to flash in a flash tank and the flash steam is separated. The wet condensate return system can be a closed system or an open system.

In an open wet condensate return, the piping is vented and the driving force to push the liquid to the condensate tank is the gravity force through the piping slope or static head. The piping slope must be adequate and continuous to overcome the line pressure drop.

In a closed wet condensate return system, the line is not vented. There must be enough pressure (i.e., after the steam trap or in the flash tank or through a condensate pump) to push the condensate to flow to the condensate collection tank.

In a dry condensate return system, the piping contains both flash steam and liquid condensate. The liquid condensate flows at the bottom and the flash steam on the top inside the pipe. Similar to a wet condensate return system, the dry system can be an open system or a closed system.

An open dry condensate return system includes vents at the coils and at the drip legs after their steam traps. The vents allow the flash steam to discharge to the outside to prevent any pressure buildup in the condensate line. The only force to move the condensate for this system is the gravity through the piping slope.

In a closed dry condensate return system, the condensate line is under pressure, and the moving force comes from the pressure difference between the steam supply pressure to the steam coil and the back pressure in the condensate line. This can only operate when the steam full pressure to the coil is available (on-off control valve).

The condensate lines are recommended to slope toward a collection point such as a dirt leg or a tank to capture the solids inside the piping for all types of condensate systems.

Open Wet Condensate Return Systems

The condensate return in these systems drains by gravity through sloped pipe or due to the static head. The piping contains only liquid. Due to the recommended condensate velocity of less than 2 ft/s (0.61 m/s) the condensate will have a laminar flow regime inside the pipe. This type condensate collection system is very rare.

The piping for this system can be sized using the Darcy Weisbach equation as described in the 2013 *ASHRAE Handbook—Fundamentals*, Chapter 22, Equation 1 or Table 22. Note that Table 22 is based on schedule 40 steel pipe or copper tubing and condensate temperature of 180°F (47°C).

For example, a 2 in. (50 mm), schedule 40 carbon steel pipe can handle approximately 5,510 lb/h (2,505 kg/h) of condensate with a pressure drop of 2 ft/100 ft of pipe. This is equivalent to approximately 10 gpm (37 l/min).

Closed Wet Condensate Return Systems

For these systems with piping filled with liquid condensate, the driving force must be adequate to overcome the line back pressure plus the piping pressure drop. An example for a closed wet condensate return is a pumped condensate return system, often used. The line size is determined similar to water piping with 10 to 20% safety factor for pressure drop. This is to cover for the aged piping and condensate pump wear.

Open Dry Return System

The condensate line in this system contains flash steam and liquid condensate as described above. The condensate drains by gravity through a sloped pipe. This type of condensate collection system is not popular, and is rarely used.

The piping can be sized using the open-channel Manning equation as described in the 2013 *ASHRAE Handbook—Fundamentals*, Chapter 22, Equation 12 or Table 21.

For example, a 2 in. (50 mm) schedule 40 carbon steel pipe installed at a ½ in./ft (13 mm/0.31 m) slope can handle up to 2,640 lb (1,199 kg)/h of condensate. This is approximately equal to 6 gpm (221/min).

Closed Dry Condensate Return Systems

The condensate line in this system contains flash steam and liquid condensate as described above. Most of the condensate collection systems are this type. This setup can operate when the full steam pressure is available to discharge the condensate from the steam coil (on-off control valve). The piping does not need to be sloped and may rise and can discharge into a pressurized condensate tank. However, it is recommended that the piping be sloped toward a collection point to collect the solids in the piping, especially before rises.

The "Dry-Closed Return" condensate table (Table 23) available in Chapter 22 of the 2013 *ASHRAE Handbook—Fundamentals* is used to size the condensate piping. The table is based on the supply steam pressure, return line pressure, and pressure drop per 100 ft of piping. A sample of the table for steam supply at 100 psig (690 kPag) and return line pressure at 15 psig (103 kPag) is shown in Table 6.2.

For example, a 2 in. (50 mm) pipe in a system with supply steam at 100 psig (690 kPag) and return line pressure of 15 psig (103 kPag) can handle 3,100 lb (1,407 kg)/h of condensate at a pressure drop of ¼ psi/100 ft (1.7 kPa/30.5 m) of pipe. The flow rate will be maintained as long as the total return line back

TABLE 6.2

Condensate Flow Rate for Dry-Closed Return System in Pounds per Hour

Steam Supply at 100 psig and Return Line Pressure at 15 psig			
P_p[a] Pipe Diameter (in.)	1/16	¼	1
¾	120	260	560
1	240	500	1,060
2	1,470	3,100	6,450
4	8,730	18,200	Velocity > 7,000 fpm, do not use
6	25,900	53,600	Velocity > 7,000 fpm, do not use

Note For SI units: 1 psi = 6.895 kPa, 1 ft = 0.305 m, 1 in. = 25 mm, 1 lb/h = 0.454 kg/h.

[a] Pressure drop (psi/100 ft of pipe).

pressure, including line pressure drop, static lifts, and return line pressure of 15 psig (103 kPa), is less than the 100 psig (690 kPag) supplied steam pressure.

According to Table 6.2 the flow rates resulting in steam velocity over 7,000 fpm (36 m/s) are not recommended.

Vent Pipe Sizing

Size vent piping based on the following criteria for the indicated application.

Vents for Pressure Relief Valves

The exhaust vent for a pressure relief valve, where installed with a drip pan elbow, must be at least one size larger than the drip pan elbow outlet size to provide an indirect connection between the drip pan elbow discharge pipe and the exhaust vent. The indirect connection allows the exhaust vent pipe and pressure relief valve discharge pipe movement with no strain effect on each other. A common exhaust vent, if the drip pan elbow exhaust vents are combined for two pressure relief valves, must have a cross section area at least equal to the sum of the individual exhaust vents' cross section areas.

Vents for Condensate Storage Tanks

Storage tanks receiving high temperature condensate must have vents with proper size to relieve the flash steam and prevent pressure buildup. The flash steam is generated as the high-temperature condensate pressure is reduced inside the condensate return system and the storage tank. The vent must be sized for flash steam discharge velocity less than 3,000 fpm (15.25 m/s).

The amount of flash steam is estimated based on Table 6.3, based on the supply steam pressure and the condensate back pressure.

It is desirable to maintain the tank pressure as close to atmospheric pressure as possible. A pressure higher than the atmospheric inside the tank will result in a higher condensate temperature that can cause pump cavitation and damage the pump seals.

For example, the amount of flash steam generated from 1,000 lb (454 kg)/h of condensate from steam at 60 psig (414 kPag) and condensate back pressure of 2 psig (14 kPag) is calculated from Table 6.3 as follows.

$$1{,}000 \times 9.3\% = 93 \text{ lb/h } (42 \text{ kg/h})$$

Refer to the 2013 *ASHRAE Handbook—Fundamentals*, Chapter 22, Figure 16, for additional information for flash steam.

TABLE 6.3
Percent Flash Steam at Different Steam and Condensate Pressures

	Condensate Back Pressure		
Steam Pressure in psig	**0 psig (Atmospheric)**	**2 psig**	**5 psig**
30	6.5	5.8	5
60	10	9.3	8.6
80	11.7	11.1	10.3
100	13.3	12.6	11.8
125	14.8	14.2	13.4
160	16.8	16.2	15.4
200	18.6	18	17.3
250	20.6	20	19.3
300	22.7	21.8	21.1

Note: For SI units: 1 psi = 6.895 kPa.

Natural Gas Pipe Sizing

Use the following formulas or sizing tables available from sources such as local gas utility companies, the 2013 *ASHRAE Handbook—Fundamentals*, Chapter 22, the National Fire Protection Association (NFPA), and the International Fuel Gas Code to calculate the pipe sizes for natural gas distribution.

The following natural gas pipe sizing methods are extracted from Chapter 4 of the 2012 International Fuel Gas Code.

The natural gas pipe sizing must be based on the connected natural gas load that assumes all the users are running at the same time. No usage diversity is used for natural gas pipe sizing.

1. Use the following formula for pipe sizing for natural gas distribution for pressure less than 1.5 psig:

$$d = Q^{0.381} \div [20.67 \times (P_p \div L_e)^{0.206}] \quad (6.7)$$

2. Use the following formula for pipe sizing for natural gas distribution for pressure 1.5 psig and higher:

$$d = Q^{0.381} \div [20.41 \times ((P_i^2 - P_o^2) \div L_e)^{0.206}] \quad (6.8)$$

where

d = Inside diameter of pipe (in.)

Q = Natural gas flow rate in ft^3/h at 60°F (15.5°C) and atmospheric pressure

P_i = Absolute inlet pressure (psia)
P_o = Absolute outlet pressure (psia)
P_p = Piping pressure drop (in. of water column)
L_e = Equivalent length of pipe (ft)

Note that the absolute pressure is defined as the gauge pressure in psi plus 14.7.

For SI units: 1 psig = 6.895 kPag, 1 ft = 0.305 m, 1 in. = 25 mm, 1 in. water column = 0.25 kPa, 1 ft^3 = 0.028 m^3, 1 psi = 27.7 in. of water column.

Use one of the following methods to size the natural gas pipe.

Longest Length Method

To determine pipe size for each piping section, use the natural gas load for that section and the longest length of gas piping. The longest gas pipe will be from the point of delivery to the plant to the farthest outlet of the system.

Branch Length Method

For the longest run (from delivery point to the plant to the farthest outlet), size each section based on the longest run and the section natural gas load. For the branch sections (not the longest run), use the section natural gas load and the longest run of that branch from the branch delivery point to the farthest outlet in the branch.

Hybrid Pressure

For systems where natural gas is supplied at higher pressure and is distributed to one or several pressure regulators and then distributed to users at lower pressure, the pipe size for upstream of the pressure regulator(s) is determined using the section load and the longest run of pipe from the delivery point to the plant to the wfarthest pressure regulator. The pipe size downstream of each pressure regulator to its users is determined using section load and the length of piping from the regulator to the farthest outlet served by that regulator.

In any case, the pressure loss under the maximum possible flow rate conditions shall be such that the delivered pressure at the user is greater than or equal to the user's minimum required pressure. And the maximum distribution pressure at any user during the low flow shall not exceed the user's maximum pressure rating.

7

Sample Steam Plant Project

Project Description and Input Data

Design a steam plant for a manufacturing facility to fulfill the following requirements:

1. Provide steam for process equipment as described below:
   a. Process steam user 1: Steam usage of 11,000 lb/h (4,994 kg/h) at approximately 140 psig (965 kPag) with 100% condensate return. Steam supply to the steam coil is controlled by an on-off valve with slow-moving actuator. The steam usage is continuous and steady during the production shifts.
   b. Process steam user 2: Steam usage of 9,000 lb/h (4,086 kg/h) at approximately 140 psig (965 kPag) with 0% condensate return. The steam is injected into the steam user. The steam usage is controlled by a modulating temperature control valve with a slow-moving actuator during the production shift.
   c. Process steam user 3: Steam usage of 10,000 lb/h (4,540 kg/h) at approximately 140 psig (965 kPag) with 100% condensate return. Steam supply to the steam coil is controlled by an on-off valve with a slow-moving actuator. The steam usage is continuous and steady during the production shifts.
   d. Process operation: The process operation is continuous, 24 h/day, 7 days/week, and 50 weeks/year. There are two production shifts and one cleaning shift per day.
2. Provide steam for building heating, ventilation, and air conditioning (HVAC) units and hot water heating systems as follows:
   a. Hot water heating system: Steam usage of 3,000 lb/h (1,362 kg/h) at approximately 30 psig (207 kPag) with 0% condensate return. The hot water heating is achieved by sparging steam into the water using a modulating temperature control valve.
   b. Air handling unit 1 (HVAC unit): Steam usage of 3,000 lb/h (1,362 kg/h) at approximately 30 psig (207 kPag) with 100%

condensate return. Steam supply is controlled by a modulating temperature control valve. Condensate is gravity drained to a condensate return pump package and is pumped to the condensate receiver tank inside the boiler room.

c. Air handling unit 2 (HVAC unit): Steam usage of 4,000 lb/h (1,816 kg/h) at approximately 30 psig (207 kPag) with 100% condensate return. Steam supply is controlled by a modulating temperature control valve. Condensate is gravity drained to a condensate return pump package and is pumped to the condensate receiver tank inside the boiler room.

d. Operation: The hot water heating system operates continuously year-round. The HVAC system operation is seasonal, approximately 4 months/year and 24 h/day.

3. Standby boiler is not required.
4. Available utilities:
   a. Fuel type: Natural gas at 5 psig (34.5 kPag) is available to be used for boiler fuel.
   b. Makeup water: City water at 65 psig (448 kPa) and 60°F (15.5°C) is available for boiler makeup water and other usages.
   c. City water hardness: City water hardness is about 6 grains/gal (103 mg/L or 103 ppm).
5. Project location elevation: 500 ft (153 m) above sea level.
6. Design criteria:
   a. Two high-pressure steam boilers are used for more reliability instead of one boiler. Each unit shall be 700 boiler hp with output of 24,150 lb/h of steam from and at 212°F at sea level (10,964 kg/h from and at 100°C at sea level).
   b. The boilers are set to generate steam at 150 psig (1,034 kPag), boiler operating pressure, to deliver the required 140 psig (965 kPag) steam to process users distribution piping and other components pressure losses.
   c. The boilers' pressure relief valves are set to relieve at 200 psi (1,379 kPa). The boilers' design pressure is 250 psi (1,723 kPa).
   d. A steam pressure reducing station is used to generate 30 psig (207 kPag) steam from 150 psig (1,034 kPag) steam for the hot water and for the HVAC systems. The steam pressure reducing station is installed close to the low-pressure steam users to reduce the large size piping run required for low-pressure steam distribution. It is assumed that the piping heat loss changes the steam state from superheat to saturation shortly after the pressure reducing station. Therefore, there is no need for a desuperheater.

e. One spray type deaerator operating at 5 psig (35 kPag) and 227°F (108°C) is used to deaerate the boiler feed water. Due to the steady steam usage with no quick changes in demand the spray type deaerator will operate satisfactorily for this project. Note that for systems with sudden demand changes (spikes) requiring a quick response from the steam plant, a tray type deaerator is recommended.

f. The deaerator package will have three boiler feed water pumps, one per boiler and the third pump as standby.

g. One condensate receiver package is used to receive pumped return condensate.

h. The condensate receiver package will have two transfer pumps, one running and one standby, to pump the returned condensate from surge tank to the deaerator.

i. A duplex (double-column) water softener is used to provide soft water for boiler makeup water. The duplex water softener allows continuous soft water generation.

j. A stack economizer is not used for this project. Due to the limited makeup water requirement and lack of other heat recovery opportunities the heat recovery from the boiler flue gas through a stack economizer is not feasible and economical.

k. Makeup water will be supplied to the deaerator instead of the condensate receiver package to minimize internal corrosion.

l. The boiler makeup water will be controlled through a modulating control valve to maintain the boiler water level at the set level.

m. The deaerator makeup water will be controlled through a modulating control valve to maintain the deaerator water level at the set level.

n. It is assumed that 3% of the generated steam is condensing inside the distribution piping due to the heat loss. The condensate is collected through the drip legs and is returned to the condensate collection system.

o. It is assumed that 3% of the generated steam is lost through the vents and through the boiler blowdown and blowoff operation.

p. The boiler surface blowdown is controlled automatically based on the boiler water conductivity.

q. The boiler bottom blowoff is manual and intermittent, not more than once per day.

r. Two chemical feed packages are used for this project. One chemical feed package is used to inject chemical into the deaerator, and the second package to inject chemical into the boilers.

s. To simplify the calculations, it is assumed that 500 lb/h of steam is equivalent to 1 gpm of water.

$$(1 \text{ gpm}) \times (\text{lb/gal for hot water}) \times 60 \text{ min/h}$$
$$= (1 \text{ gpm}) \times (8.07 \text{ lb/gal for water at } 190°\text{F}) \times 60 \text{ min/h}$$
$$= 484 \approx 500 \text{ lb/h}$$

For SI units:

$$60 \text{ kg/h of steam} = 1 \text{ L/min}$$

t. It is assumed that the pumped condensate return average temperature is approximately 190°F (88°C). However, the condensate pumps are selected to be suitable for 210°F (99°C) water.

Calculations

The following summarize the calculations and provide the required capacities and further criteria for sizing and selection of steam plant equipment:

1. Boiler output capacity:
   a. Each boiler steam generation capacity = 700 boiler hp = 24,150 lb/h (10,964 kg/h) of steam from and at 212°F (100°C) at sea level.
   b. Total steam generation capacity for two boilers = 48,300 lb/h (21,928 kg/h) at 150 psig (1,034 kPag).
2. Maximum required makeup water:
   a. The maximum required makeup water due to the lost steam in process: From the total steam supply of 30,000 lb/h (13,620 kg/h) to process equipment only, 21,000 lb/h (9,534 kg/h), is returned in condensate form. The returned condensate is 70% of the supplied steam. The lost steam through process is 9,000 lb/h (4,086 kg/h). The makeup water required for the lost steam in process equipment is

$$9{,}000 \text{ lb/h}$$

or

$$9{,}000 \text{ (lb/h)} \div 500 \text{ (lb/gpm)} = 18 \text{ gpm}$$

For SI units:

$$4{,}086 \text{ (kg/h)} \div 60 \text{ (kg/(L/min)} = 68 \text{ L/min}$$

b. The maximum required makeup water due to the lost steam in HVAC and hot water systems: From a total steam supply of 10,000 lb/h (4,540 kg/h) to HVAC and hot water systems only, 7,000 lb/h (3,178 kg/h), is returned in condensate form. The lost steam through the hot water system is 3,000 lb/h (1,362 kg/h). The makeup water required for the lost steam in the hot water system is

$$3{,}000 \text{ lb/h}$$

or

$$3{,}000 \text{ (lb/h)} \div 500 \text{ (lb/gpm)} = 6 \text{ gpm}$$

For SI units:

$$1{,}362 \text{ (kg/h)} \div 60 \text{ (kg/(L/min))} = 23 \text{ L/min}$$

c. Maximum required makeup water due to the losses through the vents and through the blowdown and blowoff operation: The maximum losses through vents and through blowdown and blowoff operation is equal to 3% of the total generated steam or 48,300 (lb/h) × 3% = 1,449 lb/h (658 kg/h). The makeup water required for the lost steam through the vents and the blowdown and blowoff operation is

$$1{,}449 \text{ lb/h}$$

or

$$1{,}449 \text{ (lb/h)} \div 500 \text{ (lb/gpm)} \approx 3 \text{ gpm}$$

For SI units:

$$658 \text{ (kg/h)} \div 60 \text{ (kg(L/min))} = 11 \text{ L/min}$$

d. Maximum total makeup water required for losses: The total maximum required makeup water for the boilers is equal to 3 + 6 + 18 = 27 gpm (102 L/min).

3. Maximum pumped condensate:

a. The only pumped condensate return comes from the HVAC air handling units 1 and 2. Due to the steam modulating control for these HVAC units, the condensate is drained from them by gravity. The condensate is collated in a condensate pump package and is pumped to the condensate receiver tank inside the boiler room.

The maximum incoming condensate from the two air handling units is

$$7{,}000 \text{ lb/h } (3{,}178 \text{ kg/h})$$

or

$$7{,}000 \text{ (lb/h)} \div 500 \text{ (lb/gpm)} = 14 \text{ gpm}$$

For SI units:

$$3{,}178 \text{ (kg/h)} \div 60 \text{ (kg/(L/min))} = 53 \text{ L/min}$$

The pumped condensate is assumed to be at an average temperature of 190°F (88°C).

4. Maximum high-temperature condensate return:
   a. Any condensate return with a temperature higher than the deaerator temperature, 227°F (108°C), is considered high-temperature condensate. The high-temperature condensate is routed directly to the deaerator to conserve energy and to be used in the deaeration process.
   b. High-temperature condensate return from process equipment: The condensate return from process equipment with an on-off control on their steam supply is high-temperature condensate. The steam supply to the process equipment is at approximately 140 psig (965 kPag). The condensate will be at a saturated steam temperature of approximately 360°F (182°C) upstream of the steam trap. The condensate will flash and its temperature will drop after it passes through the steam trap and enters the lower pressure condition.

   The condensate return from the two process equipments is

$$21{,}000 \text{ lb/h } (9{,}534 \text{ kg/h})$$

or

$$21{,}000 \text{ (lb/h)} \div 500 \text{ (lb/h/gpm)} = 42 \text{ gpm}$$

For SI units:

$$9{,}534 \text{ (kg/h)} \div 60 \text{ (kg/(L/min))} = 159 \text{ L/min}$$

Since the high-temperature condensate is routed to the deaerator, its temperature will drop to the deaerator temperature of 227°F

(108°C) as it gets close to the deaerator. This is due to some flashing (approximately 13% of the flow rate) that happens after the condensate pressure drops after passing through the steam trap and piping and enters the deaerator that is at 5 psig (34.5 kPag) pressure.

c. High-temperature condensate return from drip legs: The condensate return from drip legs is high-temperature condensate. There are two steam distribution systems, one running at approximately 150 psig (1,034 kPag) and the second one at 30 psig (207 kPag). As it is described in the system design criteria, it is assumed that approximately 3% of the steam is condensed due to the piping heat loss. The condensate is assumed to be 2% from steam at 150 psig (1,034 kPag) at 365°F (185°C) and 1% from steam at 30 psig (241 kPag) at 275°F (135°C).

The condensate return from the drip legs is equal to

$$48{,}300\ (\text{lb/h}) \times 3\% = 1{,}449\ \text{lb/h}\ (658\ \text{kg/h})$$

or

$$1{,}449\ (\text{lb/h}) \div 500\ (\text{lb/h/gpm}) \approx 3\ \text{gpm}$$

For SI units:

$$658\ (\text{kg/h}) \div 60\ (\text{kg/(L/min)}) = 11\ \text{L/min}$$

The high-temperature drip legs condensate, at approximately 3 gpm (11 L/min), will be routed to the deaerator and will be at an average temperature of

$$[(2 \times 365°\text{F}) + (1 \times 275°\text{F})] \div 3 = 335°\text{F}\ (168°\text{C})$$

As described above some condensate will flash as it approaches the deaerator to match its conditions.

5. Maximum water flow rate to the deaerator that needs deaeration:

a. The maximum deaerator water flow rate that needs deaeration is

(Makeup water) + (Pumped condensate from condensate receiver)

i. The maximum makeup water flow rate is 27 gpm (102 L/min). The makeup water temperature is 60°F (16°C).

ii. Pumped condensate from the condensate receiver to the deaerator is approximately 21 gpm (80 L/min). Refer to the "Calculations" section for transfer pump sizing in this chapter.

The pumped condensate is assumed to be at 185°F (85°C), approximately 5°F (2.5°C) cooler than the received condensate from HVAC air handling units.

b. Total deaerator water inflow = 27 gpm at 60°F + 21 gpm at 185°F = 48 gpm at 115°F.

For SI units:

102 (L/min) at 16°C + 80 (L/min) at 85°C = 182 L/min at 46°C

6. Deaerator required maximum steam flow rate for water heating: The maximum required steam flow rate for water heating for the deaerator is calculated based on heating 48 gpm (182 L/min) of water from 115°F (46°C) to 227°F (108°C) plus a 5% safety factor to account for the deaerator tank heat loss. This calculation neglects the heating effect of the returned high-temperature condensate to the deaerator as an additional safety factor.

Approximating 1 gpm of water to 500 lb/h (8.3 lb/gal × 60 min/h ≈ 500) and knowing that the water specific heat is 1 btu/(lb × °F), the required energy rate is for heating the water is

$$48\ (\text{gpm}) \times (227°\text{F} - 115°\text{F}) \times 500\ (\text{lb}/(\text{h} \times \text{gpm})) \times 1(\text{btu}/(°\text{F} \times \text{lb})) \times 1.05(\text{safety factor}) = 2{,}822{,}400\ \text{btu/h}$$

Using an approximate latent heat of 950 btu/lb of steam for steam at 5 psig pressure, the required maximum steam flow rate is equal to

$$\text{Steam flow rate} = 2{,}822{,}400 \div 950 \approx 3{,}000\ \text{lb/h}$$

For SI units: Approximating 1 L of water to 1,000 g and knowing that the water specific heat is equal to 1 [cal/(°C × g)], the required energy rate to heat 182 L/min of water from 46 to 108°C is

$$182 \times 60\ (\text{L/h}) \times 1{,}000\ (\text{g/L}) \times 1\ [\text{cal}/(°\text{C} \times \text{g})] \times (108°\text{C} - 46°\text{C}) = 677{,}040{,}000\ \text{cal/h} = 677{,}040\ \text{kcal/h}$$

Adding a 5% safety factor,

$$\text{Total energy} = 677{,}040 \times 1.05 = 710{,}892\ \text{kcal/h}$$

Using an approximate steam latent heat of 528 kcal/kg of steam for steam at 35 kPag pressure, the required maximum steam flow rate is equal to

$$\text{Steam flow rate} = 710{,}892 \div 528 \approx 1{,}350\ \text{kg/h}$$

7. Sizing the water softener: The required water softener exchange capacity assuming three regenerations per day (once every 8 h), a flow rate of 29 gpm (110 L/min), and 6 grain/gal (103 ppm) hardness is calculated as follows. The total flow rate of 29 gpm includes the maximum flow rate of 27 gpm for the deaerator plus 2 gpm for miscellaneous usages like sampler cooler and chemical feeds.

   Exchange capacity = 29 (gpm) × 60 (min/h) × 8 (h) × 6 (grain/gal)
   = 83,520 grains

   For SI units:

   110 (L/min) × 60 (min/h) × 8 (h) × 103 (mg/L) = 5,438,400 mg

   The water softener must be capable of removing 83,520 grains of hardness in 8 h (5,438,400 mg in 8 h) at a maximum flow rate of 29 gpm (110 L/min).

8. Sizing the condensate receiver tank: The condensate receiver tank size should provide a storage capacity equal to 10 to 20 min of incoming condensate flow rate. For our sample project, the incoming condensate flow rate is about 7,000 lb/h (3,178 kg/h), coming from HVAC air handling units.

   Sizing the tank for 15 min of storage, the tank storage capacity to its overflow connection is

   7,000 (lb/h) ÷ 500 (lb/h/gpm) = 14 gpm

   Tank storage capacity to overflow = 14 (gpm) × 15 (min) = 210 gal

   For SI units:

   3,178 (kg/h) ÷ 60 (kg/h/(L/min)) = 53 L/min

   Tank storage capacity to overflow = 53 (L/min) × 15 (min) = 795 L

   The tank is vented and is operating at atmospheric pressure.

9. Sizing the transfer pumps: The transfer pumps, one running and one standby, pump the condensate from the condensate receiver tank to the deaerator tank. The transfer pump is sized as follows:

   a. Pump flow rate: The transfer pump flow rate should be equal to the maximum incoming condensate plus 50%. For our sample project each transfer pump flow rate will be 7,000 lb/h (3,178 kg/h) plus 50%.

$$7{,}000 \text{ (lb/h)} \times 1.5 = 10{,}500 \text{ lb/h}$$

$$10{,}500 \text{ (lb/h)} \div 500 \text{ (lb/h/gpm)} = 21 \text{ gpm}$$

For SI units:

$$3{,}178 \text{ (kg/h)} \times 1.5 = 4{,}767 \text{ kg/h}$$

$$4{,}767 \text{ (kg/h)} \div 60 \text{ (kg/h/(L/min))} = 80 \text{ L/min}$$

b. Pump discharge pressure: The transfer pump discharge pressure should be adequate to overcome the system back pressure plus the piping and fittings pressure drop. The system back pressure includes any static lift plus the receiving tank pressure. The transfer pump discharge pressure is calculated as follows:

$$P = P_d + P_s + P_p \tag{7.1}$$

where
- P = Pump discharge pressure in psig (kPa)
- P_d = Deaerator tank pressure = 5 psig (approximately 35 kPag)
- P_s = Static lift, assumed to be 24 ft of water column or approximately 10 psi (69 kPa)
- P_p = Piping, control valve, and fitting pressure drop, assumed to be 10 psi (69 kPa)

Therefore, the pump discharge pressure is

$$P = 5 + 10 + 10 = 25 \text{ psi} = \text{approximately 58 ft of water column}$$

For SI units:

$$P = 35 + 69 + 69 = 173 \text{ kPa}$$

c. Transfer pump available net positive suction head ($NPSH_a$): The transfer pump available net positive suction head is calculated as follows:

$$NPSH_a = P_a - P_v + P_c - P_p \tag{7.2}$$

where
- P_a = Local absolute atmospheric pressure = 14.7 psia, or approximately 33.8 ft of water column (approximately 100 kPaa)
- P_v = Vapor pressure of water at 190°F = 23 ft of water column (approximately 68 kPa)
- P_p = Pump inlet piping and fitting pressure drop, assumed to be 7 ft of water column (approximately 21 kPa)

P_c = Water column above the pump inlet connection centerline, assumed to be a minimum 4 ft of water column (approximately 12 kPa)

Therefore, the transfer pump $NPSH_a$ is

$$NPSH_a = 33.8 - 23 + 4 - 7 = 7.8 \text{ ft of water}$$

For SI units:

$$NPSH_a = 100 - 68 + 12 - 21 = 23 \text{ kPa (2.3 m of water)}$$

According to the calculated $NPSH_a$, the selected transfer pump required net positive suction head ($NPSH_r$), assuming 2 ft (0.6 m) of water column as a safety factor, must be less than 5.8 ft (1.7 m) of water column.

10. Sizing the deaerator tank: The deaerator tank minimum storage capacity to its overflow must be equal to 10 min of the maximum system steam generation capacity.

    For our sample project with maximum steam generation of 48,300 lb/h (21,928 kg/h), the minimum storage is

$$48{,}300 \text{ (lb/h)} \div 500 \text{ (lb/h/gpm)} = 97 \text{ gpm}$$

Tank storage capacity to overflow = 97 (gpm) × 10 (min) = 970 gal

For SI units:

$$21{,}928 \text{ (kg/h)} \div 60 \text{ (kg/h/(L/min))} = 366 \text{ L/min}$$

Tank storage capacity to overflow = 366 (L/min) × 10 (min) = 3,660 L

11. Sizing the boiler feed water pumps: The boiler feed water pumps, one per boiler and one standby, pump feed water from the deaerator to the boilers. The sizing procedure for the boiler feed water pump is as follows:

    a. Pump flow rate: For our sample project with modulating feed water control for boilers, the recommended flow rate for each boiler feed water pump is equal to the boiler evaporation rate plus 25%.

    Pump flow rate = Boiler maximum evaporation rate × 1.25

    Knowing that each boiler maximum evaporation rate is 24,150 lb/h (10,964 kg/h), the flow rate for each pump is

$$\text{Evaporation rate} = 24{,}150\ (\text{lb/h}) \div 500\ (\text{lb/h/gpm}) \approx 48.5\ \text{gpm}$$

$$\text{Pump flow rate} = 48.5\ (\text{gpm}) \times 1.25 = 61\ \text{gpm}$$

For SI units:

$$\text{Evaporation rate} = 10{,}964\ (\text{kg/h}) \div 60\ (\text{kg/h/(L/min)}) \approx 183\ \text{L/min}$$

$$\text{Pump flow rate} = 183\ (\text{L/min}) \times 1.25 \approx 230\ \text{L/min}$$

b. Pump discharge pressure: The boiler feed water pump discharge pressure is calculated as follows:

$$P = (P_b \times 1.03) + P_s + P_p + P_l \tag{7.3}$$

where
- P = Pump discharge pressure
- P_b = Boiler pressure relief valve set point = 200 psig (1,379 kPag) for our sample project
- P_s = Static lift, assumed to be 7 ft of water column or approximately 3 psi (approximately 21 kPa)
- P_p = Piping and fitting pressure drop, assumed to be 5 psi (approximately 35 kPa)
- P_l = Boiler water level control valve pressure drop, assumed to be 10 psi (69 kPa)

Therefore, the feed water pump discharge pressure is

$$P = (200 \times 1.03) + 3 + 5 + 10 = 224\ \text{psi}$$
$$= \text{approximately } 515\ \text{ft of water column}$$

For SI units:

$$P = (1{,}379 \times 1.03) + 21 + 35 + 69 = 1{,}545\ \text{kPa}$$
$$= \text{approximately } 158\ \text{m of water column}$$

Note that the 1.03 multiplier is required by the ASME standard so that the pump can pump the water to the boiler in situations when its safety valve pops open due to overpressurization.

c. Boiler feed water pump available net positive suction head ($NPSH_a$): Boiler feed water pump available net positive suction head is calculated as follows:

$$NPSH_a = P_d - P_v + P_c - P_p \tag{7.4}$$

where

P_d = Deaerator absolute pressure = 5 (psig) + 14.7 (psi, atmospheric pressure) = 19.7 psia ≈ 45 ft of water column (136 kPaa)

P_v = Vapor pressure of water at 227°F (136°C) = 19.7 psia ≈ 45 ft of water column (136 kPaa)

P_p = Pump inlet piping and fitting pressure drop, assumed to be = 6 ft of water column (approximately 18 kPa)

P_c = Minimum water column above the pump inlet connection centerline, assumed to be 12 ft of water column (approximately 36 kPa)

Therefore, the feed water pump $NPSH_a$ is

$$NPSH_a = 45 - 45 + 12 - 6 = 6 \text{ ft of water}$$

For SI units:

$$NPSH_a = 136 - 136 + 36 - 18 = 18 \text{ kPa},$$

or approximately 1.8 m of water column

According to the calculated $NPSH_a$, the selected boiler feed water pump required net positive suction head ($NPSH_r$), assuming 2 ft (0.6 m) of water column as the safety factor, must be less than 4 ft (1.22 m) of water column.

12. Calculating the natural gas usage: The natural gas usage for a boiler can be obtained from the boiler manufacturer literature if it is known, or it can be estimated as follows:
    a. Calculate the output energy based on the evaporation rate from and at 212°F (100°C) assuming a latent heat of 970 btu/lb (0.63 kW/kg) of steam.
    b. Calculate the boiler input energy assuming 82% efficiency for gas-fired boilers.
    c. Calculate the natural gas flow rate by dividing the boiler input energy by the natural gas heat value.

Boiler evaporation rate = 24,150 lb/h (10,964 kg/h)

Boiler output energy rate = 24,150 (lb/h of steam) × 970 (btu/lb)

= 23,425,500 btu/h

Boiler input energy rate = 23,425,500 (btu/h) ÷ 82% (boiler efficiency)

= 28,567,683 btu/h

Knowing that the natural gas heat value is 1,000 btu/ft^3, the natural gas usage for one boiler is

$$28{,}567{,}683\ (\text{btu/h}) \div 1{,}000\ (\text{btu/ft}^3) = 28{,}568\ \text{ft}^3/\text{h}$$

$$\text{Total natural gas usage for two boilers} = 57{,}136\ \text{ft}^3/\text{h}$$

For SI units:

$$\text{Boiler output energy rate} = 10{,}964\ (\text{kg/h of steam}) \times 0.63\ (\text{kW/kg})$$
$$= 6{,}907\ \text{kW}$$

$$\text{Boiler input energy rate} = 6{,}907\ (\text{kW}) \div 82\%\ (\text{boiler efficiency}) = 8{,}423\ \text{kW}$$

Knowing that the natural gas heat value is 10.35 (kW-h)/(m^3), the natural gas usage for one boiler is

$$8{,}423\ (\text{kW}) \div 10.35\ (\text{kW-h/m}^3) = 814\ \text{m}^3/\text{h}$$

$$\text{Total natural gas usage for two boilers} = 1{,}628\ \text{m}^3/\text{h}$$

13. Determining the piping sizes: Our sample project piping sizes are estimated as described below. Note that due to the limited available pipe sizes, most of the pipes are oversized. For example, for a water flow rate of 400 gpm (1,514 L/min) a 6 in. (150 mm) pipe is selected since a 5 in. (125 mm) pipe is not popular and a 4 in. (100 mm) pipe size is not adequate. Here are the flow character comparisons for 400 gpm (1,514 L/min) water through different pipe sizes:
    a. For 400 gpm (1,514 L/min) of water through a 4 in. (100 mm) pipe, the velocity is approximately 10 ft/s (3.05 m/s) and the pressure drop is 9 ft/100 ft (27 kPa/30.5 m) of pipe. This pipe size is considered undersized.
    b. For 400 gpm (1,514 L/min) of water through a 5 in. (125 mm) pipe, the velocity is approximately 6 ft/s (1.8 m/s) and the pressure drop is 2.5 ft/100 ft (7.5 kPa/30.5 m) of pipe. This pipe size is the right size, but 5 in. (125 mm) pipe is not a standard size, is considered special, and is expensive.
    c. For 400 gpm (1,514 L/min) of water through a 6 in. (150 mm) pipe, the velocity is approximately 5 ft/s (1.5 m/s) and the pressure drop is 1 ft/100 ft (3 kPa/30.5 m) of pipe. This pipe size is considered oversized but is the recommended size to use.

Sizing the Final Equipment Connection Pipes

Unless noted otherwise on the following piping and instrumentation diagram (PID drawings), the connected pipes to the equipment are the same size as the equipment connection sizes.

Sizing the Steam Piping

The steam pipe sizing formulas as indicated in Chapter 6 for high-pressure steam are used to estimate the pipe sizes for different steam flow rates and steam pressures, as indicated in the Table 7.1.

Refer to the PID drawings for pipe sizes and piping setup for different users.

Equation (6.3) is used to calculate the steam velocity through the piping. The formula is

$$V = 3.057 \times [(W \times \upsilon_g) \div d^2]$$

Equation (6.4) is used to calculate the piping inside diameter at different flow rates and steam pressure. The formula is

$$d = [(3.057 \times W \times \upsilon_g) \div V]^2$$

Equation (6.6) is used to calculate the steam pressure drop thorough the piping. The formula is

$$P_p = 0.01306 \times \upsilon_g \times W^2 \times [(1 + (3.6 \div d)) \div (3{,}600 \times d^5)]$$

TABLE 7.1

Calculated Inside Pipe Diameters for Steam Distribution

Pressure (psig)	W[a]	d[b]	V[c]	P_p[d]
150	48,500	10	<5,000	<0.5
150	48,500	8	<7,000	1
150	31,000	8	<5,000	<0.5
150	11,000	4	<7,000	2.2
150	10,000	4	<6,000	2
150	9,000	4	<5,000	1.5
30	13,000	8	<7,000	<0.5
30	10,000	8	<5,000	<0.5
30	3,000	4	<6,000	<1
30	4,000	6	<4,000	<0.5

Notes: For SI units: 1 psig = 6.895 kPag, 1 in. = 25 mm, 1 ft = 0.305 m, 1 lb/h = 0.454 kg/h, 1 fpm = 0.0051 m/s, 1 ft^3/lb = 0.0623 m^3/kg.

[a] Maximum steam flow rate (lb/h).

[b] Inside pipe diameter (in.).

[c] Approximate velocity (fpm).

[d] Approximate pressure drop (psi/100 ft of pipe).

where

V = Steam velocity (fpm)

υ_g = Steam specific volume (ft^3/lb)

W = Steam flow rate (lb/h)

d = Pipe inside diameter (in.)

P_p = Steam pressure drop (psi/100 ft of pipe)

The steam specific volume, V_g in ft^3/lb of steam, is calculated using the approximate equation (6.5).

$$\upsilon = 449 \div (P + 15) \tag{6.5}$$

Specific volume for 150 psig steam ≈ 2.72 ft^3/lb

Specific volume for 30 psig steam ≈ 10 ft^3/lb

Sizing the Condensate Piping

Condensate pipe sizes are based on the following criteria using the dry-closed return system (Table 23 in Chapter 22 of the 2013 *ASHRAE Handbook—Fundamentals*). The results are shown in Table 7.2.

Refer to the PID drawings for more detail for pipe sizes and piping setup.

Sizing the Pumped Condensate Line

The pumped condensate line from the HVAC condensate pump to the condensate receiver is sized for 1½ in. (40 mm) for approximately 30 gpm (114 L/min), 5 ft/s (0.305 m/s) velocity, and 5 ft/100 ft (15 kPa/30.5 m) pressure drop through the piping. The condensate pump is selected to compensate for back pressure and the line pressure drop (see Chapter 6, steam condensate pipe sizing section, closed wet condensate return systems). See the PID drawings for pipe sizes and piping setup.

Sizing the Makeup Water Piping

The makeup/city water line is sized for 3 in. (80 mm) to allow 60 gpm (227 L/min) through a 2 in. (50 mm) connection for blowdown separator water cooling, 5 gpm (19 L/min) for water softener back wash, and approximately 30 gpm (114 L/min) for boiler makeup and sample cooler. At its peak flow rate, 95 gpm (360 L/min), the water through the 3 in. (80 mm) pipe will have a velocity of approximately 5 ft/s (1.5 m/s) and a pressure drop of 2 ft/100 ft (6 kPa/30.5 m) of pipe.

The makeup water line to the deaerator is selected to be 2 in. (50 mm) for a flow rate of approximately 30 gpm (114 L/min). The velocity and the pressure drop through this line are 3 ft/s (0.9 m/s) and 2 ft/100 ft (6 kPa/30.5 m) of pipe.

Refer to the PID drawings for pipe sizes and piping setup.

TABLE 7.2

Calculated Condensate Pipe Sizes Based on Maximum Flow Rates

Steam Trap Tag No.	System Type	Control Type	P_s[a]	P_r[b]	W_r[c]	P_p[d]	d[e]
T-1	Note 1	Note 2	150	15	600	¼	1½
T-2	Note 1	Note 2	150	15	50	1⁄16	¾
T-3	Note 1	Note 2	150	15	11,000	¼	4
T-4	Note 1	Note 2	30	0	50	1⁄16	¾
T-5	Note 1	Note 3	30	0	3,000	¼	2
T-6	Note 1	Note 3	30	0	4,000	¼	2½

Note: For SI units: 1 psig = 6.895 kPag, 1 in. = 25 mm, 1 ft = 0.305 m, 1 lb/h = 0.454 kg/h, 1 fpm = 0.0051 m/s.

[a] Supply steam pressure (psig).
[b] Condensate return line pressure (psig).
[c] Condensate flow rate (lb/h).
[d] Pressure drop (psi/100 ft of pipe).
[e] Inside pipe diameter (in.).

Notes:

1, Dry-closed system
2, On-off supply steam
3, Modulating supply steam

Sizing the Natural Gas Piping

Natural gas piping is sized based on the criteria in Table 7.3 using the sizing equation (6.8) from Chapter 6 for supplied gas pressure above 1.5 psig. The formula is

$$d = Q^{0.381} \div [20.41 \times ((P_i^2 - P_o^2) \div L_e)^{0.206}]$$

where

d = Inside diameter of pipe (in.)
Q = Maximum natural gas flow rate in ft^3/h at 60°F (15.5°C) and atmospheric pressure
P_i = Absolute inlet pressure (psia)
P_o = Absolute pressure at the boiler gas train (psia)
L_e = Longest equivalent length of pipe (ft)

TABLE 7.3

Calculated Natural Gas Pipe Sizes

Natural Gas Pipe Sizes				
P_i	Q	L_e	P_o	d
20	29,000	500	19	6
20	58,000	500	19	8

Note: For SI units: 1 psig = 6.895 kPag, 1 ft = 0.305 m, 1 in. = 25 mm, 1 in. water column = 0.25 kPa, 1 ft^3 = 0.028 m^3, 1 psi = 27.7 in. of water column.

The natural gas inlet pressure to the plant, as indicated in project description and input data, is 5 psig (34.5 kPag) or approximately 20 psia (134 kPaa). The piping inside diameter is based on 500 ft of equivalent piping length and 4 psig

(26.75 kPag) or approximately 19 psia (127 kPaa) available pressure at the boiler gas train.

Drawings

See the following drawings showing the steam generation, steam distribution, condensate collection, makeup water setup, chemical feeds, and boiler room equipment general arrangement for our sample project.

The drawings include one legend sheet, seven PID drawings, and one equipment layout.

In a typical detail design and engineering for an industrial steam system project, these drawings are started based on some initial design criteria as the preliminary phase. The drawings are brief and simple with enough information to describe the system mainly for verifying the project order of magnitude cost, the project schedule, the required spaces for equipment and piping, the required controls and instrumentation, etc., and for further defining the system requirements for the next phase. The drawings are then used as the basis to detail design the project after they are reviewed and approved by all parties involved, especially the owner and the plant staff.

The PID drawings included in this book are detailed enough to be used for a detailed design document. They include drawing notes to describe additional requirements that are not shown on the drawing. However, our sample project does not include all documents required for permitting and construction. Detailed design documents, as a minimum, for the mechanical scope of work for an industrial steam plant include the following:

- Drawings and documents for boiler room ventilation and combustion air
- Drawings and documents for boiler room plumbing systems, including safety showers and eye washes
- Drawings and documents for boiler room fire protection
- Detailed equipment layout drawings
- Piping layout drawings with proper supports based on piping stress analysis for thermal movements and seismic restrain
- Details, sections, and elevations drawings for piping and boiler room equipment
- Specifications for purchasing the equipment
- Specifications for piping, including valves and fittings
- Specifications for equipment and piping installations

- Specifications for piping pressure testing
- Specifications for system start-up, commissioning, testing, balancing, and owner staff training

More drawings and documents are needed from other engineering disciplines, like process engineering, structural engineering, architectural engineering, electrical engineering, and controls and instrumentations engineering, as well as commercial and nontechnical contract documentation to make the package complete for bidding, permitting, and for construction of the project.

Legend Sheet

This drawing includes the legend and abbreviations and general notes used to describe and clarify additional requirements for the system. The legend sheet defines all symbols and abbreviations used on the PID and layout drawings. The general notes on the legend sheet are used to describe additional project requirements that are not shown on the drawings.

Steam Generation Drawings, PID-1 and PID-2

These two drawings, one per boiler, show the steam generation equipment and their setup, including the boilers, the boiler blowdown separator, and the sample cooler. The drawings include piping and instrumentations usually used in a typical steam generating system with two boilers. The special valve set up around the boilers as required by ASME Code are shown on these drawings.

Steam Distribution Drawings, PID-3 and PID-4

These drawings show the steam distribution to different users as well as the condensate collection from them, where applicable.

PID-3 includes 30 psig (2.06 barg), medium pressure, steam distribution after the high-pressure steam at 150 psig (10.34 barg) is used to generate the 30 psig (2.06 barg) steam using a pressure reducing station.

PID-4 includes high-pressure steam distribution to the users.

Both drawings include the required piping and instrumentations usually used in a typical steam distribution and condensate collection system.

Condensate Pump and Chemical Feed, Drawing PID-5

This drawing includes a condensate pump and two chemical feed packages.

One chemical feed package is used for the deaerator. The second chemical feed package with two chemical injection pumps is to add chemical to the boilers.

The condensate pump collects the condensate from the HVAC air handling units and pumps it back to the condensate receiver tank inside the boiler room.

The drawing includes the required piping and instrumentations usually used in a typical chemical feed and condensate pump system.

Condensate Receiver Drawing, PID-6

The condensate receiver package, including the receiver tank and the transfer pumps, is shown on this drawing. This package receives all the pumped condensate return and transfers it to the deaerator.

The required piping and instrumentations, usually used in a typical condensate receiver package, are shown on the drawing.

Deaerator Drawing, PID-7

The deaerator package, including the deaerator tank and boiler feed water pumps, is shown on this drawing. The deaerator package receives transferred condensate from the condensate receiver package, the high-temperature condensate returns, and the makeup water. It then heats and deaerates the water and feeds it to the boilers.

The drawing also shows the water softener used to treat the boiler makeup water before going into the deaerator.

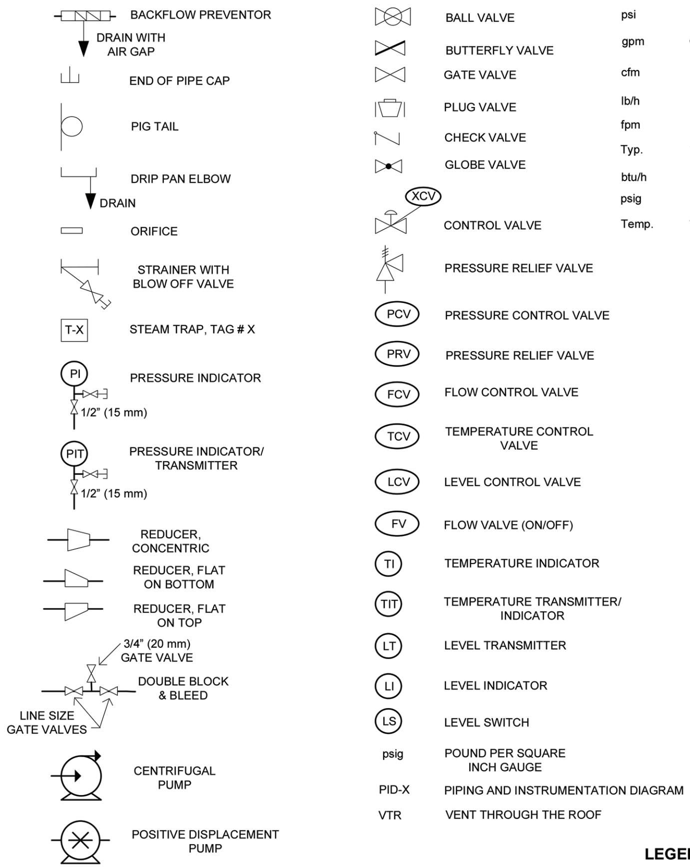
The required piping and instrumentations, usually used in a similar package, are shown in the drawing.

Equipment General Arrangement Drawing

This drawing shows equipment general arrangement/layout for a typical industrial steam plant boiler room based on our sample project requirements.

The layout provides adequate space around the equipment for maintenance and inspection and for the boiler tube pull-out for cleaning or replacement. Where there is not adequate space inside the boiler room, the boiler tube pull-out can be set up to be through properly sized overhead doors in front of the boilers, as is the case for our sample project.

LEGEND & ABBREVIATIONS



psi	Pound per square inch
gpm	Gallon per minute
cfm	Cubic feet per minute
lb/h	Pounds per hour
fpm	Feet per minute
Typ.	Typical
btu/h	Btu per hour
psig	Pound per square inch gauge
Temp.	Temperature

GENERAL NOTES

1- OBTAIN ALL REQUIRED PERMITS FOR CONSTRUCTION.

2- COMPLY WITH APPLICABLE LOCAL AND NATIONAL CODES AND MANUFACTURER'S AND OWNER'S REQUIREMENTS.

3- DRAWINGS ARE NOT INTENDED TO BE SCALED. DRAWINGS ARE INTENDED TO SHOW THE SCOPE AND GENERAL ARRANGEMENT OF THE WORK. WHERE JOB CONDITIONS REQUIRE MINOR CHANGES OR ADJUSTMENTS IN THE INDICATED LOCATIONS OR ARRANGEMENT, SUCH CHANGES SHALL BE MADE FREE OF ADDITIONAL CHARGES.

4- UNLESS NOTED OTHERWISE, ALL EQUIPMENT AND PRODUCTS SHALL BE INSTALLED PER MANUFACTURER WRITTEN INSTRUCTION. ANY CHANGES SHALL NEED PRIOR OWNER APPROVAL. PROVIDE ADEQUATE ACCESS AREAS FOR EQUIPMENT MAINTENANCE AND INSPECTION.

5- INSULATE PIPING TO CONSERVE ENERGY AND PREVENT SWEATING.

INSULATE WATER PIPING WITH 1/2" (12 mm) FLEXIBLE ELASTOMERIC INSULATION.

INSULATE STEAM AND CONDENSATE PIPING WITH FIBERGLASS INSULATION AS INDICATED BELOW. COVER INSULATION WITH 0.016" (0.41 mm) THICK CORRUGATED ALUMINUM JACKET. OFFSET INSULATION SEAMS WHERE TWO OR MORE LAYERS OF INSULATION ARE NEEDED.

A. 3" (75 mm) THICKNESS FOR PIPING UP TO 3/4" (20 mm).

B. 31/2" (90 mm) THICKNESS FOR PIPING FROM 1" TO 1 1/2" (25 TO 40 mm).

C. 4" (100 mm) THICKNESS FOR PIPING FROM 2" TO 3" (50 TO 80 mm).

D. 4 1/2" (115 mm) THICKNESS FOR 6" (150 mm) PIPING.

E. 5" (125 mm) THICKNESS FOR 8" (200 mm) PIPING.

F. 5 1/2" (140 mm) THICKNESS FOR 10" (250 mm) PIPING.

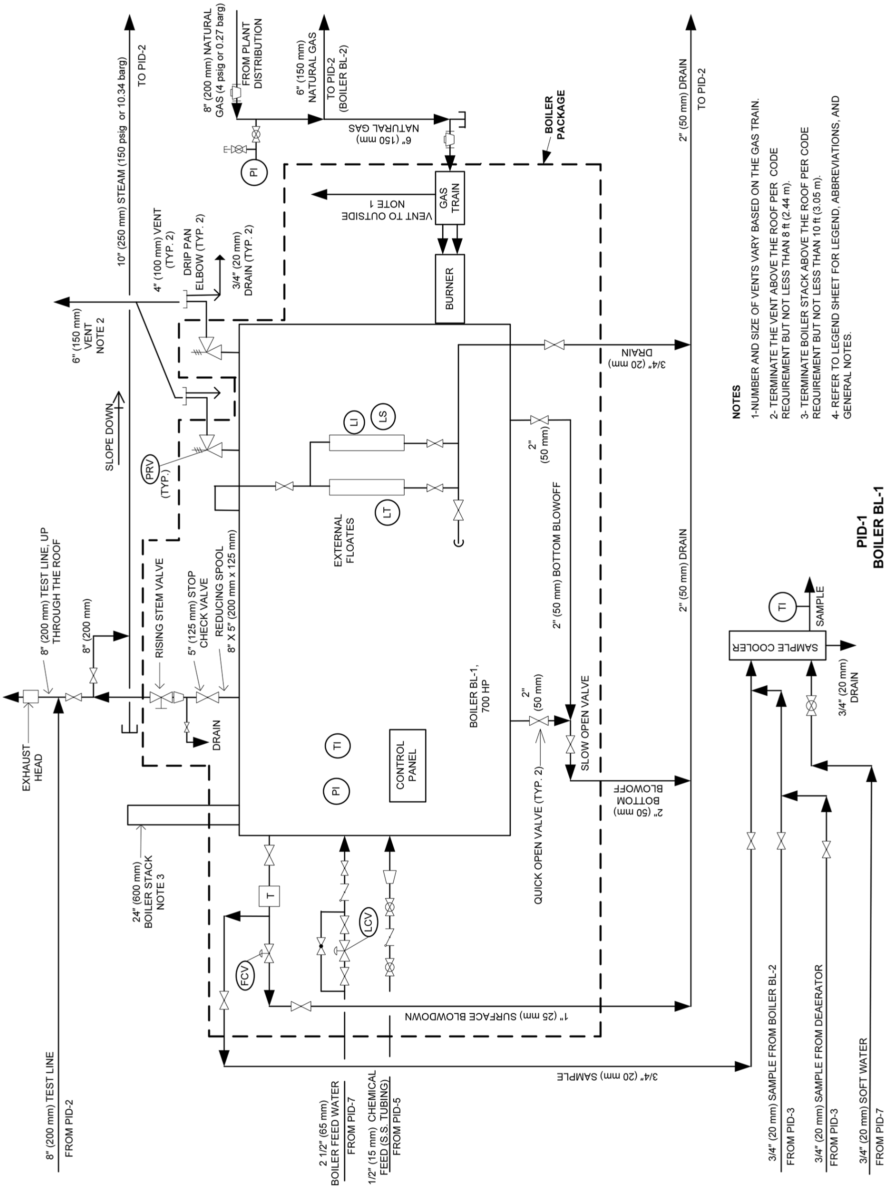
6- SUPPORT PIPING TO ACCOMMODATE EXPANSION AND CONTRACTION WITH PROPER SLOPE FOR CONDENSATE REMOVAL.

7- PROVIDE CLEARANCE FROM CONSTRUCTION MATERIAL FOR HOT VENTS PENETRATING ROOF AND WALLS PER CODE REQUIREMENTS.

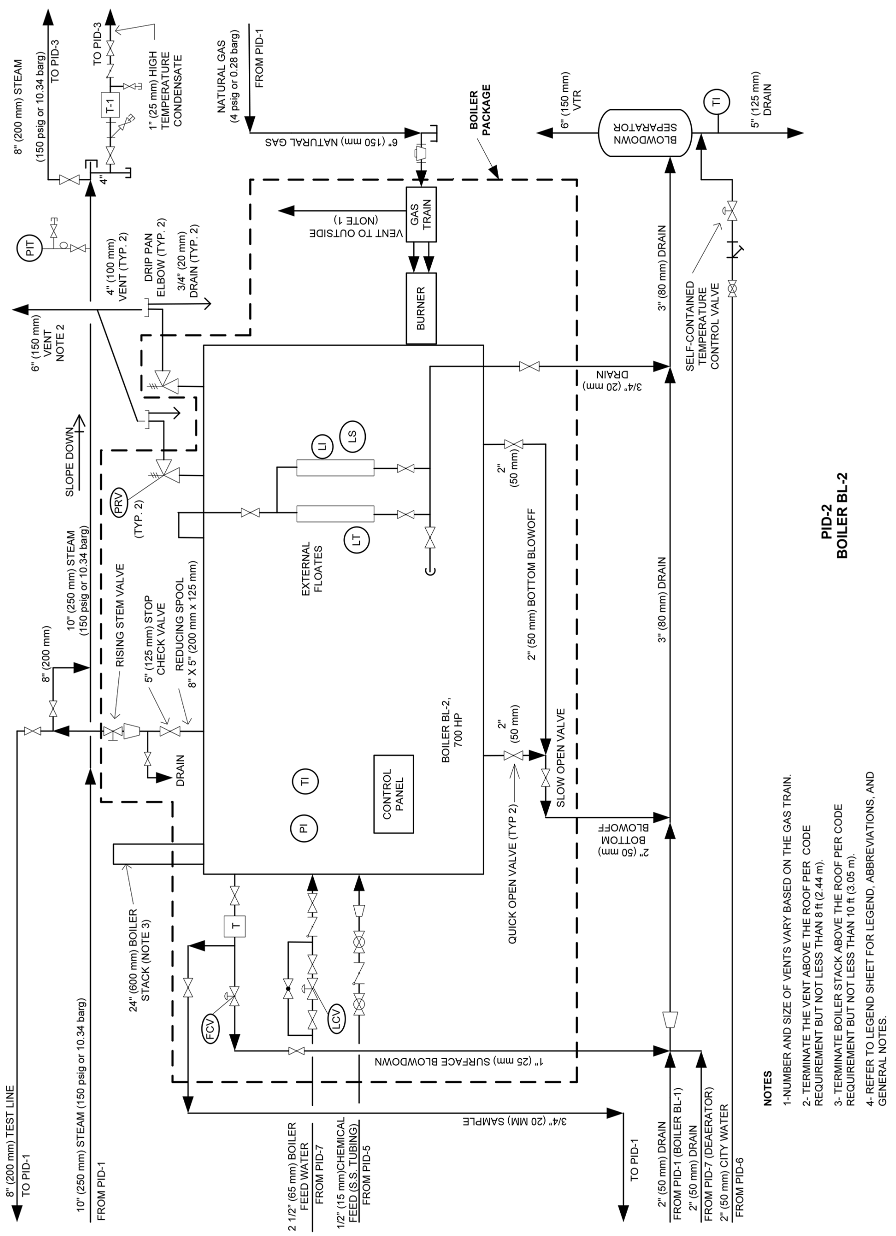
8- PROVIDE COMBUSTION AIR FOR THE BOILER ROOM AS REQUIRED BY APPLICABLE CODES AND BOILER MANUFACTURER.

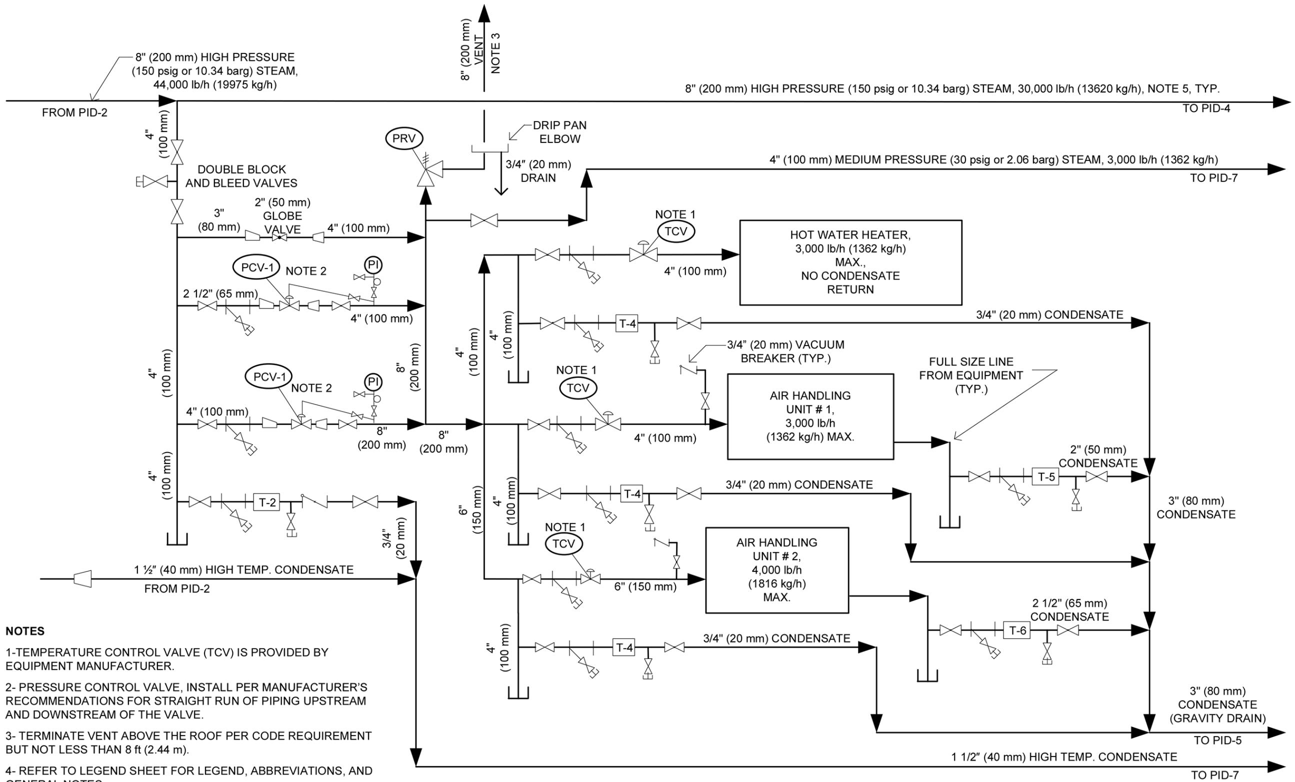
9- PROVIDE HEATING AND VENTILATION FOR BOILER ROOM TO MAINTAIN ROOM TEMPERATURE, AS A MINIMUM, BETWEEN 104°F AND 50°F (40°C AND 10°C).

LEGEND SHEET



PID-1
BOILER BL-1


8" (200 mm) STEAM
(150 psig or 10.34 barg)
TO PID-3
TO PID-3
1" (25 mm) HIGH TEMPERATURE CONDENSATE
T-1
4"
PIT
6" (150 mm) VENT NOTE 2
4" (100 mm) VENT (TYP. 2)
DRIP PAN ELBOW (TYP. 2)
3/4" (20 mm) DRAIN (TYP. 2)
NATURAL GAS
(4 psig or 0.28 barg)
FROM PID-1
6" (150 mm) NATURAL GAS
BOILER PACKAGE
VENT TO OUTSIDE (NOTE 1)
GAS TRAIN
BURNER
6" (150 mm) VTR
BLOWDOWN SEPARATOR
TI
5" (125 mm) DRAIN
3" (80 mm) DRAIN
SELF-CONTAINED TEMPERATURE CONTROL VALVE
3/4" (20 mm) DRAIN
SLOPE DOWN
PRV
(TYP. 2)
LI
LS
LT
EXTERNAL FLOATES
10" (250 mm) STEAM
(150 psig or 10.34 barg)
8" (200 mm)
RISING STEM VALVE
5" (125 mm) STOP CHECK VALVE
REDUCING SPOOL
8" X 5" (200 mm x 125 mm)
DRAIN
BOILER BL-2,
700 HP
TI
PI
CONTROL PANEL
2" (50 mm)
2" (50 mm) BOTTOM BLOWOFF
2" (50 mm)
QUICK OPEN VALVE (TYP 2)
SLOW OPEN VALVE
2" (50 mm) BOTTOM BLOWOFF
3" (80 mm) DRAIN
24" (600 mm) BOILER STACK (NOTE 3)
T
FCV
LCV
1" (25 mm) SURFACE BLOWDOWN
3/4" (20 MM) SAMPLE
8" (200 mm) TEST LINE
TO PID-1
10" (250 mm) STEAM (150 psig or 10.34 barg)
FROM PID-1
2 1/2" (65 mm) BOILER FEED WATER
FROM PID-7
1/2" (15 mm)CHEMICAL FEED (S.S. TUBING)
FROM PID-5
TO PID-1
2" (50 mm) DRAIN
FROM PID-1 (BOILER BL-1)
2" (50 mm) DRAIN
FROM PID-7 (DEAERATOR)
2" (50 mm) CITY WATER
FROM PID-6
PID-2
BOILER BL-2
NOTES
1-NUMBER AND SIZE OF VENTS VARY BASED ON THE GAS TRAIN.
2- TERMINATE THE VENT ABOVE THE ROOF PER CODE REQUIREMENT BUT NOT LESS THAN 8 ft (2.44 m).
3- TERMINATE BOILER STACK ABOVE THE ROOF PER CODE REQUIREMENT BUT NOT LESS THAN 10 ft (3.05 m).
4- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.



NOTES

1-TEMPERATURE CONTROL VALVE (TCV) IS PROVIDED BY EQUIPMENT MANUFACTURER.

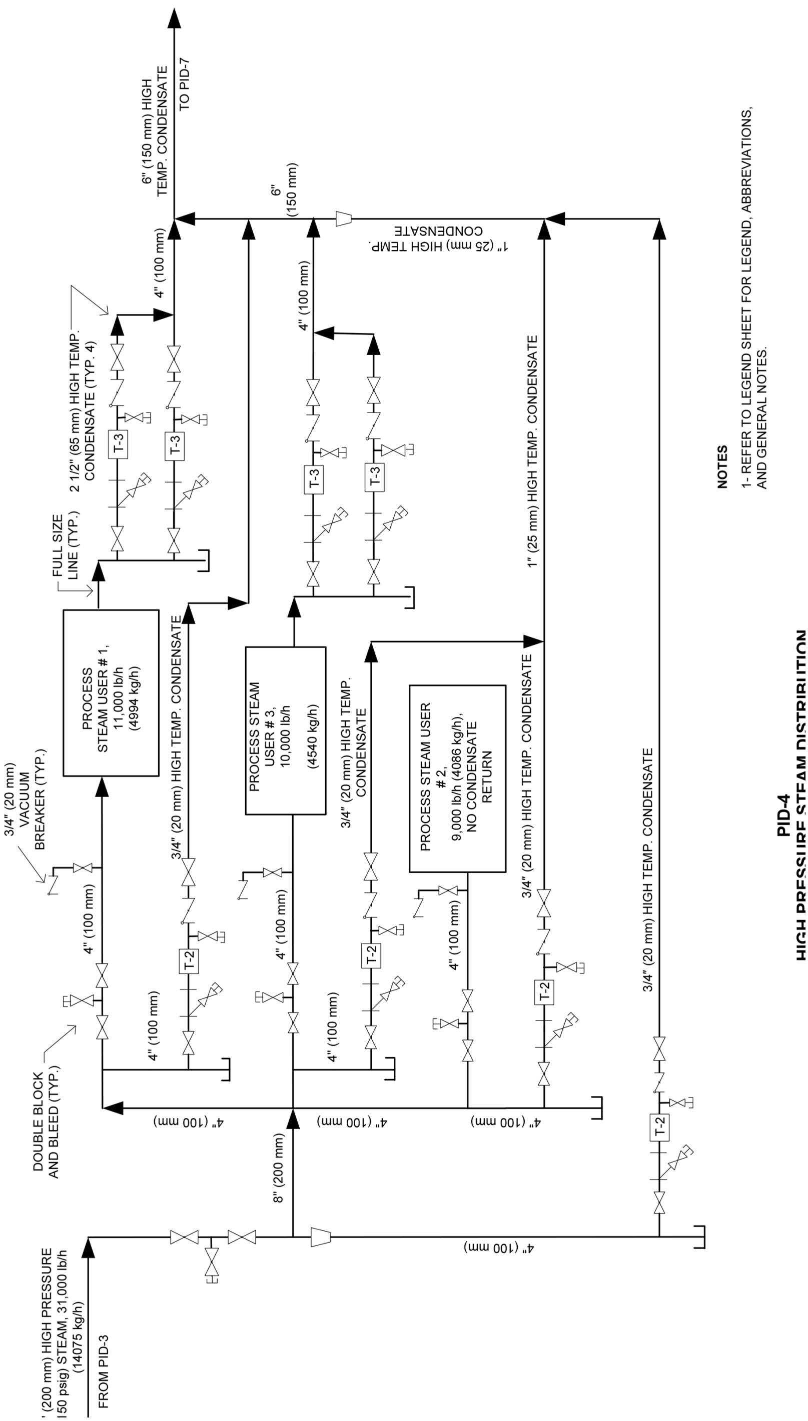
2- PRESSURE CONTROL VALVE, INSTALL PER MANUFACTURER'S RECOMMENDATIONS FOR STRAIGHT RUN OF PIPING UPSTREAM AND DOWNSTREAM OF THE VALVE.

3- TERMINATE VENT ABOVE THE ROOF PER CODE REQUIREMENT BUT NOT LESS THAN 8 ft (2.44 m).

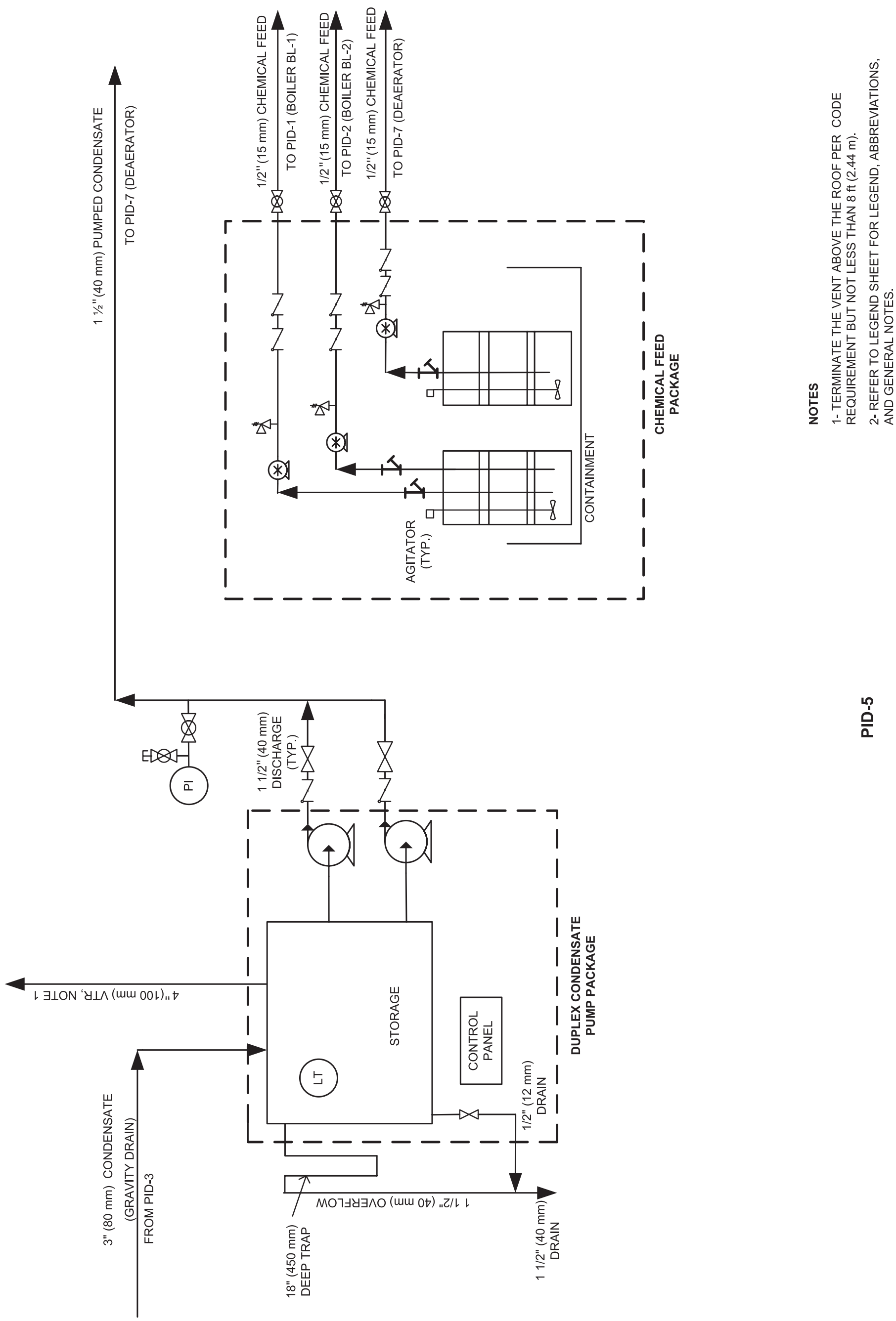
4- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.

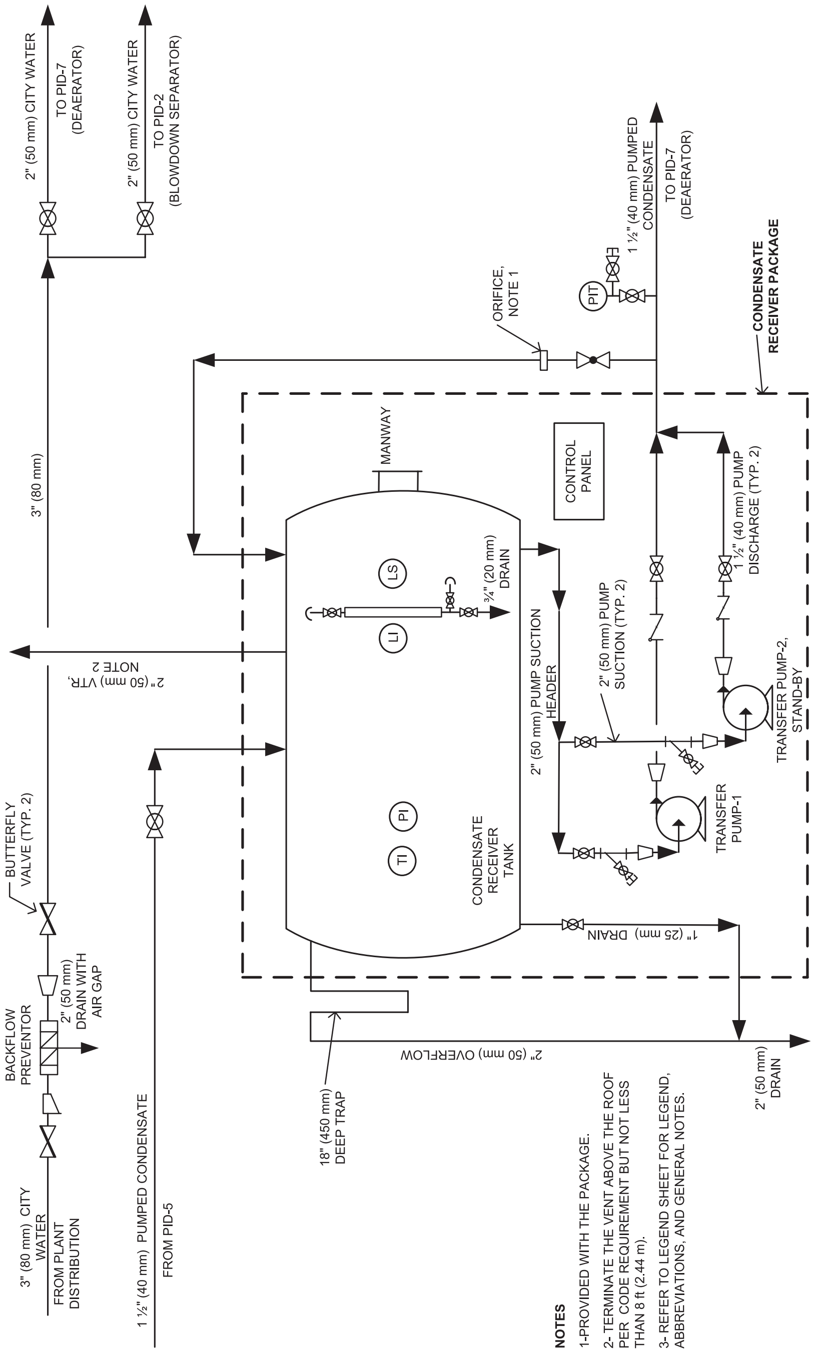
5- STEAM FLOW RATES INDICATED INCLUDE ESTIMATED LINE LOSSES.

PID-3
MEDIUM PRESSURE (30 psig, 2.06 barg)
STEAM DISTRIBUTION



6" (150 mm) HIGH TEMP. CONDENSATE
TO PID-7
6" (150 mm)
1" (25 mm) HIGH TEMP. CONDENSATE
4" (100 mm)
2 1/2" (65 mm) HIGH TEMP. CONDENSATE (TYP. 4)
T-3
FULL SIZE LINE (TYP.)
PROCESS STEAM USER # 1, 11,000 lb/h (4994 kg/h)
3/4" (20 mm) HIGH TEMP. CONDENSATE
PROCESS STEAM USER # 3, 10,000 lb/h (4540 kg/h)
3/4" (20 mm) HIGH TEMP. CONDENSATE
PROCESS STEAM USER # 2, 9,000 lb/h (4086 kg/h), NO CONDENSATE RETURN
1" (25 mm) HIGH TEMP. CONDENSATE
3/4" (20 mm) HIGH TEMP. CONDENSATE
3/4" (20 mm) VACUUM BREAKER (TYP.)
T-2
DOUBLE BLOCK AND BLEED (TYP.)
8" (200 mm)
" (200 mm) HIGH PRESSURE
150 psig) STEAM, 31,000 lb/h
(14075 kg/h)
FROM PID-3
NOTES
1- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.
PID-4


1 ½"(40 mm) PUMPED CONDENSATE
TO PID-7 (DEAERATOR)
1/2"(15 mm) CHEMICAL FEED
TO PID-1 (BOILER BL-1)
1/2"(15 mm) CHEMICAL FEED
TO PID-2 (BOILER BL-2)
1/2"(15 mm) CHEMICAL FEED
TO PID-7 (DEAERATOR)
AGITATOR (TYP.)
CONTAINMENT
CHEMICAL FEED PACKAGE
PI
1 1/2" (40 mm) DISCHARGE (TYP.)
4"(100 mm) VTR, NOTE 1
STORAGE
LT
CONTROL PANEL
DUPLEX CONDENSATE PUMP PACKAGE
1/2" (12 mm) DRAIN
3" (80 mm) CONDENSATE (GRAVITY DRAIN) FROM PID-3
18" (450 mm) DEEP TRAP
1 1/2" (40 mm) OVERFLOW
1 1/2" (40 mm) DRAIN
NOTES
1- TERMINATE THE VENT ABOVE THE ROOF PER CODE REQUIREMENT BUT NOT LESS THAN 8 ft (2.44 m).
2- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.
PID-5



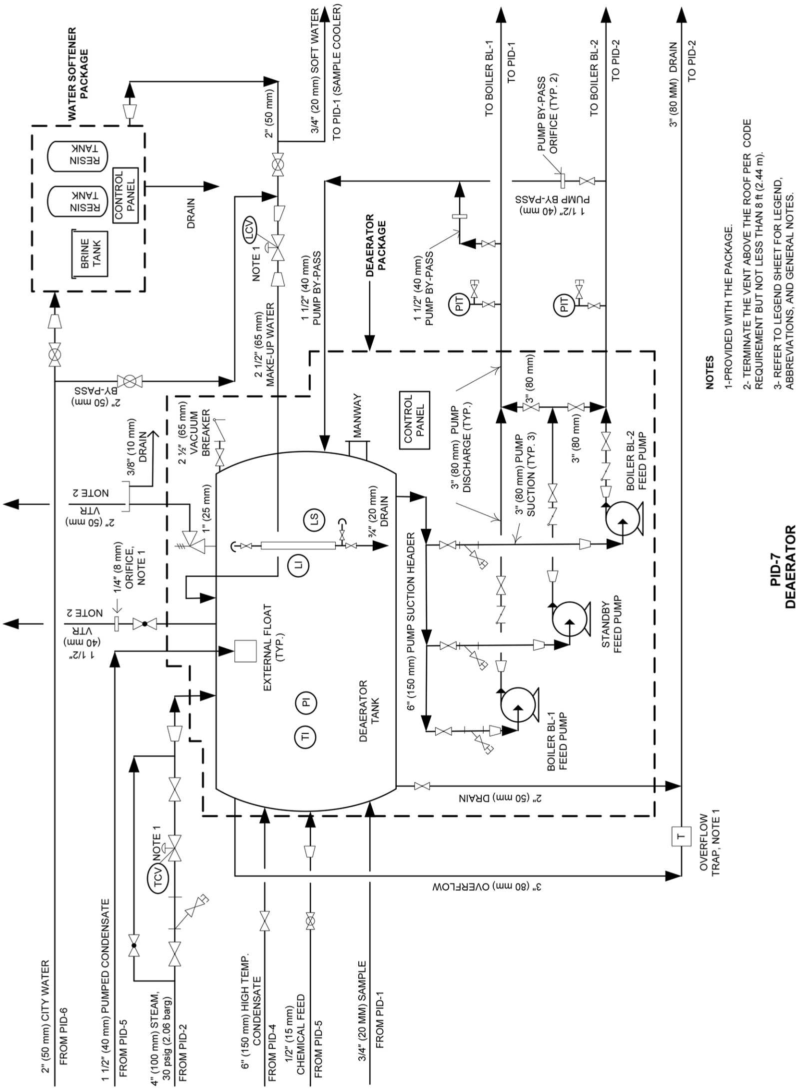
PID-6
CONDENSATE RECEIVER

NOTES

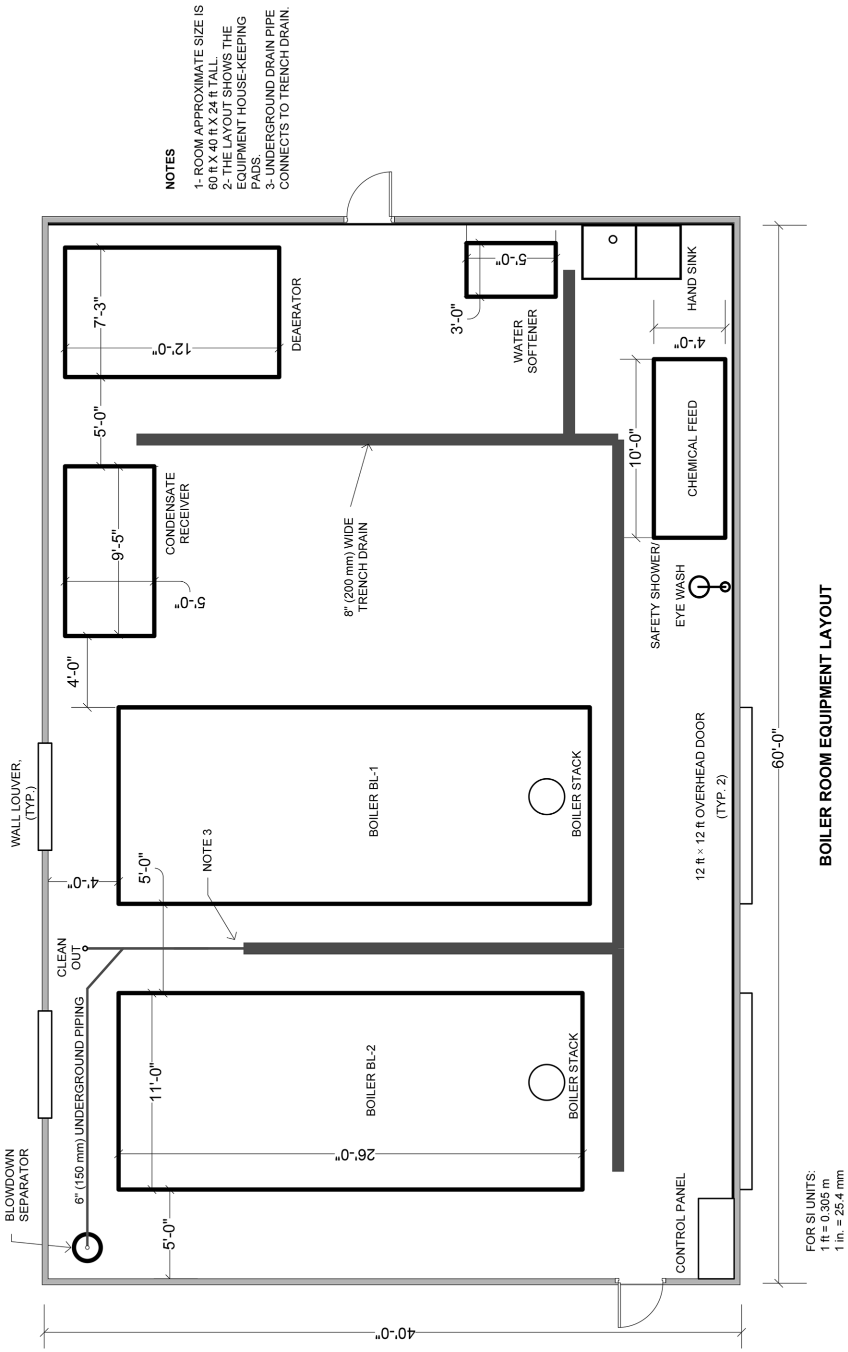
1-PROVIDED WITH THE PACKAGE.

2- TERMINATE THE VENT ABOVE THE ROOF PER CODE REQUIREMENT BUT NOT LESS THAN 8 ft (2.44 m).

3- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.



PID-7
DEAERATOR


NOTES
1- ROOM APPROXIMATE SIZE IS 60 ft X 40 ft X 24 ft TALL.
2- THE LAYOUT SHOWS THE EQUIPMENT HOUSE-KEEPING PADS.
3- UNDERGROUND DRAIN PIPE CONNECTS TO TRENCH DRAIN.
DEAERATOR
7'-3"
12'-0"
5'-0"
CONDENSATE RECEIVER
9'-5"
5'-0"
4'-0"
WATER SOFTENER
5'-0"
3'-0"
HAND SINK
4'-0"
CHEMICAL FEED
10'-0"
8" (200 mm) WIDE TRENCH DRAIN
SAFETY SHOWER/ EYE WASH
WALL LOUVER, (TYP.)
4'-0"
5'-0"
NOTE 3
BOILER BL-1
BOILER STACK
12 ft × 12 ft OVERHEAD DOOR (TYP. 2)
CLEAN OUT
6" (150 mm) UNDERGROUND PIPING
BOILER BL-2
BOILER STACK
11'-0"
26'-0"
BLOWDOWN SEPARATOR
5'-0"
CONTROL PANEL
60'-0"
40'-0"
BOILER ROOM EQUIPMENT LAYOUT
NOT TO SCALE
FOR SI UNITS:
1 ft = 0.305 m
1 in. = 25.4 mm

Equipment Selection

The following manufacturers and their published data on their websites were used to show the procedure for equipment selection for our sample project. The same procedure can be used for selecting equipment from other manufacturers not listed here.

The selected equipment includes the manufacturer name and website address so that the reader can obtain additional data if interested. The catalog pages are marked to show important information and equipment-specific performance as they relate to our sample project.

The selected equipment may not be the best or the most efficient available option. The design engineer is encouraged to always consult at least with two manufacturers for available options and compare their products and operating efficiencies.

The operating principles for equipment from different manufacturers are almost the same. However, each manufacturer's equipment is unique and must be carefully considered for its physical dimensions, power and control requirements, utility needs, and maintenance specifics.

Boilers

Two boilers, each 700 boiler hp, are selected for our sample project. The boilers are model CBEX Elite boilers as manufactured by Cleaver-Brooks.

The total generated steam from the two boilers from and at 212°F (100°C) at sea level is 48,300 lb/h (21,928 kg/h). This is to satisfy the maximum plant demand of 30,000 lb/h (13,620 kg/h) for process, 10,000 lb/h (4,540 kg/h) for HVAC and hot water systems, 3,000 lb/h (1,362 kg/h) for the deaerator, and allowing approximately 5,300 lb/h (2,406 kg/h) for line heat loss, distribution steam loss, boiler blowdown, and safety factor.

The operation is considered to be noncritical and no standby boiler is included for periods when the demand is at its maximum.

The boilers will satisfy the following performances and will include the following features and components:

1. The boiler capacity, each: 700 boiler hp, capable of generating steam up to 24,150 lb/h (10,964 kg/h) from and at 212°F (100°C) at sea level.
2. The boiler blower motor electrical characteristics (assumed 30 ppm boiler): 50 hp, 460 V, 3 phase, 60 Hz.
3. The boiler maximum natural gas usage, each: 28,574 ft^3/h at 4 psig (809 m^3/h at 28 kPag or 0.27 barg).
4. The boiler dimensions: 298 in. long × 119 in. wide × 130 in. tall (7.6 m long × 3.02 m wide × 3.30 m tall).

5. The boiler feed water connection size: 2½ in. (64 mm), provided at both sides of the boiler chamber.
6. The boiler chemical feed connection size: 1 in. (25 mm).
7. The boiler steam nozzle size: 8 in. (200 mm) with ANSI 300# flange connection.
8. The boiler bottom blowoff, front and rear, connection sizes: 2 in. (50 mm) each connection.
9. The boiler flue gas stack connection size: 24 in. (600 mm) in diameter with flange connection. The flange connection can handle a load (the weight of the stack) up to 1,500 lb (681 kg).
10. Number of required pressure relief valves for each boiler: two pressure relief valves.
11. The boiler pressure relief valve size, each: 2½ in. (65 mm).
12. The boiler pressure relief valve pressure set point: 200 psig (13.7 barg).
13. The boiler stop check valve size: 5 in. (125 mm).
14. Each boiler will be delivered as a package prepiped and prewired as shown on the PID-1 and PID-2 drawings and as described here.

Each boiler package will include, as a minimum, the following:

1. Makeup water modulating control valve with bypass and check valve, prepiped. This will maintain the boiler water level at the set point.
2. Surface blowdown control valve and manual valve, prepiped.
3. Bottom blowoff with quick-open and slow-open valves, prepiped.
4. Spool reducer piece, manual valve, and stop check valve with drain valve, prepiped at the boiler steam nozzle.
5. Boiler control panel with all required controls for controlling combustion air, steam pressure, burner firing rates, operation status indications, specific alarm for each failure, two boilers' lead lag and alternation controls, etc. Controls shall be programmable with adjustable set points.
6. Pressure relief valves factory set at proper pressure and installed.
7. Sight glass, external float controls, safety switches, pressure gauges, and thermometers all installed.
8. The burner will be provided with required regulators to accept natural gas at 4 psig (28 kPag) pressure. The burner will have 20 to 1 turndown capability with modulating controls to modulate its firing rate between 100 and 5% of its maximum capacity. The burner gas train will be prepiped and will be Factory Mutual (FM) insurance approved. This is assumed to be required by the plant insurance underwriter.
9. The boiler chemical feed piping with stop valve prepiped.

See additional manufacturer literature in Figure 7.1 for the selected boilers. Note the added notes on the boiler catalog pages that highlight the boiler's specific features. The information is included with permission from Cleaver-Brooks, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.cleaver-brooks.com.

CleaverBrooks®

Model CBEX Elite
100-800 HP

700 HP STEAM BOILER

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FIGURE 7.1
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

CBEX Elite **100-800 HP**

Table 1. CBEX Steam Boiler Ratings

BOILER H.P.	100	125	150	200	250	300	350	400	500	600	700	800
RATINGS - SEA LEVEL TO 700 FT.												
Rated Capacity (lbs-steam/hr from and at 212 °F)	3450	4313	5175	6900	8625	10350	12075	13800	17250	20700	24150	27600
Btu Output (1000 Btu/hr)	3347	4184	5021	6694	8368	10042	11715	13389	16736	20083	23430	26778
APPROXIMATE FUEL CONSUMPTION AT RATED CAPACITY BASED ON NOMINAL 82% EFFICIENCY												
Light Oil gph (140,000 Btu/gal)	29.2	36.4	43.7	58.3	72.9	87.5	102.0	116.6	145.8	174.9	204.1	233.3
Gas CFH (1000 Btu)	4082	5102	6123	8164	10205	12246	14287	16328	20410	24492	28574	32656
Gas (Therm/hr)	40.8	51.0	61.2	81.6	102.0	122.5	142.9	163.3	204.1	244.9	285.7	326.6
POWER REQUIREMENTS - SEA LEVEL TO 700 FT. (60 HZ)												
Blower Motor hp (60 ppm)A	2	7-1/2	7-1/2	10	10	20	15	15	15	25	40	50
Blower Motor hp (30 ppm)A	3	7-1/2	7-1/2	15	15	20	20	20	30	40	50	75
Blower Motor hp (9 ppm)A	3	7-1/2	7-1/2	15	15	20	20	25	30	50	75	n/a
Oil Pump Motor, No. 2 Oil	1/2	1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4	3/4	1	1
Air Compressor Motor hp (No. 2 Oil firing Only)	3	3	3	3	5	5	5	5	7-1/2	7-1/2	7-1/2	7-1/2
BOILER DATA												
Heating Surface sq-ft. (Fireside)	390	452	526	697	820	860	1122	1412	1642	1769	2230	2301

NOTES:
A. Blower motor size for boiler operating pressures 125 psig and less, contact your local Cleaver-Brooks authorized representative for higher pressures and altitude.

Table 2. CBEX Hot Water Boiler Ratings

BOILER H.P.	100	125	150	200	250	300	350	400	500	600	700	800
RATINGS - SEA LEVEL TO 700 FT.												
Btu Output (1000 Btu/hr)	3347	4184	5021	6694	8368	10042	11715	13389	16736	20083	23430	26778
APPROXIMATE FUEL CONSUMPTION AT RATED CAPACITY BASED ON NOMINAL 85% EFFICIENCY												
Light Oil gph (140,000 Btu/gal)	28.1	35.2	42.2	56.3	70.3	84.4	98.4	112.5	140.6	168.8	196.9	225.0
Gas CFH (1000 Btu)	3938	4922	5907	7876	9845	11814	13783	15752	19689	23627	27565	31503
Gas (Therm/hr)	39.4	49.2	59.1	78.8	98.4	118.1	137.8	157.5	196.9	236.3	275.7	315.0
POWER REQUIREMENTS - SEA LEVEL TO 700 FT. (60 HZ)												
Blower Motor hp (60 ppm)	2	7-1/2	7-1/2	10	10	20	15	15	15	25	40	50
Blower Motor hp (30 ppm)	3	7-1/2	7-1/2	15	15	20	20	20	30	40	50	75
Blower Motor hp (9 ppm)	3	7-1/2	7-1/2	15	15	20	20	25	30	50	75	n/a
Oil Pump Motor, No. 2 Oil	1/2	1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4	3/4	1	1
Air Compressor Motor hp (No. 2 Oil firing Only)	3	3	3	3	5	5	5	5	7-1/2	7-1/2	7-1/2	7-1/2
BOILER DATA												
Heating Surface sq-ft. (Fireside)	390	452	526	697	820	860	1122	1412	1642	1769	2230	2301

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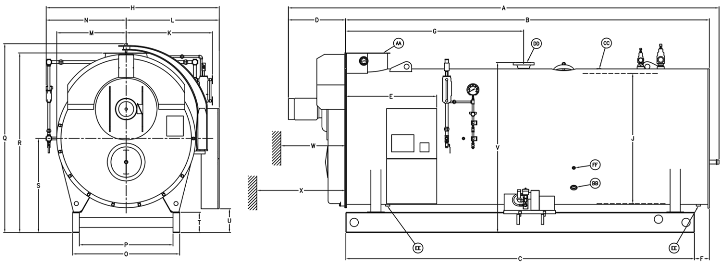
FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

100-800 HP **CBEX Elite**

Figure 1. CBEX Elite Steam Boiler Dimensions, 100-800 HP



100 THRU 200 HP BOILERS USE A FRONT DOOR HINGE (NOT DAVIT AS SHOWN)

Table 3. CBEX Elite Steam Boiler Dimensions 100-800 HP

BOILER H.P.	DIM	100	125	150	200	250	300	350	400	500	600	700	800
LENGTHS													
Overall Length (60 PPM system)	A	165	172	176.5	201.5	231.5	242.5	249	265	260.5	282.5	291	299
Overall Length (30 PPM system)	A	167	176	180.5	203.5	233.5	243.5	255	268	271.5	287.5	298	307
Overall Length (9 PPM system)	A	167	176	182.5	205.5	233.5	243.5	255	270	271.5	288.5	300	n/a
Shell	B	137.5	144.5	149	168	196	204	217.5	226.5	229	244	253	260
Base Frame	C	130.5	137.5	140	159	186	194	208.5	217.5	219.5	234.5	243.5	250.5
Front Head Extension (60 PPM system)	D	21.5	21.5	21.5	27.5	29.5	32.5	25.5	32.5	25.5	32.5	32	33
Front Head Extension (30 PPM system)	D	23.5	25.5	25.5	29.5	31.5	33.5	31.5	35.5	36.5	37.5	39	41
Front Head Extension (9 PPM system)	D	23.5	25.5	27.5	31.5	31.5	33.5	31.5	37.5	36.5	38.5	41	n/a
Front Ring Flange to Panel	E	46	46	48	48	47	47	57	57	52	52	52	52
Rear Ring Flange to Base	F	7	7	9	9	10	10	9	9	9.5	9.5	9.5	9.5
Shell Flange to Steam Nozzle	G	62.5	66	73.5	75.5	96.5	100.5	106.5	111	114.5	122	126.5	130
WIDTHS													
Overall Width	H	81	81	86	86	94	94	105	105	112	112	119	119
I.D. Boiler	J	55	55	60	60	67	67	78	78	85	85	92	92
Center to Water Column	K	42.5	42.5	45	45	48.5	48.5	54	54	57.5	57.5	61	61
Center to Panel	L	44.5	44.5	47	47	50.5	50.5	56	56	59.5	59.5	63	63
Center to Lagging	M	30.5	30.5	33	33	36.5	36.5	42	42	45.5	45.5	49	49
Center to Auxiliary LWCO	N	36.5	36.5	39	39	43.5	43.5	49	49	52.5	52.5	56	56
Base Outside	O	47.5	47.5	52.5	52.5	51	51	64	64	60	60	68	68
Base nside I	P	39.5	39.5	44.5	44.5	43	43	56	56	47	47	55	55
HEIGHTS													
Overall Height	Q	81.5	81.5	87	87	101.5	101.5	113	113	122	122	130	130
Base to Vent Outlet	R	81	81	87	87	94.5	94.5	108	108	114.5	114.5	122.5	122.5
Base o Boil r Centerline	S	41	41	46	46	50	50	56.5	56.5	61	61	65.5	65.5
Height of Base Frame	T	12	12	12	12	12	12	12	12	12	12	12	12
Base to Bottom of Panel	U	17	17	17	17	20	20	24	24	23	23	23	23
Base to Steam Outlet	V	78.5	78.5	82.5	82.5	90	90	102	102	110	110	118	118

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FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

CBEX Elite **100-800 HP**

Table 3. CBEX Elite Steam Boiler Dimensions 100-800 HP (Continued)

BOILER H.P.	DIM	100	125	150	200	250	300	350	400	500	600	700	800
BOILER CONNECTIONS													
Feedwater Inlet (Both Sides)	BB	1.25	1.5	1.5	2	2	2	2.5	2.5	2.5	2.5	2.5	2.5
Surface Blowoff	CC	1	1	1	1	1	1	1	1	1	1	1	1
Steam ozzle (300# ANSI Flange)	DD	4	4	4	4	6	6	6	6	8	8	8	8
Blowdown-Front & Rear	EE	1.25	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2
Chemical Feed	FF	1	1	1	1	1	1	1	1	1	1	1	1
VENT STACK													
Vent Stack Diameter (Flanged)	AA	16	16	16	16	20	20	24	24	24	24	24	24
MINIMUM CLEARANCES													
Front Door Swing	W	62	62	67	67	78	78	89	89	97	97	104	104
Tube Removal - Front Only	X	89	96	101	120	142	142	160	169	172	187	196	203
MINIMUM BOILER ROOM LENGTH ALLOWING FOR DOOR SWING AND TUBE REMOVAL:													
Thru Window or Door		205.5	212.5	222	241	280	288	312.5	321.5	332	347	363	370
Front of Boiler		232.5	246.5	256	294	344	352	383.5	401.5	407	437	455	469
WEIGHTS IN LBS													
Normal Water Weight		6,550	6,890	8,010	9,060	11,620	12,190	19,340	19,650	20,060	21,620	25,050	25,870
Approx. Shipping Weight - (150psig)		10,650	11,180	12,520	13,900	17,960	18,540	25,960	26,780	31,580	33,320	39,830	40,840

NOTES:

Accompanying dimensions, while sufficiently accurate for layout purposes, must be confirmed for construction by certified dimension diagram/drawing. All connections are threaded unless otherwise indicated.

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FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

100-800 HP **CBEX Elite**

TABLE 5 IS A SAMPLE OF EFFICIENCY AT 125 PSIG OPERATING PRESSURE AT DIFFERENT LOADS FOR 700 BHP BOILR. OUR SYSTEM OPERATING PRESSURE IS 150 PSIG.

PERFORMANCE DATA

Efficiency

Tables 5 and 6 show predicted fuel-to-steam efficiencies (including radiation and convection losses) for Cleaver-Brooks CBEX firetube boilers. For specific efficiencies on firetube boiler offerings not listed here, contact your local Cleaver-Brooks authorized representative.

Cleaver-Brooks offers an industry leading fuel-to-steam boiler efficiency guarantee for CBEX Firetube Boilers. The guarantee is based on the fuel-to-steam efficiencies shown in the efficiency tables and the following conditions. The efficiency percent number is only meaningful if the specific conditions of the efficiency calculations are clearly stated in the specification (see Cleaver-Brooks publication CB-7767 for a detailed description of efficiency calculations).

The boiler manufacturer shall guarantee that, at the time of startup, the boiler will achieve fuel-to-steam efficiency (as shown in the tables listed above) at 100% firing rate (add efficiency guarantees at 25%, 50%, and 75% of rating, if required). If the boiler(s) fail to achieve the corresponding guaranteed efficiency as published, the boiler manufacturer will rebate, to the ultimate boiler owner, five thousand dollars ($5,000) for every full efficiency point (1.0%) that the actual efficiency is below the guaranteed level. The specified boiler efficiency is based on the following conditions.

1. Fuel specification used to determine boiler efficiency:

• Natural Gas	• No. 2 Oil	• No. 6 Oil
Carbon,% (wt) = 69.98	Carbon,% (wt) = 85.8	Carbon,% (wt) = 86.6
Hydrogen,% (wt) = 22.31	Hydrogen,% (wt) = 12.7	Hydrogen,% (wt) = 10.9
Sulfur,% (wt) = 0.0	Sulfur,% (wt) = 0.2	Sulfur,% (wt) = 2.09
Heating value, Btu/lb = 21,830	Heating value, Btu/lb = 19,420	Heating value, Btu/lb = 18,830

2. Efficiencies are based on ambient air temperature of 80 °F, relative humidity of 30%, and 15% excess air in the exhaust flue gas.
3. Efficiencies are based on the following radiation and convection losses. Firing rate of 25% - 1.2%, 50% - 0.6%, 75% - 0.4%, and 100% - 0.3%.

Table 5. CBEX Fuel-to-Steam Efficiencies Natural Gas (with heat recovery)

BHP	OPERATING PRESSURE = 125 psig			
	% OF LOAD			
	25%	50%	75%	100%
100	84.4	84.8	84.5	84.1
125	84.2	84.7	84.6	84.4
150	84.1	84.6	84.5	84.3
200	83.7	84.4	84.4	84.3
250	84.4	84.8	84.5	84.1
300	84.2	84.6	84.4	84.0
350	84.2	84.7	84.6	84.3
400	85.0	85.1	84.9	84.5
500	84.8	84.9	84.7	84.4
600	84.8	85.0	84.8	84.5
700	84.8	85.0	84.9	84.6
800	84.7	85.0	84.8	84.6

Table 6. CBEX Fuel-to-Steam Efficiencies #2 Oil (with heat recovery)

BHP	OPERATING PRESSURE = 125 psig			
	% OF LOAD			
	25%	50%	75%	100%
100	87.2	87.6	87.3	86.9
125	87.0	87.6	87.5	87.2
150	86.9	87.5	87.4	87.1
200	86.5	87.2	87.3	87.1
250	87.2	87.6	87.3	86.9
300	87.0	87.4	87.2	86.8
350	87.0	87.5	87.4	87.1
400	87.8	88.0	87.7	87.3
500	87.6	87.7	87.5	87.2
600	87.6	87.8	87.6	87.3
700	87.6	87.8	87.7	87.4
800	87.6	87.8	87.7	87.4

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FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

CBEX Elite **100-800 HP**

Emissions

Table 6. CBEX Natural Gas Estimated Emission Levels

POLLUTANT	UNITS	60 PPM SYSTEM	30 PPM SYSTEM	9 PPM SYSTEM	7 PPM SYSTEM
CO	ppm[A]	10	10	25	50
	lb/MMBtu	0.0075	0.0075	0.018	0.037
NOx	ppm[A]	60	30	9	7
	lb/MMBtu	0.07	0.035	0.0105	0.0082
SOx	ppm[A]	1	1	1	1
	lb/MMBtu	0.001	0.001	0.001	0.001
HC/VOC5	ppm[A]	8	8	4	4
	lb/MMBtu	0.0032	0.0032	0.0016	0.0016
PM	ppm[A]	-	-	-	-
	lb/MMBtu	0.01	0.01	0.01	0.01

A. ppm levels are given on a dry volume basis and corrected to 3% oxygen (15% excess air)

Table 7. CBEX #2 Oil Estimated Emission Levels

POLLUTANT	UNITS	60 PPM SYSTEM	30 PPM SYSTEM	9 PPM SYSTEM	7 PPM SYSTEM
CO	ppm[A]	10	10	10	10
	lb/MMBtu	0.008	0.008	0.008	0.008
NOx	ppm[A]	120	90	70	70
	lb/MMBtu	0.16	0.12	0.093	0.093
SOx	ppm[A]	55	55	55	55
	lb/MMBtu	0.1	0.1	0.1	0.1
HC/VOC5	ppm[A]	4	4	4	4
	lb/MMBtu	0.002	0.002	0.002	0.002
PM	ppm[A]	-	-	-	-
	lb/MMBtu	0.025	0.025	0.025	0.025

A. ppm levels are given on a dry volume basis and corrected to 3% oxygen (15% excess air)
BASED ON THE FOLLOWING CONSTITUENT LEVELS:
Fuel-bound Nitrogen content = 0.015% or less by weight.
Sulfur content = 0.1% by weight.
Ash content = 0.01% by weight.

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FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

ENGINEERING DATA

The following engineering information is provided for CBEX Boilers. Additional detail is available from your local Cleaver-Brooks authorized representative.

Boiler Information

Tables 9 and 10 list quantity and outlet size for safety/relief valves supplied on CBEX boilers.

Table 11 shows steam volume and disengaging area.

Table 12 gives recommended steam nozzle sizes.

Table 13 shows recommended non-return valve sizes.

THIS IS THE PRESSURE RELIEF VALVE (PRV) FOR 700 HP BOILER SET AT 200 psig.

Table 8. Safety valves steam

VALVE SETTING	150 PSIG STEAM		200 PSIG STEAM		250 PSIG STEAM	
BOILER HP	NO. OF VALVES REQ'D	OUTLET SIZE	NO. OF VALVES REQ'D	OUTLET SIZE	NO. OF VALVES REQ'D	OUTLET SIZE
100	1	1-1/2"	1	1-1/2"	1	1-1/4"
125	2	1-1/4"	2	(1) 1-1/4" (1) 1"	2	1"
150	2	(1) 1-1/2" (1) 1-1/4"	2	(1) 1-1/4" (1) 1"	2	1"
200	2	1-1/2"	2	(1) 1-1/2" (1) 1-1/4"	2	1-1/4"
250	2	(1) 2" (1) 1-1/2"	2	(1) 1-1/2" (1) 1-1/4"	2	(1) 1-1/2" (1) 1-1/4"
300	2	(1) 2" (1) 1-1/2"	2	1-1/2"	2	(1) 1-1/2" (1) 1-1/4"
350	2	2"	2	(1) 2" (1) 1-1/2"	2	1-1/2"
400	2	(1) 2-1/2" (1) 2"	2	(1) 2" (1) 1-1/2"	2	(1) 2" (1) 1-1/2"
500	2	(1) 2-1/2" (1) 2"	2	(1) 2-1/2" (1) 2"	2	(1) 2" (1) 1-1/2"
600	2	2-1/2"	2	(1) 2-1/2" (1) 2"	2	2"
700	3	(2) 2-1/2" (1) 2"	2	2-1/2"	2	(1) 2-1/2" (1) 2"
800	3	(2) 2-1/2" (1) 2"	2	2-1/2"	2	(1) 2-1/2" (1) 2"

NOTE: Valve manufacturers are Kunkle, Consolidated or Conbraco, depending on availability.

Table 9. Relief valves hot water

VALVE SETTING	30 PSIG HW		125 PSIG HW	
BOILER HP	NO. OF VALVES REQ'D	OUTLET SIZE	NO. OF VALVES REQ'D	OUTLET SIZE
100	1	2-1/2"	1	1-1/4"
125	2	2"	2	1"
150	2	2"	2	1"
200	2	2"	2	(1) 1-1/4" (1) 1"
250	2	(1) 2-1/2" (1) 2"	2	1-1/4"
300	2	2-1/2"	2	1-1/4"
350	2	2-1/2"	2	2"
400	3	(2) 2-1/2" (1) 1-1/4"	2	2"
500	3	2-1/2"	2	2"
600	4	(3) 2-1/2" (1) 2"	2	2"
700	4	2-1/2"	2	(1) 2-1/2" (1) 2"
800	5	(4) 2-1/2" (1) 2"	2	(1) 2-1/2" (1) 2"

NOTE: Relief valve is Kunkle #537 for 30# & 125#(Section IV) boiler and is Kunkle #927 for 150# HTHW(Section I) boiler.

FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

CBEX Elite **100-800 HP**

Table 11. CBEX Elite steam volume and disengaging area

BOILER HP	STEAM VOLUME CU-FT	STEAM RELIEVING AREA SQ-IN
100	10.2	4291
125	10.7	4522
150	17.6	5544
200	20.1	6322
250	34.3	8597
300	35.8	8971
350	50.7	11059
400	53.0	11563
500	78.9	13550
600	84.5	14515
700	107.2	16517
800	110.3	17006

NOTE:
Based on normal water level.
Based on 150 psig design pressure.

RECOMMENDED STEAM NOZZLE SIZE IS 8 in. FOR 700 HP BOILER OPERATING AT 150 psig.

Table 12. CBEX Elite recommended steam nozzle size

OPERATING PRESSURE PSIG	BOILER HP											
	100	125	150	200	250	300	350	400	500	600	700	800
15	8	8	8	10	10	12	12	12	12	12	12	12
30	6	6	6	8	8	8	10	10	10	12	12	12
40	6	6	6	6	8	8	8	10	10	10	12	12
50	4	6	6	6	6	8	8	8	8	10	10	12
75	4	4	4	6	6	6	8	8	8	8	10	10
100	4	4	4	6	6	6	6	6	8	8	8	10
125	4	4	4	4	6	6	6	6	8	8	8	8
150	2.5	3	3	4	4	6	6	6	6	6	8	8
200	2.5	2.5	3	4	4	4	4	6	6	6	6	6
250	2	2.5	2.5	3	4	4	4	4	6	6	6	6

NOTES:
1. Steam nozzle sizes given in inches.
2. Recommended steam nozzle sizes based on 4000 to 5000 fpm steam velocity.

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FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

100-800 HP **CBEX Elite**

THIS IS THE STOP CHECK VALVE.

Table 13. CBEX Elite recommended Non-Return Valve size

BOILER HP	BOILER CAPACITY (LBS/HR)	OPERATING PRESSURE (PSIG)							
		50	75	100	125	150	175	200	250
100	3450	3	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2
125	4313	4	3	3	3	3	2-1/2	2-1/2	2-1/2
150	5175	4	4	3	3	3	3	2-1/2	2-1/2
200	6900	4	4	4	3	3	3	3	3
250	8625	4	4	4	4	3	3	3	3
300	10350	6	4	4	4	4	4	4	3
350	12025	6	6	4	4	4	4	4	3
400	13800	6	6	4	4	4	4	4	4
500	17210	6	6	6	6	4	4	4	4
600	20700	8	8	6	6	6	4	4	4
700	24150	8	8	6	6	6	6	6	6
800	27600	8	8	6	6	6	6	6	6

NOTE: Valve sizes (300 psig flanges) given in inches.

Blowdown Water Requirements

Some local codes require blowdown tanks to be constructed in accordance with recommendations of the National Board of Boiler and Pressure Vessel Inspectors.

The National Board's recommendations base the size of the blowdown tank on the removal of at least 4 inches of water from the boiler.

Table 14 lists the approximate quantity of water represented by 4 inches of water at normal operating level for Cleaver-Brooks CBEX Boilers.

A 6 in. NON-RETURN VALVE IS GOOD FOR A 700 HP BOIOER WITH LOW TURN DOWN BURNER. FOR OUR SAMPLE PROJECT WITH 20 TO 1 TURN DOWN (HIGH) A 5 in. VALVE IS RECOMMENDED.

Table 14: Blowdown tank sizing

BOILER HP	WATER (GAL)
100	84
125	89
150	106
200	120
250	161
300	167
350	205
400	214
500	247
600	264
700	300
800	309

NOTE: Quantity of water removed from boiler by lowering normal water line 4".

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FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

Gas pressure requirements

Table 14. Model CBEX Elite, Minimum Required Gas Pressure at Entrance to C-B Supplied Regulator/Gas Valve

BOILER HP	Combination Regulator and Gas Valve Size (in)	PRESSURE REQUIRED ("WC)
100	1.5	12.5
125	1.5	20
150	1.5	27.5
200	1.5	38.5
250	2	41
300	2	55
350	2	75.5
400	2	92
500	2.5	55
600	2.5	79
700	3	80.5
800	3	105

Note: For undersized or oversized gas trains or altitudes above 700 feet, contact your local Cleaver-Brooks representative.

Table 15. CBEX altitude correction for gas

ALTITUDE (FT)	CORRECTION FACTOR	ALTITUDE (FT)	CORRECTION FACTOR
1000	1.04	6000	1.25
2000	1.07	7000	1.3
3000	1.11	8000	1.35
4000	1.16	9000	1.4
5000	1.21	-	-

To obtain minimum required gas pressure at altitudes above 700 feet, multiply the pressure by the listed factors:
Inches WC x 0.577 = oz/sq-in.
oz/sq-in x 1.732 = inches WC.
Inches WC x 0.0361 = psig.
oz/sq-in x 0.0625 = psig.
psig x 27.71 = Inches WC.
psig x 16.0 = oz/sq-in.

FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.) *(continued)*

CBEX Elite **100-800 HP**

Table 19. CBEX Elite boiler mounting piers

BOILER	ALL DIMENSIONS IN INCHES								
HP	A	B	C	D	E	F	G	X1	X2
100	6	9	130.5	34.5	52.5	4	39.5	15	11.5
125	6	9	137.5	34.5	52.5	4	39.5	15	11.5
150	6	9	140	39.5	57.5	4	44.5	13	11.5
200	6	9	159	39.5	57.5	4	44.5	13	11.5
250	6	9	186.125	38	56	4	43	16	8
300	6	9	194.125	38	56	4	43	16	8
350	6	12	208.5	48	72	4	56	18	11.5
400	6	12	217.5	48	72	4	56	18	11.5
500	6	12	219.5	41.5	65.5	6.5	47	16	11.5
600	6	12	234.5	41.5	65.5	6.5	47	16	11.5
700	6	12	243.5	49.5	73.5	6.5	55	15	12.5
800	6	12	250.5	49.5	73.5	6.5	55	15	12.5

NOTE:
6-inch high mounting piers recommended for use beneath the boiler base frame. The use of these piers provides increased inspection accessibility to the boiler and added height for washing down the area beneath the boiler.

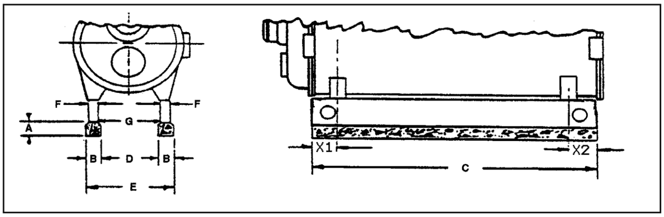


FIGURE 7.1 (continued)
Boiler selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Boiler Book 2011, Model CBEX Elite 100-800 HP. Used with permission from Cleaver-Brooks, Inc., www.cleaver-brooks.com.)

Condensate Receiver Package

A model 5S condensate receiver package manufactured by BFS Industries, LLC is selected for our sample project. The condensate receiver package, also referred to as condensate surge tank package, is installed inside the boiler room. It receives all pumped condensate returns.

The package is prepiped and prewired with all required valves and instrumentations, as shown on the PID-6 drawing and described in this section.

The package includes transfer pumps manufactured by Grundfos Pumps Corporation to pump the condensate from the surge tank to the deaerator.

According to the calculations in this chapter for the condensate receiver package, the package must be selected based on the following requirements:

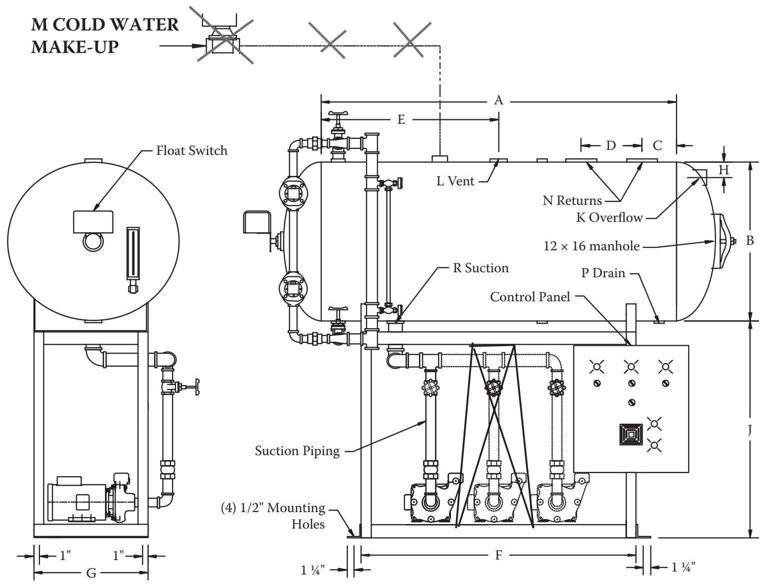
1. Receiver tank storage: 210 gal (795 L).
2. Transfer pump flow rate: 21 gpm (79.5 L/min).
3. Transfer pump discharge pressure: 25 psi or 58 ft of water column (18 m of water column).
4. Transfer pump required net positive suction head ($NPSH_r$): Less than 5.3 ft (1.6 m) of water column.

The selected package performance and features are as follows:

1. Nominal receiver tank capacity: 240 gal (910 L).
2. Number of transfer pumps: Two pumps, one running and one standby.
3. Receiver tank vent connection size: 2 in. (50 mm).
4. Receiver tank overflow connection size: 2 in. (50 mm).
5. Transfer pump's suction connection size: 2 in. (50 mm).
6. Receiver tank drain connection size: 1 in. (25 mm).
7. Receiver tank stand height (bottom of the tank to the transfer pump's inlet centerline): 4 ft (1.22 m). Note that the stand height shown in Figure 7.2 must be increased to satisfy this requirement.
8. Transfer pump's performance, each: 21 gpm (79.5 L/min) at 25 psi or 58 ft of water (18 m of water) discharge pressure.
9. Transfer pump's power requirement, each: 1 hp (0.75 kW), 460 V, 3 phase, 60 Hz.
10. Transfer pump make and model number: Grundfos model CR5-3.
11. Transfer pump net positive suction head required ($NPSH_r$): 4 ft (1.22 m) of water column.
12. Electrical and control panel: Electrical and control panel for power distribution and to house starters, breakers, programmable controller, etc., prewired.

Condensate Receiver Package

SEC. BF6.3SG PAGE 1
DATED 7/15/03



Notes:
1. This drawing is not for construction purposes.
2. All dimensions are in inches.
3. Duplex and Triplex pumps are shown in phantom.
4. This drawing shows both standard and optional equipment.

Tank No.	5S	6S	7S	8S	9S	10S	11S	12S	14S
Nominal Cap. (Gal.)	240	360	650	800	1000	1300	1600	2400	3300
A	72	72	96	120	120	96	120	120	120
B	30	36	42	42	48	60	60	72	84
C	9	9	9	9	9	9	9	9	9
D	9	9	9	9	12	12	14	14	16
E	36	36	48	60	60	48	60	60	60
F	48	52	72	84	84	72	84	84	84
G	20	24	36	36	44	56	56	66	66
H	3	3	4	4	6	6	6	6	9
J	48	48	48	60	72	72	72	84	84
K	2	2 1/2	3	3	4	4	4	6	6
L	2	2 1/2	3	3	4	4	4	6	6
M	3/4	1	1	1 1/2	1 1/2	1 1/2	1 1/2	2	2
N	3	3	3	3	4	4	6	6	8
P	1	1	1	1 1/4	2	2	2	2	2 1/2
R	2	2 1/2	3	4	4	4	4	6	6

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SURGE/TRANSFER
SYSTEM DIMENSIONS

FIGURE 7.2
Condensate receiver package selection example/procedure. (Downloaded from the Internet from BFS Industries, LLC Publications, Surge Drawings, Surge/Transfer System Dimensions Catalog, Section BF 6.3 SG, p. 1. Used with permission from BFS Industries, LLC. www.bfs-ind.com.

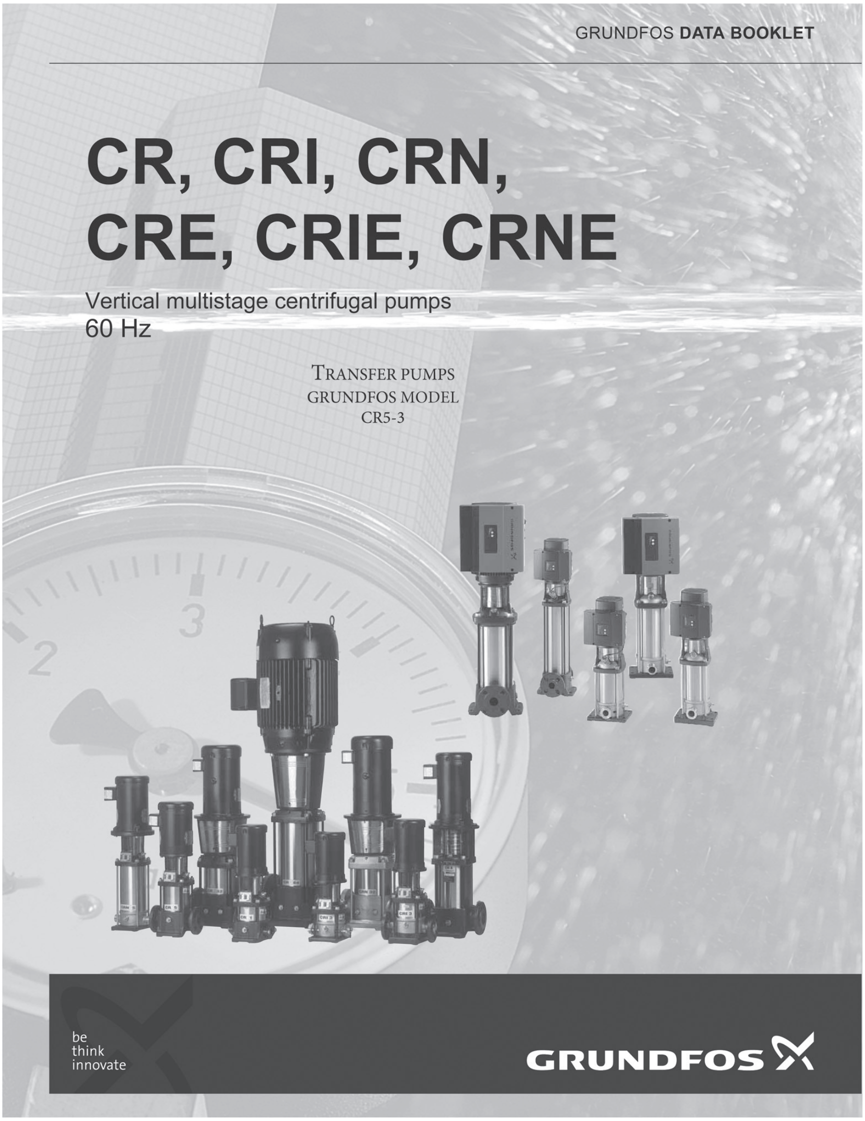


FIGURE 7.2 (continued)
Transfer pump selection example/procedure. Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.) *(continued)*

CR, CRI, CRN,
CRE, CRIE, CRNE

TRANSFER PUMPS
MODEL CR5-3

Product range

Range	**CR 1s**	**CR 1**	**CR 3**	**CR 5**	**CR 10**	**CR 15**	**CR 20**
Nominal flow rate [US gpm]	4.5	8.5	15	30	55	95	110
Temperature range [°F]				–4 to +250			
Temperature range [°F] – on request				–40 to +356			
Max. working pressure [psi]	362	362	362	362	362	362	362
Max. working pressure [psi] – on request	-	725	725	725	725	725	725
Max. pump efficiency [%]	35	49	59	67	70	72	72
CR pumps							
CR: Flow range [US gpm]	0.5-5.7	1 - 12.8	1.5 - 23.8	3 - 45	5.5 - 70	9.5 - 125	11-155
CR: Max. pump pressure (H [ft])	760	790	790	780	820	800	700
CR: Motor power [Hp]	.33 - 2	.33 - 3	.33 - 5	.75 - 7.5	.75 - 15	2 - 25	3-25
CRE pumps							
CRE: Flow range [US gpm]	-	0 - 12.8	0 - 23.8	0 - 45	0 - 70	0 - 125	0-155
CRE: Max. pump pressure (H [ft])	-	790	790	780	820	800	700
CRE: Motor power [Hp]	-	.33 - 3	.33 - 5	.75 - 7.5	.75 - 15	2 - 25	3-25
Version							
CR, CRE: Cast iron and stainless steel AISI 304	•	•	•	•	•	•	•
CRI, CRIE: Stainless steel AISI 304	•	•	•	•	•	•	•
CRN, CRNE: Stainless steel AISI 316	•	•	•	•	•	•	•
CRT, CRTE: Titanium	-			See CRT, CRTE product guide			-
CR, CRE pipe connection							
Oval flange (NPT)	1”	1”	1”	1.25”	2”	2”	2”
Oval flange (NPT) - on request	1.25”	1.25”	1.25”	1”	1.5”	-	-
ANSI flange size	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
ANSI flange size - on request	-	-	-	-	-	-	-
ANSI flange class	250 lb.	250 lb.	250 lb.	250 lb.	250 lb.	250 lb.	250 lb.
CRI, CRIE pipe connection							
Oval flange (NPT).	1”	1”	1”	1.25”	2”	2”	2”
Oval flange (NPT) - on request	1.25”	1.25”	1.25”	1”	1.5”	-	-
ANSI flange size	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
ANSI flange class	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.
Clamp coupling (NPT) - on request	1”, 1.25”	1”, 1.25”	1”, 1.25”	1”, 1.25”	1.5”, 2”	1.5”, 2”	1.5” 2”
Union (NPT ext. Thread) - on request	2”	2”	2”	2”	-	-	-
CRN, CRNE pipe connection							
PJE (Victaulic)	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
PJE (Victaulic) - on request	-	-	-	-	-	-	-
ANSI flange size	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
ANSI flange size - on request	-	-	-	-	-	-	-
ANSI flange class	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.
Clamp coupling (NPT) - on request	1”, 1.25”	1”, 1.25”	1”, 1.25”	1”, 1.25”	1.5”, 2”	1.5”, 2”	1.5”, 2”
Union (NPT ext. Thread) - on request	2”	2”	2”	2”	-	-	-
CRT pipe connection							
PJE coupling (Vitaulic)	-	- 1.25”	1.25”	1.25”	2”	2”	-
ANSI flange size - on request	-	-	-	-	2”	2”	-

• Available

FIGURE 7.2 (continued)
Transfer pump selection example/procedure. Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.) *(continued)*

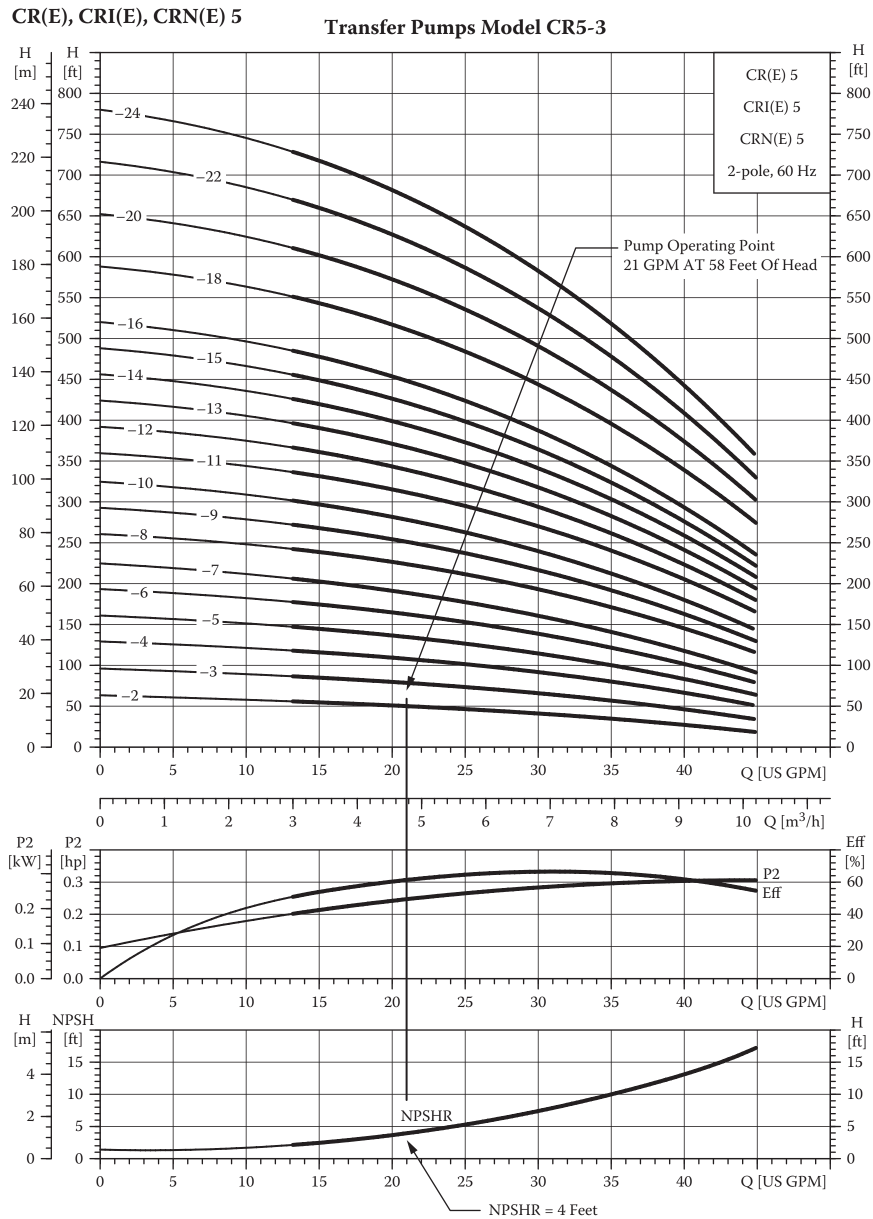
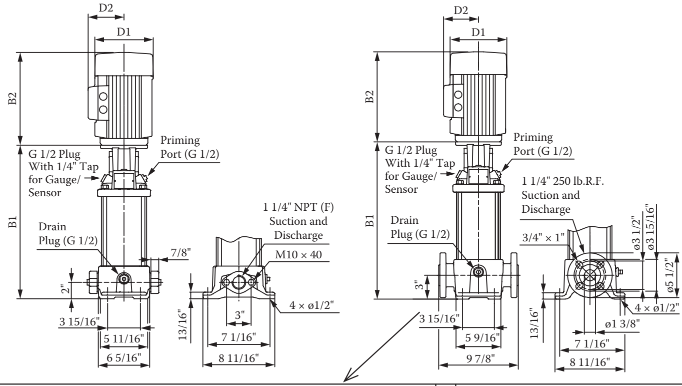


FIGURE 7.2 (continued)
Transfer pump selection example/procedure. Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.) *(continued)*

TRANSFER PUMPS
MODEL CR5-3, 1 hp, 3 phase, 460 V, 60 HZ

Transfer Pumps
Model CR5-3, 1 hp, 3 phase, 460 V, 60 HZ



Pump type	P2 [hp]	Ph.	Oval*	ANSI dimensions [inch] B1	TEFC D1	TEFC D2	TEFC B1+B2	Ship Wt. [lbs.]	ANSI dimensions [inch] MLE D1	MLE D2	MLE B1+B2	Ship Wt.[lbs.]
CR(E) 5-2	3/4	1	•	11.97	6.19	5.18	21.88	77	5.55	5.51	19.39	71
		3	•	11.97	5.55	4.57	19.41	68	-	-	-	-
CR(E) 5-3	1	~~1~~	~~•~~	~~13.03~~	~~7.19~~	~~5.73~~	~~24.22~~	~~90~~	-	-	-	-
		3	•	13.03	5.55	4.57	20.47	69	7.01	6.57	25.83	88
CR(E) 5-4	1 1/2	1	•	14.09	7.19	5.73	25.77	94	5.55	5.51	23.07	79
		3	•	14.09	5.55	4.57	22.71	71	7.01	6.57	26.89	92
CR 5-5	2	1	•	15.16	7.19	5.73	27.72	106	-	-	-	-
		3	•	15.16	7.01	4.33	26.38	93	-	-	-	-
CR(E) 5-6	2	1	•	16.22	7.19	5.73	28.78	108	-	-	-	-
		3	•	16.22	7.01	4.33	27.44	95	7.01	6.57	29.02	111
CR 5-7	3	1	•	18.39	8.60	6.87	33.04	143	-	-	-	-
		3	•	18.39	7.01	4.33	31.62	114	-	-	-	-
CR 5-8	3	1	•	19.45	8.60	6.87	34.10	145	-	-	-	-
		3	•	19.45	7.01	4.33	32.68	116	-	-	-	-
CR(E) 5-9	3	1	•	20.51	8.60	6.87	35.16	147	-	-	-	-
		3	•	20.51	7.01	4.33	33.74	118	7.01	6.57	33.82	126
CR 5-10	5	1	•	21.57	10.62	7.46	37.09	170	-	-	-	-
		3	•	21.57	8.66	5.28	37.08	168	-	-	-	-
CR 5-11	5	1	•	22.64	10.62	7.46	38.16	172	-	-	-	-
		3	•	22.64	8.66	5.28	38.15	169	-	-	-	-
CR 5-12	5	1	•	23.70	10.62	7.46	39.22	177	-	-	-	-
		3	•	23.70	8.66	5.28	39.21	170	-	-	-	-
CR(E) 5-13	5	1	•	24.76	10.62	7.46	40.28	178	-	-	-	-
		3	•	24.76	8.66	5.28	40.27	171	8.66	7.40	40.27	166
CR 5-14	5	1	•	25.83	10.62	7.46	41.35	180	-	-	-	-
		3	•	25.83	8.66	5.28	41.34	176	-	-	-	-
CR(E) 5-15	5	1	•	26.89	10.62	7.46	42.41	181	-	-	-	-
		3	•	26.89	8.66	5.28	42.40	177	8.66	7.40	42.40	169
CR(E) 5-16	5	1	•	27.95	10.62	7.46	43.47	182	-	-	-	-
		3	•	27.95	8.66	5.28	43.46	178	8.66	7.40	43.46	170
CR 5-18	7 1/2	1	-	30.59	10.22	7.62	46.12	200	-	-	-	-
		3	-	30.59	8.66	5.28	46.10	188	-	-	-	-
CR(E) 5-20	7 1/2	1	-	32.72	10.22	7.62	48.25	203	-	-	-	-
		3	-	32.72	8.66	5.28	48.23	190	8.66	7.40	48.23	204
CR 5-22	7 1/2	1	-	34.84	10.22	7.62	50.37	300	-	-	-	-
		3	-	34.84	8.66	5.28	50.35	287	-	-	-	-
CR(E) 5-24	7 1/2	1	-	36.97	10.22	7.62	52.50	302	-	-	-	-
		3	-	36.97	8.66	5.28	52.48	290	8.66	7.40	52.48	303

All dimensions in inches unless otherwise noted.
*Oval flanged pump B1 and B1+B2 dimension is one inch less than ANSI flanged pumps and weight is approximately 9 lbs. less.
• Available.

FIGURE 7.2 (continued)
Transfer pump selection example/procedure. Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.)

13. Controls and instrumentation: Programmable controller to satisfy the sequence of operation described in Chapter 4 for condensate receiver package, prewired.
14. Estimated package dimensions (not shown on the manufacturer drawing): 96 in. × 48 in. × 90 in. tall (2,438 mm × 1,220 mm × 2,286 mm tall).

See additional manufacturer literature in Figure 7.2 for the selected condensate receiver package and transfer pumps. The information is included with permission from BFS Industries, LLC and Grundfos Corporation for educational purposes only.

Consult with the manufacturers for additional guidance.

BFS Industries' website is www.bfs-ind.com.

Grundfos Pumps Corporation's website is www.grundfos.com.

Deaerator and Boiler Feed Water Package

A model 50MS deaerator package, manufactured by BFS Industries, LLC, is selected for our sample project. The deaerator package receives pumped condensate from the condensate receiver package, high-temperature condensate from the steam line's drip legs, high temperature condensate from the process high pressure steam users, and makeup water. It provides makeup water to the boilers. One deaerator is used to serve both boilers.

The deaerator package is prepiped, prewired, with all required valves, fittings, and controls and instrumentation, as shown in the PID-7 drawing and described in this section. The package includes boiler feed water pumps manufactured by Grundfos Pumps Corporation.

According to the calculations in this chapter for the deaerator package, the package must be selected based on the following requirements:

1. Deaerator capacity for serving both boilers: 48,300 lb/h (21,928 kg/h).
2. Deaerator tank storage: 970 gal (3,672 L).
3. Boiler feed water pump flow rate: 61 gpm (231 L/min).
4. Boiler feed water pump discharge pressure: 224 psi or 515 ft of water column (158 m of water column).
5. Boiler feed water pump required net positive suction head ($NPSH_r$): Maximum 4 ft (1.22 m) of water column.

The selected deaerator package performance and features are as follows:

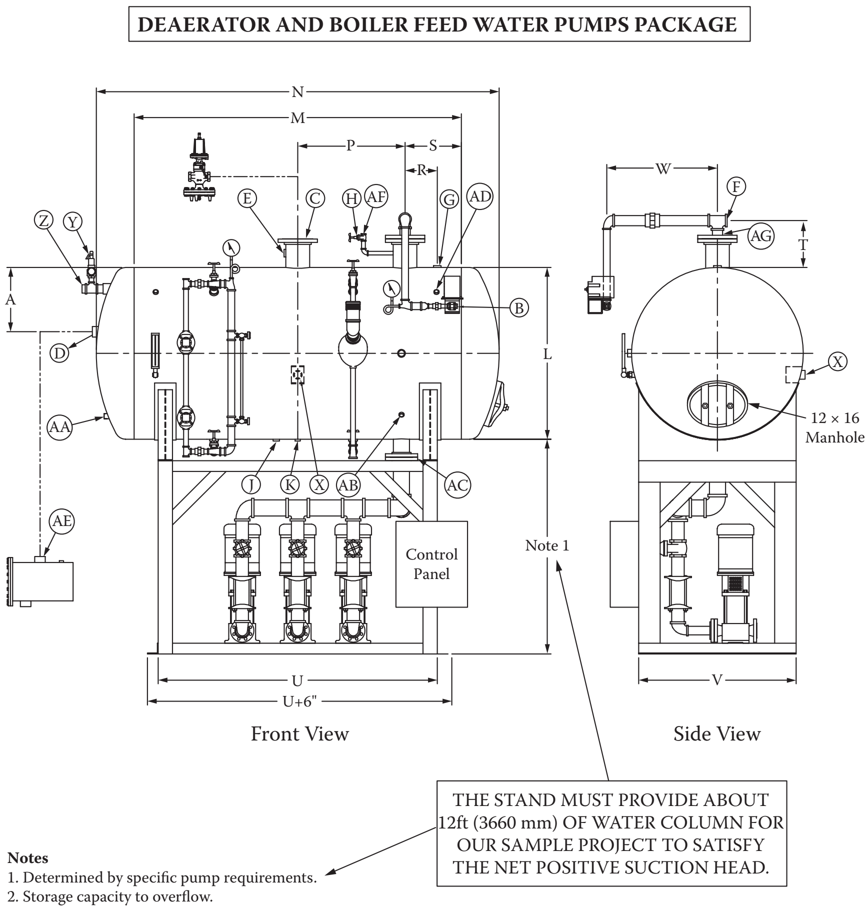
1. Deaerator package nominal capacity: 50,000 lb/h (22,700 kg/h).
2. Nominal deaerator tank capacity: 1,024 gal (3,875 L).
3. Number of boiler feed water pumps: The package includes three pumps. It is setup for one pump per boiler and one pump as standby for both boilers.
4. Deaerator tank vent connection size: 1½ in. (40 mm).
5. Deaerator tank overflow connection size: 3 in. (80 mm).
6. Deaerator feed water pumps' suction connection size: 6 in. (150 mm).
7. Deaerator tank drain connection size: 2 in. (50 mm).
8. Deaerator tank stand height (bottom of the tank to the pumps' inlet centerline): 12 ft (3.66 m). This is to provide the column of water at the pumps' suction side to satisfy the pumps' required net positive suction head.
9. Boiler feed water pumps' performance, each: 61 gpm (231 L/min) at 224 psi or 515 ft (158 m) of water column discharge head.
10. Boiler feed water pumps' power requirement, each: 20 hp (15 kW), 460 V, 3 phase, 60 Hz.
11. Boiler feed water pump make and model number: Grundfos model CR15-9.
12. Boiler feed water pump required net positive suction head ($NPSH_r$): 4 ft (1.22 m) of water column.
13. Boiler feed water pump recirculation connection: 1½ in. (40 mm).
14. Deaerator tank vacuum breaker valve connection size: 2½ in. (65 mm).
15. Deaerator tank chemical feed connection size: 1¼ in. (32 mm).
16. Deaerator sample connection size: ¾ in. (20 mm).
17. Deaerator makeup water connection size: 2½ in. (65 mm).
18. Deaerator makeup water level control: Modulating control with external float.
19. Miscellaneous components: Pressure relief valve, vacuum breaker, pressure gauges, and thermometer all installed on the deaerator tank and control panel.
20. Electrical and control panel: Electrical and control panel for power distribution and to house starters, breakers, programmable controller, etc., is included and is prewired/installed.
21. Controls and instrumentation: Programmable controller to satisfy the sequence of operation described in Chapter 4 for deaerator package is included and is prewired/installed.
22. Estimated package dimensions (not shown on the manufacturer drawing): 128 in. × 75 in. × 204 in. tall (3,251 mm × 1,905 mm × 5,182 mm tall).

See additional manufacturer literature in Figure 7.3 for the selected deaerator package and boiler feed water pumps. The information is included with permission from BFS Industries, LLC and Grundfos Corporation for educational purposes only.

Consult with the manufacturers for additional guidance.

BFS Industries' website is www.bfs-ind.com.

Grundfos Pumps Corporation's website is www.grundfos.com.



Notes
1. Determined by specific pump requirements.
2. Storage capacity to overflow.
3. "X" located far side.
4. All dimensions in inches.
5. This drawing not for construction purposes.
6. This drawing shows both standard and optional equipment. Actual equipment supplied will depend on job specific requirements.

FIGURE 7.3
Deaerator package selection example/procedure. (Downloaded from the Internet from BFS Industries, LLC Publications, Deaerator Dimensions Class "S," Catalog Section BF 6.3 S, p. 1 (two letter-size sheets). Used with permission from BFS Industries, LLC. www.bfs-ind.com.) *(continued)*

HIGH TEMPERATURE RETURN = 6″

SEC. BF6.3 S
PAGE 1
DATED 6/1/12
SUPERCEDES 5/1/10

	MODEL NO.	3.5MS	5MS	7MS	9MS	llMS	l4MS	l8MS	21MS	24MS	30MS	40MS	50MS	70MS	80MS	90MS	l00MS	l25MS
	CAP-LBS/HR	3,500	5,000	7,000	9,000	11,000	14,000	18,000	21,000	24,000	30,000	40,000	50,000	70,000	80,000	90,000	100,000	125,000
STORAGE CAPACITY (NOTE 2)	MAlNUTES	21	16	11	12	10	20	15	13	12	11	12	10	11	10	10	10	11
	GALLONS	155	155	155	234	234	563	563	563	563	686	1024	1024	1627	1627	1964	1964	2850
A	STEAM SPACE	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
B	WATER INLET MOTORIZED VALVE	½	½	½	½	½	½	¾	¾	¾	1	1	1	1	1¼	1¼	1¼	1¼
C	STEAM INLET	3	3	3	3	3	6	6	6	6	6	8	8	8	10	10	N/A	10
D	OVERFLOW	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	4
E	HIGH TEMP RETURNS	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	~~1½~~	1½	1½	1½	2½	2½
F	LOW TEMP RETURNS	1	1	1	1	1½	2	2	2½	2½	2½	2½	~~2½~~	3	3	3	4 N/A	4
G	MEDIUM TEMP RETURNS	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	~~1½~~	2	2	2	2½	2½
H	VENT	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	1½	1½	1½	1½	1½	2	2
J	VESSEL DRAIN	¾	¾	¾	¾	¾	1	1	1	1	1	2	2	2	2	2	2½	2½
K	SCRUBBER DRAIN	—	—	—	—	—	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾
L	DIAMETER	36	36	36	36	36	48	48	48	48	48	60	60	72	72	72	72	84
M	STRAIGHT LENGTH	60	60	60	96	96	96	96	96	96	120	96	96	96	96	120	120	120
N	(APPROX)	78	78	78	114	114	117	117	117	117	147	128	128	130	130	154	154	156
P		20	20	20	20	20	30	30	30	30	30	33	33	33	33	36	36	36
R		9	9	9	9	9	9	9	9	9	9	15	15	15	15	18	18	18
S		31	31	31	45	45	18	18	18	18	30	21	21	21	21	30	30	24
T	(APPROX)	14	14	14	14	14	14	14	14	14	14	19	19	19	19	19	19	22
U	STAND LENGTH	58	58	58	60	60	78	78	78	78	84	84	84	84	84	96	96	96
V	STAND WIDTH	30½	30½	30½	30½	30½	44	44	44	44	44	56	56	66	66	66	66	66
W	(APPROX)	33	33	33	33	33	39	39	39	39	39	45	45	51	51	51	51	57
X	RECIRC	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	2	2
Y	SENTINE RELIEF VALVE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Z	VACUUM BREAKER	1½	1½	1½	1½	1½	2	2	2	2	2	2½	2½	2½	2½	3	3	3
AA	CHEMICAL INJECTION	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼
AB	SAMPLE	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾
AC	PUMP SUCTION	3	3	3	3	3	4	4	4	4	4	6	6	6	6	6	8	8
AD	PRV SENSING	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾
AE	OVERFLOW TRAP	1½	1½	2	2	2	2	2	2	2	2	2	3	3	3	3	3	4
AF	VENT ORFICE	1/8	1/8	1/8	1/8	1/8	¼	¼	¼	¼	¼	¼	¼	5/16	5/16	5/16	5/16	5/16
AG	MAKE-UP WATER INLET	1½	1½	1½	2½	2½	2½	2½	2½	2½	2½	2½	2½	2½	3	3	3	4

BFS INDUSTRIES, LLC
BUTNER, NORTH CAROLINA

3.5MS THRU 125MS CLASS "s" DIMENSIONS
PACKAGED SPRAY TYPE DEAERATOR

FIGURE 7.3 (continued)
Deaerator package selection example/procedure. (Downloaded from the Internet from BFS Industries, LLC Publications, Deaerator Dimensions Class "S," Catalog Section BF 6.3 S, p. 1 (two letter-size sheets). Used with permission from BFS Industries, LLC. www.bfs-ind.com.)

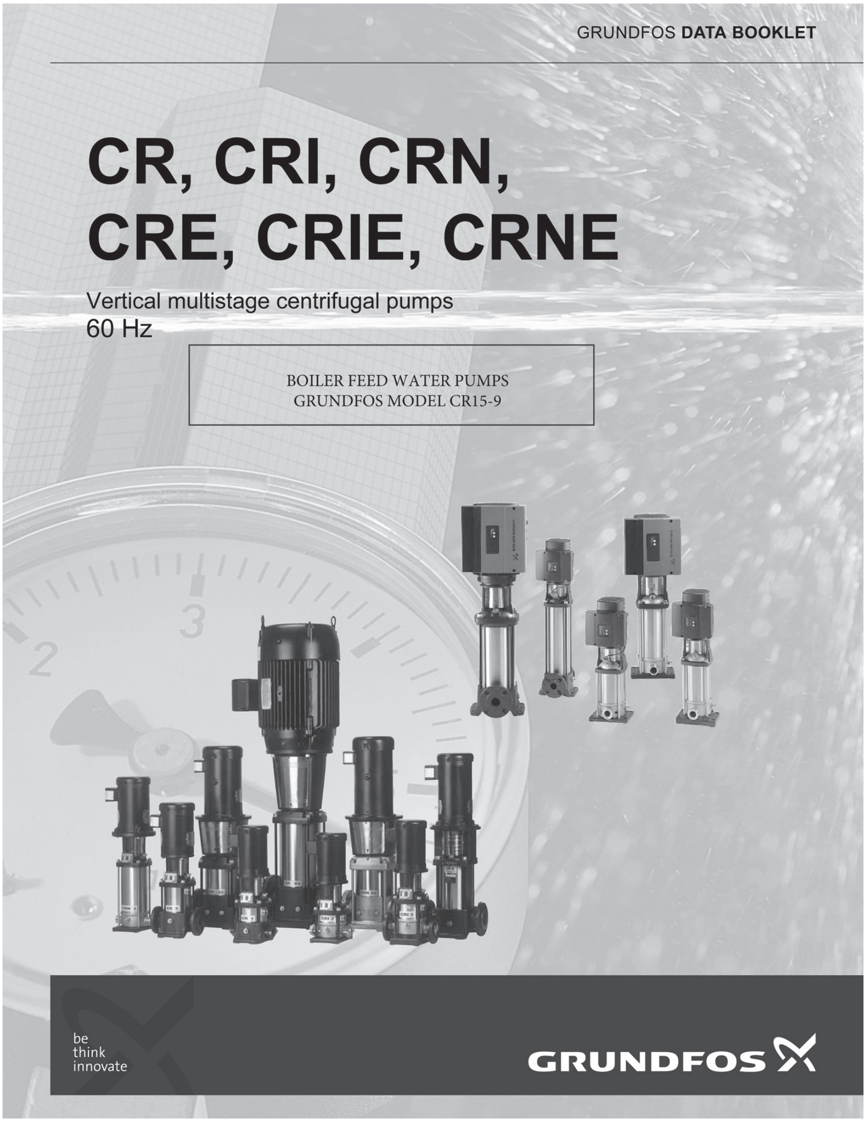


FIGURE 7.3 (continued)
Boiler feed water pump selection example/procedure. (Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.) *(continued)*

BOILER FEED WATER
PUMP CR 15-9

Product range

Range	**CR 1s**	**CR 1**	**CR 3**	**CR 5**	**CR 10**	**CR 15**	**CR 20**
Nominal flow rate [US gpm]	4.5	8.5	15	30	55	95	110
Temperature range [°F]				–4 to +250			
Temperature range [°F] – on request				–40 to +356			
Max. working pressure [psi]	362	362	362	362	362	362	362
Max. working pressure [psi] – on request	-	725	725	725	725	725	725
Max. pump efficiency [%]	35	49	59	67	70	72	72
CR pumps							
CR: Flow range [US gpm]	0.5-5.7	1 - 12.8	1.5 - 23.8	3 - 45	5.5 - 70	9.5 - 125	11-155
CR: Max. pump pressure (H [ft])	760	790	790	780	820	800	700
CR: Motor power [Hp]	.33 - 2	.33 - 3	.33 - 5	.75 - 7.5	.75 - 15	2 - 25	3-25
CRE pumps							
CRE: Flow range [US gpm]	-	0 - 12.8	0 - 23.8	0 - 45	0 - 70	0 - 125	0-155
CRE: Max. pump pressure (H [ft])	-	790	790	780	820	800	700
CRE: Motor power [Hp]	-	.33 - 3	.33 - 5	.75 - 7.5	.75 - 15	2 - 25	3-25
Version							
CR, CRE: Cast iron and stainless steel AISI 304	•	•	•	•	•	•	•
CRI, CRIE: Stainless steel AISI 304	•	•	•	•	•	•	•
CRI, CRIE: Stainless steel AISI 316	•	•	•	•	•	•	•
CRN, CRNE: Titanium	-	See CRT, CRTE product guide					-
CR, CRE pipe connection							
Oval flange (NPT).	1”	1”	1”	1.25”	2”	2”	2”
Oval flange (NPT) - on request	1.25”	1.25”	1.25”	1”	1.5”	-	-
ANSI flange size	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
ANSI flange size - on request	-	-	-	-	-	-	-
ANSI flange class	250 lb.	250 lb.	250 lb.	250 lb.	250 lb.	250 lb.	250 lb.
CRI, CRIE pipe connection							
Oval flange (NPT).	1”	1”	1”	1.25”	2”	2”	2”
Oval flange (NPT) - on request	1.25”	1.25”	1.25”	1”	1.5”	-	-
ANSI flange size	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
ANSI flange class	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.
Clamp coupling (NPT) - on request	1”, 1.25”	1”, 1.25”	1”, 1.25”	1”, 1.25”	1.5”, 2”	1.5”, 2”	1.5” 2”
Union (NPT ext. Thread) - on request	2”	2”	2”	2”	-	-	-
CRN, CRNE pipe connection							
PJE (Victaulic)	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
PJE (Victaulic) - on request	-	-	-	-	-	-	-
ANSI flange size	1.25”	1.25”	1.25”	1.25”	2”	2”	2”
ANSI flange size - on request	-	-	-	-	-	-	-
ANSI flange class	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.	300 lb.
Clamp coupling (NPT) - on request	1”, 1.25”	1”, 1.25”	1”, 1.25”	1”, 1.25”	1.5”, 2”	1.5”, 2”	1.5”, 2”
Union (NPT ext. Thread) - on request	2”	2”	2”	2”	-	-	-
CRT pipe connection							
PJE coupling (Vitaulic)	-	- 1.25”	1.25”	1.25”	2”	2”	-
ANSI flange size - on request	-	-	-	-	2”	2”	-

• Available

FIGURE 7.3 (continued)
Boiler feed water pump selection example/procedure. (Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.) *(continued)*

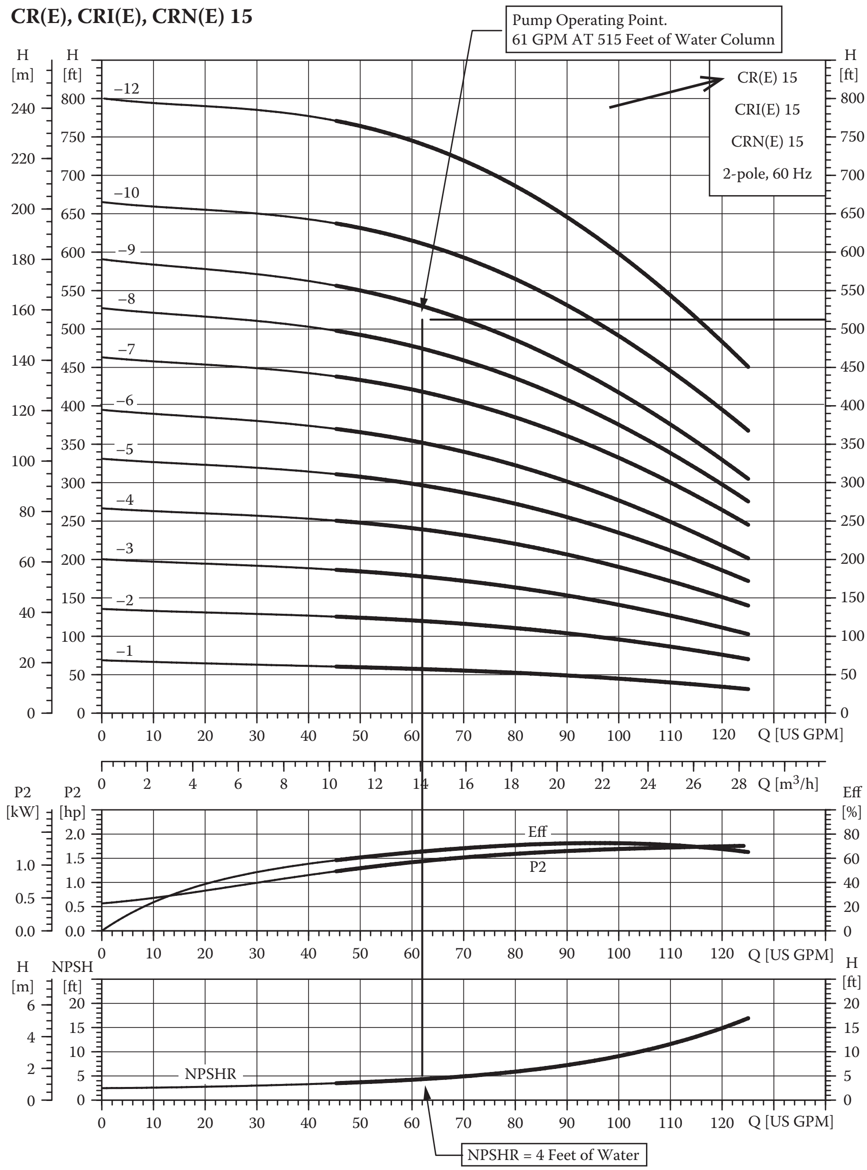
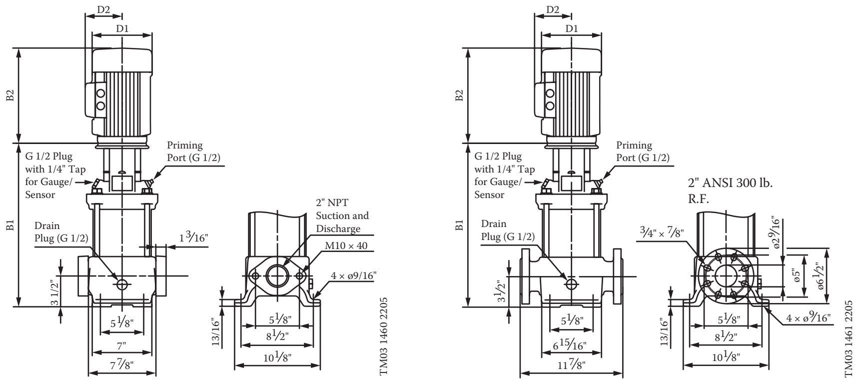


FIGURE 7.3 (continued)
Boiler feed water pump selection example/procedure. (Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.) *(continued)*

BOILER FEED WATER PUMPS MODEL CR15-9, 20 HP, 3 PHASE, 460 V, 60 HZ

Boiler Feed Water Pumps Model
CR15-9, 20 HP, 3 PHASE, 460 V, 60 HZ



				ANSI dimensions [inch]								ANSI dimensions [inch]			
					TEFC			ODP			Ship Wt. [lbs.]	MLE			Ship Wt. [lbs.]
Pump type	P2 [hp]	Ph.	Oval*	B1	D1	D2	B1+B2	D1	D2	B1+B2		D1	D2	B1+B2	
CR(E) 15-1	2	1	•	16.46	7.19	5.73	29.02	-	-	-	139	-	-	-	-
		3	•	16.46	7.01	4.33	27.68	-	-	-	128	7.01	6.57	29.26	141
CR(E) 15-2	5	1	•	17.20	10.62	7.46	32.72	-	-	-	205	-	-	-	-
		3	•	17.20	8.66	5.28	32.71	-	-	-	201	8.66	7.40	30.00	194
CR(E) 15-3	7 1/2	1	•	19.29	10.22	7.62	34.82	-	-	-	223	-	-	-	-
		3	•	19.29	8.66	5.28	34.80	-	-	-	212	8.66	7.40	19.29	206
CR(E) 15-4	7 1/2	1	•	21.06	10.22	7.62	36.59	-	-	-	225	-	-	-	-
		3	•	21.06	8.66	5.28	36.57	-	-	-	214	8.66	7.40	34.37	227
CR(E) 15-5	10	1	•	22.83	10.23	10.30	38.90	-	-	-	342	-	-	-	-
		3	•	22.83	8.66	5.28	38.34	-	-	-	218	10.24	8.39	22.83	238
CR(E) 15-6	15	3	-	27.17	10.22	8.67	43.75	10.62	7.33	43.48	376	13.39	12.13	45.95	402
CR 15-7	15	3	-	28.94	10.22	8.67	45.52	10.62	7.33	45.25	407	-	-	-	-
CR(E) 15-8	15	3	-	30.71	10.22	8.67	47.29	10.62	7.33	47.02	438	13.39	12.13	49.49	504
CR 15-9	20	3	-	32.48	10.22	8.67	49.06	11.50	8.92	52.17	446	-	-	-	-
CR(E) 15-10	20	3	-	34.25	10.22	8.67	50.83	11.50	8.92	53.94	450	13.39	12.13	53.03	517
CR(E) 15-12	25	3	-	37.17	12.94	11.52	56.99	11.50	8.94	57.98	505	13.39	12.13	59.89	552

All dimensions in inches unless otherwise noted.
*Oval flanged pump B1 and B1+B2 dimension is equal to ANSI flanged pumps and weight is approximately 3 lbs. less.
• Available.

FIGURE 7.3 (continued)
Boiler feed water pump selection example/procedure. (Downloaded from the Internet from Grundfos Data Booklet CR, CRI, CRN, Vertical Multistage Centrifugal Pumps, 60 Hz, Grundfos Literature 1847. Used with permission from Grundfos Corporation. www.grundfos.com.)

Water Softener

A Cleaver-Brooks twin alternating water softener model FMR 90M is selected for our sample project. The package includes two columns (duplex type) of media, one in service and one in regeneration, for continuous operation. The package is prepiped and prewired for controlling the media column alternation based on the measured total water volume through the column.

The package capacity is 90,000 grains (5,832 g) at a 31 gpm (115 L/min) nominal flow rate per media column. Our sample project requirement is to soften 29 gpm (110 L/min) of water and remove approximately 83,520 grains (5,412 g) of hardness per every 8 h.

The water softener package has the following features:

1. The package overall dimensions: 38 in. × 18 in. × 65 in. tall (965 mm × 457 mm × 1,651 mm tall).
2. Mineral/media tanks: Two fiberglass (FRP) tanks, each 14 in. (356 mm) in diameter × 65 in. (1,650 mm) tall.
3. Salt tank: One plastic tank, 18 in. (257 mm) in diameter × 40 in. (1,016 mm) tall.
4. Additional features: Control valve package for each media tank with demand base alternating controls, all prepiped and prewired.
5. Water softener bypass will be installed at the field by others.
6. Package inlet and outlet pipe sizes: 1 in. (25 mm).
7. Water pressure drop through the water softener: 15 psi (1.03 bar).
8. Acceptable incoming water temperature: 30 to 100°F (1 to 38°C).
9. Acceptable incoming water pressure: 30 to 120 psig (2.06 to 8.3 barg).

At its full flow rate, the package with 90,000 grains (5,832 g) capacity, will regenerate once every 8 h, requiring a maximum of 45 lb (20 kg) of salt. With salt storage capacity of 270 lb (122 kg), the maximum salt refill period will be once every 2 days.

The required power feed to the package is approximately 2 amps at 110 V, single phase, 60 Hz.

See additional manufacturer literature in Figure 7.4 for the selected water softener. The information is included with permission from Cleaver-Brooks, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer’s website is www.cleaver-brooks.com.

FMR 15M–120M SXT 3/4”-1” TWIN ALTERNATING METERED
SYSTEM INFORMATION

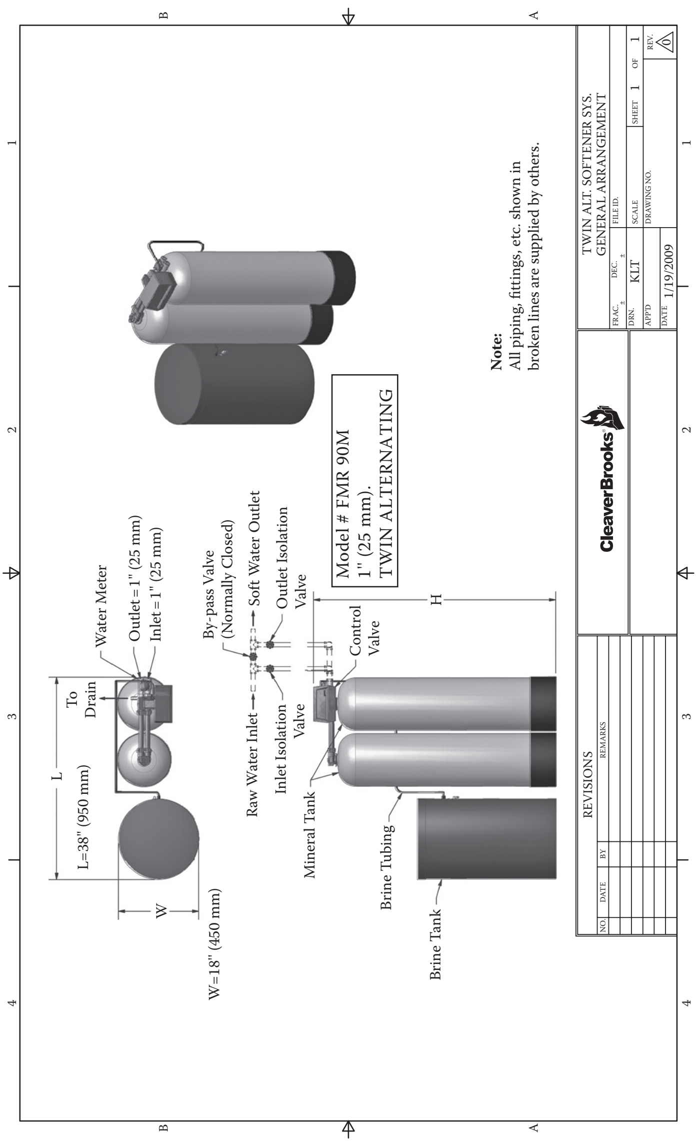


FIGURE 7.4
Water softener selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Installation, Operation, and Maintenance Manual, FMR 15M-120M, 9100-Twin Alternating Metered, 3/4”–1”, SXT Series, Commercial Water Conditioners. Used with permission from Cleaver-Brooks, Inc. www.cleaver-brooks.com.) *(continued)*

CleaverBrooks

FMR 15M–120M SXT 3/4”-1” TWIN ALTERNATING METERED
SYSTEM INFORMATION

DIMENSION CHART

MODEL	INLET SIZE (Inches)	TANK SIZE SOFTENER (Inches)	TANK SIZE BRINE (Inches)	LENGTH (Inches)	WIDTH (Inches)	HEIGHT* (Inches)
15	3/4	7×44	18×33	38	18	52
22	3/4	8×44	18×33	40	18	52
30	3/4 or 1	9×48	18×33	42	18	48
45	3/4 or 1	10×54	18×40	45	18	62
60	3/4 or 1	12×52	18×40	36	18	65
90	1	14×65	18×40	38	18	78
120	1	16×65	24×40	46	25	78

*Leave a minimum 24 inch clearance to the height of the unit for loading media.
Dimensions are for general arrangement use only.

Model # FMR 90M
1 in. (25 mm), TWIN
ALTERNATING

FIGURE 7.4 (continued)
Water softener selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Installation, Operation, and Maintenance Manual, FMR 15M-120M, 9100-Twin Alternating Metered, 3/4″–1″, SXT Series, Commercial Water Conditioners. Used with permission from Cleaver-Brooks, Inc. www.cleaver-brooks.com.) *(continued)*

CleaverBrooks

FMR 15M–120M SXT 3/4"-1" TWIN ALTERNATING METERED SYSTEM INFORMATION

SPECIFICATION CHART

90,000 GRAINS

		MODE	15	22	30	45	60	90	120
SYSTEM SIZE		VALVE SIZE (IN)	3/4	3/4	3/4	3/4	1	1	1
SYSTEM SIZE		MAX CAPACITY (KILOGRAINS)	15	22	30	45	60	90	120
SYSTEM SIZE		MIN CAPACITY (KILOGRAINS)	10	15	20	30	40	60	80
FLOWRATE (GPM)		SERVICE - CONTINUOUS (GPM)	12	13	14	13	28	31	34
FLOWRATE (GPM)		SERVICE - PEAK (GPM)	16	17	19	18	39	42	46
FLOWRATE (GPM)		BACKWASH & FAST FLUSH (GPM)	1.2	1.6	2	2.4	3.5	5	6
FLOWRATE (GPM)		BRINE DRAW & RINSE (GPM)	.31	.45	.45	1	1	1	1.2
FLOWRATE (GPM)		BRINE TANK REFILL (GPM)	.25	.25	.5	1	1	1	1
TIMER SETTINGS		BACKWASH & FAST FLUSH (MIN)	10	10	10	10	10	10	10
TIMER SETTINGS		BRINE DRAW & RINSE (MIN)	60	60	60	60	60	60	60
TIMER SETTINGS		FAST FLUSH (MIN)	10	10	10	10	10	10	10
TIMER SETTINGS		BRINE TANK REFILL (MIN)	10	16	10	8	10	16	20
SOFTENER TANK		SIZE (IN)	7×44	8×44	9×48	10×54	12×52	14×65	16×65
SOFTENER TANK		GRAVEL (LBS)	0	0	0	0	0	30	35
SOFTENER TANK		RESIN (FT^3)	0.5	0.75	1	1.5	2	3	4
SOFTENER TANK		FREEBOARD (IN)	17	15	8	17	16	21	21
SOFTENER TANK		TANK SIZE	18×33	18×33	18×33	18×40	18×40	18×40	24×40
BRINE SYSTEMS	EQUIPMENT	MAX SALT STORAGE (LBS)	290	290	290	320	320	270	550
BRINE SYSTEMS	EQUIPMENT	INJECTOR CODE	0	1	3	3	3	3	4
BRINE SYSTEMS	EQUIPMENT	INJECTOR COLOR	RED	WHT	YEL	YEL	YEL	YEL	GRN
BRINE SYSTEMS	SALT	SALT DOSAGE- MAX (LBS)	7.5	11.25	15	22.5	30	45	60
BRINE SYSTEMS	SALT	SALT DOSAGE- MIN (LBS)	3	4.5	6	9	10	16	20
BRINE SYSTEMS	REFILL	REFILL TIME - MAX (MIN)	10	16	10	8	10	16	19
BRINE SYSTEMS	REFILL	REFILL TIME - MIN (MIN)	4	4	4	4	4	6	8
BRINE SYSTEMS	REGEN	REGEN PER SALT REFILL-MAX	39	26	19	14	10	6	9
BRINE SYSTEMS	REGEN	REGEN PER SALT REFILL-MIN	97	64	48	36	26	15	23
BRINE SYSTEMS	REGEN	REGENERATION WASTE VOLUME (GAL)	40	52	64	116	126	156	188

SPECIFICATION NOTES

Maximum salting is 15 pounds of salt per cubic foot of resin.
Minimum salting is 6 pounds of salt per cubic foot of resin.

The regeneration timer is setup for maximum salting at the factory.
The Timer Settings are factory set and user adjustable.

On continuous flow rates pressure loss does not exceed 15 psig.
On peak flow rates pressure loss does not exceed 30 psig.

Minimum operating pressure is 30 psi.
Maximum operating pressure is 120 psi.

Standard units are designed to soften unheated water within the range of 35-100°F.
Power requirements are 120 Volt, 60 Hertz, Single Phase, 2 amps non-interrupted.

Freeboard is the distance between the surface of the resin and the top of the tank.
Salt specifications are pelletized or solar salt, 99% pure, containing less than 1% insolubles.

FIGURE 7.4 (continued)
Water softener selection example/procedure. (Downloaded from the Internet from Cleaver-Brooks Installation, Operation, and Maintenance Manual, FMR 15M-120M, 9100-Twin Alternating Metered, 3/4″–1″, SXT Series, Commercial Water Conditioners. Used with permission from Cleaver-Brooks, Inc. www.cleaver-brooks.com.)

Blowdown Separator

A Penn Separator model A56B blowdown separator is selected for our sample project. The blowdown separator has a 2 in. (50 mm) inlet connection, the same as the boiler blowoff valve size.

The blowdown separator has the following features:

1. Material of construction: Carbon steel separator, ASME stamped to 250 psig (17.2 barg) at 450°F (232°C).
2. Mounting type: Three legs for floor mounting.
3. Vent size: 6 in. (150 mm).
4. Drain size: 5 in. (125 mm).
5. Cooling valve and line size: 2 in. (50 mm).
6. Connections type: Flanged.
7. Physical dimensions: 14 in. (360 mm) in diameter and 56 in. (1,422 mm) tall. The height does not include the cooling section and the after-cooler fitting.
8. Additional features: The unit comes with a cooling section complete with a cooling water line strainer, self-contained temperature control valve with capillary tube and bulb, temperature indicator on the drain line, after-cooler fitting, etc., to cool the boiler blowoff and blowdown water to a minimum of 140°F (60°C) using city water at 60°F (15.5°C) and 50 psig (3.45 barg) pressure.

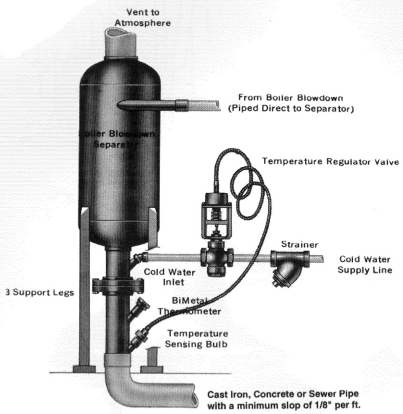
The blowdown separator is selected for one boiler operation, assuming boilers' blowoff will not happen at the same time.

See additional manufacturer literature in Figure 7.5 for the selected blowdown separator. The information is included with permission from Penn Separator Corporation for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.pennseparator.com.

FIGURE 7.5
Blowdown separator selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation literature library Bulletin BD-1105 and Bulletin BD-8-98-6S. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*

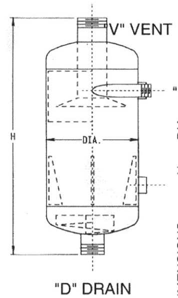


Check

TYPICAL INSTALLATION

This drawing shows a typical installation of a Blowdown Separator packaged with Accessories for automatic cooling of blowdown to drain or sewer. This includes a Blowdown Separator Model A34B, Three Angle Leg Supports, a Model 18DF Automatic Aftercooler Fitting, Self Actuating Temperature Regulator Valve, Strainer, and Bi-Metal Thermometer. In place of the accessories shown, you may select the desired accessories to obtain a complete package designed to your own specific needs.

DIMENSIONS



DIMENSIONS	H	DIA.
MODEL A14B	21	10
MODEL A20B	22	14
MODEL A34B	34	14
MODEL A56B	56	14

SUGGESTED SPECIFICATIONS

Blowdown Separator

Furnish and install as shown on plans:
(   ) Boiler Blow-Down Separator(s). Model________" Height________" Inlet________" Drain______" Vent .... Select Plate Thickness 5/16" or 3/8" thk..........ASME Code 250 psig @ 450 Deg. F...........w/Screwed, Weld Bevel, or Flanged connections. Separator to have Stainless Steel Striking Plate at point of inlet impingement, as manufactured by Penn Separator Corp., Brookville, PA.

Separator Accessories

Furnish and install a Penn Separator w/3 Angle Legs for Floor Mounting (   ) or Wall Brackets (   ).

AND

Furnish and install as shown on plans for Manual Cooling of Drain Water Temperature Penn Separator Aftercooler Model A5D-______"w/______"C.W.I. (cold water inlet)

OR

Furnish and install as shown on plans for Automatic Control of Drain Water Temperature Penn Separator Aftercooler Model 18DF______ ", 16DS ______", or 20AO______" w/ ______" C.W.I., a Temperature Regulator Valve, Strainer, and 2" Dial Bimetal Thermometer.

Penn
SEPARATOR CORPORATION
P.O. Box 340 • Brookville, PA 15825
Tel. (814) 849-7328 • Fax (814) 849-4510

REPRESENTED BY:

Bulletin BD-1105

FIGURE 7.5 (continued)
Blowdown separator selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation literature library Bulletin BD-1105 and Bulletin BD-8-98-6S. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*

Penn BLOWDOWN SEPARATOR

SELECTOR CHART

USING CHART A

1. Select Separator Size from Chart "A" below by matching your Operating Pressure and Bottom Blowdown Valve Size. The largest size valve and highest pressure should be used for multiple boilers.
2. From Chart "A" read the height "H" of the separator, "I" the inlet size to match blowdown valve size, "D" the drain and "V" atmospheric steam vent recommended sizes. All connections come standard as NPT. Flanges are optional.
3. All Separators are 14" diameter and are ASME Code "UM" designed and stamped for 250 psig at 450 deg. F. Select plate thickness of 5/16" or 3/8" as local regulations require. Add for National Board "U" Stamping when required. Flanged units are limited in pressure to flange rating and would be stamped accordingly.
4. The separator size is now determined and the piping can follow these sizes. Separators are designed to quietly exhaust steam to atmosphere at 90 dB(A) or less and operate at a pressure of less than 5 psig. Drain sizing includes cooling water required for 140 deg. F. drain temperature. Select cooling valve size from chart "B" below.

CHART A — BOILER BLOWDOWN SEPARATORS

Blowdown Valve Size	*1"				1-1/4"				1-1/2"				2"				2-1/2"				3"			
Separator Dimensions / Boiler Oper. Pressure	H	I	D	V	H	I	D	V	H	I	D	V	H	I	D	V	H	I	D	V	H	I	D	V
0-15	14	1	2	2-1/2	20	1-1/4	3	4	20	1-1/2	3	4	20	2	4	5	34	2-1/2	5	6	34	3	6	5
16-50	20	1	2	2-1/2	20	1-1/4	3	4	34	1-1/2	3	4	34	2	4	5	34	2-1/2	5	6	34	3	6	5
51-100	20	1	3	2-1/2	34	1-1/4	4	4	34	1-1/2	4	4	34	2	5	5	34	2-1/2	6	6	34	3	8	6
101-125	34	1	3	3	34	1-1/4	4	4	34	1-1/2	4	4	34	2	5	5	56	2-1/2	6	6				
126-150	34	1	3	3	34	1-1/4	4	4	34	1-1/2	4	5	56	2	5	6	56	2-1/2	6	6				
151-175	34	1	3	4	34	1-1/4	4	4	34	1-1/2	4	5	56	2	5	6	56	2-1/2	6	8				
176-200	34	1	3	4	34	1-1/4	4	5	56	1-1/2	5	5	56	2	6	6	56	2-1/2	6	8				
201-225	34	1	4	4	56	1-1/4	4	5	56	1-1/2	5	5	56	2	6	6	56	2-1/2	8	8				
226-300	56	1	4	4	56	1-1/4	4	5	56	1-1/2	5	6	56	2	6	8	56	2-1/2	8	8				

* Miniature Boilers: 1/2"-1" Blowdown Valve up to 1000#/hr Blowdown use 14" High, 1" Inlet, 2" Drain, 2-1/2" Vent.
For Boilers above 300 PSIG see Selector Chart H.

CHART B — COOLING WATER LINE AND VALVE SIZE

	Separator Inlet Size	1"			1-1/4"			1-1/2"			2"			2-1/2"			3"		
	Cooling Water Pressure (PSI) / Boiler Oper. Pressure	40#	50#	60#	40#	50#	60#	40#	50#	60#	40#	50#	60#	40#	50#	60#	40#	50#	60#
	0-50	1/2	1/2	1/2	1	1	1	1-1/4	1	1	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/2	2	2	2
Use For	51-100	1	3/4	3/4	1	1	1	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	2	2-1/2	2-1/2	2-1/2
50-70° F	101-125	1	3/4	3/4	1-1/4	1	1	1-1/4	1-1/4	1-1/4	2	2	1-1/2	2	2	2	2-1/2	2-1/2	2-1/2
Cooling	126-175	1	1	1	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	2	2	2	2-1/2	2-1/2	2	2-1/2	2-1/2	2-1/2
Water	176-225	1	1	1	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	2	2-1/2	2-1/2	2	3	3	2-1/2
Temp.	226-250	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	2	2-1/2	2-1/2	2	3	3	2-1/2
	251-300	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	2	2-1/2	2-1/2	2-1/2	3	3	3
	0-50	3/4	1/2	1/2	1	1	1	1-1/4	1	1	1-1/4	1-1/4	1-1/4	2	2	1-1/2	2-1/2	2-1/2	2
	51-100	1	3/4	3/4	1-1/4	1	1	1-1/4	1-1/4	1-1/4	2	2	1-1/2	2	2	2	2-1/2	2-1/2	2-1/2
Use For	101-125	1	1	1	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	2	2	2	2-1/2	2-1/2	2	2-1/2	2-1/2	2-1/2
71-80° F	126-175	1	1	1	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	2	2-1/2	2-1/2	2	3	3	2-1/2
Cooling	176-225	1	1	1	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	2	2-1/2	2-1/2	2-1/2	4	3	3
Water	226-250	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2-1/2	2-1/2	2	2-1/2	2-1/2	2-1/2	4	4	3
Temp.	251-300	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/4	2	2	1-1/2	2-1/2	2-1/2	2	2-1/2	2-1/2	2-1/2	4	4	3

USING CHART B

1. Depending upon the temperature of the cooling water used, locate the section of the chart which applies, 50-70° or 71-80° F.
2. At the top of the chart locate Separator inlet size and in left column under the section selected in step one, locate Boiler Operating Pressure. You now have a selection of three valve sizes.
3. From the top of chart select the cooling water line pressure, either 40, 50 or 60 and read the desired valve and line size.
4. A pressure reducing valve should be used prior to temp regulator for cooling water above 60 PSIG.

CHART C — SAFETY/RELIEF VALVE SEPARATORS

Set Pressure Valves (PSI)	0-49#			50-99#			100-150#			151-200#			201-250#			251-350#			351-400#		
Separator Dimensions / Boiler MBH	H	D	V	H	D	V	H	D	V	H	D	V	H	D	V	H	D	V	H	D	V
0-500	14	1-1/2	3	14	1-1/2	3	14	1-1/2	3	14	1-1/2	3	14	1-1/2	3	14	1-1/2	3	14	1-1/2	3
501-670	14	2	3	14	2	3	14	2	3	14	2	3	14	2	3	14	2	3	14	2	3
671-1005	14	2	3	14	2	3	14	2	3	14	2	3	14	2	3	14	2	3	14	2	3
1006-1340	14	2-1/2	3	14	2-1/2	3	14	2-1/2	3	14	2-1/2	3	14	2-1/2	3	14	2-1/2	3	14	2-1/2	3
1341-1675	14	3	3	14	3	3	14	3	3	14	3	3	14	3	3	14	2-1/2	3	14	2-1/2	3
1676-2010	14	3	3	14	3	3	14	3	3	14	3	3	14	3	3	20	3	4	20	3	4
2011-2345	20	3	4	20	3	4	20	3	4	20	3	4	20	3	4	20	3	4	20	3	4
2346-2680	20	3	4	20	3	4	20	3	4	20	3	4	20	3	4	20	3	4	20	3	4
2681-3350	20	4	4	20	4	4	20	4	4	20	4	4	20	3	4	20	3	4	20	3	4
3351-4185	20	4	5	20	4	5	20	4	5	20	4	5	20	4	5	20	4	5	20	4	5
4186-5025	20	4	5	20	4	5	20	4	5	20	4	5	20	4	5	20	4	5	20	4	5
5026-6695	20	5	5	20	5	5	20	5	5	20	4	5	20	4	5	20	4	5	20	4	5
6696-8370	20	5	5	20	5	5	20	5	5	20	5	5	34	5	6	34	5	6	34	5	6
8371-10045	34	5	6	34	5	6	34	5	6	34	5	6	34	5	6	34	5	6	34	5	6
10046-11720	34	6	6	34	6	6	34	6	6	34	6	6	34	5	6	34	5	6	34	5	8
11721-13400	34	6	6	34	6	6	34	6	8	34	6	8	34	6	8	34	6	8	34	6	8
13401-16740	34	6	8	34	6	8	34	6	8	34	6	8	34	6	8	34	6	8	34	6	8
16741-20080	34	8	8	34	8	8	34	8	8	34	8	8	34	6	8	34	6	8	34	6	8

USING CHART C

1. Use Set Pressure of Valves and Boiler MBH or BHP x 33.3 to determine *Sep. "H"eight, "D"rain and "V"ent Size.*
2. *Separator Inlet Size* is determined by Relief Valve, Outlet Size. When two or more valves are manifolded together, the Inlet size must be larger than the combined Cross Sectional area of the Valves' Outlets (See Chart C_1).
3. *Separator Diameter* is 14" except:
   16" diameter when Inlet is 4" and Vent is 5" or larger
   18" diameter when Inlet is 5" and Vent is 5" or larger
4. *Plate Thickness* 5/16" or 3/8" as required by Local Regulations. All Separators are constructed to ASME Code.

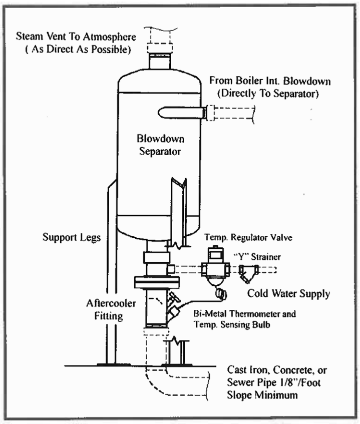
CHART C_1 INLET AREAS

Relief Valve Outlet and Separator Inlet	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	4"	6"
Area Square Inches	.533	.864	1.495	2.036	3.355	4.788	7.393	12.730	28.891

For Example: Two Relief Valves 1-1/2" and 2" (2.036 + 3.355 = 5.39) Separator Inlet 3" (7.393). When combined area is greater than 6" Inlet, use Individual Separators.

A2

FIGURE 7.5 (continued)
Blowdown separator selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation literature library Bulletin BD-1105 and Bulletin BD-8-98-6S. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*



Typical Installation

Shown is a typical installation of a Blowdown Separator with Accessories. This package is shown with a A34B Separator, A18DF drain automatic aftercooler fitting with self actuating temperature regulator valve, for automatic cooling of blowdown to the drain to 140 deg. F., strainer, bi-metal thermometer to show the drain temperature, and three angle legs to lift the separator off the floor. Length is determined for each size of drain and aftercooler.

Four different separators and aftercooler packages are available all sized to calculated blowdown flows depending on the size of blowdown valve and operating pressure. Once the separator is selected no further sizing is needed and the connections can follow the sizes provided.

Other Available Accessories include wall brackets instead of angle legs, solenoid valve with aquastat instead of self actuating valve, pressure gauge with siphon, vent exhaust head, cooling water check valve and pressure reducing valve. You can choose the desired accessories from the front side to select the package for your own specific needs.

CHART B - Cooling Water and Valve Size

		BLOWDOWN VALVE SIZES														
		1"			1 1/4"			1 1/2"			2"			2 1/2"		
	PRESSURES	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
50-70 Deg. F Cooling Water	0-50	1/2	1/2	1/2	1	1	1	1 1/4	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2
	51-100	1	3/4	3/4	1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	2
	101-125	1	3/4	3/4	1 1/4	1	1	1 1/4	1 1/4	1 1/4	2	2	1 1/2	2	2	2
	126-175	1	1	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	2	2	2	2 1/2	2 1/2	2
	176-225	1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	2	2 1/2	2 1/2	2
	226-250	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	2	2 1/2	2 1/2	2
	251-300	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	2	2 1/2	2 1/2	2 1/2

		BLOWDOWN VALVE SIZES														
		1"			1 1/4"			1 1/2"			2"			2 1/2"		
	PRESSURES	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
71-80 Deg. F Cooling Water	0-50	3/4	1/2	1/2	1	1	1	1 1/4	1	1	1 1/4	1 1/4	1 1/4	2	2	1 1/2
	51-100	1	3/4	3/4	1 1/4	1	1	1 1/4	1 1/4	1 1/4	2	2	1 1/2	2	2	2
	101-125	1	1	3/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	2	2	2	2 1/2	2 1/2	2
	126-175	1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	2	2 1/2	2 1/2	2
	176-225	1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	2	2 1/2	2 1/2	2 1/2
	226-250	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2 1/2	2 1/2	2	2 1/2	2 1/2	2 1/2
	251-300	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	2	2	1 1/2	2 1/2	2 1/2	2	2 1/2	2 1/2	2 1/2

Instructions for Using Chart B

Step 1: Select the chart for the cooling water temperature available 50-70 or 71-80 deg. F.

Step 2: From this chart the blowdown valve size along the top and the boiler pressure listed vertically on the chart should be determined. You now have three valve sizes shown.

Step 3: With these three sizes the valve listed under the cooling water pressure available is the recommended size.

FIGURE 7.5 (continued)
Blowdown separator selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation literature library Bulletin BD-1105 and Bulletin BD-8-98-6S. Used with permission from Penn Separator Corporation. www.pennseparator.com.)

Boiler Stack

Double-wall 316 stainless steel (inner and outer pipes), model IPSC1 boiler stack, as manufactured by Selkirk Corporation, is selected for our sample project. The inner pipe is 20 gauge and the outer pipe is 24 gauge.

The boiler stack will connect to the boiler flue gas discharge connection and will extend up through the roof to the outside. Unless a higher termination point is required by the applicable codes, the boiler stack will terminate at least 10 ft (3.05 m) above the roof.

The boiler stack inner pipe diameter is 24 in. (610 mm). There is 1 in. (25 mm) ceramic fiber insulation between the boiler stack's two walls to minimize the heat transfer and the surface temperature. According to the manufacturer literature (see the following pages), assuming a boiler room temperature of 110°F (43°C) and a boiler flue gas temperature of 510°F (265°C), the boiler stack surface temperature will be approximately 175°F (80°C).

In addition to the straight sections of boiler stack pipe, the boiler stack requires additional fittings and parts for supports, turns, penetration through the roof, expansion and contraction, and protection from the rain. These components are unique for each installation. Several of these fittings and parts are indicated in the following pages.

The applicable codes must be consulted for boiler stack penetration through the roof. The boiler stack is considered a hot vent, and depending on the roof materials, a minimum clearance is required between the boiler stack and the roof opening edges.

Usually the boiler stack can be supported from the boiler on its flue gas flange connection. However, the boiler stack weight and the boiler supporting capability must be verified since the boiler stack height, stack configuration, and type of roof penetration are different for each installation.

See additional manufacturer literature in Figure 7.6 for the selected boiler stack. The information is included with permission from Selkirk Corporation for educational purposes only.

Consult with the manufacturer for additional guidance for boiler stack support, layout, roof penetration, and rain protection.

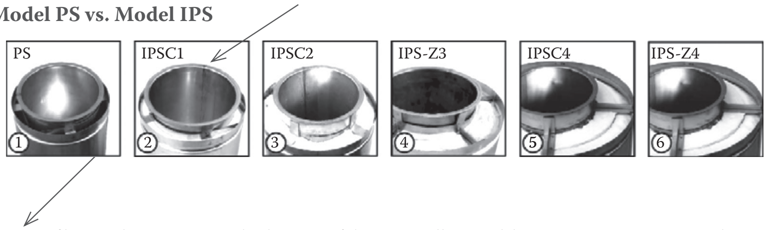
The manufacturer's website is www.selkirkcommercial.com.

Boiler stack

FIGURE 7.6
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

PRODUCT IDENTIFICATION

Model PS vs. Model IPS



Ceramic fiber insulation increases the diameter of the outer wall on Models IPS-C2, IPS-Z3, IPS-C4 and IPS-Z4 pipe and fittings. Shown in this sequence is the same 8-inch diameter inner pipe. (Photo 1) Without insulation the outside diameter of the pipe is 10-inches. (Photo 2) This is also true of the same pipe with a 1-inch layer of insulation. (Photo 3) However, the same 8-inch pipe with 2-inch insulation results in an outside diameter of 12 inches. (Photo 4) Adding 3 inches of ceramic fiber insulation to the same 8-inch pipe makes the diameter of the outer wall 14 inches. (Photos 5 & 6) Adding 4 inches of ceramic fiber insulation makes the diameter of the outer wall 16 inches.

Understanding Product Codes and Part Numbers

All parts manufactured by Selkirk are identified by a series of numbers and letters which describe their makeup and function.

Here is how to interpret the Part Number designation for Model PS and IPS products.

1. It begins with the pipe or fitting's Internal Diameter (in inches) such as **8, 22, 36**, etc.
2. This is followed by the *Model* designation, **P** for air- insulated (Model PS), or **IP** for parts that are ceramic fiber insulated (Model IPSC1, C2, Z3, C4 or Z4).
3. Next, is the product's Material designation, such as **316** or **304/304**. The first item indicates the makeup of the inner liner, while the second half indicates the material content of the outer wall, if stainless. If aluminized outer, the Part Number indicates inner material only.
4. Then, following a long dash, the product's Code name is listed, such as **AG30**, **JY**, or **MVT**. If the product is air insulated, the product identification ends with this Code.

   (For Product Code listings, refer to page 2.)

5. Finally, when a product is ceramic fiber insulated, a designation is added at the end to indicate *Insulation Thickness*. **C1** means a thickness of 1 -inch; **C2**, 2-inches; **Z3**, 3-inches; and **C4/Z4**, 4-inches.

   (For comparison, see photos above.)

Thus, the Ordered Part Number for a 30-inch Adjustable Pipe, with a 6-inch I.D., made of 304 Stainless Steel inner and Aluminized Steel outer, packed with 2-inch ceramic fiber insulation, is listed:

6IP304- AG30C2*

*** Note:** For products with reduction or increaser parts, the Part Number changes as follows:

MT and JL - Diameter of Body listed in front of Model P or IP. Diameter of Snout listed in front of Code designation

Example - For a Manifold Tee with a 42" dia. Body and 30" dia. Snout:

42P304-30MT

OT and OS - Smaller diameter listed first (before Model designation) Larger diameter listed before Code designation

Example - For a Tapered Increaser with an 8" to 16"dia. Body:

8P304-160T

FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

SUPPORT/GUIDE ACCESSORIES

Angle Rings
Codes: HR & FR

Used for guiding and/or supporting horizontal installations.

Half Ring (HR)

Full Ring (FR)

Materials Available:

Painted Steel

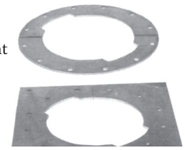
Notes:
1. Model PS part used for IPSC1 applications.

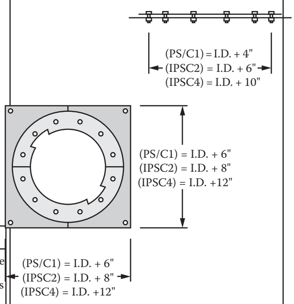
Product			Dimensions (inches) - HR				
(pipe I. D.)			Bolt Hole Circle	I.D. of Ring	No Holes-sof (HR)	Size of Angles	Angle of Holes
PS	IPSC2	IPSC4					
5	–	–	9	$7^{1}/_{8}$	6	(1)	45
6	5		10	$8^{1}/_{8}$	6	(1)	45
8	6		12	$10^{1}/_{8}$	6	(1)	45
10	8		14	$12^{1}/_{8}$	6	(1)	45
12	10	6	16	$14^{1}/_{8}$	6	(1)	45
14	12	8	18	$16^{1}/_{8}$	6	(1)	45
16	14	10	20	$18^{1}/_{8}$	6	(1)	45
18	16	12	22	$20^{1}/_{8}$	6	(1)	45
20	18	14	24	$22^{1}/_{8}$	6	(1)	45
22	20	16	26	$24^{1}/_{8}$	10	(2)	22.5
24	22	18	28	$26^{1}/_{8}$	10	(2)	22.5
26	24	20	30	$28^{1}/_{8}$	10	(2)	22.5
28	26	22	32	$30^{1}/_{8}$	10	(2)	22.5
30	28	24	34	$32^{1}/_{8}$	10	(2)	22.5
32	30	26	36	$34^{1}/_{8}$	10	(2)	22.5
–	32	28	38	$36^{1}/_{8}$	10	(2)	22.5
36	–	30	40	$38^{1}/_{8}$	10	(2)	22.5
–	36	32	42	$40^{1}/_{8}$	10	(2)	22.5
42	–	36	46	$44^{1}/_{8}$	10	(2)	22.5
–	42	–	48	$46^{1}/_{8}$	10	(2)	22.5
48	–	42	52	$50^{1}/_{8}$	10	(2)	22.5
–	48	–-	54	$62^{1}/_{8}$	10	(2)	22.5
–	–	48	58	$66^{1}/_{8}$	10	(2)	22.5

(1) Size of Angles = 1½ × 1½ × $^{3}/_{16}$
(2) Size of Angles = 2 × 2 × $^{3}/_{16}$

Plate Support Assembly
Code: PA

Used for supporting the load of the stack, and as a fixed point anchor near fittings.





Materials Available:

Painted Steel

Ordered Part Includes:

Split (square) plate, one CF, two HCB's and hardware.

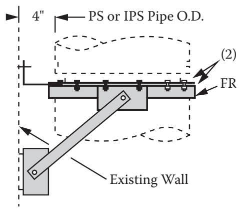
Plate Thickness:

0.188" for sizes 6" through 20" diameters
0.250" for sizes 22" through 36" diameters
0.375" for sizes 42" through 48" diameters

Notes:
1. Two 316 Stainless Steel HCB's should be ordered separately for stainless steel outer projects.
2. PA fabricated from 304 Stainless Steel is available upon request and is nonreturnable. Allow extra manufacturing time.

Wall Support Assembly
Code: WA

"Limited" support assembly with factorysupplied bracing.



Materials Available:

Painted Steel

Ordered Part Includes:

One FR, two CF's, two HCB's, five brackets, two struts, and all hardware except connection at wall.

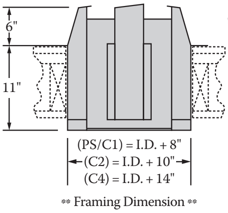
Notes:
1. Assembly will maintain a 4" clearance between pipe O.D. and supporting structure.

FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

ROOF PENETRATIONS

Ventilated Thimble
Code: THB

Body part of MVT, MRS, and PVT. Also can be used by itself for a wall penetration.



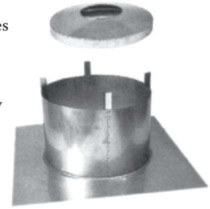
Materials Available:

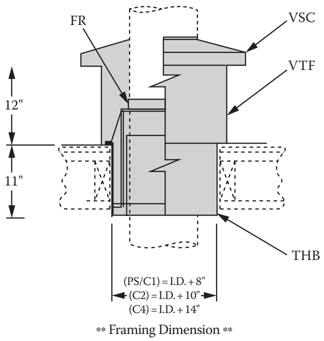
Galvanized Steel

Notes:
1. Model PS part used for IPSC1 applications.

Ventilated Roof Thimble Assembly
Code: MVT

For use where pipe passes through a combustible roof or structure. Also guides the chimney 6" above the roof line.





Materials Available (shaded areas):

Aluminized or Galvanized Steel	304	316

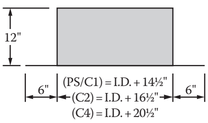
Ordered Part Includes:

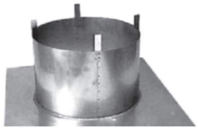
One THB, one FR, one VTF, and one VSC.

Notes:
1. Model PS part used for IPSC1 applications.

Ventilated Tall Flashing
Code: VTF

Encloses the THB, offers protection from weather and moisture penetration.





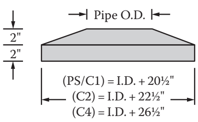
Materials Available (shaded areas):

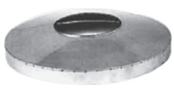
Aluminized or Galvanized Steel	304	316

Notes: 1. Model PS part used for IPSC1 applications.

Ventilated Storm Collar
Code: VSC

Protects the VTF from weather and moisture penetration.





Materials Available (shaded areas):

Aluminized or Galvanized Steel	304	316

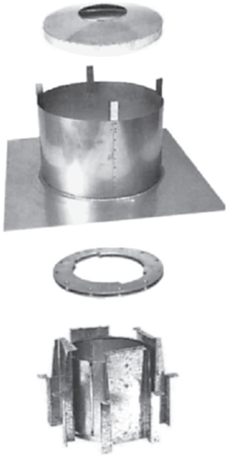
Notes: 1. Model PS part used for IPSC1 applications.

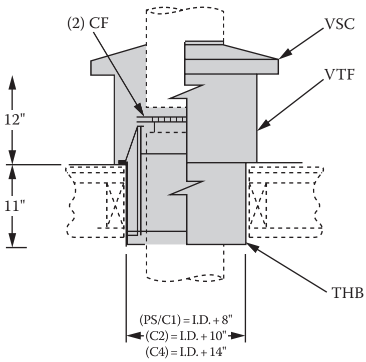
FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

ROOF PENETRATIONS

Ventilated Roof Support Assembly
Code: MRS

For use where pipe passes
through a combustible roof or
structure. Supports the chimney
6" above the roof line which
may require an expan-sion joint
(AG or BJ) below the roof.





Materials Available (shaded areas):

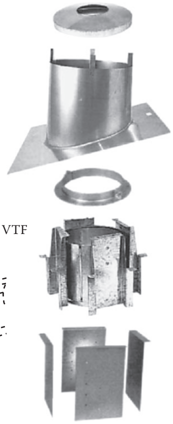
Aluminized or Galvanized Steel | 304 | 316

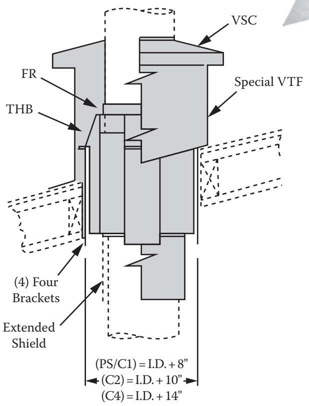
Ordered Part Includes:

One THB, two CF's, one VTF, and one VSC.

Pitched Ventilated Roof Thimble
Code: PVT

For use where pipe passes through
a combustible pitched roof or
structure. Above 24" sizes and
steep pitches are not available.





Materials Available (shaded areas):

Aluminized or Galvanized Steel | 304 | 316

Ordered Part Includes:

One THB, 4 brackets, extended shield, special VTF, one FR, and one VSC.

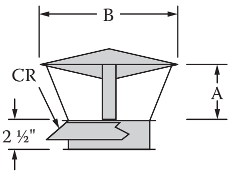
Notes:
1. Does not provide lateral support. An additional FR is required below the roof.
2. May require extra manufacturing time and is non-returnable.
3. Model PS part used for IPSC1 applications.

FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

TERMINATIONS

Stack Cap
Code: SK

Provides partial protection with low flow resistance. May require a drain at base of stack.



Materials Available (shaded areas):

304/Alum	316/Alum	304/304	316

Ordered Part Includes:

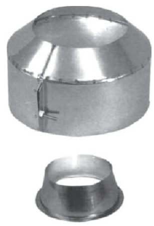
SK, plus one CR and one VB.

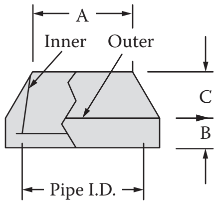
Notes:
1. Model PS part used for IPSC1 applications.
2. K = 0.5 Flow Resistance Factor

Product (pipe I. D.)	Dimensions (inches)	
PS IPSC1 IPSC2 IPSC4	A	B
5	2½	10¼
6	3	10¼
8	4	13⅝
10	5	17
12	6	20½
14	7	24
16	8	27⅜
18	9	30¾
20	10	34⅛
22	11	37⅝
24	12	41
26	13	44⅜
28	14	47⅞
30	15	51¼
32	16	54⅝
36	18	61½
42	21	71¾
48	24	82

Insulated Exit Cone
Code: EC

Will increase stack exit velocity 1½ times. Requires a drain at bottom of stack.





Materials Available (shaded areas):

304/Alum	316/Alum	304/304	316/316

Ordered Part Includes:

One inner cone, one outer finish collar, and one VB.

Notes:
1. K = 1.25 Flow Resistance Factors

Product (pipe I. D.)	Dimensions (inches)		
All Models	A	B	C
5	4⅞	4	1⅜
6	4⅞	4	1½
8	6 9/16	4	1¾
10	8 3/16	4	3⅜
12	9⅞	4	3¾
14	11½	4	24
16	13 1/16	6	4⅜
18	14¾	6	4⅝
20	16 5/16	6	5
22	18	6	5¼
24	19⅝	6	5⅝
26	21¼	6	6
28	22⅞	8	6¼
30	24½	8	6⅝
32	26⅛	8	6⅞
36	29⅜	10	7½
42	34 5/16	12	8½
48	39 3/16	12	9½

FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

TECHNICAL DATA

Material Thickness - Model PS

Air Space	Size	Inner Gauge*	Inner Material	Outer Gauge*	Outer Material
1"	5"-32"	20 20	.035" - 304 SS or .035" - 316 SS	24 24	.025" Alum Steel or 304 & 316 SS
1"	36"	20 20	.035" - 304 SS or .035" - 316 SS	21 20	.034" Alum Steel or .035" 304 & 316 SS
1"	42" - 48"	18 18	.048" - 304 SS or .048"-304 & 316 SS	21 20	.034" Alum Steel or .035" 304 & 316 SS

* Gauge is approximate.

Approximate Outer Pipe Surface Temperatures

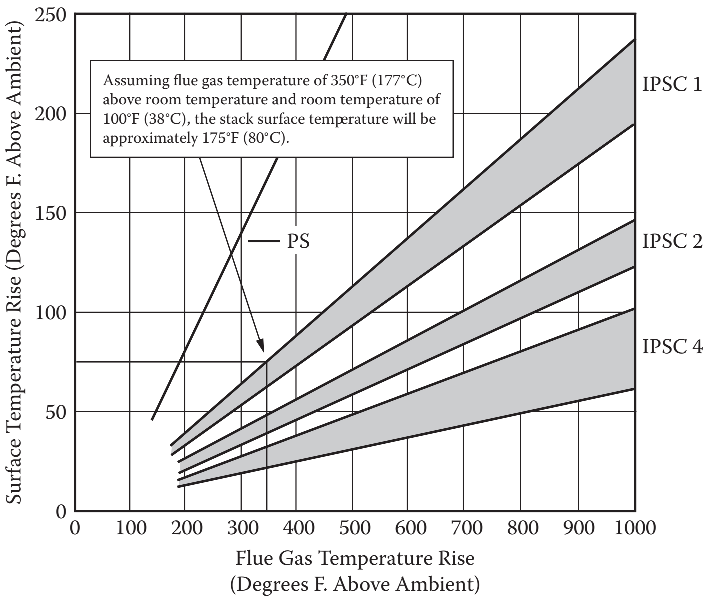


FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.) *(continued)*

TECHNICAL DATA

Operating Temperatures and Clearances

Criteria	Type L Vent	Restaurant Grease Duct	Building Heating Appliance Chimney*	1400° F. Factory-Built Chimney
Application	Chimneys and stacks for appliances Listed suitable for venting with Type L or Type B venting systems.	Cooking Appliances Ventilation Hoods Restaurant Grease Ducts Pizza Oven Exhausts	Low and High Pressure Steam Boilers Diesel and Turbine Exhausts Building Heating Equipment	Industrial Furnaces Processing Equipment Kilns and Ovens Diesel and Turbine Exhausts Text
Maximum Operating Temperatures	550° F Continuous 1700° F. Intermittent	500° F. Continuous 2000° F. Intermittent	1000° F. Continuous 1400° F. Intermittent	1400° F. Continuous 1800° F. Intermittent
Clearances To Combustibles: Model PS	N.A.	5-10" I.D. = 5" 12" I.D. = 6" 14" I.D. = 7" 16" I.D. = 8" 18" I.D. = 9" 20" I.D. = 10" Over20"I.D.=**	5-16" I.D. = 6" 18-20" I.D. = 7" 22-26" I.D. = 8" 28-30" I.D. = 9" 32-36" I.D. = 10" 42" I.D. = 11" 48" I.D. = 12"	5-16" I.D. = 6" 18" I.D. = 8" 20" I.D. = 9" 22" I.D. = 10" 24" I.D. = 12" 26" I.D. = 13" 28" I.D. = 14" 30" I.D. = 16" Over 30" I.D. = **
Model IPSC1	5-24" I.D. = 3"	5-6" I.D. = 2" 8-16" I.D. = 3" 18-24" I.D. = 4" 26-32" I.D. = 5" 36" I.D. = 6" 42-48" I.D. = 7"	5-8" I.D. = 1" 10-16" I.D. = 2" 18-24" I.D. = 3" 26-32" I.D. = 4" 36" I.D. = 5" 42-48" I.D. = 6"	5-6" I.D. = 1" 8-16" I.D. =2" 18-24" I.D. = 3" 26-32" I.D. = 4" 36" I.D. = 5" 42-48" I.D. = 6"
Models IPS C2 &C4	5-24" I.D. = 2"	5-16" I.D. = 1" 18-20" I.D. = 2" 22-24" I.D. = 3" 26-32" I.D. = 4" 36" I.D. = 5" 42-48" I.D. = 6"	5-16" I.D. = .5" 18" I.D. = 1" 20" I.D. = 1.5" 22-24" I.D. = 2" 26-32" I.D. = 3" 36" I.D. = 4" 42-48" I.D. = 5"	5-16" I.D. = .5" 18-24" I.D. = 2" 26-32" I.D. = 3" 36" I.D. = 4" 42-48" I.D. = 5"

*Under the "Building Heating Appliance Chimney" Listing, 5" through 24" Model IPS have qualified for UL's additional, optional "Type HT" rating for chimneys for certain appliance venting applications; especially solid fuel.

** See Installation Instruction Manual

FIGURE 7.6 (continued)
Boiler stack selection example/procedure. (Downloaded from the Internet from Selkirk Commercial & Industrial Catalog Model PS/IPS. Used with permission from Selkirk Corporation. www.selkirkcommercial.com.)

Chemical Feed Packages

Two Cleaver-Brooks chemical feed packages are selected for our sample project. One package is used to add chemicals to the deaerator water. The second package adds chemical to the boilers.

The boiler chemical feed package is a duplex type model 100-P-2-V-10. The package includes:

1. Two skids, pumps skid and tank skid, with structural steel to support each skid.
2. Dimensions for the tank skid: 31 in. × 32 in. × 72 in. tall (788 mm × 813 mm × 1,829 mm tall).
3. Dimensions for the pumps skid: 42 in. × 22 in. × 28 in. tall (1,067 mm × 559 mm × 711 mm tall).
4. One 100 gal (378 L) polyethylene tank with hinged door.
5. Two injection pumps (one per boiler), adjustable from 0 to 6.2 gal/h (23 L/h).
6. The pumps are prepiped with a double-stainless steel discharge check valve, stainless steel relief valve, and stainless steel suction strainer.
7. One agitator with stainless steel shaft and propeller.
8. The package required power is ¼ hp (0.2 kW), 120 V, single phase, 60 Hz.

The deaerator chemical feed is a simplex sulfite injector model 55-P1-V-10. The package includes:

1. One skid with structural steel to support it.
2. Dimensions for the skid: 26 in. × 23 in. × 64 in. tall (660 mm × 584 mm × 1,626 mm tall).
3. One 55 gal (208 L) polyethylene tank with cap.
4. One injection pump, adjustable from 0 to 6.2 gal/h (23 L/h).
5. The pump is prepiped with a double-stainless steel discharge check valve, stainless steel relief valve, and stainless steel suction strainer.
6. One agitator with stainless steel shaft and propeller.
7. The package required power is ¼ hp (0.2 kW), 115 V, single phase, 60 Hz power.

See additional manufacturer literature in Figure 7.7 for the chemical feed packages. The information is included with permission from Cleaver-Brooks, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.cleaver-brooks.com.

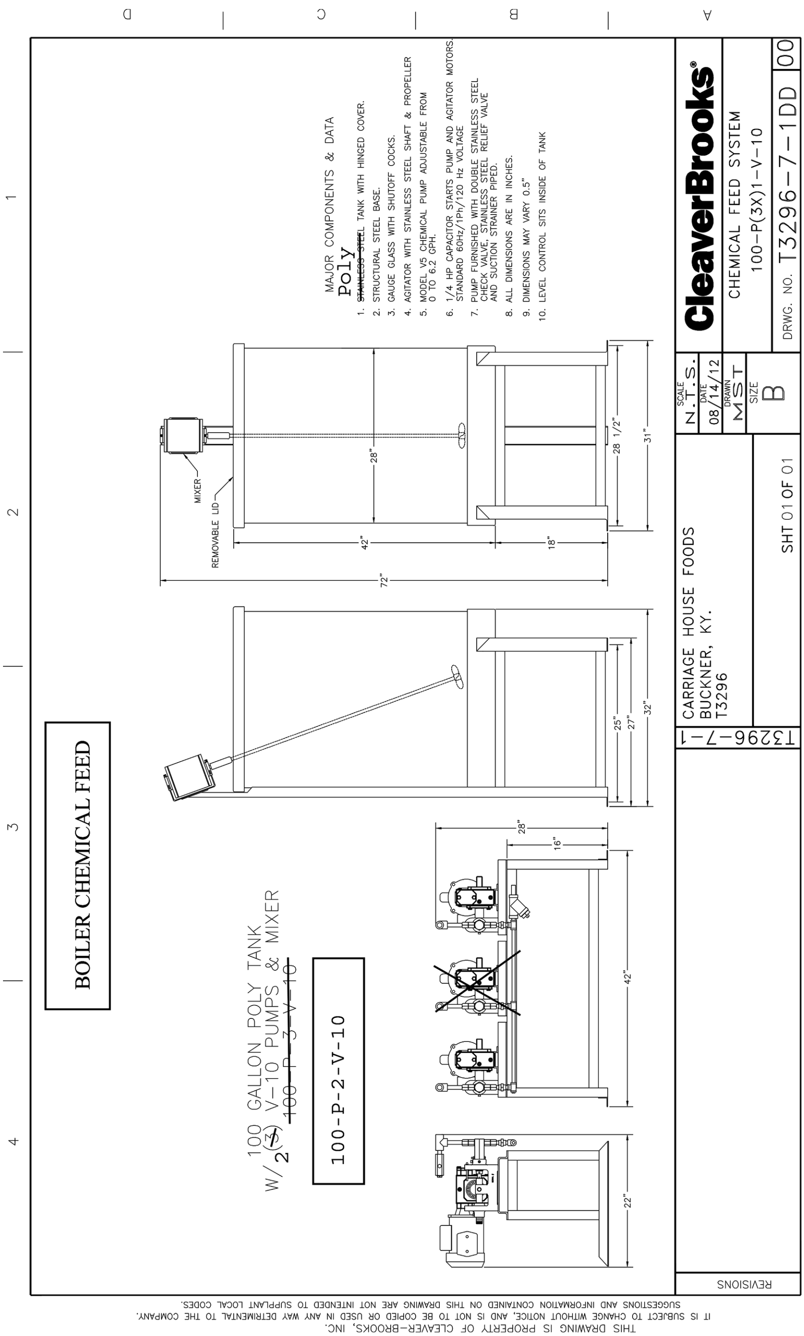


FIGURE 7.7
Chemical feed system package selection example/procedure. (Chemical feed system package drawing T3296-7-1DD from Cleaver-Brooks. Used with permission from Cleaver-Brooks, Inc. www.cleaver-brooks.com.)

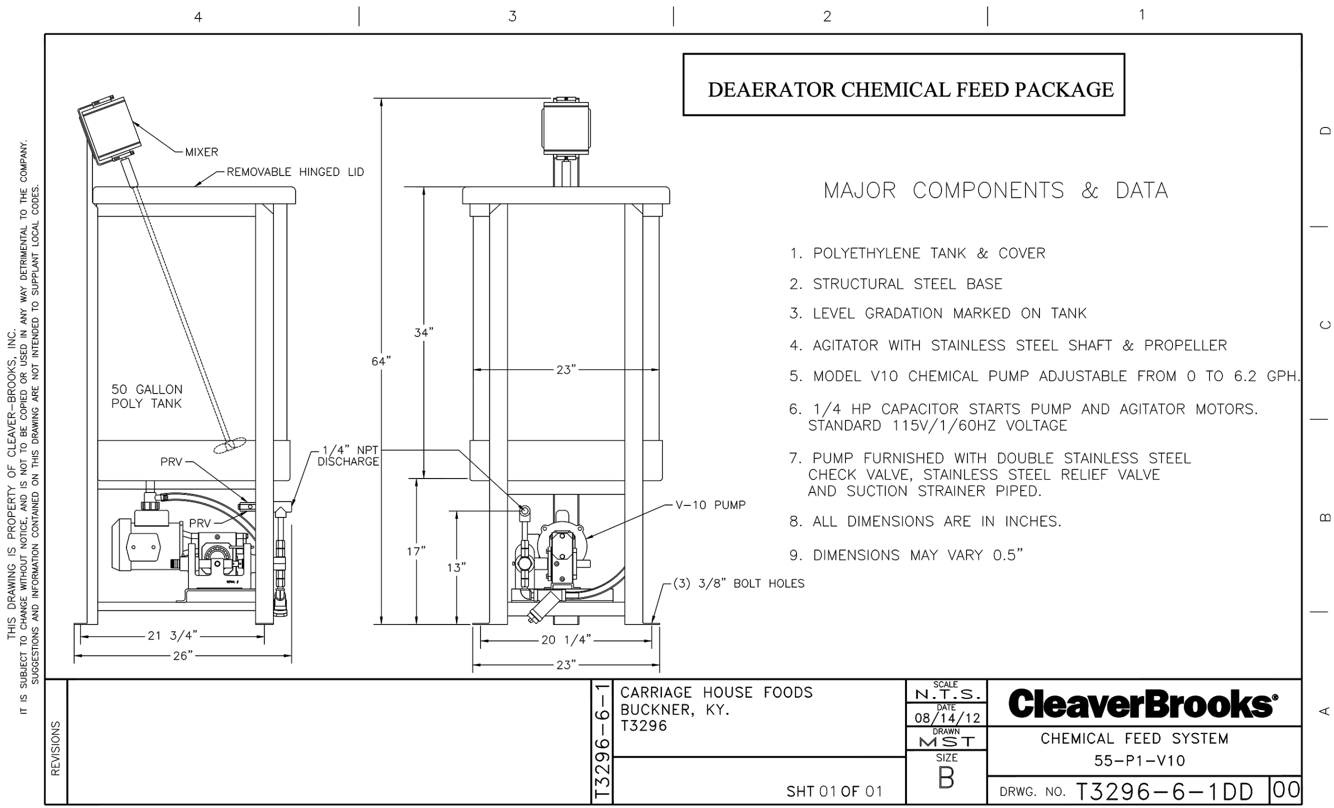


FIGURE 7.7
Chemical feed system package selection example/procedure. (Chemical feed system package drawings T3296-6-1DD from Cleaver-Brooks. Used with permission from Cleaver-Brooks, Inc. www.cleaver-brooks.com.)

Sample Cooler

A Spirax Sarco model SC20 sample cooler is selected for our sample project. One sampler cooler is used to cool samples from the deaerator and the two boilers.

According to the sample cooler performance (see Figure 7.8) using 1.6 gpm (6 L/min) of cooling water at 60°F (15.5°C) at a sample flow rate of 33 lb/h (15 kg/h), the cooled sample will be 18°F (8°C) warmer than the cooling water temperature or 78°F (26°C).

The sample cooler has the following features:

1. Material of construction: 316 L stainless steel.
2. Cooling water connection size: ½ in. (15 mm).
3. Sample connection size: ¼ in. (8 mm).

See additional manufacturer literature in Figure 7.8 for the selected sample cooler. The information is included with permission from Spirax Sarco, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.spiraxsarco.com.

Condensate Pump

A duplex condensate pump package is selected for our sample project. The package is model number 303-PECD3, as manufactured by Shippensburg Pump Company. The package includes two pumps, one running and one standby. Each pump can deliver 30 gpm (114 L/min) at 30 psi (2.07 bar) discharge pressure. The pump flow rate is approximately twice the condensate inflow rate of 7,000 lb/h (3,178 kg/h), coming from the HVAC system. The 30 psi (2.07 bar) pump discharge pressure is the estimated piping pressure drop plus the static lift to pump the condensate to the condensate receiver tank in the boiler room.

The pumps are selected with suitable materials, seals, and low net positive suction head to handle high-temperature condensate up to 212°F (100°C).

The package includes a 37 gal (140 L) cast iron receiver, two pumps, motor starters, disconnect switches, a control circuit transformer, a mechanical alternator, an auto-off selector switch, alarm lights, and contact for remote alarming. The package is piped and wired at the manufacturer's plant.

The package controls are set up for the two pumps lead lag and alternation operation. One pump runs when activated through the receiver level controller, and the second pump stays in standby mode. Each pump is driven by a 1 hp (0.75 kW) motor needing 460 V, three-phase 60 Hz power. Pumps are of the closed coupled type and run at 3,500 RPM speed.

spirax sarco®

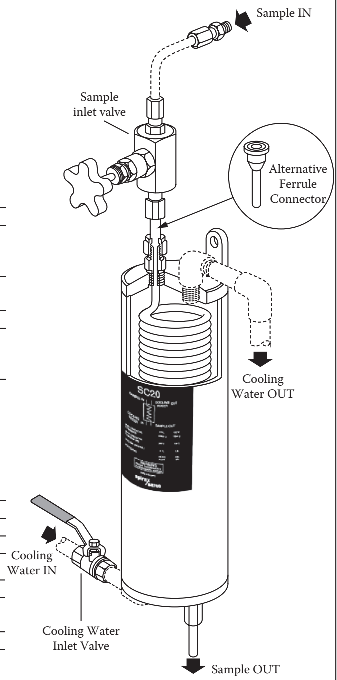
Sample cooler

SC20
Sample Coolers

- For accurate sampling of water, steam and process liquors
- Stainless steel coil and body minimizes corrosion
- Counter current flow for efficient cooling
- For water, steam, or condensate sampling

Description

The Spirax Sarco SC20 sample cooler is used to cool samples of boiler water, process liquor, or steam from vessels at high temperature and pressure. The cooler consists of a stainless steel coil, through which the sample flows, and a stainless steel body, through which cooling water flows in the opposite direction. A pre-drilled mounting bracket is incorporated into both end caps. The SC20 is also available with a ferrule for connecting to an industry standard 1/2" sanitary clamp fitting.



Available types

The SC20 sample cooler is available in five variants:-
BSP connections (6 mm O/ D tube).
NPT connections (6 mm O/ D tube). A 1/4" NPT male × 6 mm O/ D stud coupling is supplied loose for connecting the sample inlet tube to an NPT inlet valve or fitting.
BSP sample cooler kit (SCS20), complete with sample inlet valve, cooling water inlet valve, and carbon steel fittings.
A kit (SCS20), as above, but with stainless steel fittings.
A sample cooler (BSP or NPT) with a ferrule suitable for connection to an industry standard 1/2" sanitary clamp fitting (clamp not supplied).

Note: The sample cooler is not polished or specially treated internally, and the internal finish is not specified.

Stainless steel couplings are also available separately:-
1/4" BSP male × 6 mm O/ D tube.
1/4" NPT male × 6 mm O/ D tube.

Sizes and pipe connections

Cooling water IN and OUT connections

BSP version	NPT version	Ferrule versions
1/2" BSP	1/2" NPT	1/2" BSP or 1/2" NPT

Sample tube diameter (inlet and outlet)

BSP version	NPT version	Ferrule versions
6 mm O/ D	6 mm O/ D*	6 mm O/ D with 1/2" ferrule for clamp fitting

* A 1/4" NPT male × 6 mm O/ D stud coupling is provided.

Limiting conditions

Part	Design temperature	Design pressure
	572°F (300°C)	464 psig (32 barg)
Coil	500°F (260°C)	638 psig (44 barg)
	248°F (120°C)	913 psig (63 barg)
Body	212°F (100°C)	145 psig ((10 barg)
Cold hydraulic test pressure		232 psig (16 barg)

Clamp adaptor - Pressure and temperature dependent on clamp manufacturers recommendation.

Materials

Body and Coil	Austenitic stainless steel grade 316L

Local regulations may restrict the use of this product below the conditions quoted. Limiting conditions refer to standard connections only.
In the interests of development and improvement of the product, we reserve the right to change the specification.

FIGURE 7.8
Sample cooler selection example/procedure. (Downloaded from the Internet from Spirax Sarco SC20 Sample Cooler, TI-10-3705-US. Used with permission from Spirax Sarco, Inc. www.spiraxsarco.com.) *(continued)*

Performance

The tables below show typical sample outlet temperatures above cooling water inlet temperatures for several pressures and cooling water flowrates.

Example

A sample flowrate of 0.13 GPM is required from a boiler operating at 145 psig. For a cooling water flow - rate of 4.8 GPM from Table 1 the sample outlet temperature would be 7°F above the cooling water inlet temperature. If the cooling water is at 60°F, the sample temperature would be 67°F.
Table 2 is used in the same way for steam.
Samples may not be taken where marked '-' as the flow is limited by the sample inlet valve capacity.

Table 1 Saturated water (e.g. boiler water)

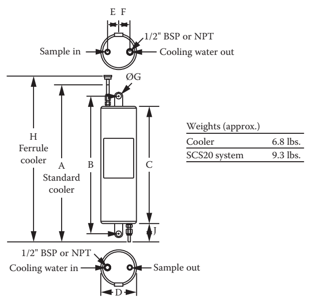
Sample Flowrate GPM	Cooling water flowrate 1.6 GPM					Cooling water flowrate 4.8 GPM					Cooling water flowrate 9.5 GPM				
	Boiler pressure psig														
	15	43	101	145	290	15	43	101	145	290	15	43	101	145	200
0.04	2°F	2°F	5.5°F	11°F	11°F	0°F	0°F	2°F	2°F	7°F	0°F	0°F	0°F	0°F	3.5°F
0.09	3.5°F	3.5°F	11°F	14.5°F	14.5°F	2°F	2°F	3.5°F	3.5°F	11°F	0°F	0°F	0°F	2°F	7°F
0.13	9°F	9°F	14.5°F	20°F	20°F	5.5°F	5.5°F	7°F	7°F	14.5°F	0°F	0°F	3.5°F	5.5°F	11°F
0.18	12.5°F	12.5°F	20°F	23.5°F	23.5°F	9°F	9°F	11°F	11°F	18°F	2°F	2°F	3.5°F	5.5°F	14.5°F
0.22	18°F	18°F	23.5°F	27°F	27°F	11°F	11°F	14.5°F	14.5°F	21.5°F	5.5°F	5.5°F	7°F	9°F	16°F
0.26	25°F	25°F	29°F	32.5°F	32.5°F	16°F	16°F	18°F	18°F	25°F	7°F	9°F	9°F	11°F	20°F
0.35	29°F	32.5°F	36°F	39.5°F	39.5°F	20°F	21.5°F	23.5°F	25°F	32.5°F	11°F	12.5°F	14.5°F	16°F	27°F
0.44	32.5°F	36°F	43°F	47°F	48.5°F	27°F	29°F	29°F	32.5°F	39.5°F	18°F	20°F	21.5°F	23.5°F	32.5°F
0.53	39.5°F	41.5°F	52°F	54°F	56°F	30.5°F	32.5°F	36°F	41.5°F	47°F	20°F	23.5°F	27°F	30.5°F	39.5°F

Table 2 Saturated steam

Sample Flowrate lb/h	Cooling water flowrate 1.6 GPM						Cooling water flowrate 4.8 GPM						Cooling water flowrate 9.5 GPM					
	Boiler pressure psig																	
	7.5	15	43	101	145	290	7.5	15	43	101	145	290	7.5	15	43	101	145	290
11	5.5°F	5.5°F	7°F	9°F	11°F	11°F	3.5°F	3.5°F	5.5°F	5.5°F	7°F	7°F	2°F	2°F	2°F	3.5°F	3.5°F	3.5°F
22	-	12.5°F	14.5°F	14.5°F	14.5°F	16°F	-	7°F	7°F	7°F	7°F	9°F	-	2°F	3.5°F	3.5°F	3.5°F	3.5°F
33	-	-	16°F	18°F	18°F	20°F	-	-	9°F	11°F	11°F	12.5°F	-	-	3.5°F	3.5°F	5.5°F	7°F
44	-	-	-	21.5°F	23.5°F	25°F	-	-	-	14.5°F	16°F	16°F	-	-	-	7°F	9°F	11°F
66	-	-	-	-	38°F	38°F	-	-	-	-	25°F	25°F	-	-	-	-	16°F	18°F
88	-	-	-	-	-	50.5°F	-	-	-	-	-	36°F	-	-	-	-	-	23.5°F
110	-	-	-	-	-	63°F	-	-	-	-	-	45°F	-	-	-	-	-	30.5°F
132	-	-	-	-	-	75.5°F	-	-	-	-	-	54°F	-	-	-	-	-	38°F
155	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Dimensions (approximate) in inches

A	B	C	D	E	F	G	H	J
16.1	13.8	11.8	3.5	1.0	0.9	0.5	17.7	2.2



Weights (approx.)	
Cooler	6.8 lbs.
SCS20 system	9.3 lbs.

Installation

See Installation and Maintenance Instructions for full details, as insufficient information is given here for safe installation.

Notes on installation

WARNING:-To avoid the risk of scalding, it is essential that cooling water is flowing before opening the sample inlet valve. Always close the sample inlet valve before turning off the cooling water.

Sample pipework becomes very hot under normal working conditions, and will cause burns if touched.

We recommend the use of corrosion resistant pipework suitable for the fluid being sampled.
Keep the length of all pipe runs to the minimum.
Cooling water must be clean and free from scale forming salts.
The sample cooler must be mounted vertically.
The cooling water inlet is connected in ½" nominal bore pipe via an inlet valve.
The cooling water outlet should be piped to an open drain or tundish.
The sample inlet pipe should be in 6 mm O/ D tube.
The sample inlet to the cooler can be taken direct from a boiler or steam line isolating valve, or if a Spirax Sarco TDS control system is fitted, from the take-off point provided on the blowdown valve.
We recommend that a tundish piped to drain is located under the outlet, with sufficient space below it for a beaker or similar sample container.

Maintenance

No routine maintenance is required.

How to order

1 - Spirax Sarco SC20 sample cooler - NPT connections.

TI-**10-3705**-US 01.05

Spirax Sarco, Inc., 1150 Northpoint Blvd., Blythewood, SC 29016

Telephone: (803) 714-2000 FAX (803) 714-2222

FIGURE 7.8 (continued)
Sample cooler selection example/procedure. (Downloaded from the Internet from Spirax Sarco SC20 Sample Cooler, TI-10-3705-US. Used with permission from Spirax Sarco, Inc. www.spiraxsarco.com.)

Insulation must be provided for the package for personnel protection. A full size (1 1/2 in.) overflow, 18 in. deep trap, together with 4 in. vent and 1/2 in. drain are required.

See additional manufacturer literature in Figure 7.9 for the condensate pump package. The information is included with permission from Shippensburg Pump Company, Inc. for educational purposes only.

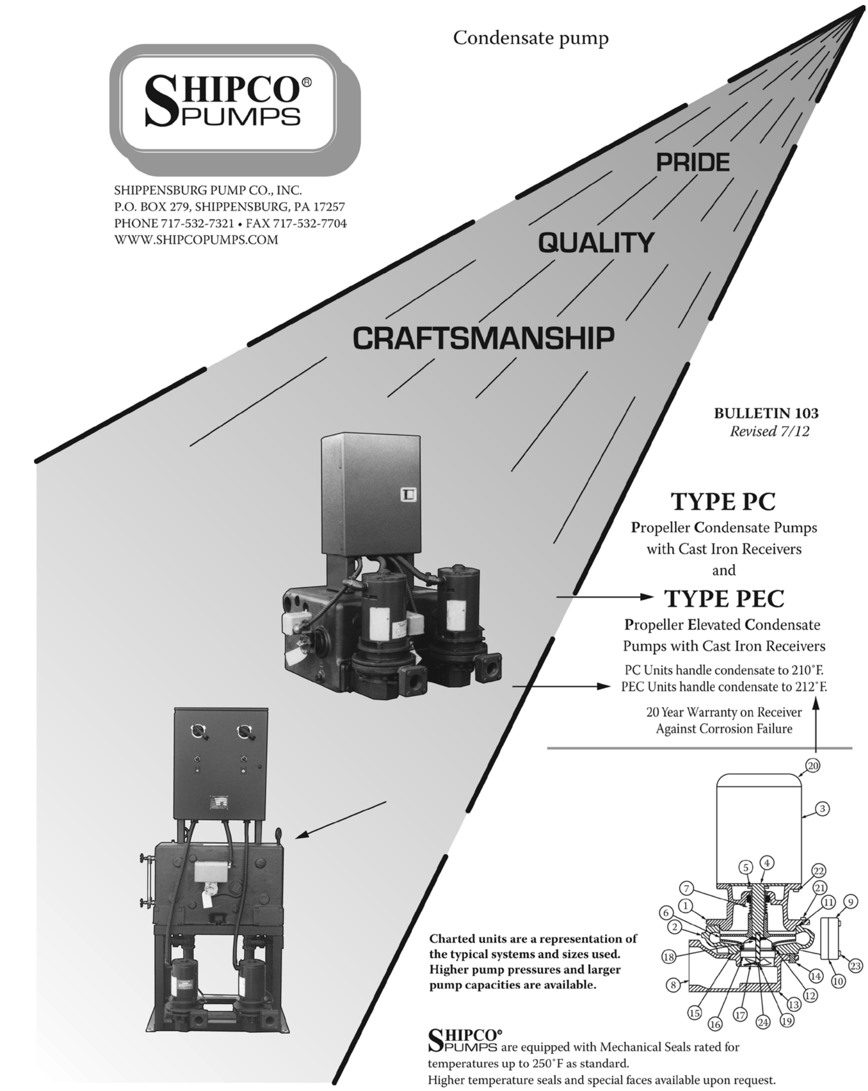


FIGURE 7.9
Condensate pump selection example/procedure. (Downloaded from the Internet from Shipco Pumps Bulletin 103, revised 7/12, Type PC and PEC. Used with permission from Shipco Pump Company, Inc. www.shipcopumps.com.) *(continued)*

ENGINEERING SELECTION DATA

Shipco® PUMPS has the panel assemblies to make your installation an easy and fast connection. Control Panels are available to comply with all Nema and JIC specifications. The controls are designed for efficient automatic operation of the condensate, vacuum and boiler feed pumps, as required. Panels are clearly identified with nameplates for easy reference to unit serial number and corresponding wiring diagrams.

Panels feature independent pump control circuits. This allows partial operation of duplex units for servicing and repairs. Internal wiring is numbered to match the wiring diagram for identification.

Magnetic Starters are usually required for single phase motors 1 horsepower and over, and all 3 phase motors. Overload relays are recommended to protect the wiring and motors, should an unbalanced condition occur.

Disconnects are available as an integral part of the panel to meet electrical code and service requirements.

Selector Switches are available for pump control. **Shipco®** PUMPS recommends two normal types.

Lead-off-Lag selector switches allow manual alternation of the lead pump for even wear.
Auto-Off selector switches with test push buttons — for use with mechanical or electrical alternators.

Mechanical Alternators are provided by float operated switching devices.

Electrical Alternators are available as an integral part of the panel. Two float switches are required to be used with the electrical alternator.

Control Circuit Transformers provide step down voltage for control circuits. Control circuits are normally recommended to be 115/1/60.

Relay, Pilot Lights, Alarm Lights, Alarm Bells, etc. are available upon request.

TYPE PEC CONDENSATE UNITS

CAP. SQ.FT. EDR	PUMP CAP. GPM	DISCH. PRESS. PSIG	MOTOR HP 3500 RPM ONLY	PHASE	DISCH. SIZE INCHES	SIMPLEX CATALOG NO.	DUPLEX CATALOG NO.	REC. CAP. GALS.	INLET SIZE INCHES	INLET HEIGHT INCHES
6,000	6	10	⅓	1	¾"	60 PEC1	60 PECD1	15	2"	33½"
		10	⅓	3		60 PEC3	60 PECD3			
		15	⅓	1		61 PEC1	61 PECD1			
		15	⅓	3		61 PEC3	61 PECD3			
		20	⅓	1		62 PEC1	62 PECD1			
		20	⅓	3		62 PEC3	62 PECD3			
		25	½	3		62.5 PEC1	62.5 PECD1			
		25	½	3		62.5 PEC3	62.5 PECD3			
		30	¾	3		63 PEC1	63 PECD1			
		30	¾	3		63 PEC3	63 PECD3			
		40	1½	3		64 PEC1	64 PECD1			
		40	1½	3		64 PEC3	64 PECD3			
		50	1½	1		65 PEC1	65 PECD1			
		50	1½	3		65 PEC3	65 PECD3			
		60	3	3		66 PEC3	66 PECD3			
		70	3	3		67 PEC3	67 PECD3			
		80	5	3		68 PEC3	68 PECD3			
		90	5	3		69 PEC3	69 PECD3			
9,000	9	10	⅓	1	¾"	90 PEC1	90 PECD1	15	2"	33½"
		10	⅓	3		90 PEC3	90 PECD3			
		15	⅓	1		91 PEC1	91 PECD1			
		15	⅓	3		91 PEC3	91 PECD3			
		20	⅓	1		92 PEC1	92 PECD1			
		20	⅓	3		92 PEC3	92 PECD3			
		25	½	1		92.5 PEC1	92.5 PECD1			
		25	½	3		92.5 PEC3	92.5 PECD3			
		30	¾	1		93 PEC1	93 PECD1			
		30	¾	3		93 PEC3	93 PECD3			
		40	1½	1		94 PEC1	94 PECD1			
		40	1½	3		94 PEC3	94 PECD3			
		50	1½	1		95 PEC1	95 PECD1			
		50	1½	3		95 PEC3	95 PECD3			
		60	3	3		96 PEC3	96 PECD3			
		70	3	3		97 PEC3	97 PECD3			
		80	5	3		98 PEC3	98 PECD3			
		90	5	3		99 PEC3	99 PECD3			
12,000	12	10	⅓	1	¾"	120 PEC1	120 PECD1	15	2"	33½"
		10	⅓	3		120 PEC3	120 PECD3			
		15	⅓	1		121 PEC1	121 PECD1			
		15	⅓	3		121 PEC3	121 PECD3			
		20	½	1		122 PEC1	122 PECD1			
		20	½	3		122 PEC3	122 PECD3			
		25	¾	1		122.5 PEC1	122.5 PECD1			
		25	¾	3		122.5 PEC3	122.5 PECD3			
		30	¾	1		123 PEC1	123 PECD1			
		30	¾	3		123 PEC3	123 PECD3			
		40	1½	1		124 PEC1	124 PECD1			
		40	1½	3		124 PEC3	124 PECD3			
		50	1½	1		125 PEC1	125 PECD1			
		50	1½	3		125 PEC3	125 PECD3			
		60	3	3		126 PEC3	126 PECD3			
		70	3	3		127 PEC3	127 PECD3			
		80	5	3		128 PEC3	128 PECD3			
		90	5	3		129 PEC3	129 PECD3			

FIGURE 7.9 (continued)
Condensate pump selection example/procedure. (Downloaded from the Internet from Shipco Pumps Bulletin 103, revised 7/12, Type PC and PEC. Used with permission from Shipco Pump Company, Inc. www.shipcopumps.com.) *(continued)*

TYPE PEC CONDENSATE UNITS

CAP. SQ.FT. EDR	PUMP CAP. GPM	DISCH. PRESS. PSIG	MOTOR HP 3500 RPM ONLY	PHASE	DISCH. SIZE INCHES	SIMPLEX CATALOG NO.	DUPLEX CATALOG NO.	REC. CAP. GALS.	INLET SIZE INCHES	INLET HEIGHT INCHES
15,000	15	10	⅓	1	¾"	150 PEC1	150 PECD1	15	2"	33½"
		10	⅓	3		150 PEC3	150 PECD3			
		15	⅓	1		151 PEC1	151 PECD1			
		15	⅓	3		151 PEC3	151 PECD3			
		20	½	1		152 PEC1	152 PECD1			
		20	½	3		152 PEC3	152 PECD3			
		25	¾	1		152.5 PEC1	152.5 PECD1			
		25	¾	3		152.5 PEC3	152.5 PECD3			
		30	1	1		153 PEC1	153 PECD1			
		30	1	3		153 PEC3	153 PECD3			
		40	1½	1		154 PEC1	154 PECD1			
		40	1½	3		154 PEC3	154 PECD3			
		50	2	1		155 PEC1	155 PECD1			
		50	2	3		155 PEC3	155 PECD3			
		60	3	3		156 PEC3	156 PECD3			
		70	5	3		157 PEC3	157 PECD3			
		80	5	3		158 PEC3	158 PECD3			
		90	5	3		159 PEC3	159 PECD3			
18,000	18	10	½	1	1½"	180 PEC1	180 PECD1	25	2"	34"
		10	½	3		180 PEC3	180 PECD3			
		15	½	1		181 PEC1	181 PECD1			
		15	½	3		181 PEC3	181 PECD3			
		20	½	1		182 PEC1	182 PECD1			
		20	½	3		182 PEC3	182 PECD3			
		25	¾	1		182.5 PEC1	182.5 PECD1			
		25	¾	3		182.5 PEC3	182.5 PECD3			
		30	1	1		183 PEC1	183 PECD1			
		30	1	3		183 PEC3	183 PECD3			
		40	1½	1		184 PEC1	184 PECD1			
		40	1½	3		184 PEC3	184 PECD3			
		50	2	1		185 PEC1	185 PECD1			
		50	2	3		185 PEC3	185 PECD3			
		60	3	3		186 PEC3	186 PECD3			
		70	5	3		187 PEC3	187 PECD3			
		80	5	3		188 PEC3	188 PECD3			
		90	5	3		189 PEC3	189 PECD3			
22,000	22	10	½	1	1½"	220 PEC1	220 PECD1	25	2"	34"
		10	½	3		220 PEC3	220 PECD3			
		15	½	1		221 PEC1	221 PECD1			
		15	½	3		221 PEC3	221 PECD3			
		20	¾	1		222 PEC1	222 PECD1			
		20	¾	3		222 PEC3	222 PECD3			
		25	¾	1		222.5 PEC1	222.5 PECD1			
		25	¾	3		222.5 PEC3	222.5 PECD3			
		30	1	1		223 PEC1	223 PECD1			
		30	1	3		223 PEC3	223 PECD3			
		40	1½	1		224 PEC1	224 PECD1			
		40	1½	3		224 PEC3	224 PECD3			
		50	2	1		225 PEC1	225 PECD1			
		50	2	3		225 PEC3	225 PECD3			
		60	3	3		226 PEC3	226 PECD3			
		70	5	3		227 PEC3	227 PECD3			
		80	5	3		228 PEC3	228 PECD3			
		90	5	3		229 PEC3	229 PECD3			
30,000	30	10	¾	1	1½"	300 PEC1	300 PECD1	37	3"	38"
		10	¾	3		300 PEC3	300 PECD3			
		15	¾	1		301 PEC1	301 PECD1			
		15	¾	3		301 PEC3	301 PECD3			
		20	¾	1		302 PEC1	302 PECD1			
		20	¾	3		302 PEC3	302 PECD3			
		25	¾	1		302.5 PEC1	302.5 PECD1			
		25	¾	3		302.5 PEC3	302.5 PECD3			
		30	1	1		303 PEC1	303 PECD1			
		30	1	3		303 PEC3	303 PECD3			
		40	2	1		304 PEC1	304 PECD1			
		40	2	3		304 PEC3	304 PECD3			
		50	2	1		305 PEC1	305 PECD1			
		50	2	3		305 PEC3	305 PECD3			
		60	5	3		306 PEC3	306 PECD3			
		70	5	3		307 PEC3	307 PECD3			
		80	5	3		308 PEC3	308 PECD3			
		90	7½	3		309 PEC3	309 PECD3			
37,000	37	10	¾	1	1½"	370 PEC1	370 PECD1	37	3"	38"
		10	¾	3		370 PEC3	370 PECD3			
		15	¾	1		371 PEC1	371 PECD1			
		15	¾	3		371 PEC3	371 PECD3			
		20	¾	1		372 PEC1	372 PECD1			
		20	¾	3		372 PEC3	372 PECD3			
		25	1	1		372.5 PEC1	372.5 PECD1			
		25	1	3		372.5 PEC3	372.5 PECD3			
		30	1½	1		373 PEC1	373 PECD1			
		30	1½	3		373 PEC3	373 PECD3			
		40	2	1		374 PEC1	374 PECD1			
		40	2	3		374 PEC3	374 PECD3			
		50	3	3		375 PEC3	375 PECD3			
		60	5	3		376 PEC3	376 PECD3			
		70	5	3		377 PEC3	377 PECD3			
		80	5	3		378 PEC3	378 PECD3			
		90	7½	3		379 PEC3	379 PECD3			

FIGURE 7.9 (continued)
Condensate pump selection example/procedure. (Downloaded from the Internet from Shipco Pumps Bulletin 103, revised 7/12, Type PC and PEC. Used with permission from Shipco Pump Company, Inc. www.shipcopumps.com.) *(continued)*

PC & PEC UNIT DESCRIPTION

PC & PEC Pumps are "The Pumps That Pump" even when traps start to leak and temperatures go to boiling!

Propeller Condensate pumps are designed to handle hot condensate with low NPSH requirements. The type P pumps require only 2 feet of NPSH to handle water at its saturation temperature. Floor mounted units can handle condensate at temperatures to 210°F.

Elevated units can handle condensate at temperatures to 212°F.

Cast Iron Receivers provide years of service even with the most aggressive waters. Receivers are available from 10 gallon to 500 gallon capacity. The receivers are fully vented and operate at atmospheric pressure. (Receivers are not ASME code stamped.)

Butterfly Suction Valves are an optional part of the service features of the PC units. By closing the butterfly suction valves the PC pumps are isolated from the receiver for servicing without draining the receiver. PEC units (elevated) have valves in the suction piping as standard.

Basket Inlet Strainers are a recommended feature of the PC units.The large dirt pocket and vertical self cleaning screens help prevent unnecessary wear and problems with the PC pumps.

Gauge Glass provides a quick check of receiver water level.

Dial Thermometer provides a quick check of the condensate temperature in a receiver.

Discharge Pressure Gauges provide a quick check of the condensate pressure as it is discharged from the receiver's pump.

The heart of the PC & PEC unit is the type P pump. The type P pump is designed for vertical flange mounting as shown.

Pump Head and Case are made of close grained cast iron.

Impeller is cast bronze, enclosed vane, precision balanced, and trimmed to design conditions for smooth durable operation.

Case Wearing Ring is bronze and easily renewable to keep the type P pump at peak performance.
Motors are heavy duty ball bearing design.

Water Safety Slingers are installed to help prevent water from entering the motor from seal leakage.

Motor Shaft is stainless steel on 56J Frame motors. JM motors have a bronze shaft sleeve or optional stainless steel shaft sleeve.

Straightening Vanes provide a directed flow into the eye of the centrifugal impeller.

Axial Flow Impeller provides low NPSH characteristics and is precision finished for smooth vibration-free operation.

Discharge Companion Flange allows the pump to be removed and eliminates the need of additional unions.

All Units are completely assembled, piped, wired, and individually tested before shipment. Testing includes a complete hydrostatic test for leaks, electrical tests for controls and accessories, and performance test for pumps at design conditions. After testing, the units are packaged for shipment.

ENGINEERING SELECTION DATA

Receiver Sizing – PC & PEC Units

The receivers in this series of units are sized to allow for approximately one minute net storage capacity (where practical). The condensate return pumps need to run for approximately a one minute period to prolong the life of the motors in intermittent operation. The condensate is returned to the boiler room as quickly as possible to reduce make-up requirements and heat loss.

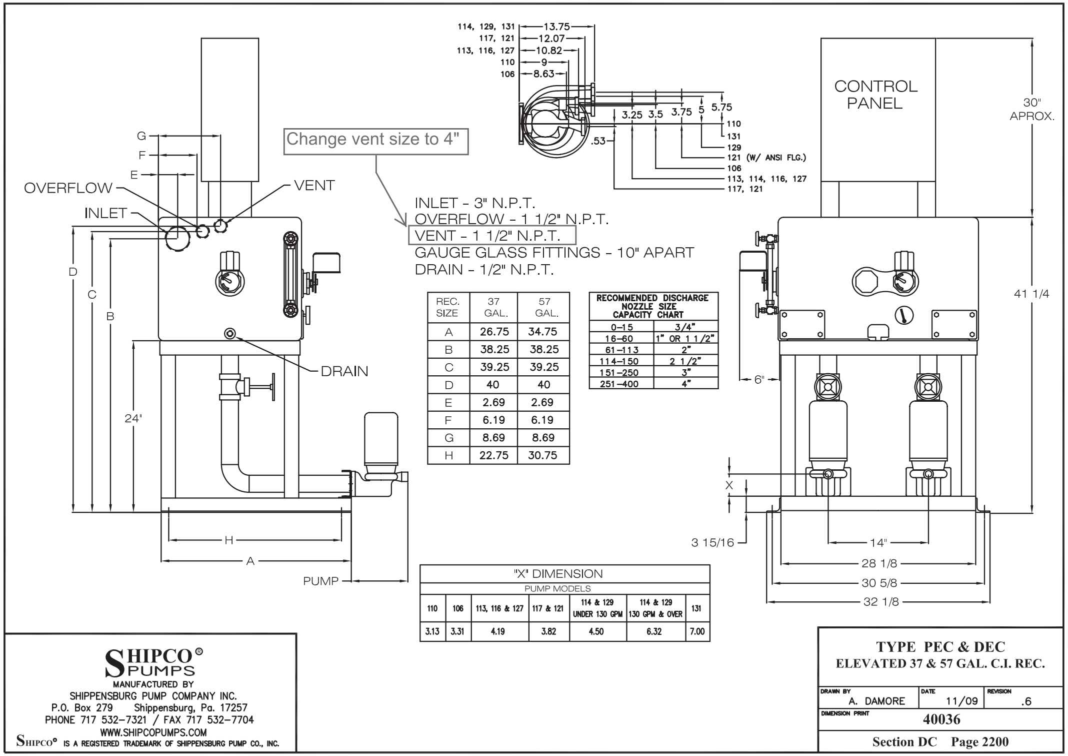
Condensate Pump Sizing – PC & PEC Units

The condensing rate for 1,000 sq. ft. EDR is .5 GPM (see table). The type PC Condensate return pumps are sized at twice (2 times) the normal condensing rate or 1.0 GPM per 1,000 sq. ft. EDR. The low NPSH requirements and minimal capacity loss of centrifugal pumps from normal wear has shown from experience to provide more than adequate pump capacity.

Table — Values of Heat and Power

	GPM	BTU	Lbs/Hr	Sq. Ft. EDR
1 Boiler Horsepower	.069	33,475	34.5	139.4
1,000 sq. ft. EDR	.50	240,000	247.3	1,000

FIGURE 7.9 (continued)
Condensate pump selection example/procedure. (Downloaded from the Internet from Shipco Pumps Bulletin 103, revised 7/12, Type PC and PEC. Used with permission from Shipco Pump Company, Inc. www.shipcopumps.com.) *(continued)*



REC. SIZE	37 GAL.	57 GAL.
A	26.75	34.75
B	38.25	38.25
C	39.25	39.25
D	40	40
E	2.69	2.69
F	6.19	6.19
G	8.69	8.69
H	22.75	30.75

RECOMMENDED DISCHARGE NOZZLE SIZE CAPACITY CHART	
0–15	3/4"
16–60	1" OR 1 1/2"
61–113	2"
114–150	2 1/2"
151–250	3"
251–400	4"

"X" DIMENSION — PUMP MODELS						
110	106	113, 116 & 127	117 & 121	114 & 129 UNDER 130 GPM	114 & 129 130 GPM & OVER	131
3.13	3.31	4.19	3.82	4.50	6.32	7.00

FIGURE 7.9 (continued)
Condensate pump selection example/procedure. (Downloaded from the Internet from Shipco Pumps Bulletin 103, revised 7/12, Type PC and PEC. Used with permission from Shipco Pump Company, Inc. www.shipcopumps.com.)

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.shipcopumps.com.

Pressure Control Valves

Due to the need for low-pressure steam for building HVAC and hot water systems, a pressure reducing station is included in our sample project. The pressure reducing station regulates the steam pressure from 150 psig (10.34 barg) to 30 psig (2.06 barg). The maximum required steam flow rate at 30 psig (2.06 barg) is calculated to be 13,000 lb/h (5.902 kg/h).

As indicated on the PID drawings, the pressure reducing station is set up with two parallel pressure control valves. This setup is referred to as a 1/3 (30% of total flow capacity), 2/3 (70% of total flow capacity) pressure reducing station. The setup provides more flexibility and better pressure control at varying steam flow rates due to the steam demand changes.

The HVAC system demand is seasonal; at times it can be very small. Usually the smaller pressure control valve (the 1/3 valve) is set at 2 psi (13.8 kPa) higher pressure than the larger pressure control valve (the 2/3 valve) and 1 psi (6.9 kPa) higher than the low-pressure steam set point. As long as the downstream steam pressure is above the larger pressure control valve set point the valve will stay closed. When the low-pressure steam demand, downstream of the pressure reducing station, exceeds the small valve capacity (valve wide open), the downstream steam pressure will drop. The lowered downstream pressure, when dropped to below the large pressure control valve, activates the large pressure control valve. The large valve will modulate open to supply the additional steam and will maintain downstream pressure at its set point that is 1 psi (6.9 kPa) below the low steam pressure set point.

The selected pressure control valves for our sample project are from Armstrong International, Inc. The valves are the pilot-operated type (refer to Chapter 4 Steam Pressure Control Valve Section). They have been selected based on the following criteria:

1. One pressure control valve is selected for approximately 4,500 lb/h (2,043 kg/h) of steam, reducing the pressure from 150 psig (10.34 barg) to 30 psig (2.06 barg). This valve is an Armstrong model GP-2000, size 1½ in. (40 mm), with threaded connections. The valve pressure set point is at 31 psi (214 kPa or 2.14 bar).
2. The second pressure control valve is selected for approximately 9,000 lb/h (4,086 kg/h) of steam, reducing the pressure from 150 psig (10.34 barg) to 29 psig (2 barg). This is an Armstrong model GP-2000, size 2½ in. (65 mm), with 150 lb flange connections. The valve pressure set point is at 29 psi (2 bar).

The Armstrong pressure control valve selection software was used to size and select the pressure control valves and other recommended components by the manufacturer.

An orifice plate, 5 in. (125 mm) in diameter with nine holes of 23/32 in. (18 mm) each, is selected for reducing the pressure reducing station operating noise down to 88 dBA. The orifice plate is installed downstream of the larger pressure control valve. This is recommended by the manufacturer.

According to the manufacturer's recommendations:

1. The pressure control valves must be installed with a minimum 10 pipe diameter of straight pipe run at their inlet sides.
2. The pressure control valves must be installed with a minimum 20 pipe diameter of straight pipe run at their outlet sides.
3. The pressure control valves' pilot pressure sensing pipe/tubing must connect to the downstream low-pressure steam pipe with proper slope and at a point where the regulated steam pressure is stabilized. The sensing tube must drain to the steam pipe. Refer to the PID-3 drawing for more details.

The steam pressure reducing station must include a pressure relief valve capable of discharging steam at a maximum possible flow rate that the steam pressure reducing station can pass at the highest possible steam pressure at its high side. The pressure set point must be acceptable to the downstream equipment pressure rating. This can happen due to a pressure reducing valve malfunction or an open manually controlled bypass valve. The pressure relief valve pressure set point is usually set to relief at either 10% above or 10 psi (69 kPa) higher than the low steam pressure set point, whichever is higher. For our sample project the pressure relief valve pressure set point is set at 40 psi (2.76 bar or 276 kPa), 10 psi (69 kPa) above the low pressure steam.

The maximum steam flow rate for our sample project, approximately 15,200 lb/h (6,900 kg/h), can happen through the large pressure control valve. This is the pressure control valve maximum flow rate capacity that is indicated by the valve manufacturer for the purpose of pressure relief valve sizing. The pressure relief valve, set at 40 psi (2.76 bar), must be capable of relieving 15,200 lb/h (6,900 kg/h) of steam at a pressure not to exceed 10% over its set point or 44 psi (3.03 bar).

See additional manufacturer literature in SI and PI units in Figure 7.10 for the pressure control valves. The information is included with permission from Armstrong International, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.armstronginternational.com.

DIMENSIONS & DATA CERTIFIED FOR:

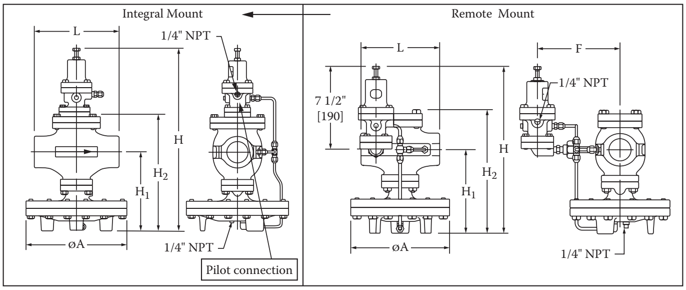
Representative: Order:

Customer: Order:

Project: **Sample project**

Requirements:
Pressure control valve PCV-1 is set at 31 psig.
The valve regulates the pressure from 150 psig to 30 psig.
The valve capacity is 4,542 1bs/hr.
Maximum capacity for safety relief valve sizing = 5,300 1bs/hr.

By: Date:



Dimensions & Weights

SIZE	L	A	F	H Integral	H Remote	H_1	H_2	Weight	Cv [Kv]
1/2" [15]	5-15/16" [151mm]	7-15/16" [202mm]	6-15/16" [176mm]	15-3/4" [400mm]	14-1/4" [362mm]	6-3/4" [171mm]	9-5/8" [244mm]	34 Ibs. [15 kgs.]	5 [4.3]
3/4" [20]	5-15/16" [151mm]	7-15/16" [202mm]	6-15/16" [176mm]	15-3/4" [400mm]	14-1/4" [362mm]	6-3/4" [171mm]	9-5/8" [244mm]	34 Ibs. [15 kgs.]	7.2 [6.2]
1" [25]	6-5/16" [160mm]	8-15/16" [227mm]	7-1/8" [181mm]	15-15/16" [405mm]	14-7/16" [367mm]	6-15/16" [176mm]	10" [254mm]	44 Ibs. [20 kgs.]	10.9 [9.4]
1-1/4" [32]	7-1/8" [181mm]	8-15/16" [227mm]	7-1/8" [181mm]	17-1/8" [435mm]	15-1/8" [384mm]	7-5/8" [194mm]	11-1/8" [283mm]	51 Ibs. [23 kgs.]	14.3 [12.4]
1-1/2" [40]	7-1/8" [181mm]	8-15/16" [227mm]	7-1/8" [181mm]	17-1/8" [435mm]	15-1/8" [384mm]	7-5/8" [194mm]	11-1/8" [283mm]	51 Ibs. [23 kgs.]	18.8 [16.3]
2" [50]	9-1/16" [230mm]	10-15/16" [278mm]	7-3/4" [197mm]	19-5/8" [498mm]	16" [406mm]	8-1/2" [216mm]	12-5/8" [321mm]	75 Ibs. [34 kgs.]	32 [27.7]

NOTE: 1/2" thru 2" standard in integral mount.
Remote mount available.

Armstrong

Armstrong-Yoshi take, Inc.
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Three Rivers, MI. 49093
(616) 279-3600 Fax(616) 273-8656
Posted on Armstrong's homepage www.ormstrong-intl.com

Product	CDY No.	Date
GP- 2000 THREADED CONNECTIONS	CDY1008	1/28/98
		Rev A

FIGURE 7.10
Pressure control valve selection example/procedure. (Downloaded from the Internet from Armstrong International Products & Services, Pressure and Temperature Controls, Externally Piloted Diaphragm-Operated Pressure-Reducing Valves, GP-2000 Ductile Iron/Spring Operated. Used with permission from Armstrong International, Inc. www.armstronginternational.com.) *(continued)*

Specifications

Application	Inlet Pressure	Reduced Pressure	Spring Color Code	Maximum Temperatur	Minimum Differential
Steam	15-300 psig [1-20.4 bar)	* 1.5-3 psig [.1-.2 bar]	YELLOW	450 °F [232 °C]	7 Psig [.48 bar]
		3–21 psig [.2–1.4 bar]	YELLOW		
		15–200 psig [1–13.6 bar]	GREEN		

*Note: When using this spring range, remove one (1) pilot diaphragm. Capacities are reduced by 1/2 of capacity chart when this spring is being used.

List Of Materials	
Body	Ductile Iron ASTM A536
Main Valve/Seat	Stainless Steel AISI 420
Pilot Valve/Seat	Stainless Steel AISI 420
Diaphragm	Stainless Steel AISI 301

Armstrong

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Product	CDY NO.	Date 1/28/98
GP-2000 THREADED CONNECTIONS	CDY1008	REV. A

FIGURE 7.10 (continued)
Pressure control valve selection example/procedure. (Downloaded from the Internet from Armstrong International Products & Services, Pressure and Temperature Controls, Externally Piloted Diaphragm-Operated Pressure-Reducing Valves, GP-2000 Ductile Iron/Spring Operated. Used with permission from Armstrong International, Inc. www .armstronginternational.com.) *(continued)*

DIMENSIONS & DATA CERTIFIED FOR:

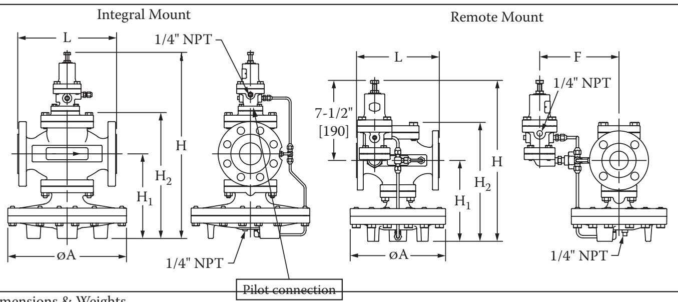
Representative: Order:

Customer: Order:

Project: **Sample project**

Requirements:
Pressure control valve PCV-2 is set at 29 psig.
The valve regulates pressure from 150 psig to 29 psig.
The valve capacity is 9,060 pounds per hour. Maximum valve capacity for pressure relief valve sizing is 15,200 pounds per hour.

By: Date:



Dimensions & Weights

SIZE	Flange Class	L	A	F	H Integral	H Remote	H1	H2	Weight	Cv [Kv]
2" [50]	150	8-9/16" [217mm]	10-15/16" [278mm]	7-3/4" [197mm]	19-5/8" [498mm]	16" [406mm]	8-1/2" [216mm]	12-5/8" [321mm]	81 Ibs. [37 kgs]	32 [28]
	300	9-1/8" [232mm]							84 Ibs. [38 kgs]	
2-1/2" [65]	150	10-15/16" [278mm]	13-13/16" [351mm]	8-5/16" [211mm]	21-3/4" [552mm]	17-5/16" [440mm]	9-13/16" [249mm]	14-3/4" [375mm]	142 Ibs. [64 kgs]	60 [52]
	300	11-1/2" [292mm]							150 Ibs. [68 kgs]	
3" [80]	150	11-3/4" [298mm]	13-13/16" [351mm]	8-3/4" [222mm]	22-5/8" [552mm]	17-15/16" [456mm]	10-7/16" [265mm]	15-3/4" [400mm]	155 Ibs. [70 kgs]	78 [67]
	300	12-7/16" [316mm]							166 Ibs. [75 kgs]	
4" [100]	150	13-1/2" [343mm]	15-13/16" [402mm]	9-7/16" [240mm]	25-15/16" [659mm]	20-1/8" [511mm]	12-5/8" [321mm]	19-1/4" [489mm]	247 Ibs. [112 kgs]	120 [104]
	300	14-1/8" [359mm]							264 Ibs. [120 kgs]	
6" [150]	150	18-1/8" [460mm]	19-3/4" [502mm]	11-5/16" [135mm]	31-3/4" [806mm]	27-1/4" [692mm]	27-1/4" [692mm]	15-15/16" [405mm]	553 Ibs. [252 kgs]	250 [215]
	300	19" [483mm]								

NOTE: 2" thru 4" standard in integral mount.

Armstrong
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Product	CDY No.	Date 1/23/98
GP- 2000 FLANGED	CDY1007	Rev. B

FIGURE 7.10 (continued)
Pressure control valve selection example/procedure. (Downloaded from the Internet from Armstrong International Products & Services, Pressure and Temperature Controls, Externally Piloted Diaphragm-Operated Pressure-Reducing Valves, GP-2000 Ductile Iron/Spring Operated. Used with permission from Armstrong International, Inc. www .armstronginternational.com.) *(continued)*

Specifications					
Application	Inlet Pressure	Reduced Pressure	Spring Color Code	Maximum Temperatur	Minimum Differential
STEAM	→ CL. 150 FLG. 15–185 Psig [1-12.6 bar]	* 1.5-3 psig [.1-.2 bar]	SILVER	450 °F [232 °C]	7 Psig [.48 bar]
		3–21 psig [.2–1.4 bar]	YELLOW		
	CL. 300 FLG. 15–300 psig [1-20.4 bar]	15–200 psig [1–13.6 bar]	GREEN ←		

Note: *When using this spring range, remove one (1) pilot diaphragm.
Capacities are reduced by 1/2 of capacity chart when this spring is being used.

List Of Materials	
Body	Ductile Iron ASTM A536
Main Valve	Stainless Steel AISI 420
Main Valve Seat	Stainless Steel AISI 420
Pilot Valve	Stainless Steel AISI 420
Pilot Valve Seat	Stainless Steel AISI 420
Diaphram	Stainless Steel AISI 301
Bolting	Carbon Steel

Armstrong

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Product	CDY NO.	Date 1/28/98
GP-2000 FLANGED	CDY1007	REV. B

FIGURE 7.10 (continued)
Pressure control valve selection example/procedure. (Downloaded from the Internet from Armstrong International Products & Services, Pressure and Temperature Controls, Externally Piloted Diaphragm-Operated Pressure-Reducing Valves, GP-2000 Ductile Iron/Spring Operated. Used with permission from Armstrong International, Inc. www.armstronginternational.com.)

Pressure Relief Valve

A cast iron pressure relief valve is selected for our sample project for the steam pressure reducing station. The pressure relief valve is installed downstream of the pressure reducing station to relieve pressure in case a pressure control valve fails.

The selected pressure relief valve is model 0041PMD as manufactured by Spence Engineering Company, Inc. It complies with ASME Section VIII, "Rules for Construction of Pressure Vessels."

The pressure relief valve is set at 40 psig (2.75 barg) and can relieve up to 17,422 lb/h (7,910 kg/h) of saturated steam at 10% pressure rise over its set point, or at 44 psig (3.03 barg).

The pressure relief valve is a cast iron body with bronze trim and fitted with a 4 in. (100 mm) flange inlet connection and 6 in. (150 mm) flange outlet connection. The inlet flange is rated at 250 lb and the outlet flange at 150 lb.

See additional manufacturer literature in SI and PI units in Figure 7.11 for the pressure relief valve. This information is included with permission from Spence Engineering Company, Inc. for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.spenceengineering.com.

Drip Pan Elbow

A drip pan elbow is used for each pressure relief valve to safely handle the pressure relief valve steam discharge. The drip pan elbow is installed on the pressure relief valve discharge pipe and provides an indirect connection to its downstream exhaust vent, allowing the vent movement without affecting the pressure relief valve.

The drip pan elbow model DPE manufactured by Spirax Sarco is selected for our sample project. The drip pan elbow inlet and outlet sizes are the same size as the pressure relief valve discharge connection size. The drip pan elbow exhaust vent size must be one or two sizes larger than its discharge connection size to provide the indirect connection by slipping over it.

Refer to the schedule in Table 7.4 for selected drip pan elbows for each pressure relief valve.

See additional manufacturer literature in SI and PI units in Figure 7.12 for the selected drip pan elbow. The information is included with permission from Spirax Sarco, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.spiraxsarco.com.

FIGURE 31 CAST IRON SERIES

FIGURE 31 / 41
CAST IRON SERIES

SIZES 1 1⁄2" – 6"
PRESSURES to 250 PSIG at 406°F

- **Meets ASME Section I & VIII Code for Steam, Air & Non-hazardous Gas Service**
- **“V” or “UV” National Board Certified**
- **Dual Ring Control** See page 12
- **Heavy Duty Construction**
- **Flanged or Threaded Connections**
- **SS Trim Design Available**
- **Heavy Duty Open Lever Assembly**

Options
- SS Trim
- BSP Connections
- Test Reports Available

Application Data
- Steam Boilers
- Pressure Reducing Stations ←
- Unfired Steam Pressure Vessels & Lines
- Air compressors, Cookers, Receivers
- Pneumatic Systems
- OEM Equipment

Valve Ratings *See Capacity Charts beginning on page 21*

Model	Pressure PSIG (bar)	Temperature °F (°C)
All	10 to 250 (.7 to 17.2)	-20 to 406 (-29 to 208)

Models
- 0031 - ASME Section I Steam, Bronze Trim
- → 0041 - ASME Section VIII Steam, Bronze Trim ←
- 041A - ASME Section VIII Air, Bronze Trim
- 0032 - SS Base & Disc on 0031
- 0042 - SS Base & Disc on 0041
- 042A - SS Base & Disc on 041A

Applicable Codes
- ASME Section I “V” for Steam
- ASME Section VIII “UV” for Steam/Air/Gas
- API 527
- Canadian Registration # 0G0591.9C

pressure set point = 40 psig

Code Selection Chart

Model				Orifice	Inlet Size	Connections	Set Pressure		
0	4	1	A	K	H	C -	1	0	0
1	2	3	4	5	6	7	8	9	10

Model-
Position 1, 2, 3 & 4
0031 = ASME Section I Steam, Bronze Trim
→ 0041 = ASME Section VIII Steam, Bronze Trim
041A = ASME Section VIII Air, Bronze Trim
0032 = SS Base & Disc on 0031
0042 = SS Base & Disc on 0041
042A = SS Base & Disc on 041A

Orifice-
Position 5
J
K
L
M
N
→ P
Q
R

Inlet Size-
Position 6
G = 1½
H = 2
J = 2½
K = 3
→ M = 4
P = 6

Connections-
Position 7
B = FPT × FPT
C = 250# × FPT
D = 250# × 125# ←
Z = Other

Set Pressure-
Position 8, 9 & 10
__ __ __ = Actual Setting
LAS - Loosely Assembled†

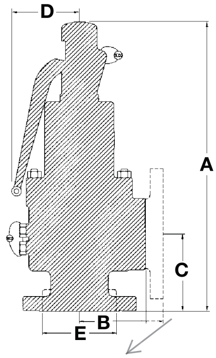
†Spence Certified Assemblers Only (use 0031or 0032 only)

FIGURE 7.11
Pressure relief valve selection example/procedure. (Downloaded from the Internet from Spence Engineering, Safety Relief Valves, Figure 31/41 Cast Iron Series. Used with permission from Spence Engineering Company, Inc. www.spenceengineering.com.) *(continued)*

FIGURE 31 / 41
CAST IRON SERIES

SPECIFICATION

The valve shall meet the ASME Section I or VIII Code for steam, air and gas services. It shall be "V" or "UV" National Board Certified. The valve shall have dual blowdown ring to allow better adjustment of the pop and blowdown. The valve shall be top guided and shall have a semi nozzle for optimum flow performance. The valve shall have an open lever assembly. The valve shall meet the API 527 leakage standard requiring bubble tight shutoff up to 90% of set pressure.



0031, 0041, 041A
0032, 0042, 042A

DIMENSIONS* inches (mm) **AND WEIGHTS** pounds (kg)

Model	Inlet	Orifice	Outlet	A	B	C	D[(1)]	E	Weight
****JGB	1½" FPT (40)	J	2½" FPT (65)	15⅛ (384.2)	3½ (88.9)	4¼ (108)	3 (76.2)	3¼ (82.6)	29 (13.2)
****JGC	1 1⁄2" 250# (40)	J	2½" FPT (65)	15⅛ (384.2)	3½ (88.9)	4¼ (108)	3 (76.2)	—	36 (16.3)
****JHC	2" 250# (50)	J	3" FPT (80)	15¾ (400.1)	4 (101.6)	4⅝ (117.5)	3½ (88.9)	—	42 (19.1)
****KHB	2" FPT (50)	K	3" FPT (80)	15¾ (400.1)	4 (101.6)	4⅝ (117.5)	3½ (88.9)	3⅝ (92.1)	36 (16.3)
****KHC	2" 250# (50)	K	3" FPT (80)	15¾ (400.1)	4 (101.6)	4⅝ (117.5)	3½ (88.9)	—	42 (19.1)
****KJC	2½" 250# (65)	K	3" FPT (80)	15¾ (400.1)	4 (101.6)	4¾ (120.7)	3½ (88.9)	—	45 (20.4)
****LJB	2½" FPT (65)	L	4" FPT (100)	23[(2)] (584.2)	5⅛ (130.2)	5½ (139.7)	6 (152.4)	4½ (114.3)	97 (44.0)
****LJC	2½" 250# (65)	L	4" FPT (100)	23[(2)] (584.2)	5⅛ (130.2)	5½ (139.7)	6 (152.4)	—	105 (47.6)
****KKC	3" 250# (80)	K	3" FPT (80)	15¾ (400.1)	4 (101.6)	5 (127)	3½ (88.9)	—	48 (21.8)
****LKC	3" 250# (80)	L	4" FPT (100)	23[(2)] (584.2)	5⅛ (130.2)	5½ (139.7)	6 (152.4)	—	107 (48.5)
****MKB	3" FPT (80)	M	4" FPT (100)	23⅛ [(2)] (587.4)	5⅛ (130.2)	55/8 (142.9)	6 (152.4)	4½ (114.3)	99 (44.9)
****MKC	3" 250# (80)	M	4" FPT (100)	23 (2) (584.2)	5⅛ (130.2)	5½ (139.7)	6 (152.4)	—	107 (48.5)
****NMD	4" 250# (100)	N	6" 125# (150)	29½ [(2)] (749.3)	7¼ (184.2)	6¾ (171.5)	6 (152.4)	—	215 (97.5)
****PMD	4" 250# (100)	P	6" 125# (150)	39 1⁄2 [(2)] (749.3)	7¼ (184.2)	6¾ (171.5)	6 (152.4)	—	215 (97.5)
****QPD [(2)]	6" 250# (150)	Q	8" 125# (200)	39½ (2) (1003.3)	10 (254)	9¼ (235)	10½ (266.7)	—	605 (274.4)
****RPD [(2)]	6" 250# (150)	R	8" 125# (200)	39½ (2) (1003.3)	10 (254)	9¼ (235)	10½ (266.7)	—	605 (274.4)

*Accurate to ±1/8".
**** Use appropriate Model Number.

(1) Add 50% to D Dimension when lever is pulled out to manually operate valve.
(2) Dimensions are current as of printing, consult factory for updated dimensions as they may change.

FIGURE 7.11 (continued)
Pressure relief valve selection example/procedure. (Downloaded from the Internet from Spence Engineering, Safety Relief Valves, Figure 31/41 Cast Iron Series. Used with permission from Spence Engineering Company, Inc. www.spenceengineering.com.) *(continued)*

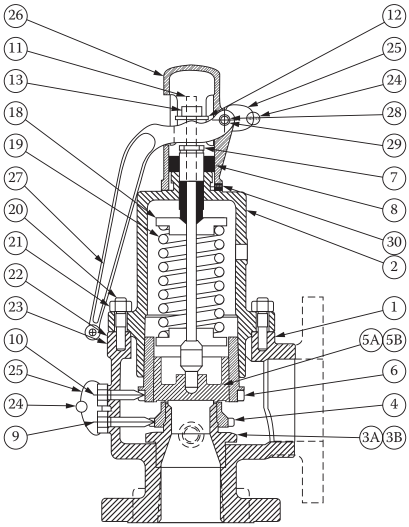
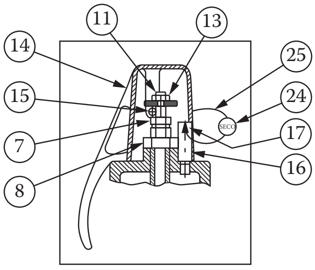


FIGURE 31 CAST IRON SERIES



CAP & LEVER CONFIGURATION
FOR J & K ORIFICES

FIGURE 31 / 41
CAST IRON SERIES

Materials of Construction

Ref	Part Name	Material
1	Body	Cast Iron ASTM A126-B
2	Bonnet	Cast Iron ASTM A126-B
3A	Nozzle - Bronze	Brass or Bronze ASTM B16 or B62
3B	Nozzle - SST	SST ASME SA351, CF8M or ASME SA479, S31600
4	Nozzle Ring	Bronze ASTM B584-C84400
5A	Disc - Bronze	Brass or Bronze ASTM B16 or B62
5B	Disc - SST	SST ASTM A479, S31600
6	Guide Ring	ASTM B584-C84400
7	Adjusting Bolt	Brass ASTM B16
8	Adjusting Bolt Locknut	Steel, Zinc Plated
9	Nozzle Ring Set Screw	Brass ASTM B16
10	Guide Ring Set Screw	Brass ASTM B16
11	Spindle	Steel ASTM A108 Grade 1212
12	Spindle Nut	Steel ASTM A108 Grade 1212
13	Spindle Nut Locknut	Steel, Zinc Plated
14	Lifting Cap	Zinc Alloy Zamac #3
15	Lifting Cap Pins	Steel, Zinc Plated AISI 1020
16	Pivot Post	Steel AISI 1020
17	Post Pin	Steel, Zinc Plated AISI 1070
18	Spring Washer	Steel AISI 1212
19	Spring	Steel Zinc Plated
20	Stud	Steel, Chrome-Moly ASTM A193 B7
21	Stud Nut	Steel, Chrome-Moly ASTM A194 2H
22	Nameplate	SST AISI 304
23	Nameplate Screws	SST Commercial 18-8
24	Lead Seal	Lead
25	Seal Wire	SST AISI 304
26	Lifting Cap	Cast Iron A126-B*
27	Lifting Lever	Cast Iron ASTM A126-B
28	Clevis Pin	Steel, Zinc Plated
29	Cotter Pin	Steel
30	Liftcap Lockscrew	Steel

*Ductile Iron for 4" and above.

ASTM A395 Grade 60-40-18

FIGURE 7.11 (continued)
Pressure relief valve selection example/procedure. (Downloaded from the Internet from Spence Engineering, Safety Relief Valves, Figure 31/41 Cast Iron Series. Used with permission from Spence Engineering Company, Inc. www.spenceengineering.com.) *(continued)*

SATURATED STEAM CAPACITY CHART

CAST IRON MODELS 41 & 42

ASME Section VIII "UV" 90% rated at 10% Overpressure LBS/HR (KGS/HR)

Flow Coefficient = .9 × .975 = .878

LBS/HR

Set Pressure PSIG	Orifice Area, in^2 J 1.391	K 1.892	L 2.935	M 3.715	N 4.468	P 6.564	Q 11.365	R 16.475
10*	1742	2251	3676	4653	5596	8221	14235	20635
15	2057	2798	4340	5494	6606	9706	16804	24360
20	2371	3225	5003	6335	7617	11190	19374	28085
25	2686	3653	5667	7175	8627	12674	21943	31809
30	3000	4081	6330	8015	9637	14158	24513	35534
35	3346	4551	7060	8939	10748	15790	27339	39631
40	3692	5022	7790	9863	11859	17422	30165	43729
45	4038	5492	8520	10787	12970	19055	32992	47826
50	4384	5963	9250	11711	14081	20687	35818	51923
55	4730	6433	9980	12636	15193	22320	38645	56020
60	5076	6904	10710	13560	16304	23952	41471	60117
65	5422	7374	11440	14484	17415	25585	44297	64215
70	5768	7845	12170	15408	18526	27217	47124	68312
75	6114	8316	12900	16332	19637	28849	49950	72409
80	6460	8786	13630	17256	20748	30482	52777	76506
85	6805	9257	14359	18180	21860	32114	55603	80604
90	7151	9727	15089	19105	22971	33747	58429	84701
95	7497	10198	15819	20029	24082	35379	61256	88798
100	7843	10668	16549	20953	25193	37012	64082	92895
105	8189	11139	17279	21877	26304	38644	66909	96992
110	8538	11609	18009	22801	27415	40276	69735	101090
115	8881	12080	18739	23725	28527	41909	72561	105187
120	9227	12550	19469	24649	29638	43541	75388	109284
125	9573	13021	20199	25574	30749	45174	78214	113381
130	9919	13491	20929	26498	31860	46806	81041	117479
135	10265	13962	21659	27422	32971	46438	83867	121576
140	10611	14432	22388	28346	34082	50071	86693	125673
145	10957	14903	23118	29270	35194	51703	89520	129770
150	11303	15373	23848	30194	36305	53336	92346	133868
155	11648	15844	24578	31118	37416	54968	95173	137965
160	11994	16314	25308	32043	38527	56601	97999	142062
165	12340	16785	26038	32967	39638	58233	100825	146159
170	12686	17256	26768	33891	40749	59865	103652	150256
175	13032	17726	27498	34815	41861	61498	106478	154354
180	13378	18197	28228	35739	42972	63130	109305	158451
185	13724	18667	28958	36663	44083	64763	112131	162548
190	14070	19138	29688	37587	45194	66395	114957	166645
195	14416	19608	30418	38512	46305	68028	117784	170743
200	14762	20079	31147	39436	47416	69660	120610	174840
205	15108	20549	31877	40360	48527	71292	123437	178937
210	15454	21020	32607	41284	49639	72925	126263	183034
215	15800	21490	33337	42208	50750	74557	129089	187131
220	16146	21961	34067	43132	51861	76190	131916	191229
225	16492	22431	34797	44057	52972	77822	134742	195326
230	16837	22902	35527	44981	54083	79455	137569	199423
235	17183	23372	36257	45905	55194	81087	140395	205320
240	17529	23843	36987	46829	56306	82719	143221	207618
245	17875	24313	37717	47753	57417	84352	146048	211715
250	18221	24784	38447	48677	58528	85984	148874	215812
1.0	69.2	94.0	146.0	184.8	222.2	326.4	565.2	819.4

*Pressure settings below 15 PSIG (1.034 barg) are non code.

KGS/HR

Set Pressure PSIG	Orifice Area, cm^2 J 8.97	K 12.21	L 18.94	M 23.97	N 28.83	P 42.35	Q 73.32	R 106.29
0.4*	670	912	1414	1790	2153	3163	5477	7939
0.6*	753	1024	1589	2011	2419	3554	6153	8919
0.8*	836	1137	1763	2232	2685	3944	6829	9899
1*	918	1249	1938	2453	2950	4334	7504	10879
1.2	1001	1362	2113	2674	3216	4725	8180	11858
1.4	1084	1474	2287	2895	3482	5115	8856	12838
1.6	1167	1587	2462	3116	3747	5505	9532	13818
1.8	1249	1699	2636	3337	4013	5896	10208	14798
2	1332	1812	2811	3558	4279	6286	10884	15777
2.2	1420	1932	2997	3793	4562	6702	11604	16821
2.4	1511	2056	3189	4036	4854	7131	12347	17899
2.6	1602	2179	3381	4279	5146	7561	13091	18977
2.8	1693	2303	3573	4522	5439	7990	13834	20055
3	1784	2427	3765	4765	5731	8420	14578	21132
3.2	1875	2551	3957	5008	6023	8849	15321	22210
3.4	1966	2674	4149	5251	6316	9278	16065	23288
3.6	2057	2798	4341	5494	6608	9708	16808	24365
3.8	2148	2922	4533	5737	6900	10137	17552	25443
4	2239	3046	4725	5980	7192	10567	18295	26521
4.2	2330	3169	4917	6223	7485	10996	19038	27599
4.4	2421	3293	5109	6466	7777	11425	19782	28676
4.6	2512	3417	5301	6709	8069	11855	20525	29754
4.8	2603	3541	5493	6952	8362	12284	21269	30832
5	2694	3665	5685	7195	8654	12713	22012	31910
5.2	2785	3788	5877	7438	8946	13143	22756	32987
5.4	2876	3912	6069	7681	9238	13572	23499	34065
5.6	2967	4036	6261	7924	9531	14002	24243	35143
6	3149	4283	6645	8410	10115	14860	25730	37298
6.5	3377	4593	7125	9018	10846	15934	27588	39993
7	3604	4902	7605	9626	11577	17007	29447	42687
7.5	3832	5212	8085	10233	12307	18081	31305	45381
8	4059	5521	8565	10841	13038	19154	33164	48075
8.5	4287	5830	9045	11448	13769	20228	35023	50770
9	4514	6140	9525	12056	14499	21301	36881	53464
9.5	4742	6449	10005	12663	15230	22375	38740	56158
10	4969	6759	10485	13271	15961	23448	40599	58853
10.5	5196	7068	10965	13878	16691	24522	42457	61547
11	5424	7378	11445	14486	17422	25595	44316	64241
11.5	5651	7687	11925	15094	18153	26669	46174	66936
12	5879	7996	12404	15701	18884	27742	48033	69630
12.5	6106	8306	12884	16309	19614	28816	49892	72324
13	6334	8615	13364	16916	20345	29889	51750	75019
13.5	6561	8925	13844	17524	21076	30963	53609	77713
14	6789	9234	14324	18131	21806	32036	55468	80407
14.5	7016	9543	14804	18739	22537	33110	57326	83102
15	7244	9853	15284	19346	23268	34183	59185	85796
15.5	7471	10162	15764	19954	23998	35256	61044	88490
16	7699	10472	16244	20562	24729	36330	62902	91185
16.5	7926	10781	16724	21169	25460	37403	64761	93879
17	8154	11091	17204	21777	26191	38477	66619	96573
0.1	45.5	61.9	96	121.5	146.1	214.7	371.7	538.9

FIGURE 7.11 (continued)
Pressure relief valve selection example/procedure. (Downloaded from the Internet from Spence Engineering, Safety Relief Valves, Figure 31/41 Cast Iron Series. Used with permission from Spence Engineering Company, Inc. www.spenceengineering.com.)

TABLE 7.4
Drip Pan Elbow Schedule

Equipment Served	Drip Pan Elbow Inlet Size (in.)	Drip Pan Elbow Inlet Connection Type	Drip Pan Elbow Exhaust Vent Size (in.)	Drip Pan Elbow Drain Size (in.)
Deaerator	1	NPT	2	⅜
Boiler	2½	NPT	4	¾
Pressure reducing station	6	Flanged	8	¾

Note: For SI units: 1 in. = 25 mm.

Steam Traps

Different types of steam traps are selected for our sample project to best satisfy each application (refer to Chapter 4 Steam Trap Section guide). The steam traps are manufactured by Armstrong International, Inc., as scheduled in Table 7.5.

Refer to the PID drawings for steam traps' location, application, and tag number.

The Armstrong steam trap selection software was used to size and select the steam traps.

See additional manufacturer literature in SI and PI units in Figure 7.13 for the selected steam traps.

The information is included with permission from Armstrong International, Inc., for educational purposes only.

Consult with the manufacturer for additional guidance about selection and application of steam traps.

The manufacturer's website is www.armstronginternational.com.

Exhaust Silencer

An exhaust silencer is used for our sample project to reduce the noise during boiler capacity tests. The generated noise is at the steam discharge point during the test. The silencer is installed horizontally at the boiler test connection discharge pipe on the roof. The silencer must be properly supported for thermal expansion and contraction movements and wind and seismic loads.

Drip pan Elbow
inlet size:
Boiler PRV = 2 1/2”
Deaerator PRV = 1”
PCV station PRV = 6”

spirax sarco®

Drip Pan Elbow

The Drip Pan Elbow, when used in conjunction with a safety relief valve, provides a suitable unrestricted, self-draining outlet. This improves the performance and longevity of the safety valve by alleviating axial loads on the valve, which could impair its operation and shut off.

Model ⇨	DPE	
Sizes	3/4” to 4”	6” & 8”
Connections	Female NPT	Flanged ANSI 125
Construction	Cast Iron (ASTM A126 CL B)	

Typical Applications

Specifically for use on the outlet connection of safety/relief valves to assure unrestricted discharge.

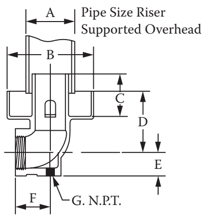
DA tank

Dimensions (nominal) in inches and *millimeters*

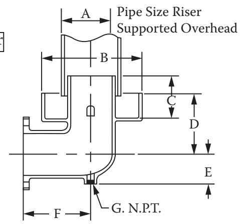
SIZE INLET *in/mm*	A in *(mm)*	B in *(mm)*	C in *(mm)*	D in *(mm)*	E in *(mm)*	F in *(mm)*	G. NPT in *(mm)*	Weight Lb. *(kg.)*
3/4” *(20)*	**2.00** *(51)*	**3.75** *(95)*	**1.88** *(48)*	**2.00** *(51)*	**1.00** *(25)*	**1.50** *(38)*	**3/8** *(10)*	**2** *(1)*
1” *(25)*	**2.00** *(51)*	**3.75** *(195)*	**1.88** *(48)*	**2.00** *(51)*	**1.00** *(25)*	**1.50** *(38)*	**3/8** *(10)*	**2** *(1)*
1-1/4” *(32)*	**2.00** *(51)*	**5.50** *(140)*	**2.47** *(63)*	**4.13** *(105)*	**1.44** *(37)*	**2.13** *(54)*	**3/8** *(10)*	**7.5** *(3)*
1-1/2” *(40)*	**2.00** *(51)*	**5.50** *(140)*	**2.47** *(63)*	**4.13** *(105)*	**1.44** *(37)*	**2.13** *(54)*	**3/8** *(10)*	**7.5** *(3)*
2” *(50)*	**3.00** *(76)*	**6.25** *(159)*	**2.31** *(159)*	**3.63** *(92)*	**1.63** *(41)*	**2.25** *(57)*	**1/2** *(15)*	**8.5** *(4)*
2-1/2” *(65)*	**4.00** *(102)*	**7.38** *(187)*	**3.00** *(176)*	**4.31** *(109)*	**1.94** *(49)*	**2.69** *(68)*	**3/4** *(20)*	**12** *(5)*
3” *(80)*	**4.00** *(102)*	**8.00** *(203)*	**3.050** *(89)*	**4.88** *(124)*	**2.31** *(59)*	**3.13** *(80)*	**3/4** *(20)*	**19** *(9)*
4” *(100)*	**6.00** *(152)*	**9.63** *(245)*	**4.50** *(114)*	**5.75** *(146)*	**2.88** *(73)*	**3.75** *(95)*	**3/4** *(20)*	**25** *(11)*
6” *(150)*	**8.00** *(203)*	**12.75** *(324)*	**6.63** *(168)*	**7.44** *(189)*	**4.19** *(106)*	**8.00** *(203)*	**3/4** *(20)*	**105** *(48)*
8” *(200)*	**10.00** *(254)*	**16.50** *(419)*	**7.50** *(191)*	**9.44** *(240)*	**5.38** *(137)*	**10.75** *(273)*	**1** *(25)*	**202** *(92)*

Boiler

PCV



Sizes: 3/4" –4"
Construction Material: A126-B Cast Iron



Sizes: 6" - 8"
Construction Material: A126-B Cast Iron

Limiting Operating Conditions

Max. Operating Pressure (PMO)	250 psig (17) barg)
Max. Operating Temperature (TMO)	450°F (232°C) at all operating pressures

Installation

The Drip Pan Elbow is to be connected to the discharge connection of the safety/relief valve by a short pipe nipple. Flanged valves 4” and smaller will require a companion flange and short nipple the same size as the valve outlet. The drain connection on the bottom of the elbow should be piped to waste. Please refer to ASME code for additional installation details.

Sample Specification

Drip Pan Elbows for use with safety/relief valves shall be ASTM A126 CL B Cast Iron, and be of the same size as the valve outlet or larger. Pipe as shown on the drawings.

Local regulation may restrict the use of this product below the conditions quoted. Limiting conditions refer to standard connections only.
In the interests of development and improvement of the product, we reserve the right to change the specification.

FIGURE 7.12
Drip pan elbow selection example/procedure. (Downloaded from the Internet from Spirax Sarco Safety Valves, Technical Information, Drip Pan Elbow, TI-3-2142-US. Used with permission from Spirax Sarco, Inc. www.spiraxsarco.com.)

The selected silencer is a model SP 8-30 manufactured by Penn Separator Corporation.

The silencer combined noise reduction at 24,150 lb/h (10,964 kg/h) of saturated steam flow rate at an operating pressure of 150 psig (10.34 barg), as indicated in the manufacturer’s catalog charts, is 41.8 dB. The steam pressure drop through the silencer is approximately 5 psi (34.5 kPa).

TABLE 7.5

Steam Traps Schedule

Tag No.	*Q*[a]	Type[b]	Model	Orifice Size	*P*[c]	NPT[d]	Notes
T-1	3,300	IB	813	7/32 in.	180	1	2, 3, 6, 7, 10
T-2	200	IB	800	# 38	150	¾	1, 2, 3, 10
T-3	11,000	IB	816	⅜ in.	250	2½	2, 3, 10, 11
T-4	150	IB	800	# 38	150	¾	3, 8, 9, 10
T-5	6,000	F&T	30-L10	1⅝ in.	30	2	4, 5, 10, 12
T-6	8,000	F&T	30-L10	1⅝ in.	30	2½	4, 5, 10, 13

Note: For SI units: 1 lb/h = 0.454 kg/h, 1 in. = 25 mm, 1 psig = 6.895 kPag = 0.069 barg.

Notes:

1. Sized for 65 lb/h (29.5 kg/h) load with 300% safety factor.
2. Sized based on 130 psi (8.9 bar) differential pressure across the trap.
3. Sized based on on-off (nonmodulating) supply steam pressure.
4. Sized based on modulating supply steam pressure.
5. Sized based on 2 psi (0.14 bar) differential pressure across the trap.
6. Sized for 2,250 lb/h (1,022 kg/h) load to capture water carryover from boilers with 50% safety factor.
7. Includes optional large vent with the trap, Inverted Bucket with Large Vent (IBLV).
8. Sized for 50 lb/h (23 kg/h) load with 300% safety factor.
9. Sized based on 27 psi (1.9 bar) differential pressure across the trap.
10. Selected for horizontal flow direction.
11. Sized for 5,500 lb/h (2,497 kg/h) load with 200% safety factor.
12. Sized for 3,000 lb/h (1,362 kg/h) load with 200% safety factor.
13. Sized for 4,000 lb/h (1,816 kg/h) load with 200% safety factor.

[a] Flow rate (lb/h).
[b] IB = inverted bucket, F&T = float and thermostatic.
[c] Maximum operating pressure (psig).
[d] NPT connection size (in.).

The silencer physical dimensions are as follows:

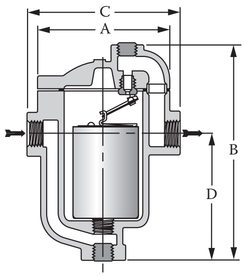
1. Length: 15 ft (4.6 m).
2. Diameter: 30 in. (760 mm).
3. Inlet connection size: 8 in. (200 mm) with 150# ANSI flange.
4. Drain connection size: 1½ in. (40 mm) with threaded connection.

See additional manufacturer literature in Figure 7.14 with several noted features for the selected exhaust silencer. The information is included with permission from Penn Separator Corporation for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer’s website is www.pennseparator.com.

800-813 Series Inverted Bucket Steam Trap
Cast Iron for Horizontal Installation
For Pressures to 250 psig (17 bar)...Capacities to 4,400 lb/hr (2,000 kg/hr)



Description
The most reliable steam trap known—the inverted bucket—provides efficient condensate drainage of virtually all types of steam-using equipment. Put the inverted bucket to work in a tough cast iron package, and you have the best of both worlds. Because they operate efficiently for longer periods of time, Armstrong cast iron inverted buckets add solid energy savings to lower replacement/labor costs. All Armstrong cast iron inverted bucket steam traps are repairable for even bigger maintenance savings.

A unique leverage system multiplies the force provided by the bucket to open the valve against system pressure.The mechanism is free-floating, and has no fixed pivots to create wear or friction.

Because the mechanism is located at the top of the trap, no dirt can collecton the orifice.Small particles of dirt are held in suspension until discharged by the full differential purging action when the bucket sinks, pulling the valve off the seat.

The discharge orifice is surrounded by a water seal, preventing live steam loss.Automatic air venting is provided by a small vent hole in the bucket, which provides continuous automatic air and CO_2 venting at steam temperature.

Inverted bucket traps drain continuously, although discharging intermittently, allowing no condensate backup.They are also resistant to water hammer.

Maximum allowable pressure (vessel design):	250 psig @ 450°F (17 bar @ 232°C)
Maximum operating pressure:	Model 800: 150 psig (10 bar) Model 811-813: 250 psig (17 bar)

Maximum Operating Conditions

Connections
Screwed NPT and BSPT

Materials
Body: ASTM A48 Class 30
Internals: All stainless steel—304
Valve and seat: Hardened chrome steel—440F
Test plug: Carbon steel

Options
- Stainless steel internal check valve
- Thermic vent bucket
- Stainless steel pop drain
- Probe connection
- Thermo drain
- Scrub wire

Specification
Inverted bucket steam trap, type ...in cast iron, with continuous air venting at steam temperature, free-floating stainless steel mechanism, and discharge orifice at the top of the trap.

How to Order
Specify:
- Model number
- Size and type of pipe connection
- Maximum working pressure that will be encountered or orifice size
- Any options required

T-1

For a fully detailed certified drawing, refer to CD #1000.

T-2 & T4

800-813 Series Side Inlet, Side Outlet Traps. Add suffix “CV” to model number for internal check valve, “T” for thermic vent bucket.

Model No.	800*		811		812		813	
	in	mm	in	mm	in	mm	in	mm
Pipe Connections	1/2, 3/4	15, 20	1/2, 3/4, 1	15, 20, 25	1/2, 3/4	15, 20	3/4, 1	20, 25
Test Plug	1/4	6	1/4	6	1/2	15	3/4	20
“A” (Flange Diameter)	3-3/4	95.2	3-3/4	95.2	5-5/8	143	7	178
“B” (Height)	5-7/16	138	6-7/8	175	9-1/16	230	11-3/4	298
“C” (Face-to-Face)	5	127	5	127	6-1/2	165	7-3/4	197
“D” (Bottom to CL Inlet)	2-3/4	70	4-1/4	108	5-3/8	137	7-1/32	179
Number of Bolts	6							
Weight lb (kg)	5 (2.3)		6 (2.7)		15(6.8)		27-1/2(12.5)	

*Cannotbefurnishedwithboththermicventbucketandcheckvalve.

FIGURE 7.13
Steam traps selection example/procedure. (Downloaded from the Internet from Armstrong International, Armstrong Products & Services, Steam Traps, Inverted Bucket Traps (800-813 Series Inverted Bucket Steam Traps—Product Literature and 814-816 Series Inverted Bucket Steam Traps—Product Literature). Used with permission from Armstrong International, Inc. www.armstronginternational.com.) *(continued)*

800-813 Series Inverted Bucket Steam Trap
Cast Iron for Horizontal Installation

For Pressures to 250 psig (17 bar)...Capacities to 4,400 lb/hr (2,000 kg/hr)

Armstrong®

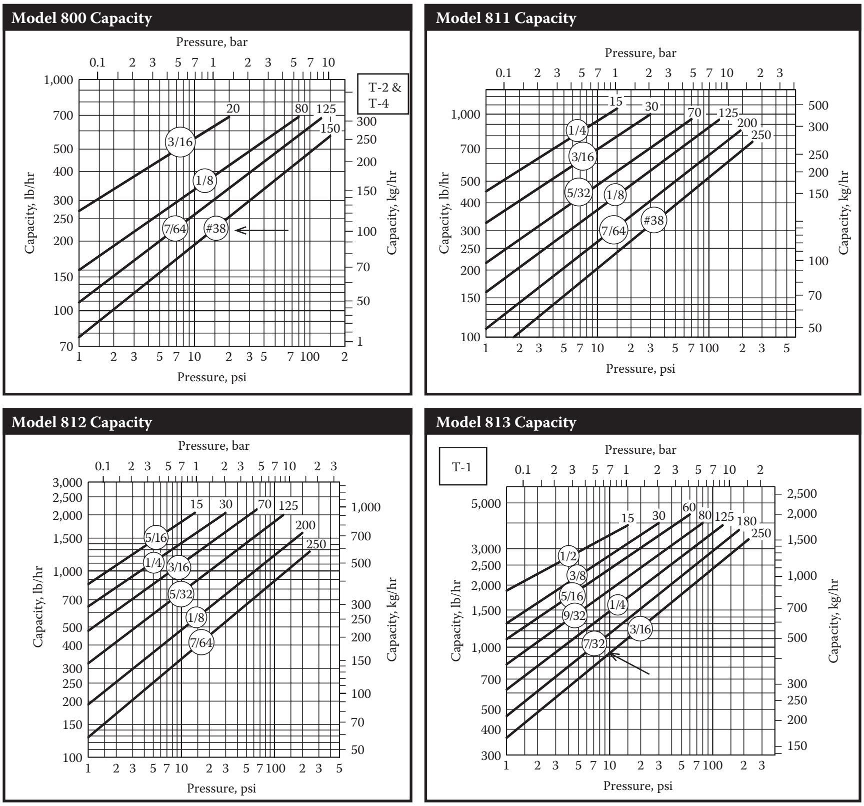
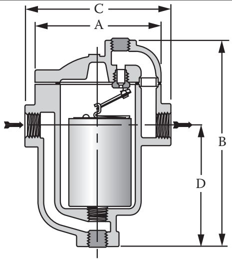


FIGURE 7.13 (continued)
Steam traps selection example/procedure. (Downloaded from the Internet from Armstrong International, Armstrong Products & Services, Steam Traps, Inverted Bucket Traps (800-813 Series Inverted Bucket Steam Traps—Product Literature and 814-816 Series Inverted Bucket Steam Traps—Product Literature). Used with permission from Armstrong International, Inc. www.armstronginternational.com.) *(continued)*

814-816 Series Inverted Bucket Steam Trap
Cast Iron for Horizontal Installation
For Pressures to 250 psig (17 bar)...Capacities to 20,000 lb/hr (9,072 kg/hr)

Armstrong®



Description

The most reliable steam trap known—the inverted bucket—provides efficient condensate drainage of virtually all types of steam-using equipment. Put theinverted bucket to work in a tough cast iron package, and you have the best of both worlds. Because they operate efficiently for longer periods of time, Armstrong cast iron inverted buckets add solid energy savings to lower replacement/labor costs. All Armstrong cast iron inverted bucket steam trap sare repairable for even bigger maintenance savings.

A unique leverage system multiplies the force provided by the bucket to open the valve against system pressure. The mechanism is free-floating, and has no fixed pivots to create wear or friction.

Because the mechanism is located at the top of the trap, no dirt can collect on the orifice. Small particles of dirt are held in suspension until discharged by the full differential purging action when the bucket sinks, pulling the valve off the seat.

The discharge orifice is surrounded by a water seal, preventing live steamloss.Automatic air venting is provided by a small vent hole in the bucket, whichprovides continuous automatic air and CO_2 venting at steam temperature.

Inverted bucket traps drain continuously, although discharging intermittently,allowing no condensate backup. They are also resistant to water hammer.

Maximum Operating Conditions

Maximum allowable pressure (vessel design):	250 psig @ 450°F (17 bar @ 232°C)
Maximum operating pressure:	Model 811-813: 250 psig (17 bar)

Connections

Screwed NPT and BSPT

Materials

Body: ASTM A48 Class 30
Internals: All stainless steel—304
Valve and seat: Hardened chrome steel—440F
Test plug: Carbon steel

Options

- Stainless steel internal check valve
- Thermic vent bucket
- Stainless steel pop drain
- Probe connection
- Thermo drain
- Scrub wire

Specification

Inverted bucket steam trap, type ...in cast iron, with continuous air venting at steam temperature, free-floating stainless steel mechanism, and discharge orifice at the top of the trap.

How to Order

Specify:
- Model number
- Size and type of pipe connection
- Maximum working pressure that will be encountered or orifice size
- Any options required

For a fully detailed certified drawing, refer to CD #1000. T-3

814-816 Series Side Inlet, Side Outlet Traps. Add suffix "CV" to model number for internal check valve, "T" for thermic vent bucket.

Model No.	814		815		816	
	in	mm	in	mm	in	mm
Pipe Connections	1, 1-1/4	25,32	1,1-1/4, 1-1/2, 2	25, 32, 40, 50	2, 2-1/2	50, 65
Test Plug	1	25	1-1/2	40	2	50
"A" (Flange Diameter)	8	203	9	229	11-1/2	292
"B" (Height)	13-5/8	346	16-1/4	413	21-5/16	541
"C" (Face-to-Face)	9	229	10-1/4	260	13	330
"D" (Bottom to CL Inlet)	7-13/16	198	8-1/16	205	11	279
Number of Bolts	8					
Weight lb (kg)	44 (20.0)		71 (32.2)		131 (59.4)	

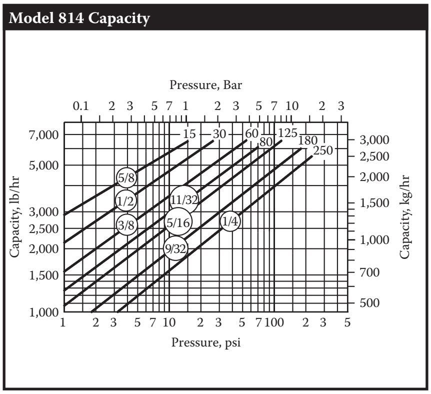
FIGURE 7.13 (continued)
Steam traps selection example/procedure. (Downloaded from the Internet from Armstrong International, Armstrong Products & Services, Steam Traps, Inverted Bucket Traps (800-813 Series Inverted Bucket Steam Traps—Product Literature and 814-816 Series Inverted Bucket Steam Traps—Product Literature). Used with permission from Armstrong International, Inc. www.armstronginternational.com.) *(continued)*

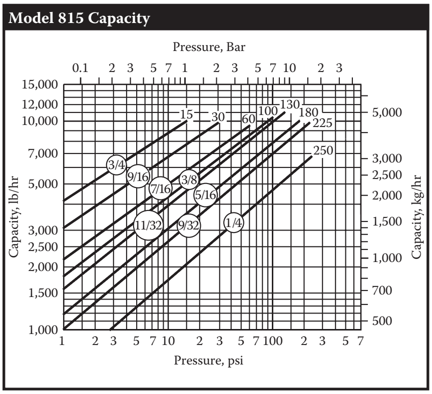
814-816 Series Inverted Bucket Steam Trap

Cast Iron for Horizontal Installation

For Pressures to 250 psig (17 bar)...Capacities to 20,000 lb/hr (9,072 kg/hr)

Armstrong®





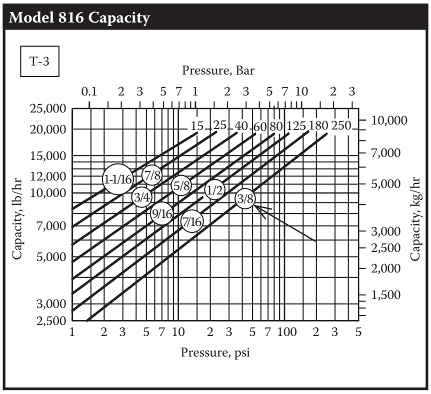
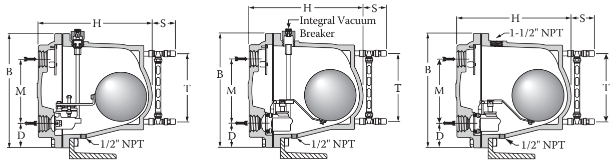


FIGURE 7.13 (continued)

Steam traps selection example/procedure. (Downloaded from the Internet from Armstrong International, Armstrong Products & Services, Steam Traps, Inverted Bucket Traps (800-813 Series Inverted Bucket Steam Traps—Product Literature and 814-816 Series Inverted Bucket Steam Traps—Product Literature). Used with permission from Armstrong International, Inc. www.armstronginternational.com.) *(continued)*

Armstrong®

L & M Series Ultra-Capacity Float & Thermostatic Steam Trap
Cast Iron for Horizontal Installation, With Thermostatic Air Vent
For Pressures to 250 psig (17 bar)…Capacities to 208,000 lb/hr (94,348 kg/hr)



Series L, F&T shown   Series M, CC shown   Series M, LD shown

Description

The simple yet rugged cast iron construction of the L & M Series Ultra-Capacity F&T steam traps offers long, trouble-free service. All floats, valves and seats, and lever mechanisms are constructed of stainless steel.

The integral thermostatic air vent is a balanced-pressure phosphor bronze bellows caged in stainless steel. It is designed especially for heavy-duty industrial applications where highly efficient, uninterrupted service is essential. This balanced pressure type air vent will respond to the pressure-temperature curve of steam at any pressure from zero to 250 psig (17 bar). Thus—up to 250 psig (17 bar)—air is vented at slightly below steam temperature.

Maximum Operating Conditions

Maximum allowable pressure (vessel design):
- Model L: 250 psig @ 450°F (17 bar @ 232°C)
- Model M: 250 psig @ 450°F (17 bar @ 232°C)

Maximum operating pressure:
- Model 30-L: 30 psig (2 bar) saturated steam
- Model 100-L: 100 psig (7 bar) saturated steam
- Model 150-L: 150 psig (10 bar) saturated steam
- Model 250-L: 250 psig (17 bar) saturated steam
- Model 250-M: 250 psig (17 bar) saturated steam

Maximum operating temperature bellows: 422°F (217°C)

Connections

Screwed NPT and BSPT ←
Flanged (screw on)

Materials

Body and cap:	ASTM A48 Class 30
Internals:	All stainless steel—304
Valve(s) and seat(s):	Stainless steel
Drain plug:	Carbon steel
Thermostatic air vent:	Stainless steel and bronze with phosphor bronze bellows, caged in stainless steel

Options

- Integral vacuum breaker 150 psig (10 bar) maximum. Add suffix VB to model number
- No internal thermostatic air vent for liquid drainer service. Add suffix LD to model number
- Integral flash release for syphon drainage service. Add suffix CC to model number
- Armored gauge glass 250 psig @ 424°F (17 bar @ 218°C)
- L and M Series available with floor mounting bracket. Consult factory.

Specification

Float thermostatic steam trap, type … in cast iron, with thermostatic air vent.

For a fully detailed certified drawing, refer to CD #1010.

How to Order

Pressure	Model	Connection Size	Options
250	**M**	**12**	**GG**
→ 30 100 150 250	L	8 = 2" 10 = 2-1/2"	VB = Vacuum Breaker LD = Liquid Drainer CC = Condensate Controller G/G = Gauge Glass FLG = Specify type and class of flange
250	M	12 = 3"	

Special Configurations

Condensate controller with flash release for syphon drainage and/or cascade service. The condensate controller (CC) configuration was developed especially to meet very large capacity needs in applications where condensate must be lifted from the drain point to the trap. Under such conditions—often referred to as syphon drainage—the reduction in pressure that occurs when condensate is elevated causes a portion of the condensate to flash into steam. Ordinary traps, unable to differentiate between flash steam and live steam, close and impede drainage.

The L & M Series condensate controllers (CC) are equipped with a fixed, restricted orifice near the top of the body to bleed off the flash steam (and all air present). This permits the trap to function properly on condensate.

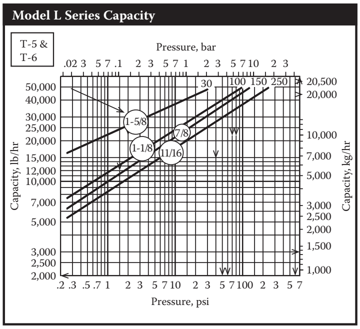
Liquid drainer with back vent for exceptionally high capacity drainage of liquid from gas under pressure. The liquid drainer (LD) configuration was developed to meet very large capacity needs in draining water and other liquids from air or other gases under pressure. To prevent air or gas binding, the access port in the top of the body serves as a back vent connection to the equipment being drained. For capacity data, see pages LD-30 and LD-49 or consult your Armstrong Representative.

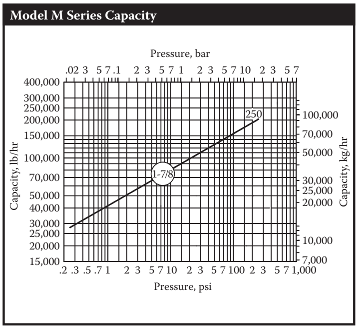
L and M Series Traps				
Trap Series	**L**	**M**	**L**	**M**
Pipe Connection	**in**		**mm**	
	2, 2-1/2	3	50, 65	80
"B" (Height)	20-1/4		514	
"C" (Width)	14-3/4		375	
"D"(Bottom to CL)	4-3/16		106	
"H" (Length)	19-3/4		502	
"M" (CL to CL)	11-5/16		287	
"S" (Gauge Glass Width)	3-3/4		95.2	
"T" (Gauge Glass Height)	12		305	
Weight lb (kg)	196 (88.9)			

FIGURE 7.13 (continued)
Steam traps selection example/procedure. (Downloaded from the Internet from Armstrong International, Armstrong Products & Services, Steam Traps, Float & Thermostatic (L&M Series Float & Thermostatic Steam Traps—Product Literature). Used with permission from Armstrong International, Inc. www.armstronginternational.com.) *(continued)*

L & M Series Ultra-Capacity Float & Thermostatic Steam Trap
Cast Iron for Horizontal Installation, With Thermostatic Air Vent
For Pressures to 250 psig (17 bar)...Capacities to 208,000 lb/hr (94,348 kg/hr)

Armstrong®





Installation Notes
Under conditions where the load may approach the maximum capacity of the trap, it is recommended that the size of the discharge line be increased one size as close to the trap cap as is practical.When L and M Series units are used in severe service conditions or at pressures exceeding 30 psig, use an anchoring bracket or other supportive measures to minimize stress on piping.

Ultra-Capacity L and M Series units MUST BE WARMED UP in the proper sequence and gradually. Recommended warm-up rate—not to exceed 100°F/8 minutes.

See your Armstrong Representative.

Vacuum Breaker—3/8" (10 mm) and 1/2" (15 mm) NPT
Many times, condensate will be retained ahead of steam traps because of the presence of a vacuum.To break a vacuum, air must be introduced into the system by means of a vacuum breaker.

For maximum protection against freezing and water hammer in heating coils under modulated control, for example, vacuum breakers are recommended

Vacuum Breaker				
Size	in	mm	in	mm
	1/2NPT	15	3/8 NPT	10
"B" Pipe Connections	3/8 NPT	10	1/4 NPT	6
"C" Height	1-1/4	30	1-3/32	28
"D" Width	7/8 Hex	22 Hex	11/16 Hex	17 Hex

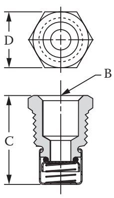


FIGURE 7.13 (continued)
Steam traps selection example/procedure. (Downloaded from the Internet from Armstrong International, Armstrong Products & Services, Steam Traps, Float & Thermostatic (L&M Series Float & Thermostatic Steam Traps—Product Literature). Used with permission from Armstrong International, Inc. www.armstronginternational.com.)

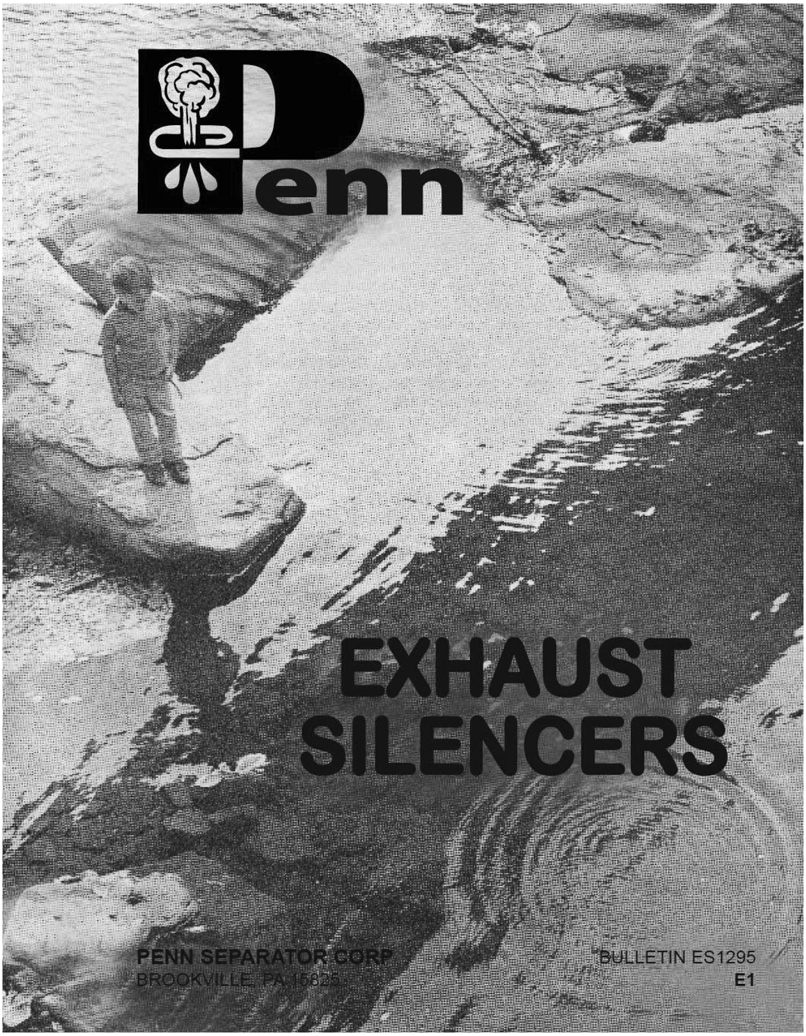


FIGURE 7.14
Exhaust silencer selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation's literature library Bulletin ES 1295. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*

THE SP SILENCER

For Maximum Noise Reduction

The SP Exhaust Silencer is a single pass silencer designed to give maximum attenuation of both low and high frequency noise for air, steam, or gas exhausting to atmosphere.

The gas enters the inlet of the silencer where the flow is disbursed through the inlet diffuser tube into hundreds of small jet flows. This provides for quite flow of the gas into the silencer and the first stage silencing chamber. The diffuser also directs the flow toward the outer walls of the silencer body. The gas then repeats the same process contracting and expanding into the second storage chamber. The second chamber reacts with the noise the same way as the fist chamber dissipating and absorbing the noise that is left over. The second chamber also has an important function as a reflow area. It allows for an even flow of gas to the outlet. This assures the quiet release of gases to the atmosphere through an adequately sized outlet.

The first and second absorption chambers are lined with 1/2" Dalcon Acoustical Material protected by perforated plate. The perforated plate creates a dimple effect on the acoustical material. This feature is similar to dimpled acoustical tile. It is this design that is very efficient in absorbing medium and high frequency noise. Besides the absorption material please note the strategically placed dissipative chamber openings on the perforated plate where there is no acoustical material. These areas are specifically designed to absorb low frequency noise. This means the silencer will work for both low and high frequency noise.

Each silencer reduces noises differently. The larger the size, the higher the reduction. These reductions range from 34.9 to 48.4dB. The following page gives these combined reductions as well as reductions at various frequencies.

Both the SP and SP-S Silencer are designed to take high inlet velocities of 900 fps. So they make excellent exhaust Silencers. The acoustical material "Dalcon" is rated for 1250 deg. F so that this silencer works well on steam conditions. The SP and SP-S Exhaust Silencers have the same quality of workmanship that has gone into all Penn Products for so many years and is guaranteed for a year against defects in materials or workmanship.

For maximum noise reduction choose Penn's SP Exhaust Silencer.

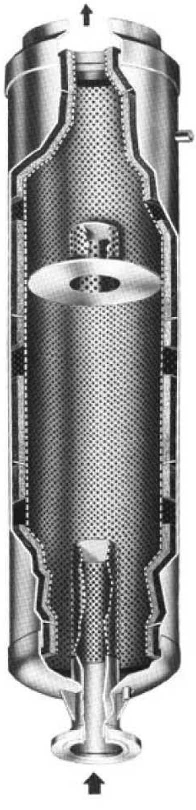


FIGURE 7.14 (continued)
Exhaust silencer selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation's literature library Bulletin ES 1295. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*

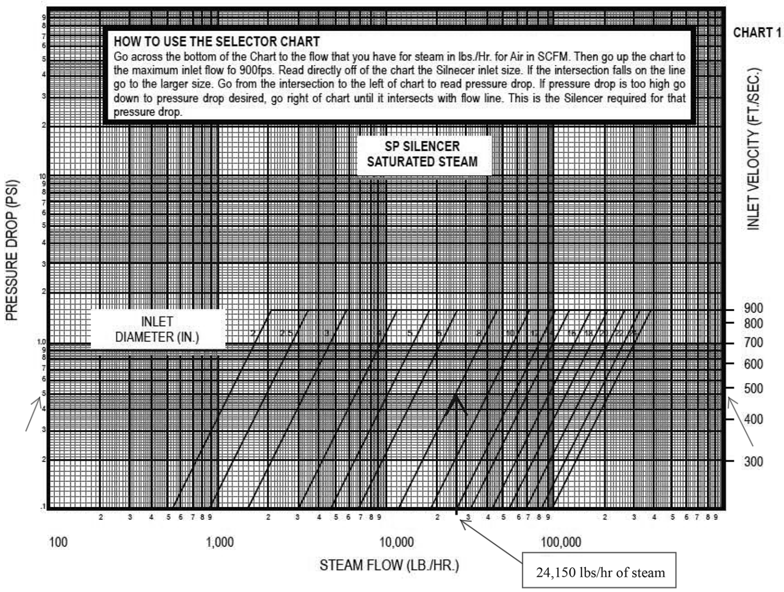
SP SILENCER — ATTENUATION LEVELS ON STEAM

Frequency	31.5	63	125	250	500	1K	2K	4K	8K	16K	Combined
SP 2-14	1.6	1.4	6.9	11.0	22.8	32.0	37.9	40.6	36.8	26.9	**34.9**
SP 2.5-14	2.9	3.3	5.6	10.5	22.0	30.9	38.0	41.3	39.5	27.6	**36.5**
SP 3-18	3.5	4.0	4.9	11.5	21.8	34.0	39.0	43.5	40.0	28.0	**36.8**
SP 4-20	4.3	4.6	4.7	14.5	22.4	31.6	40.4	41.5	37.9	30.0	**38.2**
SP 5-24	5.0	4.9	5.0	15.5	25.4	35.1	42.2	43.4	40.4	28.1	**38.4**
SP 6-24	6.1	4.8	5.5	17.1	25.4	32.8	40.6	45.0	42.6	31.8	**39.9**
SP 8-30	8.8	3.7	6.4	15.4	28.0	36.2	42.4	44.5	42.1	32.9	**41.8**
SP 10-36	9.2	3.6	7.6	15.2	28.0	34.8	42.2	46.2	43.1	31.3	**42.0**
SP 12-42	10.4	4.2	11.4	19.3	27.4	36.6	42.8	48.5	42.9	34.2	**43.7**
SP 14-48	11.1	5.3	12.9	21.7	28.3	38.5	45.0	47.0	43.9	35.5	**45.2**
SP 16-48	11.2	5.8	15.1	19.4	29.6	39.0	44.4	50.2	44.7	34.3	**46.5**
SP 18-48	11.2	5.9	15.3	19.4	32.2	39.9	45.7	49.0	48.6	37.7	**47.0**
SP 20-54	11.3	5.9	15.3	19.0	32.1	40.6	48.7	50.7	45.3	36.8	**48.4**
SP 24-54	11.3	5.9	15.3	19.0	32.1	40.6	48.7	50.7	45.3	36.8	**48.4**

SP SILENCER — ATTENUATION LEVELS ON AIR

Frequency	31.5	63	125	250	500	1K	2K	4K	8K	16K	Combined
SP 2-14	1.9	2.2	5.1	9.8	22.3	29.3	37.4	41.7	38.5	27.3	**34.9**
SP 2.5-14	3.6	3.6	3.7	14.2	24.1	33.5	39.8	43.7	40.4	29.3	**36.4**
SP 3-18	4.3	3.5	4.0	14.9	25.2	30.6	40.9	44.3	40.3	27.2	**36.8**
SP 4-20	5.3	3.0	3.7	16.1	22.1	34.4	40.0	41.3	39.4	30.0	**38.1**
SP 5-24	6.0	2.4	3.4	13.5	23.0	32.2	39.6	44.2	41.2	30.3	**38.3**
SP 6-24	7.1	1.6	5.3	13.3	26.4	31.9	42.5	42.7	41.3	28.2	**39.7**
SP 8-30	8.4	2.6	10.3	19.1	25.1	36.2	43.9	47.2	44.4	33.4	**41.7**
SP 10-36	8.3	2.8	11.2	18.5	25.4	36.0	42.8	45.0	43.0	31.4	**41.5**
SP 12-42	7.9	2.6	11.0	16.3	27.5	37.9	44.5	45.9	43.3	35.0	**43.6**
SP 14-48	7.3	3.7	9.8	21.1	30.2	37.3	47.0	50.2	46.7	33.4	**45.1**
SP 16-48	7.3	6.7	9.8	19.9	29.4	37.6	44.6	51.1	47.4	34.0	**46.5**
SP 18-48	7.5	8.6	10.7	19.3	31.8	38.3	49.0	51.2	47.9	34.0	**46.8**
SP 20-54	7.4	7.5	9.8	18.8	31.8	41.1	48.4	50.2	44.9	35.0	**46.7**
SP 24-54	7.4	7.5	9.8	18.8	31.8	41.1	48.4	50.2	44.9	35.0	**46.7**

FIGURE 7.14 (continued)
Exhaust silencer selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation's literature library Bulletin ES 1295. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*



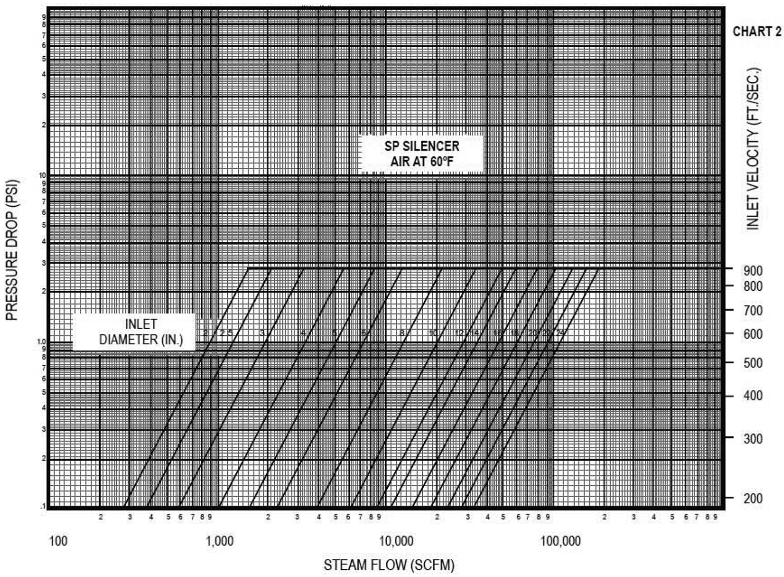
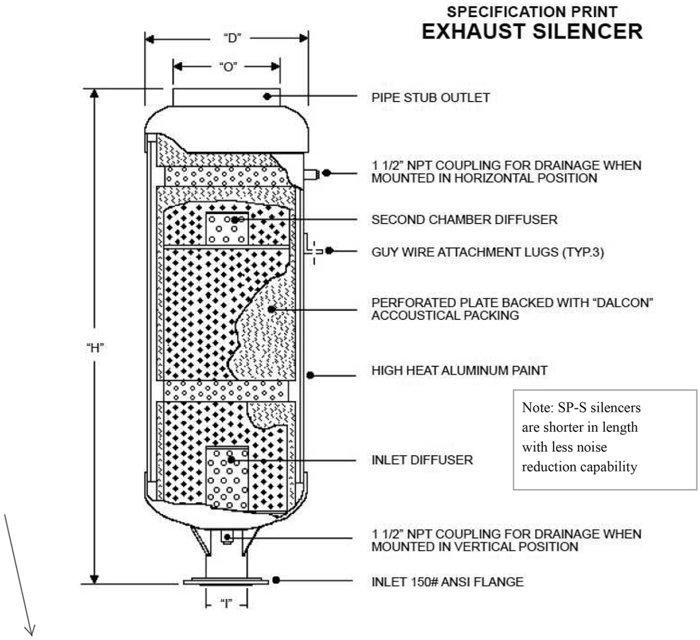


FIGURE 7.14 (continued)
Exhaust silencer selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation's literature library Bulletin ES 1295. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*

DIMENSIONS — SP AND SP-S SILENCER



SP SILENCER

MODEL	DIMENSIONS I	D	O	H	PL Min.
SP 2-14	2	14	5	60	7 Ga.
SP 2.5-14	2 1/2	14	6	84	7 Ga.
SP 3-18	3	18	8	96	7 Ga.
SP 4-20	4	20	10	108	7 Ga.
SP 5-24	5	24	12	120	7 Ga.
SP 6-24	6	24	14	135	7 Ga.
SP 8-30	8	30	18	180	7 Ga.
SP 10-36	10	36	24	195	7 Ga.
SP 12-42	12	42	30	216	1/4"
SP 14-48	14	48	30	252	1/4"
SP 16-48	16	48	36	276	1/4"
SP 18-48	18	48	42	288	1/4"
SP 20-54	20	54	48	288	1/4"
SP 24-54	24	54	48	288	1/4"

SP-S SILENCER

MODEL	DIMENSIONS I	D	O	H	PL Min.
SP 2-14-S	2	14	5	40	7 Ga.
SP 2.5-14-S	2 1/2	14	6	56	7 Ga.
SP 3-18-S	3	18	8	64	7 Ga.
SP 4-20-S	4	20	10	72	7 Ga.
SP 5-24-S	5	24	12	80	7 Ga.
SP 6-24-S	6	24	14	90	7 Ga.
SP 8-30-S	8	30	18	120	7 Ga.
SP 10-36-S	10	36	24	130	7 Ga.
SP 12-42-S	12	42	30	144	1/4"
SP 14-48-S	14	48	30	168	1/4"
SP 16-48-S	16	48	36	184	1/4"
SP 18-48-S	18	48	42	192	1/4"
SP 20-54-S	20	54	48	192	1/4"
SP 24-54-S	24	54	48	192	1/4"

FIGURE 7.14 (continued)
Exhaust silencer selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation's literature library Bulletin ES 1295. Used with permission from Penn Separator Corporation. www.pennseparator.com.) *(continued)*

"DALCON" — AN EFFECTIVE ACOUSTICAL MATERIAL

An acoustical material which absorbs 90% of the sound energy has an absorption coefficient of .9. We tested "DalCon" under different conditions — up to 50% saturated with moisture. This is important because in operation a Silencer can get wet. Under these wet conditions acoustical material can lose its sound absorbing qualities. "DalCon" has an absorption coefficient of .9 on noise with a frequency above 1400Hz. It will absorb 50% of the noise down to 800Hz. This is important because a predominate amount of the noise on exhaust conditions is medium and high frequency noise. We protect the acoustical material with perforated plate with 1/8" dia. Holes. This serves two purposes: prevents the erosion of the acoustical material by the gases flowing through the Silencer and helps reduce the noise level by providing a dimple effect that one finds on acoustical ceiling tile. "DalCon" also has a good temperature rating, 1250°F, which makes it ideal for Steam Silencers.

HOW TO DETERMINE YOUR NOISE LEVEL REDUCTION

We know that for each model Exhaust Silencer a level of reduction is produced. These reductions are stated on the previous pages. The Silencers will reduce the initial noise by the rated reductions listed for each model. The best way to get initial noise levels is by taking actual levels. This level less the silencers rated reduction will equal the final noise level. The initial noise level for this method can be taken at any location. The final level would be the level at this same location. Once a noise level is known for one location other locations can be calculated. It is a rule in acoustics that for every doubling of distance away from the nose source the noise can be reduced by another 3dB (in a semi-reverberant field-buildings near by) and 6 dB in a free field (unobstructed). So by doubling the distance that levels are made estimates of final levels at other locations can be established. Estimates of noise levels can be made when actual noise levels cannot be taken. Information about these calculations is contained in our engineering brochure E-2 Exhaust Noise and Penn Silencers. These estimated levels along with the silencers rated reduction will give estimated final noise levels. Using a Penn Silencer will bring noise on most applications to within required levels.

SOME SATISFIED PENN SILENCER CUSTOMERS

Gulf Oil Refinery, Philadelphia, Pa.
G.E., Mt. Vernon, Ind.
Community College, Memphis, Tenn.
Marchel Paper Co., E. Patterson, N.J.
Naval Amm. Dept., Hawthorne, Nev.
Tougher Ind., Albany, N.Y.
Cam. Ind., Kent, Wash.
Dixie Furniture, Lexington, N.C.
Youngstown Sheet & Tube, Youngstown, Ohio
Allied Chemical, Moncure, N.C.
Merk & Co., Rahway, N.J.
Merch Sharp & Dome, Ireland
Dow Chemical, Freeport, Tx.
Gulf & Western Food, S. Bay, Fla.
Great Lakes Cemical Co., Eldora, Co.
Gen. Motors Assembly Div., Willow Run, Mich.

Your de Penn dable boiler accessories...

FIGURE 7.14 (continued)
Exhaust silencer selection example/procedure. (Downloaded from the Internet from Penn Separator Corporation's literature library Bulletin ES 1295. Used with permission from Penn Separator Corporation. www.pennseparator.com.)

Backflow Preventer

A 2 in. (50 mm) backflow preventer is selected for our sample project. It is model 909M1 Reduced Pressure Zone Assembly type as manufactured by Watts.

The backflow preventer includes:

1. Cap and tether test cocks
2. Flanged adaptor ends
3. Quarter turn ball valves
4. 909 AG air gap for indirect drain

The backflow preventer is a bronze body with bronze test cocks. It is installed horizontal in a place accessible inside the boiler room for annual test. The drain air gap is piped to a hub drain installed under the unit or can be hard connected to a vented and trapped underground waste system.

The water pressure drop through the selected backflow preventer is approximately 10 psi (69 kPa).

See additional manufacturer literature with marked features in Figure 7.15 in PI and SI units for the selected backflow preventer.

The information is included with permission from Watts for educational purposes only.

Consult with the manufacturer for additional guidance.

The manufacturer's website is www.watts.com.

For Health Hazard Applications

Job Name **Sample project** ______________

Contractor ______________

Job Location ______________

Approval ______________

Engineer ______________

Contractor's P.O. No. ______________

Approval ______________

Representative ______________

LEAD FREE*

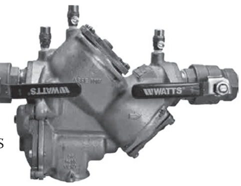
Series LF909

Reduced Pressure Zone Assemblies

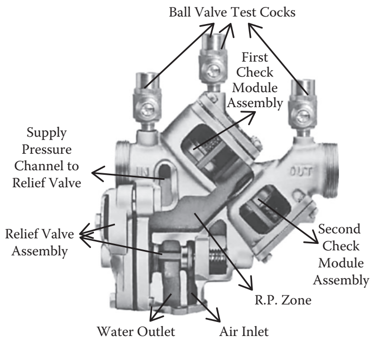
LF909 Sizes: ¾", 1" (20, 25mm)

LF909M1 Sizes: 1¼", 1 ½", 2" (32, 40, 50mm)

Series LF909 Reduced Pressure Zone Assemblies are designed to provide superior cross-connection control protection of the potable water supply in accordance with national plumbing codes and containment control for water authority requirements. This series can be utilized in a variety of installations, including health hazard cross-connections in plumbing systems or for containment at the service line entrance. The LF909 features Lead Free* construction to comply with Lead Free* installation requirements. With its exclusive, design incorporating the "air-in/water-out" principle it provides maximum relief valve discharge during the emergency conditions of combined backsi-phonage and backpressure with both checks fouled. Model LF909QT, standardly furnished with full port, resilient seated and Lead Free* cast copper silicon alloy ball valve shutoffs. Sizes 3⁄4" and 1" (20 and 25mm) shutoffs have tee handles.



Model LF909M1QT-S 1½" (40 mm)



Features

- Modular design
- Replaceable seats
- Compact for installation ease
- Horizontal or vertical (up or down) installation
- No special tools required for servicing

Specifications

A Reduced Pressure Zone Assembly shall be installed at each cross-connection to prevent backsiphonage and backpressure of hazardous materials into the potable water supply. The assembly shall consist of a pressure differential relief valve located in a zone between two positive seating check valves. Backsiphonage protection shall include provision to admit air directly into the reduced pressure zone via a separate channel from the water discharge channel, or directly into the supply pipe via a separate vent. The assembly shall be constructed using Lead Free* cast copper silicon materials. The Lead Free* reduced pressure zone assembly shall comply with state codes and standards, where applicable, requiring reduced lead content. The assembly shall include two tightly closing shutoff valves before and after the assembly, test cocks and a protective strainer upstream of the No. 1 shutoff valve. The assembly (specify Model LF909 for temperatures up to 140°F (60°C) or Model LF909HW for temperatures up to 210°F (99°C)) shall meet the requirements of ASSE Std. 1013; AWWA Std. C-511-92 CSA B64.4; FCCCHR of USC Manual Section 10. Listed by IAPMO (UPC). SBCCI (Standard Plumbing code). The assembly shall be a Watts LF909QTS or LF909QTSHW.

Now Available
WattsBox Insulated Enclosures.
For more information, send for literature ES-WB.

***The wetted surface of this product contacted by consumable water contains less than 0.25% of lead by weight.**

Watts product specifications in U.S. customary units and metric are approximate and are provided for reference only. For precise measurements, please contact Watts Technical Service. Watts reserves the right to change or modify product design, construction, specifications, or materials without prior notice and without incurring any obligation to make such changes and modifications on Watts products previously or subsequently sold.

WATTS®

FIGURE 7.15
Backflow preventer selection example/procedure. (Downloaded from the Internet from Watts, Backflow Prevention, Reduced Pressure Zone Assemblies, Bronze, ES-LF909S-1421, 2014. Used with permission from Watts. www.watts.com.) *(continued)*

Models

Suffix

QT Quarter-turn ball valves
S Bronze strainer
HW Stainless steel check modules for hot and harsh water conditions

NOTICE

The installation of a drain line is recommended. When installing a drain line, an air gap is necessary.

Materials

Body: Lead Free* Cast Copper Silicon Alloy
Check Seats: 909 Celcon®
Relief Valve Seats: Stainless steel 909HW
Test Cocks: Lead Free* Cast Copper Silicon Alloy
Celcon® is a registered trademark of Celanese, Limited

Connections

¾" – 1" (19 – 25mm) 909-NPT Female threaded body connection
1¼" – 2" (32 – 50mm) 909-M1-NPT Male threaded body connection

Standards

AWWA C-511-92
FCCCHR of USC Manual Section 10
IAPMO (UPC), SBCCI (Standard Plumbing code)

Approvals

Listed by IAPMO
Listed by SBCCI

1013 **B64.4**

‡Approved by the Foundation for Cross-Connection Control and Hydraulic Research at the University of Southern California. (QT and S Modes)

Horizontal and vertical "flow-up" approval on ¾" (20mm) and 1" (25mm) sizes (models 909QT).

Pressure — Temperature

Temperature Range: 33°F – 140°F (0.5°C – 60°C) continuos, 180°F (82°C) intermittent

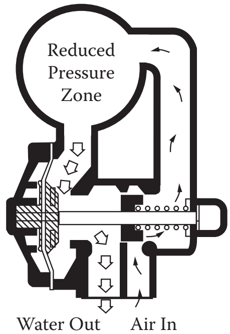
Maximum Working Pressure: 175psi (12.1 bar)

Series 909HW:

Temperature Range: 33°F – 210°F (0.5°C – 99°C)
Maximum Working Pressure: 175psi (12.1 bar)

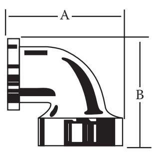
How it Operates

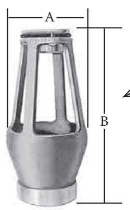
The unique relief valve construction incorporates two channels: one for air, one for water. When the relief valve opens, as in the accompanying air-in/water-out diagram, the right-hand channel admits air to the top of the reduced pressure zone, relieving the zone vacuum. The channel on the left then drains the zone to atmosphere. Therefore, if both check valves foul, and simultaneous negative supply and positive backpressure develop, the relief valve uses the air-in/water-out principle to stop potential backflow.

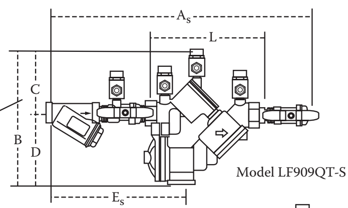


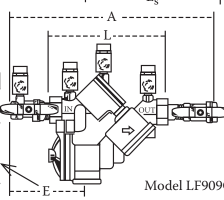
Dimensions — Weights

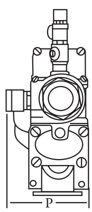
When installing a drain line use 909AG series Air Gaps on Series 909 backflow preventers. ††909EL series elbows are for air gaps on backflow preventers in vertical installations.











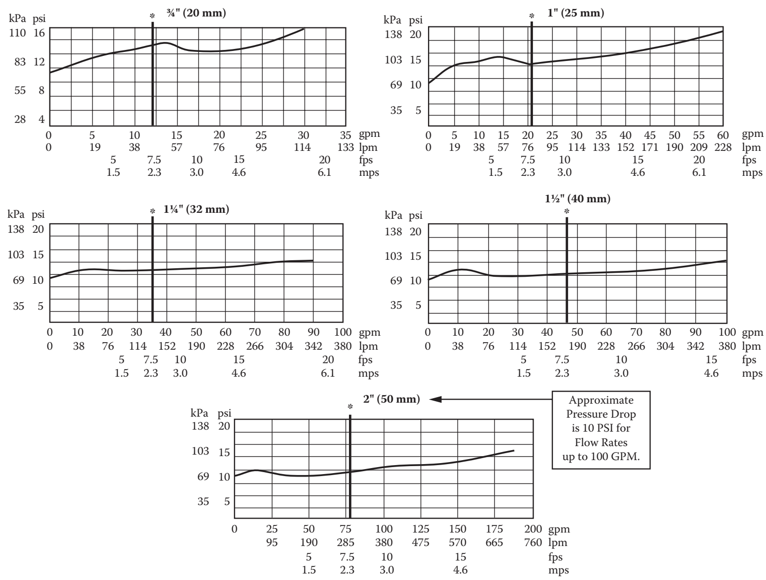
909 DRAIN OUTLET DIMENSIONS WEIGHTS											
Iron Body		Sizes		Sizes		A		B			
No.	*Desc.*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*lbs.*	*kg.*
909AG-C	Air Gap	¾,1	19,25	1	25	3¼	83	4⅞	124	1½	.7
909EL-C	Elbow††	¾,1	19,25	–	–	2⅜	60	2⅜	60	⅜	.2
909AG-F	Air Gap	1¼-2	32-50	2	50	4⅜	111	6¾	171	3¼	1.5
909EL-F	Elbow††	1¼-2	32-50	–	–	3⅝	92	3⅝	92	2	.9

FIGURE 7.15 (continued)
Backflow preventer selection example/procedure. (Downloaded from the Internet from Watts, Backflow Prevention, Reduced Pressure Zone Assemblies, Bronze, ES-LF909S-1421, 2014. Used with permission from Watts. www.watts.com.) *(continued)*

Capacity

As compiled from documented Foundation for Cross-Connection Control and Hydraulic Research of the University of Southern California lab tests.

◊Typical maximum system flow rate (7.5 feet/sec.)



LF909QT, LF909QT-S

SIZE (DN)	DIMENSIONS																		WEIGHT	
	A		As		B		C		D		E		Es		L		P		QT		QT-S
	in.	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*in.*	*mm*	*lbs.*	*kgs.*	*lbs.*	*kgs.*
¾″	14⅜	365	18 1/16	459	8¾	222	4	102	4¾	121	6¾	171	10 3/16	259	7 5/16	186	3⅞	98	14	6.4	15.6	7.1
1″	15⅜	391	19⅝	498	8¾	222	4	102	4¾	121	7	178	11	279	7 5/16	186	3⅞	98	15	6.8	17.5	7.9
1¼″M1	18½	470	23 7/16	595	11⅝	295	5½	140	6½	165	7½	191	12 3/16	310	10⅜	264	5¼	133	40	18.1	42.8	19.4
1½″M1	19	483	24⅜	619	11⅝	295	5½	140	6½	165	7½	191	12⅝	321	10⅜	264	5¼	133	40	18.1	44.0	20.0
2″M1	19½	495	25 15/16	659	11⅝	295	5½	140	6½	165	7¾	197	13 15/16	354	10⅜	264	5¼	133	40	18.1	47.4	21.5

Subscript 'S' = strainer model

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FIGURE 7.15 (continued)
Backflow preventer selection example/procedure. (Downloaded from the Internet from Watts, Backflow Prevention, Reduced Pressure Zone Assemblies, Bronze, ES-LF909S-1421, 2014. Used with permission from Watts. www.watts.com.)

Appendix A: Tables

TABLE A.1

Equivalent Length of Fittings and Valves (Approximate)

Description	(L_e/d)[a]
Screwed 45 elbow	14
Screwed 90 elbow	30
Screwed 180 turn bends	67
Screwed tee through-flow	50
Screwed tee branch flow	65
Welded 90 elbow, R/d[b] = 1	16
Welded 90 elbow, R/d = 1.33	12
Welded 90 elbow, R/d = 2	9
Welded 90 elbow, R/d = 4	7
Welded 90 elbow, R/d = 6	9
Welded 90 elbow, R/d = 8	12
Welded tee branch flow	45
Welded tee through-flow	15
Gate valve	3
Globe valve	333
Angle valve	167
Swing check valve	83

Note: For SI units: 1 in. = 25 mm, 1 ft = 0.305 m.

[a] L_e = equivalent length (ft), d = inside diameter (in.).

[b] R/d is the ratio of the elbow centrline radius (R) in inches divided by the elbow inside diameter (d) in inches.

TABLE A.2

Orifice Steam Relieving Capacity (pounds per hour per square inch)

	Pressure Control Valve									
Outlet Pressure (psig)	Inlet Pressure (psig)									
	250	200	175	150	125	100	75	60	50	30
200	10,900	—	—	—	—	—	—	—	—	—
175	12,600	7,250	—	—	—	—	—	—	—	—
150	13,400	9,540	6,750	—	—	—	—	—	—	—
125	13,600	10,800	8,780	6,220	—	—	—	—	—	—
110	13,600	11,000	9,460	7,420	4,550	—	—	—	—	—
100	13,600	11,000	9,760	7,970	5,630	—	—	—	—	—
85	13,600	11,000	—	8,480	6,640	4,070	—	—	—	—
75	13,600	11,000	—	—	7,050	4,980	—	—	—	—
60	13,630	11,000	—	—	7,200	5,750	3,520	—	—	—
50	—	11,000	—	—	—	5,920	4,230	2,680	—	—
40	—	11,000	—	—	—	—	4,630	3,480	2,470	—
30	—	11,050	—	—	—	—	—	3,860	3,140	—
25	—	—	—	—	—	—	—	—	3,340	1,485
15	—	—	—	—	—	—	—	—	—	2,320
—	—	—	—	—	—	—	—	—	—	—

Note: Where capacities are not shown for inlet and outlet conditions, use the highest capacity shown under the applicable inlet pressure column.

For SI units: 1 psig = 6.895 kPag, 1 in. = 25 mm, 1 in.^{2} = 645 mm^2, 1 in.^{2} = 6.45 cm^2, 1 lb/h/in.^{2} = 70.5 g/h/cm^2.

TABLE A.3

Approximate Internal Pipe Cross-Sectional Area for Standard Weight Pipe

Nominal Pipe Size (in.)	Actual External Diameter (in.)	Approximate Internal Diameter (in.)	*A*[a]
½	0.840	0.62	0.30
¾	1.050	0.82	0.53
1	1.315	1.05	0.86
1¼	1.660	1.38	1.50
1½	1.900	1.61	2.04
2	2.375	2.07	3.36
2½	2.875	2.47	4.78
3	3.50	3.07	7.39
4	4.50	4.03	12.73
6	6.625	6.07	28.89
8	8.625	8.07	51.15
10	10.750	10.19	81.55
12	12.750	12.09	114.80
—	—	—	—

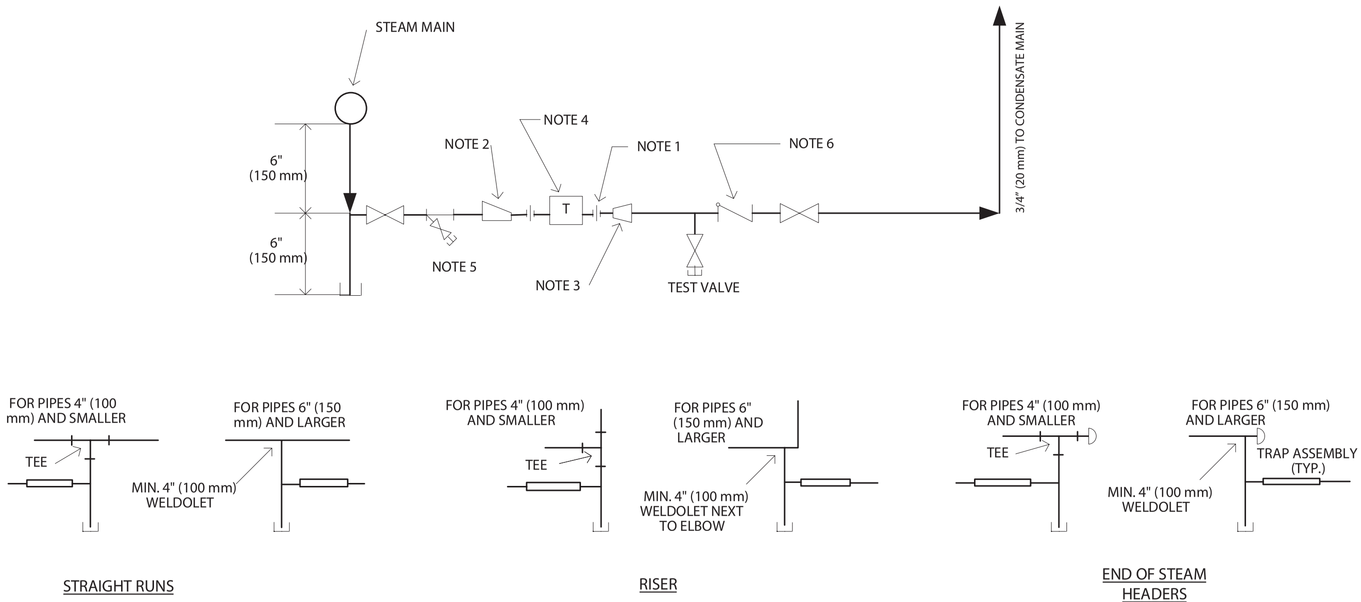
Note: For SI units: 1 in. = 25 mm, 1 in.^{2} = 645 mm^2.

[a] *A* is the approximate pipe internal cross-sectional area in square inches.

Appendix B: Piping Details

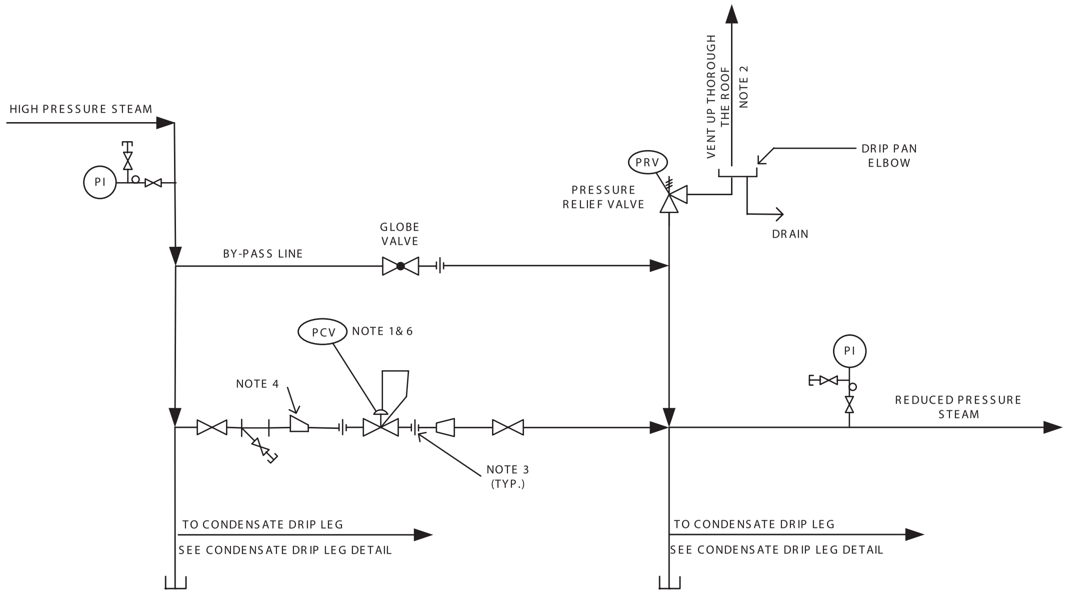
Refer to the following pages for piping details mostly used in industrial steam systems. The details are as follows:

1. Drip leg detail
2. Pressure reducing station
3. Steam heating coil piping detail
4. Culinary steam station



NOTES
1- PROVIDE UNION IF THE CONNECTION IS NOT FLANGED.
2- FLAT ON BOTTOM REDUCER IF REQUIRED.
3- CONCENTRIC REDUCER IF REQUIRED.
4- INVERTED BUCKET STEAM TRAP.
5- STRAINER WITH BLOW OFF VALVE.
6- CHECK VALVE IS NOT NEEDED FOR GRAVITY DRAIN.
7- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.

DRIP LEG DETAIL



NOTES

1- INSTALL PER MANUFACTURER RECOMMENDATIONS FOR STRAIGHT RUN OF PIPING UPSTREAM AND DOWNSTREAM OF PRESSURE CONTROL VALVE (PCV).

2- TERMINATE VENT ABOVE THE ROOF PER APPLICABLE CODES BUT NOT LESS THAN 8 ft (2.44 m) .

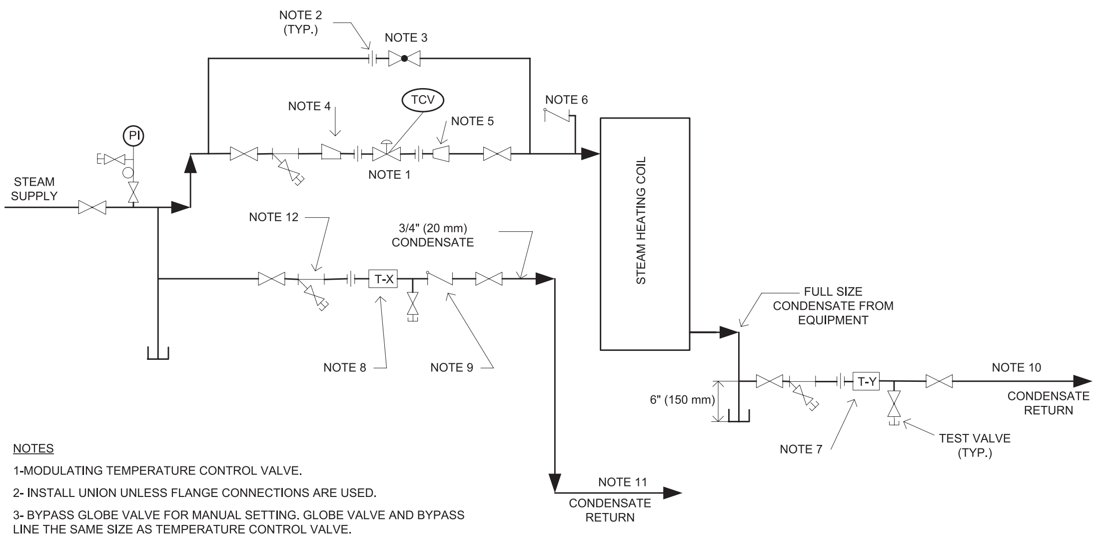
3- PROVIDE UNION IF THE VALVE IS NOT FLANGED.

4- FLAT ON BOTTOM REDUCER.

5- REFER TO LEGEND SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.

6- SELF-CONTAINED PRESSURE CONTROL VALVE (PCV) IS SHOWN. FOR PILOT-OPERATED PCV THE DOWNSTREAM PRESSURE SENSING ELEMENT MUST BE MINIMUM 10 PIPE DIAMETER DOWNSTREAM OF VALVE OUTLET.

PRESSURE REDUCING STATION



NOTES

1-MODULATING TEMPERATURE CONTROL VALVE.

2- INSTALL UNION UNLESS FLANGE CONNECTIONS ARE USED.

3- BYPASS GLOBE VALVE FOR MANUAL SETTING. GLOBE VALVE AND BYPASS LINE THE SAME SIZE AS TEMPERATURE CONTROL VALVE.

4- FLAT ON BOTTOM REDUCER.

5- ECCENTRIC REDUCER.

6- VACUUM BREAKER.

7- FLOAT & THERMOSTATIC STEAM TRAP.

8- INVERTED BUCKET TRAP.

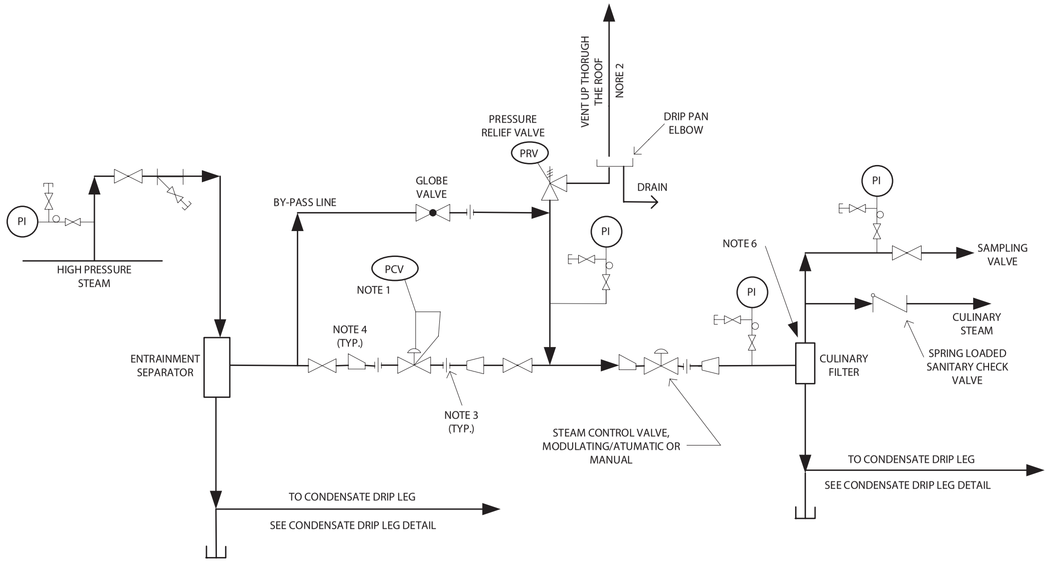
9- CHECK VALVE IS ONLY REQUIRED IF THE CONDENSATE IS NOT GRAVITY DRAINED.

10- GRAVITY DRAIN ONLY FOR COILS WITH MODULATING CONTROL VALVE. ADD A CHECK VALVE AFTER TEST VALVE FOR APPLICATION WITH ON/OFF CONTROL VALVE WHERE THE CONDENSATE IS LIFTED.

11- THE DRIP LEG CONDENSATE CAN BE LIFTED ACCORDING TO SUPPLIED STEAM PRESSURE.

12- STRAINER WITH BLOWOFF VALVE.

STEAM HEATING COIL
PIPING DETAIL



CULINARY STEAM
STATION

NOTES

1 – INSTALL PER MANUFACTURER RECOMMENDATIONS FOR STRAIGHT RUN OF PIPING UPSTREAM AND DOWNSTREAM OF PRESSURE CONTROL VALVE.

2 – TERMINATE VENT ABOVE THE ROOF PER CODE REQUIREMENT BUT NOT LESS THAN 8 ft (2.44 m).

3 – PROVIDE UNION IF THE VALVE IS NOT FLANGED.

4 - FLAT ON BOTTOM REDUCER.

5 – REFER TO LEGENG SHEET FOR LEGEND, ABBREVIATIONS, AND GENERAL NOTES.

6 – USE STAINLESS STEEL MATERIAL AFTER CULINARY FILTER.

Appendix C: Resources

Resources used or reviewed are listed below:

1. Armstrong International, Inc., www.armstronginternational.com. Product literature for steam traps and pressure control valves.
2. Armstrong International, Inc., www.armstronginternational.com. Material from Armstrong College of Steam Principles.
3. BFS Industries, LLC, www.bfs-ind.com. Product literature for condensate receiver package and deaerator package.
4. Cleaver-Brooks, Inc., www.cleaver-brooks.com. Product literature for steam boiler, water softener package, and chemical feed packages.
5. Cleaver-Brooks, Inc., www.cleaver-brooks.com. Material from Cleaver Brooks Boiler Book 2011.
6. Grundfos Pumps Corporation, www.grundfos.com. Product literature for boiler feed water pump and transfer pump.
7. Penn Separator Corporation, www.pennseperator.com. Product literature for blowdown separator and exhaust silencer.
8. Shippensburg Pump Company, Inc., www.shipcopumps.com. Product literature for condensate pump.
9. Selkirk Corporation, www.selkirkcorp.com. Product literature for boiler stack.
10. Spirax Sarco, Inc., www.spiraxsarco.com. Product literature for sample cooler and drip pan elbows.
11. Spirax Sarco, Inc., www.spiraxsarco.com. Design of fluid systems hook-ups, Spirax Sarco, 2011.
12. Spence Engineering Company, www.spenceengineering.com. Product literature for pressure relief valves.
13. Watts, a division of Water Technologies, Inc., www.watts.com. Product literature for backflow preventer.
14. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), www.ashrae.com.
15. ASHRAE Standards 62.1-2013, Ventilation for Acceptable Indoor Air Quality.
16. ASHRAE Standards 90.1-2013, Energy Standard for Building Except Low-Rise Residential Building.
17. American Society of Mechanical Engineers (ASME), www.asme.org.
18. ASME B31.1, Power Piping.
19. ASME Boiler and Pressure Vessel Code.
20. National Fire Protection Association (NFPA), www.nfpa.org.
21. National Fire Protection Association Standard 31 (NFPA 31), Standard for the Installation of Oil-Burning Equipment.
22. ASTM International, originally American Society for Testing and Materials, www.astm.org.

23. International Code Council (ICC), www.iccsafe.org.
24. International Fuel Gas Code (IFGC) 2012, www.iccsafe.org.
25. *Handbook of Air Conditioning System Design* by Carrier Air Conditioning Company.
26. ASHRAE HANDBOOK 2013, FUNDAMENTALS.
27. CAMERON HYDRAULIC DATA, Sixteen Edition, published by Ingersoll-Rand.

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Fundamentals and Best Design Practices

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