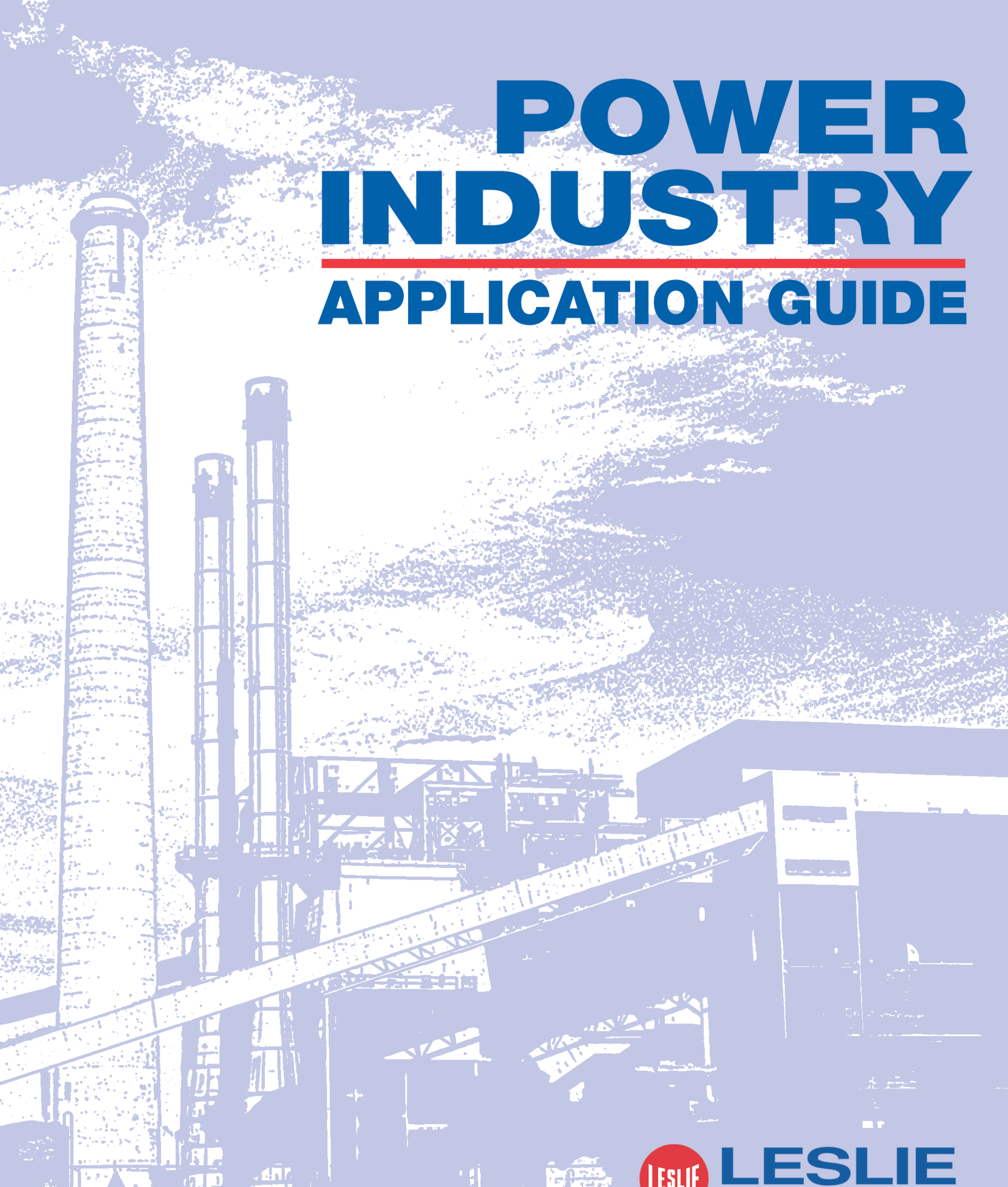
POWER INDUSTRY

APPLICATION GUIDE



LESLIE

CONTROLS, INC.

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INTRODUCTION

The generation of electricity is accomplished in many different ways, base load thermal plants, nuclear powered plants, hydroelectric plants, gas turbine generators, combined cycle plants, diesel engine generators, geothermal energy, solar and wind powered plants. This application guide discusses those plants that utilize control valves of the type that Leslie Controls manufactures; Simple Cycle Gas Turbine Plants, Combined Cycle Gas and Steam Turbine Plants, and Conventional Fossil Fueled Steam Turbine Plants.

Simple Cycle Plant (Gas Turbine)

Simple Cycle Combustion Turbines have been used for many years to generate relatively small amounts of electricity during peak demand periods. These generators basically use a jet engine to burn natural gas to power a turbine generator.

In the past, Simple Cycle plants were primarily used to generate small amounts of electricity for peaking power demand. Today these units generate up to 375 MW of electricity and can be base loaded.

This method of power generation is often preferred due to its clean operation, smaller site requirement and short lead-time to license, construct and commission into operation.

Conventional Fossil Plant (Steam Turbine)

This is the most common form of generation installed during the last half of the 20th Century. A field-erected boiler provides high pressure, superheated steam to a steam turbine generator. The common fuels for the boiler are natural gas, oil or coal.

These plants have different operating pressures and therefore efficiencies. The boiler is usually a drum type field erected unit that supplies 900 to 2500 PSIG steam at temperatures up to 1050ºF to the steam turbine. Ultra high-pressure plants or Supercritical Units supply steam pressures up to 3600 PSIG. Conventional fossil plants most often utilized for the base power requirements of the utility.

Combined Cycle Plant (Gas and Steam Turbine)

In recent years new power plant designs, combining a combustion turbine with a waste heat recovery boiler, have proven to yield a much higher efficiency than a simple cycle or conventional fossil-fueled plant. The common term used for the waste heat recovery boiler is HRSG, Heat Recovery Steam Generator. A combined cycle plant can operate with outputs of up to 800MW, with thermal efficiencies up to 60%. A conventional fossil-fueled power plant is limited to approximately 30% thermal efficiency.

This type of plant uses the exhaust gases from a combustion turbine to fuel the waste heat recovery boiler. The multi-drum boiler uses the latent heat of the hot exhaust gas to generate steam. The HRSG is also fired with supplemental gas to maintain steam temperatures required by the steam turbine. The steam produced by the boiler is then used to drive a steam turbine and generate additional electricity. The HRSG can be used in conjunction with either one, two or three steam turbines.

Much of the new generation capacity being developed worldwide today utilizes this design.

SIMPLE CYCLE TURBINE PLANT

Simple Cycle Power Plant (Gas Turbine)

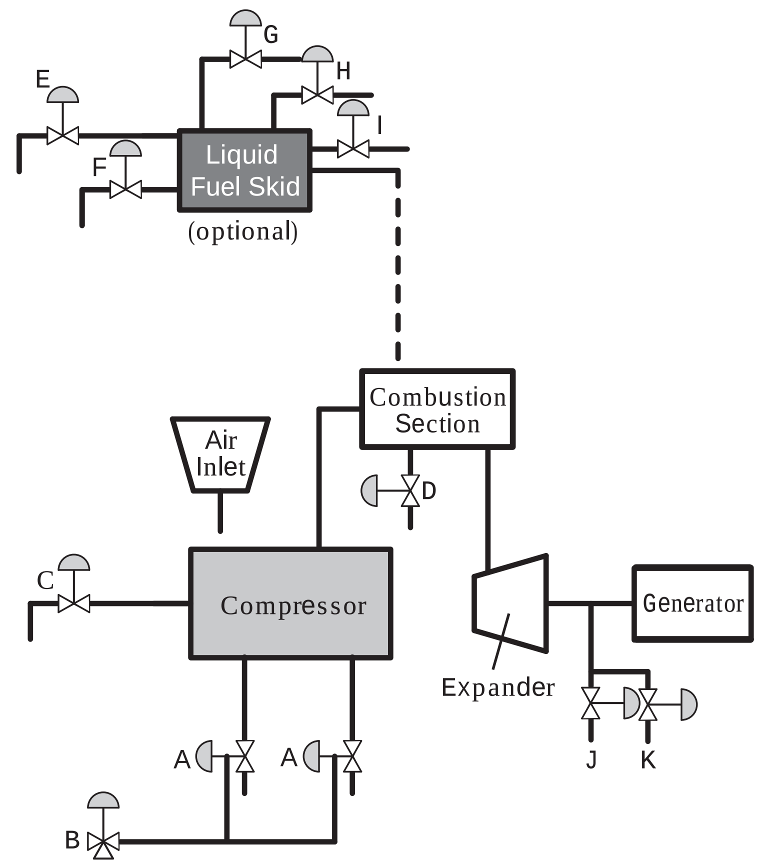
Simple Cycle Power Plants have been used for many years to provide additional generating capacity to a utility during peak demand periods. Peak demand periods generally occur during the summer months, when air conditioning operation consumes large amounts of electricity for a relatively short period of time. During this time some utilities, for various reasons such as lack of capacity or unanticipated emergency shutdowns, can not meet the demand on their system. It is then when simple cycle power stations are brought on line to supply additional power rather than having to purchase power on the open market. Likewise during the coldest winter months, where electric heat is the main source of residential home heating, peaking power is often required from simple cycle plants. This type of electric generation is also popular where relatively small amounts of electricity are needed at an industrial or commercial facility and it is more economical to generate the required power than to purchase it.

Simple Cycle plants get their name when comparing this form of power generation to the conventional thermal fossil plant or a combined cycle plant. A Simple Cycle Power Plant can be called a once-through power generator. This plant is fueled by either natural gas or if it is a dual fuel combustion turbine, natural gas and a liquid fuel. The fuel is burned in a combustion section that converts that energy to a rotary motion that then drives an electric generator. The hot exhaust gases from the combustion section are discharged to atmosphere and not used for any other purpose. Thus the term simple cycle or once-through.

Gas turbines are actually composed of an air compressor segment, a combustion segment, and turbine segment. The air compressor section takes in air and increases its pressure to approximately 225 PSI at 595ºF just prior to entering the combustion segment. At the combustion segment, the fuel burns with the air, releasing energy to the turbine segment. The turbine rotates the shaft, providing the energy needed for a compressor, a generator, a pump, and other load. Auxiliary systems, such as a fuel skid for dual fuel usage, support the segments of the turbine and required actuated valves to control their operation.

The Simple Cycle Power Plant plays a critical role in the efficient delivery of our electrical requirements. These units are essentially jet engines attached to electric generators. Thus safe, reliable control equipment is of utmost importance to its owner and operators.

Simple Cycle Power Plant (Gas Turbine)



Key:
- A - Compressor Air Extraction Valve
- B - Air Extraction Pilot Valve
- C - Trip Oil Solenoid Valve
- D - False Start Drain Valve
- E - Gas Purge Vent Valve
- F - Gas Purge Block Valve
- G - Liquid Fuel Stop Valve
- H - Fuel Nozzle Purge Valve
- I - Atomizing Air Bypass Valve
- J - Generator Bearing Hydrogen Shutoff Valve
- K - Generator Bearing CO_2 Purge Valve

Compressor Air Extraction Valve

Purpose

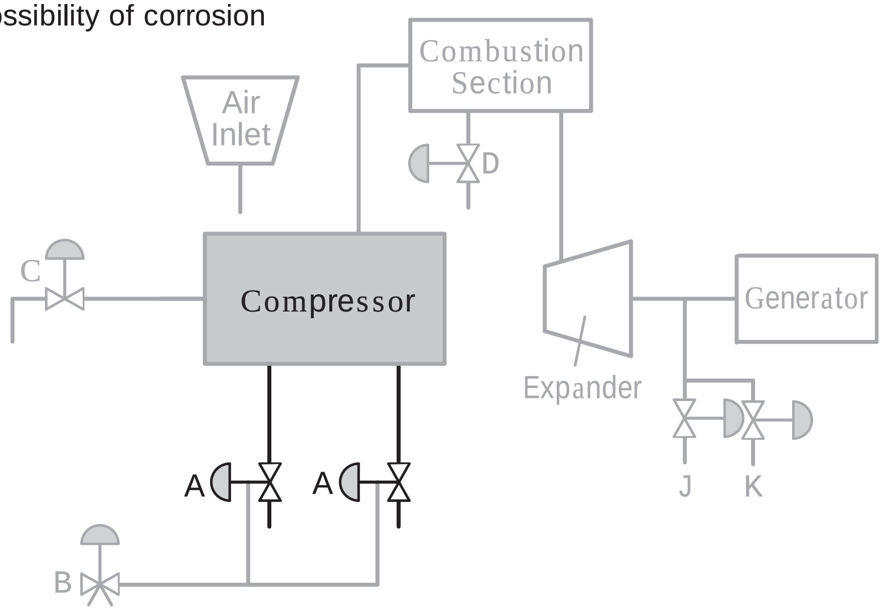
The initial segment of a Combustion Turbine is an air compressor. The air compressor takes in air and increases its pressure just prior to entering the combustion segment of the turbine. The Compressor Air Extraction Valve, sometimes referred to as a “bleed” valve, is critical to the operation and protection of the combustion turbine. The purpose of this valve is to quickly dump the compressed air out of the compressor when an upset condition occurs. By doing so the turbine avoids an overspeed or surge situation.

Operating Conditions

The Compressor Air Extraction Valve is operated by an air cylinder where the operation is air to close/spring to open thus fail open. Upon startup the valve is open and remains open as the turbine accelerates. When the turbine reaches approximately 95% full speed, the valve is closed and remains closed while the turbine is running. Immediately upon a turbine trip the valve reopens quickly to dump the air from the compressor portion of the turbine to slow the rotation of the shaft. Two important design considerations for the extraction valves are the excessively hot environment and the possibility of corrosion with time. The ambient temperature can be as high as 425ºF. In addition, the extraction air going through the valves can exceed 600ºF. Because these valves often remain closed for months at a time while the combustion turbine is operating, there is a real likelihood that moisture will condense around the seat ring and result in valve body corrosion. This corrosion can result in the valve disc sticking in the seat thus greatly elevating the opening torque requirement of the valve. For this reason valves without the proper material selection can be problems waiting to happen. Should this valve fail to open, serious damage can be done to the turbine.

Leslie Solution

Laurence solved these problems by providing a butterfly valve with an all stainless steel valve body and an all stainless steel actuator with a single main bearing to prevent binding from heat distortion. The Laurence Compressor Air Extraction Valve is available in 6", 8" and 10" sizes, with spacers to adapt to various turbine configurations. The all stainless, high temperature design sets the Laurence valve apart from standard butterfly valves and provides years of trouble free service.



Air Extraction Pilot Valve

Purpose

The purpose of the Compressor Air Extraction Pilot Valve is to control the operation of the Compressor Air Extraction Valve. This valve is de-energized when the turbine trips thus venting the air from the extraction valve actuator and opening the extraction valve. A solenoid pilot valve provides reliable, safe operation of the extraction valves.

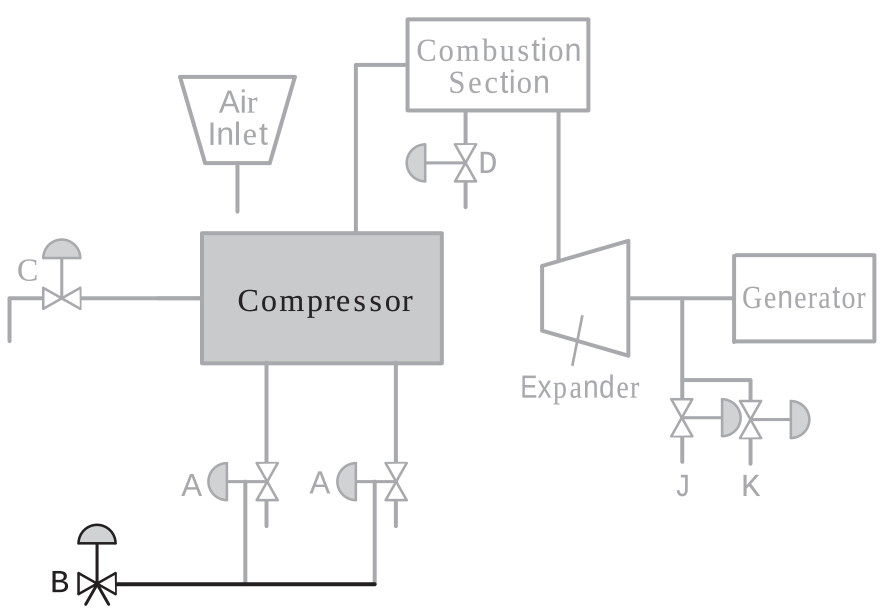
Operating Conditions

This application requires a valve that can reliably operate in a high temperature environment, with moist, corrosive air, and provide a high factor of safety for operating, with no minimum pressure or flow requirement. The Three-way Compressor Air Extraction Pilot Valve is normally closed (energized) while the turbine is running (95% full speed or greater). In the closed position it maintains a constant air pressure on the extraction valve actuator to keep the valve closed. When a turbine trip occurs the pilot valve is de-energized and the extraction valve's actuator air is vented causing the Compressor Air Extraction Valve to be opened by the spring force of the actuator.

Normal operating temperatures are between 420 and 550ºF.

Leslie Solution

Laurence provides a Three-way Rotary Solenoid Actuated Valve with greater actuation and return reliability than conventional solenoid valves. This is possible because of the mechanical advantage achieved by using a long external operating level to actuate the valve. The external lever connects the lifting action of the linear actuator to the valve plug through a rotary shaft seal. The Soli-Con Electric Actuator, provided exclusively by Laurence, is a solid-state controlled actuator whose circuitry delivers a direct current to the coil regardless of the type input voltage. The Soli-Con Actuator incorporates an internal timer to control the inrush current; thus the current is not dependent on the plunger position. This eliminates coil burnouts due to the valve failing to stroke. The timer automatically resets upon de-energization. Due to its unique design and highly reliable Soli-Con Electric Actuator the Laurence Three-way Compressor Air Extraction Pilot Valve has offered years of low cost, maintenance free service in this harsh environment.



Trip Oil Solenoid Valve

Purpose

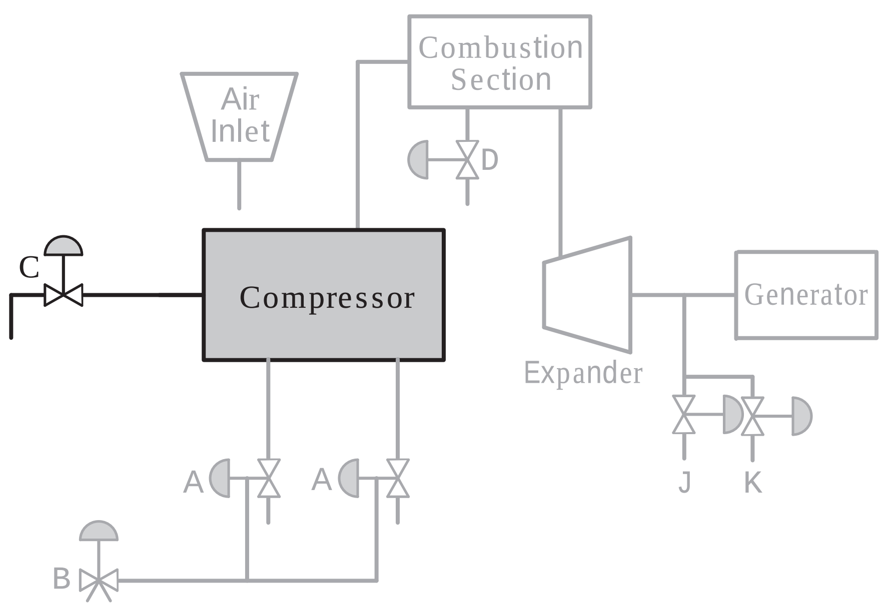
The purpose of this valve is to dump hydraulic oil quickly when the load is suddenly taken off the shaft of the turbine or in a normal shutdown to prevent damaging overspeed. This can take place in one to two seconds. The hydraulic oil is the pilot operating fluid for the main gaseous fuel shutoff valve, the main liquid fuel shutoff valve, and the piston actuator operating the compressor inlet guide vanes.

Operating Conditions

These valves are normally open, energized to close with oil pressure under the seat tending to open the valve. The valve is de-energized to open and dump hydraulic oil. These valves are open when the turbine is down, or individually when that particular fuel is not being used. They are closed when that particular fuel is being used. When selecting a valve for this application, particular care needs to be taken to insure that the valve selected can operate reliably under conditions where the oil is susceptible to contamination and where high temperature is common.

Leslie Solution

The Laurence Two-way Rotary Valve is particularly well suited for this application. By design the Laurence poppet-type plug is pushed open by the oil pressure even if the return spring weakens providing an extra measure of safety to this function. Some valves are designed with a closely fitted spring returned cartridge plug. These valves are vulnerable to foreign matter in the oil and binding from temperature distortion. The Laurence Two-way Rotary Valve overcomes these problems with a superior design concept.



False Start Drain Valve

Purpose

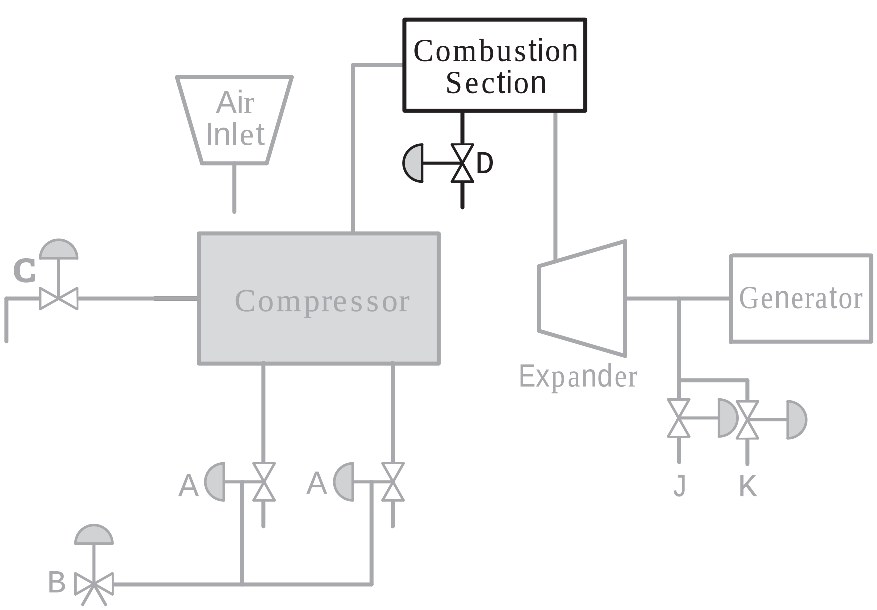
This valve is intended to drain the collective combustion cans and related piping on the turbine of unburned fuel that may exist after a fault trip during startup. This valve is also used to drain any condensate that may accumulate while the turbine in not operating.

Operating Conditions

The False Start Drain Valve is critical to the safe operation of a gas turbine. If this valve fails to open the result could be a flash fire that would seriously damage the combustion section of the turbine. The minimum result of not draining the residual fuel in the turbine would be an uneven combustion resulting in a loss of generation capacity or a turbine trip. Typically this application requires a valve that is normally open, air-to-close, fail open. Pilot air comes directly from the compressor discharge. When the turbine is down the valve is open. Upon startup the air pressure from the compressor increases until it overcomes the return spring force at which time the valve closes. Upon a trip or deceleration of the turbine the air pressure decreases and the spring opens the valve. Because closing and reopening occurs at very low compressor discharge pressures (4 to 10 PSI), this valve must always remain totally free operating. An absolute minimum of breakaway force (friction) is necessary for the valve to respond to the very low forces from these pressures.

Leslie Solution

Laurence's solution to this application is a 1" Two-way Rotary Cylinder Actuated Valve. Unlike conventional solenoid actuated valves, this valve offers a metal to metal seat for tight shutoff yet is sensitive to very low differential pressures in the actuator. The rotary seal and actuator are specifically designed with low friction materials to insure that the valve opens without fail at low actuator pressures. Reliable operation at low air pressure differentials and tight shutoff are critical to this application.



Optional Liquid Fuel Skid Control

Application
GAS PURGE VENT VALVE

Purpose
One of these valves is used between the two Gas Purge System Block Valves to vent any fuel gas that leaks by the first block valve, as a safety precaution. The gas is vented either to atmosphere or to a flare. Failure to reopen when switching fuels could cause a trip of the turbine and in some cases damage.

Operating Conditions
This valve is normally open, energized to close, and designed to fail open. It is open whenever the turbine is down or whenever it is running on gaseous fuel. It is energized closed whenever the turbine is running on liquid fuel. This valve indirectly sees the high temperature compressor discharge air (up to 795ºF) at its inlet.

Leslie Solution
Leslie Controls solution to this application is the Laurence Two-way Rotary Soli-Con Actuated Valve. This valve is well suited for the high temperature environment in which it operates. The minimum shaft rotation and lever arm operation makes this valve a safe, reliable choice for this critical application.

Application
GAS PURGE BLOCK VALVE

PURPOSE
Two of these valves are used in series as a double block to prevent fuel gas from passing into the compressor of the turbine, which obviously could lead to a disastrous explosion. They are open when the turbine is running on liquid fuel and allow compressor discharge air to pass in the opposite direction to maintain a continuous purge of the gas nozzles to prevent liquid fuel backup and choking of the nozzles.

Operating Conditions
These valves are closed whenever the turbine is down and whenever it is running on gaseous fuel. They are normally closed, with air to open and air to close. Normally these valves are fail closed.

Leslie Solution
Laurence supplies a Two-way Rotary Cylinder Actuated Globe Valve for this application. They have a return spring strong enough to insure that the valve will return to the fail closed position when the turbine trips or in the event of a pilot air or electric failure. A double acting cylinder actuator is used so that the valve can hold closed against a negative differential of gas pressure as a redundant safety measure. This has proven to be a problem with single acting diaphragm actuators which are unable to hold against the negative differential.

Optional Liquid Fuel Skid Control

Application

LIQUID FUEL STOP VALVE

Purpose

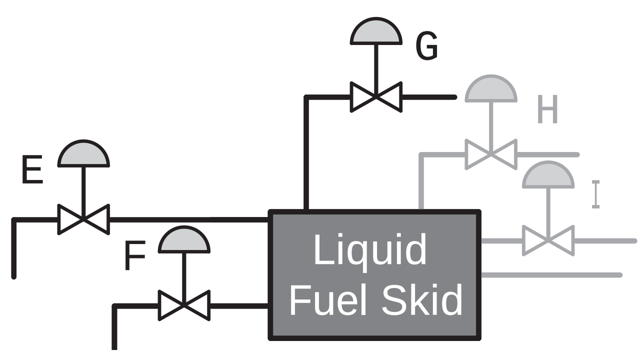
The Fuel Stop Valve is used as a safety shutoff valve for liquid fuels. The purpose of using this valve is to isolate the turbine from fire and to provide a double barrier to preclude leakage and gradual buildup of unburned fuel on the turbine base. They are always installed off base on a separate skid called the Fuel Forwarding Skid. In most cases this skid is in close proximity to the turbine, but in some cases is quite distant. The valves are almost always mounted outdoors and subject to the full brunt of local weather conditions and to hazardous fuel vapors.

Operating Conditions

As a safety valve this valve's performance is a critical component of the Gas Turbine System on dual fuel turbines. When the unit is operating with natural gas fuel this valve is required to operate reliably and maintain a tight shutoff. Naturally when the combustion turbine is switched to liquid fuel, this valve opens and remains open during turbine operation.

Leslie Solution

For many years the Laurence Soli-Con Actuated Globe Valve has been used for this application. The Rotary Solenoid Valve has proven to be a reliable economic valve for this service. The strength and reliability of the Soli-Con Electric Actuator make it the safe choice for liquid fuel shutoff applications.



Optional Liquid Fuel Control

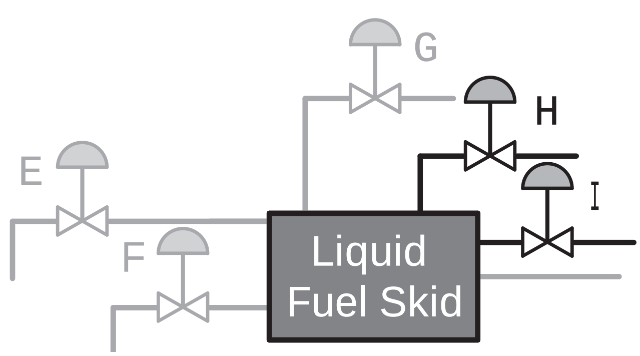
Application
ATOMIZING AIR BYPASS VALVE

Purpose
This valve is used to divert or bypass atomizing air away from the liquid fuel nozzle on dual fuel units when the turbine is running on gas fuel. When a dual fuel combustion turbine is operated on a liquid fuel atomizing air is needed to break up the liquid into a fine spray for more efficient combustion. But when the turbine is being operated on gas, the liquid fuel does not need the atomizing air thus it is diverted.

Operating Conditions
Operating off of air from the compressor portion of the turbine, this valve is normally closed, air to open, fail closed by return spring. It is actuated open when firing on gas; it is closed when the turbine is down or when firing liquid fuel.

Leslie Solution
Until 1994 Laurence supplied a 3" Two-way Rotary Cylinder Actuated Globe Valve for this application. This valve is still offered in spares or replacement situations.

Due to design changes, the valve of choice on new units is a high performance butterfly valve. Laurence now supplies both 4" and 6" wafer valves with a reinforced Teflon seat and pneumatic actuator.



Application
FUEL NOZZLE PURGE VALVE

Purpose
This valve is used to purge any fuel oil from the gas nozzles while the turbine is running on a gaseous fuel. Conversely it is also used to vent any residual gas in the system once the turbine has switched over to liquid fuel. It uses atomizing air for this purpose.

Operating Conditions
This application requires a three-way valve that is normally closed to the fuel oil when the turbine is operation on liquid and opened to vent any residual gas in the system. When air is applied to the actuator the valve opens to purge any fuel oil from the gas nozzles and closes the gas fuel vent. A critical design consideration for this valve is that it has the ability to operate using high temperature actuator air up to 425ºF.

Leslie Solution
The Laurence solution to this application is a Three-way Rotary Cylinder Actuated Valve with indirect lever actuation of the valve plug. The indirect lever action on the valve plug has a mechanical force advantage compared to direct acting solenoid valves. Because the rotary motion that actuates this valve is so slight (20-30 degree arc) it is able to provide reliable operation for a long time period without a requirement for seal maintenance. The cylinder actuator is also designed to provide long service life operating with air temperatures up to 550ºF.

Generator Gas Control Valves

Purpose

The electric generator segment of a combustion or steam turbine utilizes two industrial gases to improve efficiency and protect the turbine from explosion or fire. Hydrogen gas is injected into the turbine to cool the turbine bearings and to give the turbine a lighter gas environment in which to operate. By operating the generator in a hydrogen environment there is less molecular resistance created in the generator thus it operates more efficiently. However, uncontrolled hydrogen gas is very volatile and can cause an explosion if ignited by a spark. For this reason, carbon dioxide gas is supplied to the generator to evacuate the hydrogen gas and prevent a flammable situation when the turbine trips.

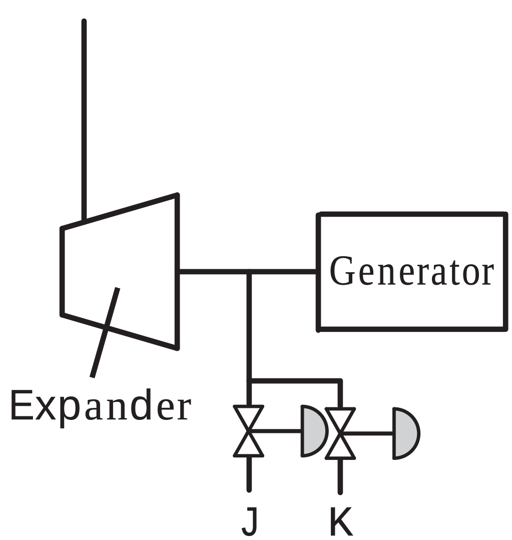
Operating Conditions

The hydrogen supply line to the generator requires a fast acting shutoff valve to close off the gas supply when an emergency situation arises. Upon trip of the turbine an electric signal is sent to the shutoff valve to close and stop the flow of hydrogen to the generator. This valve is equipped with a manual reset to open it when it is safe to restart the generator.

Conversely when a trip situation occurs, carbon dioxide gas is injected into the generator to purge the hydrogen gas out and prevent a fire or explosion. This valve also needs to be a fast acting, fail safe design with a manual reset. Both valves are installed in the generator cab next to the generator.

Leslie Solution

Leslie supplies a Two-way Rotary Solenoid Actuated Globe Valve for both of these applications. They are FM approved explosion proof valves for Group B applications. These valves are provided with weld end connections to insure the integrity of the installation. The Laurence Two-way Rotary Globe Valve offers a safe, reliable, fast acting solution to a very critical application where a failure to operate properly could result in a catastrophic situation.



Gas Turbine Valve Selection Guide (GE)

GAS TURBINE APPLICATIONS	VALVE TYPE	FRAME SIZES 5, 6, 6F	FRAME SIZES 7, 7F	FRAME SIZE 9	FRAME SIZE 9F
Compressor Air Extraction	Butterfly Cylinder	6" 6509/6512	8" 6515	8" 6515	10" 6519/21/22
Three-way Pilot for CAE	Three-way Solenoid	3/4" 3315V788DCS-M	3/4" 3315V788DCS-M	1" 3319V1208DCS	1" 3319V1208DCS
False Start Drain Valve	Two-way Cylinder	1" CYS516J42LCS	1" CYS516J42LCS	1" CYS516J42LCS	1" CYS516J42LCS
Gas Purge System Block Valve	Two-way Cylinder	2" CYD506882	4" CYD610994	4" CYD610994	4" CYD610994
Gas Purge System Vent Valve	Two-way Solenoid	3/4" 641SC364	1-1/2" 641SC720	1-1/2" 641SC720	1-1/2" 641SC720
Atomizing Air Bypass Valve	Two-way Cylinder	3" CYS50697	3" CYS50697	3" CYS50697	3" CYS50697
Fuel Nozzle Purge Valve	Three-way Cylinder	3/4" CYS3305X	3/4" CYS3305X	3/4" CYS3305X	3/4" CYS3305X
Liquid Fuel Stop Valve	Two-way Solenoid	2" 629GSC860	3" 629GSC960	3" 629GSC960	4" 629GSC980
Trip Oil Solenoid Valve	Two-way Solenoid	3/4" 532GE38	3/4" 532GE38	3/4" 532GE38	3/4" 532GE38
Generator Hydrogen Shutoff Valve	Two-way Cylinder	1/2" 1129G14SW	1/2" 1129G14SW	1/2" 1129G14SW	1/2" 1129G14SW
Generator CO_2 Supply Valve	Two-way Cylinder	1" 1269G34DCSWS	1" 1269G34DCSWS	1" 1269G34DCSWS	1" 1269G34DCSWS
Generator CO_2 Vent Valve	Two-way Cylinder	2" 1279G69DCSW	2" 1279G69DCSW	2" 1279G69DCSW	2" 1279G69DCSW

Note: Frame Sizes Shown are General Electric Model Numbers

CONVENTIONAL & COMBINED CYCLE POWER PLANTS

Conventional Fossil Fueled Plant (Steam Turbine Generator)

The generation of electric power begins with the generation of steam. Water is pumped under high pressure from the boiler feedpump to the boiler. The flow of the feedwater to the boiler is regulated by the feedwater control valve (1).

A special startup feedwater control valve (1A) is installed parallel with the main feedwater control valve. This control valve is used during plant startup with smaller flows and severe cavitation as the boiler comes up to pressure.

Another element of the feedwater control system is the feedpump recirculation control valve (2). The purpose of this control valve is to maintain a minimum flow through the pump by diverting back to the deaerator. This valve prevents damage to the feedpump that occurs at low flow.

Once inside the boiler this high pressure water is converted to steam. The steam is superheated before it leaves the boiler, due to tube surface area and fluctuating flows, the temperature can fluctuate. The steam turbine rotates at 3600 RPM and cannot tolerate temperature swings. The attemperator (reheat/superheat) spray CV (3) regulates water spray of the steam to control temperature. The superheat section feeds the HP section of the turbine, then the steam is returned to the reheat section of the boiler for additional energy. Again, spray tempers the steam to return to the IP or LP turbine section.

Main steam headers are equipped with drain valves (4) to remove condensate build up so that downstream equipment such as the steam turbines are not damaged by slugs of water.

Often these sections have a bypass loop to divert steam from turbine to condenser or atmosphere. This is used during startup for boiler minimum flow or to avoid boiler trip during system load rejection. A turbine bypass CV (5) controls flow through this loop. This bypass often requires a water control valve (6) to control the desuperheating water injected into the steam to cool it down.

To expel any condensate that forms in turbines, turbine drain CV's (4) are used. These are on-off applications with flashing. Turbine gland seal steam CV's (7) regulate steam to bearings during startup to seal air from entering bearing area.

Steam from the low pressure turbine is condensed in the condenser to be recirculated back to the boiler. After undergoing chemical treatment, the condensate travels through a series of feedwater heaters. Each successive heater uses higher pressure (temperature) turbine extraction steam. The condensate in the heater is flashed to lower pressure heater through heater drain CV (9). Each feedwater heater has an emergency level or drain valve (9), this valve dumps to condenser on run away level.

Before entering the boiler feedwater system the water has air/oxygen removed in the Deaerator. This also provides some heating of the water. Makeup water from the BFP Discharge can be supplied via Deaerator Level CV (8). During turbine trip conditions it is necessary to provide deaeration of water, the pegging steam CV provides makeup.

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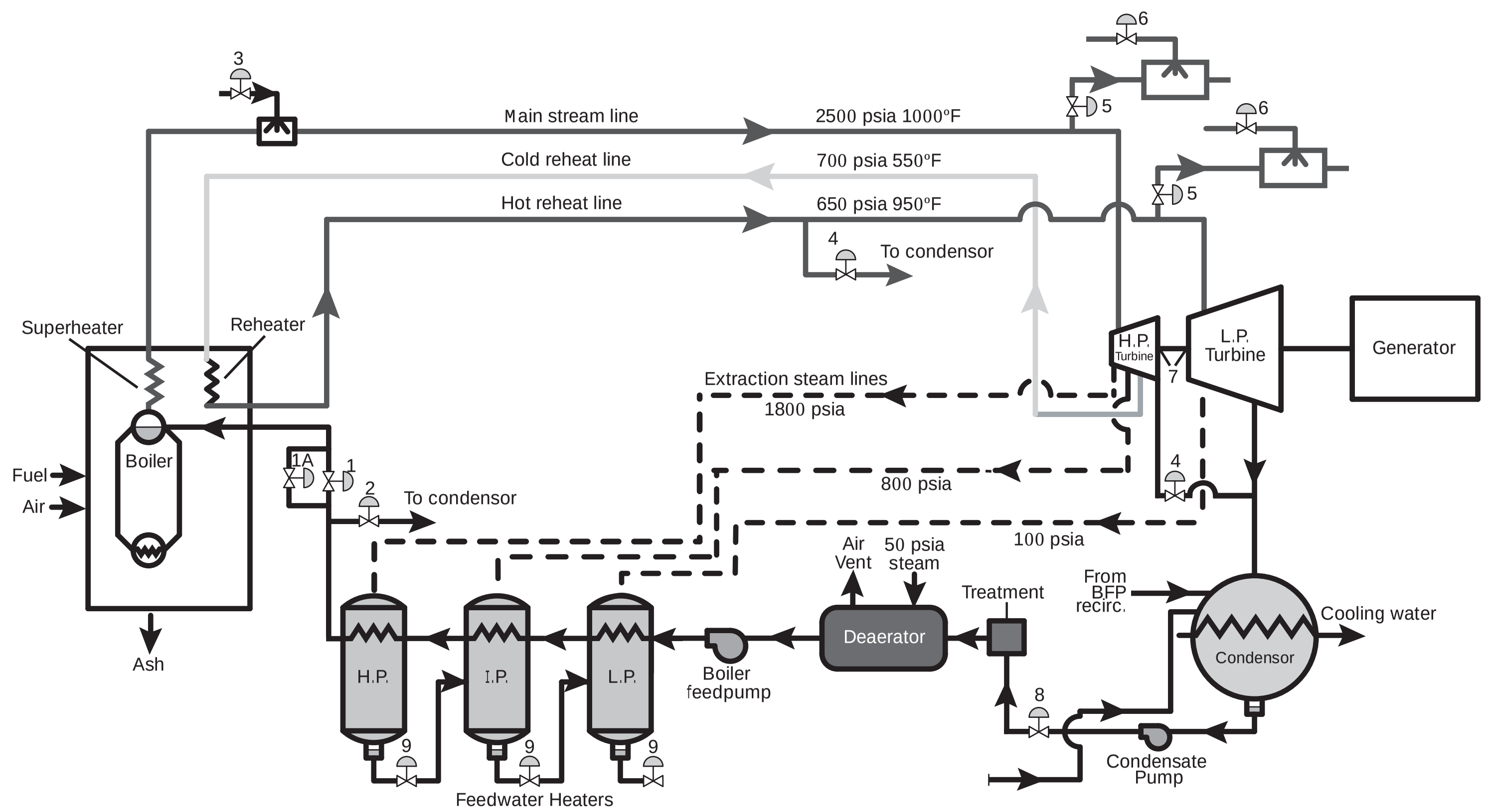
Conventional Fossil Fueled Power Plant



Key:
- Thermal steam lines
- Extraction steam lines
- Condensate steam lines

1 - Feedwater Control Valve
1A - Startup Feedwater Control Valve
2 - BFP Recirculation Control Valve
3 - Attemperator Spray Control Valve
4 - Turbine and Header Drain Control Valve
5 - Turbine Bypass Control Valves
6 - Desuperheater Spray Control Valves
7 - Gland Seal Control Valves
8 - Deaerator Level Control Valve
9 - Heater Drain Control Valves

Note: Temperatures and pressures shown are illustrative only.

Combined Cycle Power Plant (Gas and Steam Turbine Generator)

A Combined Cycle Power Plant consists of at least one gas and/or liquid fueled combustion turbine, a heat recovery steam generator (HRSG) and a steam turbine generator. The term Combined Cycle comes from the fact that you are generating electricity with both a gas turbine and a steam turbine at the same unit. The exhaust gases from the combustion turbine are routed to the HRSG and are used to produce high pressure steam to drive a steam turbine generator.

As mentioned above, this combination results in a plant with thermal efficiency in the 60% range.

Increased efficiency can be achieved by supplementary firing of the HRSG with natural gas.

An HRSG can have one, two or three stages of steam production (low, intermediate, and high pressure) and up to three steam turbine generators.

The control valves associated with the HRSG section of the Combined Cycle are similar to those found on a traditional fossil fueled power plant. Steam and condensate pressures to 2700 PSI and temperatures up to 1070ºF are not uncommon. Severe service control valve designs are required to meet these conditions.

The Combined Cycle Power Plant has many advantages when compared to Simple Cycle or Conventional Fossil Fuel Fired Power Plants. The following are some of the reasons that Combined Cycle Power Plants are one of the most popular design choices for utilities and independent power developers.

- Greater thermal efficiency when compared to a Simple Cycle Power Plant.
  60% for CC vs. 30% for SC.
- Much shorter construction cycle allows units to come on line quicker. Generate profits faster.
- Lower capital requirements than conventional fossil fuel plant.
- Cheap, plentiful natural gas fuel availability.
- Much lower emission output when compared to a traditional power plant.
- Reduced operating and maintenance costs.
- More cost effective than simple cycle units.
- Smaller site requirements and faster regulatory approval.
- CC units can often fit on the property of an existing power plant.

Combined Cycle Power Plant (Gas and Steam Turbine Generator)

Key:
- A - Compression Air Extraction Valve
- B - Air Extraction Pilot Valve
- C - Trip Oil Solenoid Valve
- D - False Start Drain Valve
- E - Gas Purge Vent Valve
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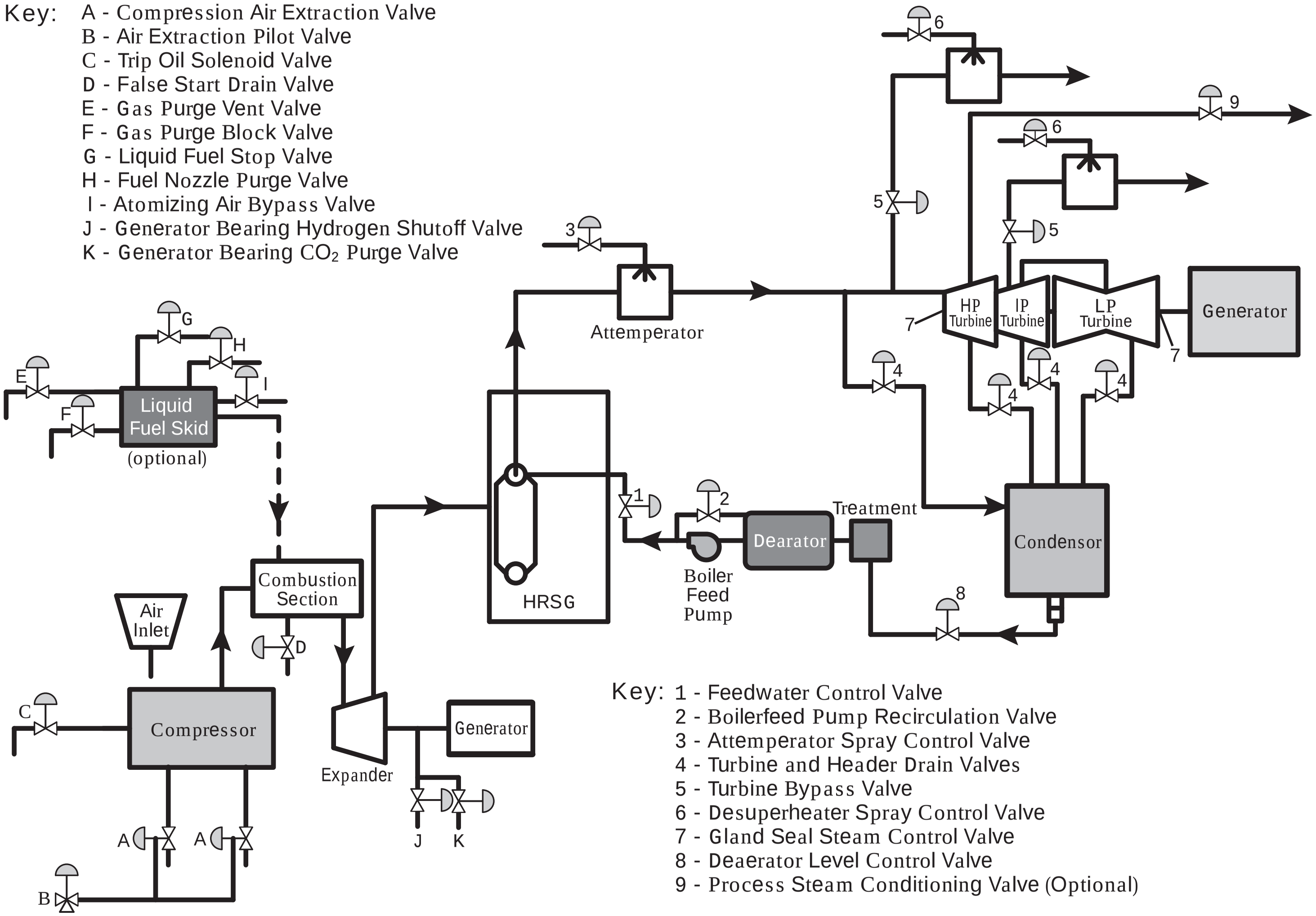


Key:
- 1 - Feedwater Control Valve
- 2 - Boilerfeed Pump Recirculation Valve
- 3 - Attemperator Spray Control Valve
- 4 - Turbine and Header Drain Valves
- 5 - Turbine Bypass Valve
- 6 - Desuperheater Spray Control Valve
- 7 - Gland Seal Steam Control Valve
- 8 - Deaerator Level Control Valve
- 9 - Process Steam Conditioning Valve (Optional)

Feedwater Control Valve

Purpose

The purpose of the Feedwater Control Valve is to regulate the level of water in the boiler drum. A conventional fossil fueled plant will have one steam drum. In a combined cycle plant there can be up to three drums depending on the HRSG design. A low pressure, intermediate pressure, and high pressure drum are not uncommon. This control valve receives water flow from a constant speed pump and supplies water to the drum to make up for that used to produce steam. Typically the control system measures drum level, uses feedwater flow to compensate for errors and steam flow as a feedforward to anticipate changes in level. This design is called three element control, during startup the control uses drum level only (single element).

Operating Conditions

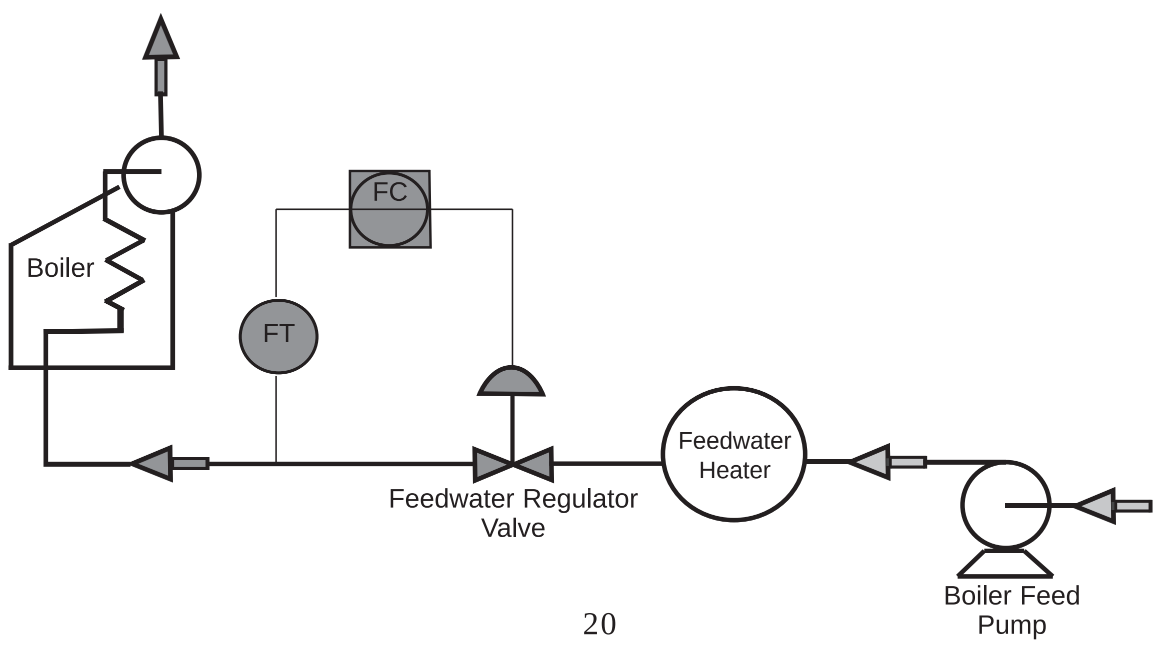
The main Feedwater Control Valve is a high pressure, low differential application. This application usually requires a cage guided control valve for control characteristics and economy of actuator size. During startup and shutdown this application can see high pressure and differential, requiring cavitation trim to prevent damage. Usually a startup feedwater valve is installed parallel to main feedwater valve with cavitation trim.

The most common problem is selection of proper body and trim for the conditions. Many times body velocities can exceed 30 feet per second. Carbon steel bodies will erode over time, C9 is the choice when velocities exceed these levels on a continuous bases.

Leslie Solution

The high pressure and low differential pressure makes this application ideal for Aeroflow cage guided balanced plug control valve. The balanced plug allows for stable control and economic actuator selection. Aeroflow's standard custom cage gives Leslie the ability to match capacity with the application requirements. Normally this valve does not require a tight shutoff.

In situations where the pump discharge pressure is less than 2500 psi, the C3 cage option affords the customer one valve to handle startup and main feedwater control. The cavitation trim exists for the first 40% travel, the control system limits travel to 40% until drum pressure is sufficient to stop cavitation.



Boiler Feedpump Recirculation Valve

Purpose

The function of a boiler feedpump recirculation valve is to insure that adequate flow is maintained through the boiler feedpump to prevent overheating of the pump and cavitation. The pump manufacturer calculates the minimum flow required to prevent the risk of premature pump failure due to bearings overheating and seizure or excessive thermal expansion of impeller blades.

A minimum flow through the boiler feedpump also protects against erosion and instability caused by cavitation at low flow conditions. Because the highest pressure in a power plant is produced at the boiler feedpump discharge, this equipment has the highest damage potential.

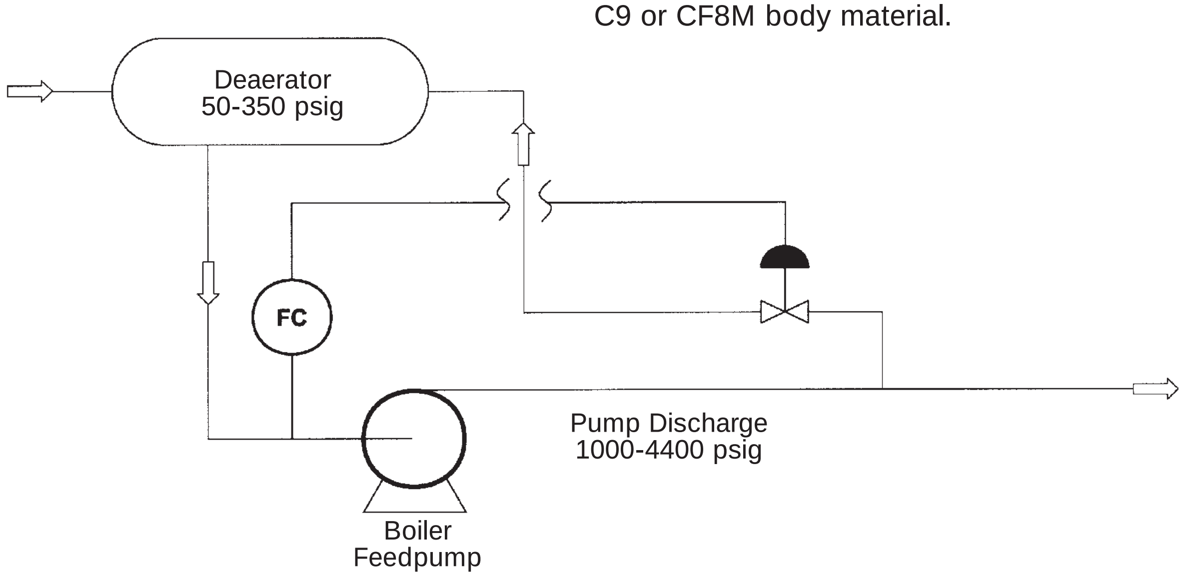
Operating Conditions

The Boiler Feedpump Recirculation Valve protects the pump during boiler startup and shutdown. Recirculation flow either goes to the deaerator (fossil units) or the condenser (nuclear units). Discharge pressures are typically 10 to 20 percent above the boiler's design pressure. Since most fossil units operate between 1,500 and 3,600 psi, feedpump discharge operates between about 1,750 and 4,400 psi at 350 to 400ºF.

Due to valve design limitations, these valves are generally either open or closed. The system monitors flow and fully opens the valve when flow is below a minimum value, typically between 25 and 35 percent. As long as the pump is operating above the recommended minimum flow, the valve is closed against the highest pressure in the plant. The combination of head pressure and deaerator operation can produce a back pressure on the valve of 50 to 250 psi. The typical valve specified for boiler feed water recirculation is an ANSI Class V shutoff valve with metal to metal seat.

Leslie Solution

The optimum valve for this application offers zero leakage at the rated pressure differential. The Leslie Aeroflow Valve offers Class 8, ZERO leakage, regardless of pressure drop or size. The Aeroflow Valve utilizes a Tri Shear plug design that protects the seat from wire drawing and erosion damage, to insure ZERO leakage performance for an extended period of time. Les-Cav Trim is normally used, with up to five stages of pressure reduction to prevent damage due to cavitation. This is normally a carbon steel valve, 900 to 2500 ANSI Class. Some applications due to high body velocity and erosion concerns require a C9 or CF8M body material.



Attemperator Spray Control Valves

Purpose

The Superheat, Reheat or Attemperator Spray Control Valve is used for controlling steam temperature to the turbine. The turbine is rotating at 3600 RPM and requires constant temperature to prevent damage. This application provides control of temperature that varies with flow, constant surface area, burner tilts and varying heat release of fuels. The control of optimum temperature maintains optimum turbine efficiency.

Turbines are designed with a maximum (trip) temperature in mind (usually 1100°F). Above this temperature turbine damage due to material constraints and clearance would result. As the trip temperature is approached maximum turbine efficiency is achieved. The purpose of the spray control valve is to maintain a tight temperature band which results in maximum turbine efficiency (usually 1005-1050°F).

Today all utilities are seeking the best heat rate or efficiency. With the improvements of measurement of temperature and accuracy of control systems, the weakest link is the spray control valve.

Operating Conditions

The supply water for the spray valves usually comes from the Feedpump discharge. The outlet pressure is equal to the superheater or reheat pressure plus nozzle back pressure. The superheat spray valve sees a low DP, usually 200 to 300 psi. Turndown and accuracy of positioning is of key concern. The reheat spray valve is normally a high DP, with cavitation and seat leakage a major concern.

The major problem exists with reheat spray. High DP causes excessive seat leakage and the valve normally operates close to the seat. Seat leakage, wire draw and inaccurate control causes a reduction in steam temperature and efficiency.

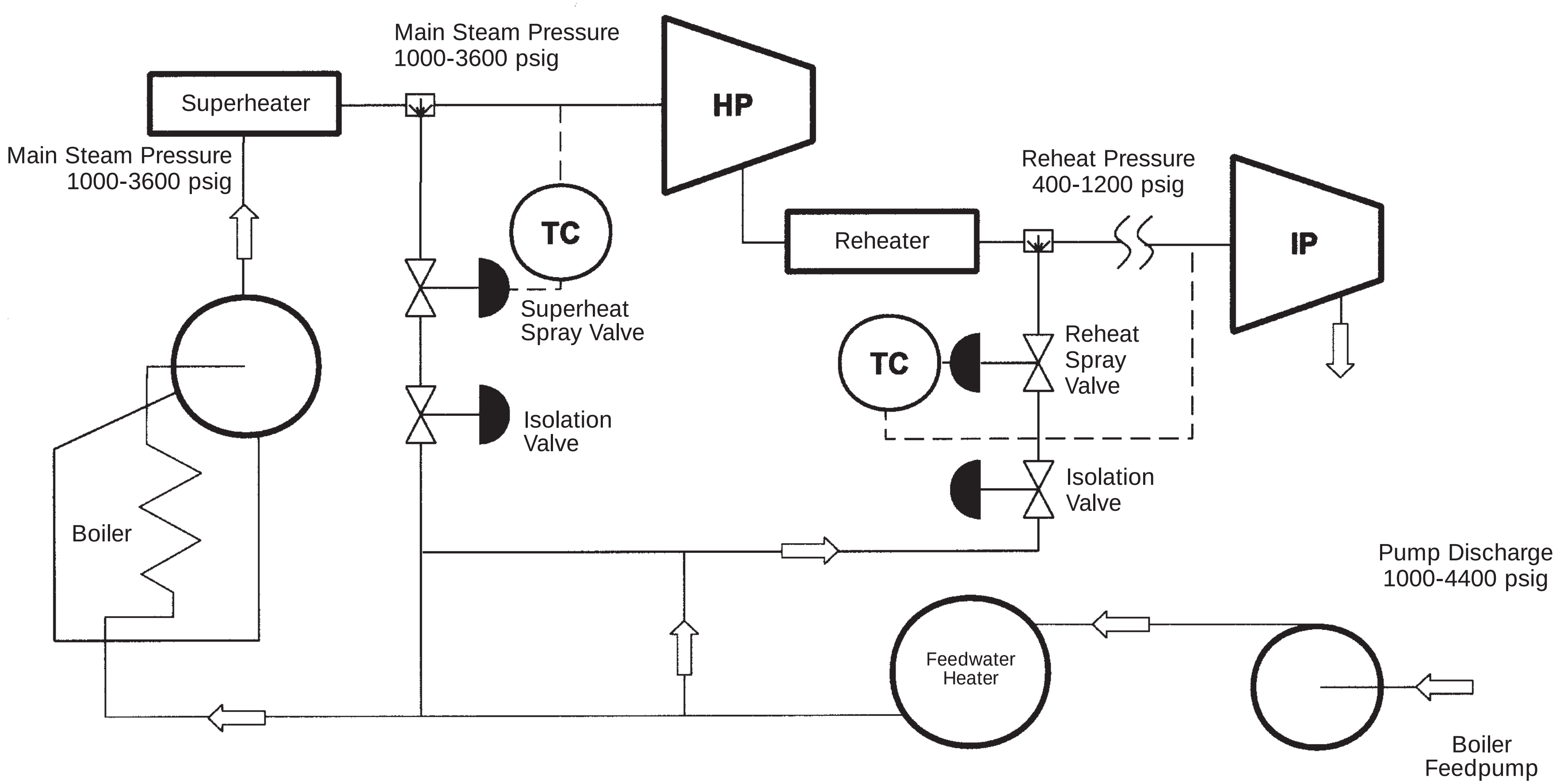
Leslie Solution

This application is ideal for Leslie's T^2 High Gain Trim. The accurate and fast positioning provides for a very tight band of temperature. The internal pilot allows stem sizes of 3/8" to 1/2" minimizing stem seal concerns. The custom cage for Reheat Spray allows for proper stroke versus flow and tight control. The Mini-P Trim is used for low flow control with cavitation protection to 2000 psid.

The DPS (digital positioning system) utilizing optical position feedback for .00125" positioning accuracy provides superior position ability . This positioner with Leslie's T^2 Trim insures accurate step changes in less than a second with no overshoot or undershoot.

The characterized T^2 Trim also has Leslie's Class 8 Shutoff, less than one drop per minute at rated DP. With no seat leakage, there is no unnecessary loss of steam temperature. Leslie's solution can turn a 15ºF band of temperature to a 3ºF band, saving the otherwise lost energy. Nominal savings for drum units of 400MW is $4500 per degree per year.

Attemperator Spray Valve Applications



Gland Seal Steam Control Valve

Purpose

The Gland Seal Steam Control Valves are used to maintain a constant steam pressure of 5-10 psig in the gland to seal air from the turbine. At low loads (<25%) steam must be supplied to the gland, at high loads the turbine gland is self supplying. During normal operation excess steam is vented to the condenser, low load supply comes from main or auxiliary steam sources.

Operating Conditions

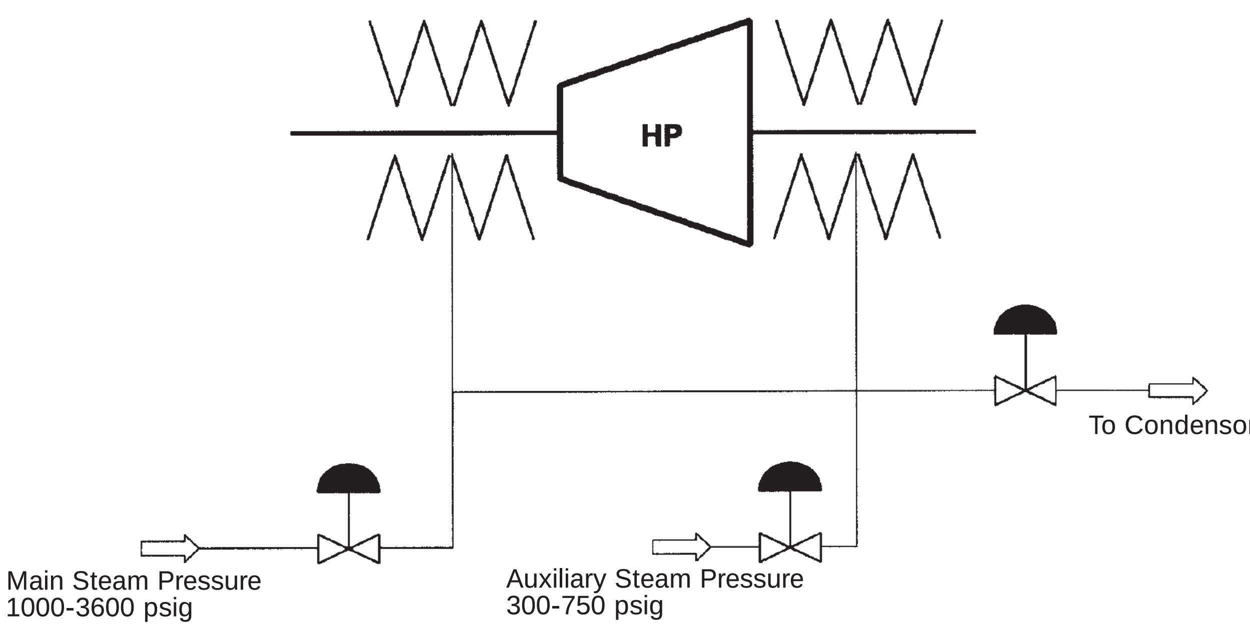
The supply valve sees high pressure steam from superheater outlet or reheat steam from adjacent unit. These valves are throttling a low flow at high pressure drops. They are closed during normal unit operation. The exhaust or vent valve, vents excess steam at 7-10 psig to the condenser. Typically these valves operate in a split range mode. One pressure control signal either loads or vents steam to the gland.

Leslie Solution

This application is ideal for Leslie's Aeroflow Control Valve. The major problems with the supply valves is seat leakage due to wire draw of plug and seat ring. They supply steam when it's not needed and vent energy to condenser (lost efficiency).

Leslie Class VIII Shutoff prevents wire draw, lost efficiency and frequent maintenance/repair. Leslie characterized trim allows for the proper C_V for this low flow high pressure drop application.

The vent valve typically has been a globe valve, but a K-Max will work well in this application.



Turbine Bypass Valve

Purpose

The Turbine Bypass Control Valve is used to divert steam from the turbine to the condenser or atmosphere. In nuclear plants it buffers the slow response of the reactor to turbine trip or rapid load changes. In fossil fueled plants it is used for startup and to prevent solid particle erosion to the turbine at low flows. The bypass system provides the ability to avoid a boiler/reactor trip in the event of system load rejection.

Operating Conditions

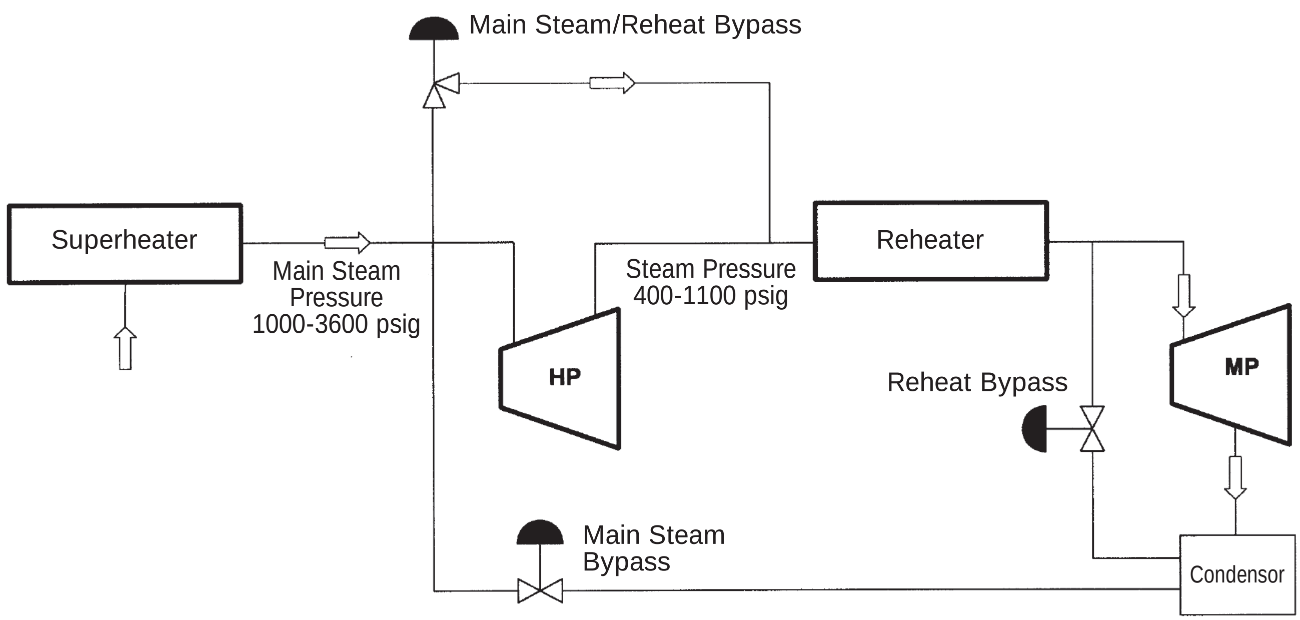
This service sees turbine throttle pressures and temperatures, typically of 1500 to 3600 psi at 1050ºF on fossil units. The outlet pressure is very low, although some fossil bypass applications are to the reheater section at 600 to 900 psi. This service will see thermal shocks and requires tight shutoff with fast response.

Leslie Solution

This application is ideal for Leslie's Aeroflow Control Valve. The major problems with bypass valves is seat leakage with wire draw of plug and seat ring. Leslie's Class VIII Shutoff pays for itself in saved maintenance and energy.

Many bypass applications require one second stroke time. Hydraulic Actuators are often required to obtain these speeds. Aeroflow's T^2 Trim can obtain the required speeds with less expensive actuation and still maintain stable control.

Common problems with turbine bypass are binding and/or seal washout due to thermal cycling. Leslie's piloted trim self aligns the plug, cage and seat ring for positive seating repetitively. The top hung cage allows it to expand freely through sudden wide variations in fluid temperature. This tolerance for cage expansion solves the typical problems seen in cage retained designs such as cage warping, plug binding, galling, and crushed gaskets.



Auxiliary Steam Pressure Reduction

There are many applications for steam pressure reduction in the conventional fossil fired generation plant. Some applications call for high pressure drops and intermittent operation; soot blower header pressure control, building heat regulator and pegging steam to deaerator.

Soot Blower Header PRV

Fossil fired plants use soot blowers to remove soot from the boiler tubes to increase thermal efficiencies. Soot blowers are high temperature pipes (lances) which traverse the boiler blowing superheated steam on the boiler walls to remove scale and buildup. Typically there are 20 or more lances for one boiler.

Each bank of lances has a header to supply them 200 to 500 psi steam. Steam is supplied to the header from superheater outlet. The steam PRV sees a high pressure drop and very intermittent operation. This application is closed most of the time and sees rapid load swings as soot blowers are inserted and retracted.

This application is ideal for Aeroflow T^2 Trim. Tight shutoff is required to keep seat leakage and wire draw from happening. Seat leakage will cause the header to build pressure wasting steam and blowing safetys. The speed and accuracy of T^2 Trim will keep up with the rapid swings for tight pressure control, preventing the safetys from lifting. We can supply low makeup pressure requirements by throttling through the pilot. The DPS Positioner provides precise positioning of the stem.

Building Heat PRV

Many plants use extraction steam for building heat. The application uses HP steam to provide 100-200 psi steam for building heating systems. The valve is closed in the summer and used intermittently in the heating season.

Aeroflow's Class VIII Shutoff and noise control options provide the long term solution for this application. Try to keep velocities below .5 Mach for noise and erosion concerns.

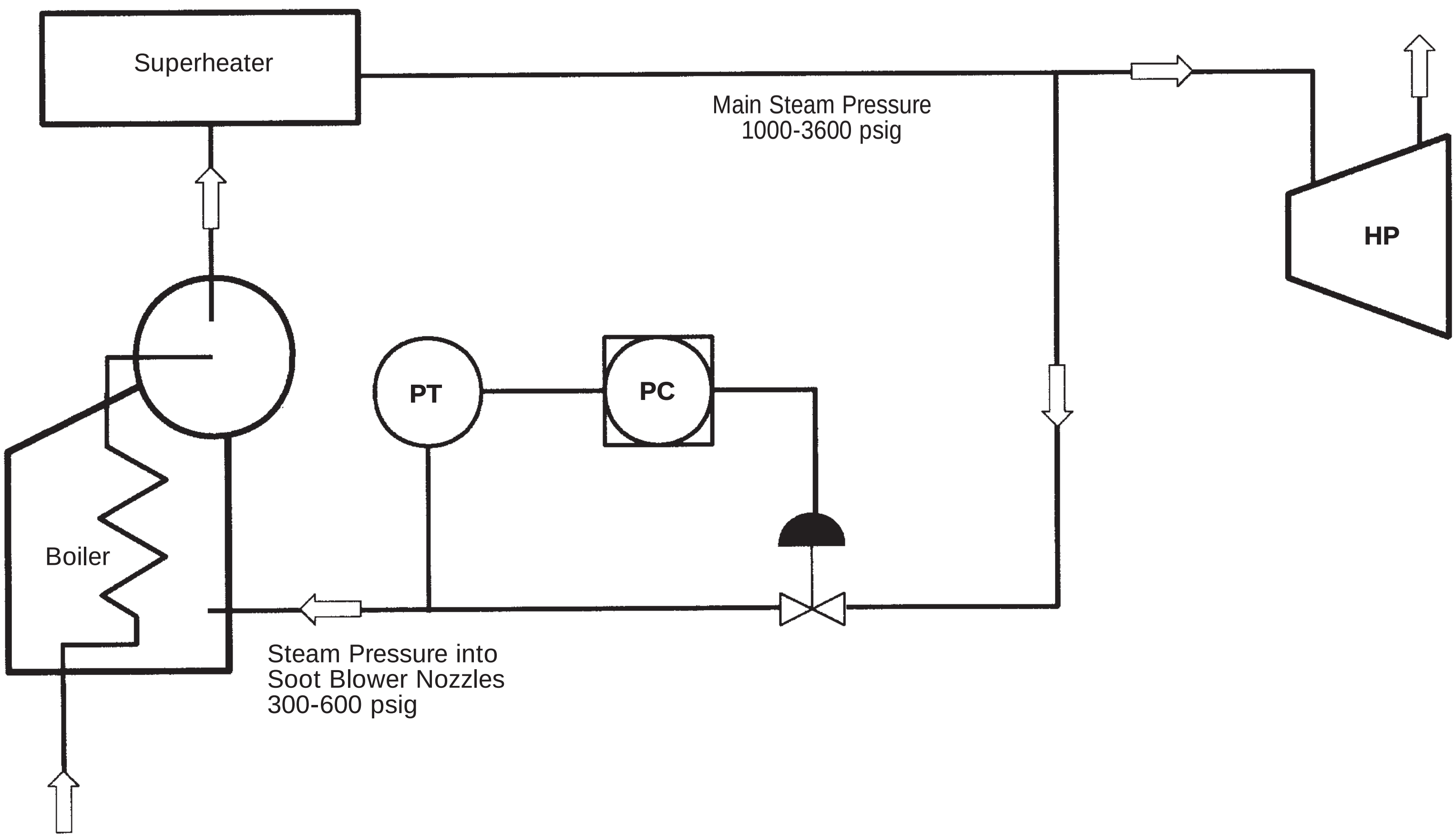
Deaerator Pegging Steam

Deaerators use superheated steam to heat and remove air from the condensate. This process uses 50 to 250 psi superheated steam. Normal supply is from a low pressure turbine extraction, but under trip conditions high pressure (1500 - 3000psi) superheated steam is used as backup.

This application is normally closed against a high DP, Leslie's Class VIII Shutoff prevents wear and unnecessary heat loss. Stable control and immunity to thermal shock add to this application need. Aeroflow is the solution.

These are some of the applications where Aeroflow has solved difficult Power Plant valve problems. There are many more waiting for solutions. Find them and let us know.

Auxiliary Steam Pressure Reduction (Soot Blower Pressure Reducing) Valve Application



Turbine & Header Drain Valves

Purpose

In addition to drain valves removing condensate from low points in main steam, superheat and reheat piping, drains are also required for the HP and IP turbines. The presence of condensate in the turbine at startup or shutdown can be extremely damaging.

At startup of the turbine, the turbine drain valves are opened to insure that, at these low temperatures, any condensate that condenses in or before the turbine is immediately removed. As the steam temperature and pressure increase the drain valves are gradually throttled closed until full power is reached. Once the turbine is in full operation the drain valves are fully closed and a tight shutoff is desirable.

Operating Conditions

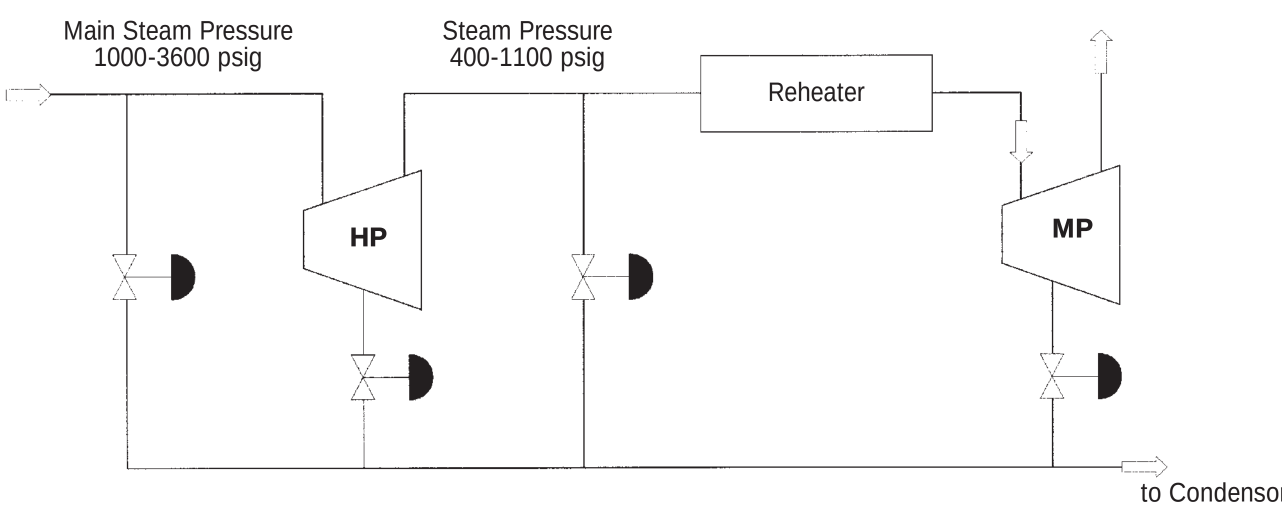
The drain valve service is one of the most severe applications for any valve in a power plant. These valves normally see a wide range of conditions; first cool condensate, followed by ever increasing pressure and temperature that causes the condensate to flash into steam and ultimately high pressure and temperature steam. The outlet condition is condenser vacuum.

One of the main considerations in this application is seat leakage. During turbine operation this valve is closed against a high pressure with a vacuum on the outlet. Seat leakage is not only expensive from a maintenance standpoint but the cost of generating turbine grade steam is expensive as well.

The power industry has determined that a throttling control valve in this application will improve the reliability and efficiency of this type drain system.

Leslie Solution

Aeroflow's Zero leakage metal to metal seat provides the solution for this application. With our piloted plug there is no friction when seating, hydraulic lift for clean opening and thermal immunity for long life. The best configuration for this application is an angle body, in flow to close orientation, with anti-cavitation trim.



Heater Drain Valve

Purpose

Feedwater heaters are used in power plants to preheat the feedwater using extraction steam from the turbine. Heaters are arranged in a cascaded manner, so that steam and condensate are drained from a higher pressure (temperature) in one heater stage to a lower pressure until the last stage drains to the condenser.

The feedwater piping is coiled through the heater and surrounded by turbine extraction steam. Below the coils condensate is collected and drained off by the heater drain to insure that condensate does not back up on the coils.

The heater drain valve is normally operated through a local pneumatic level controller. Recent advances in control strategy have put this control in the DCS. The heater drain valve is fail closed and has a redundant emergency drain which is fail open.

Operating Conditions

The drain valve controls condensate at saturation temperature to a vessel at lower pressure, flashing is always present. High pressure heaters operate at 800-900 psi at 850ºF down to the low pressure heaters at 100 psi and 400ºF. There could be a many as 6 or 8 stages of heaters.

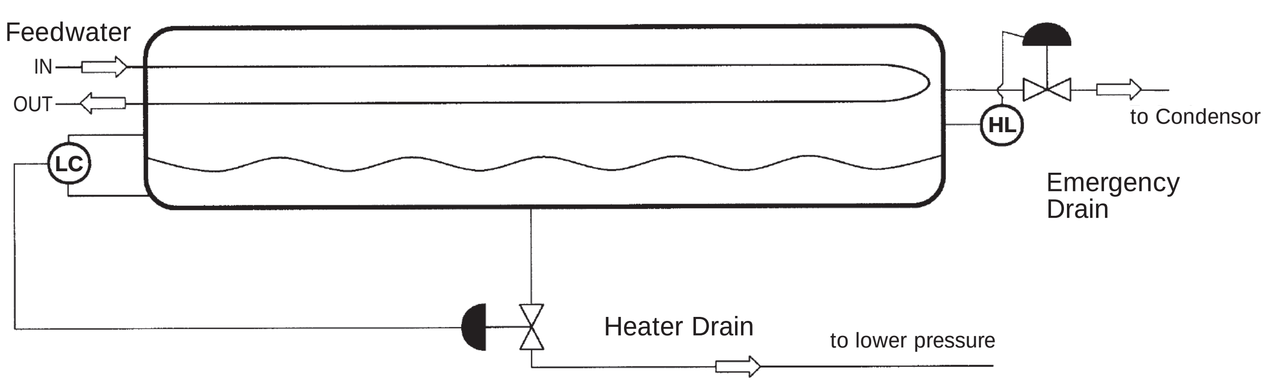
The flash dictates that line size globe valve be used to control velocities. Usually C5 or C9 material will be supplied to control erosion. Some high pressure heaters require 900# ANSI, most require 300 or 600#.

The emergency drains normally are closed against the extraction steam in the heater. These valves require tight shutoff and quick operation.

Leslie Solution

The turbine drain application traditionally has called for a welded globe valve with C5 or C9 body to prevent flash erosion. Today the utility industry has selected a flanged CS body K-Max type rotary CV. This allows use of a CS body with flow to close orientation and .2 or .4 trim to keep flash in center of pipe and down-stream of valve body.

The emergency drain application is ideal for Leslie's Aeroflow Control Valve. The major problems with this valve application is seat leakage with condenser vacuum on outlet. Leslie's Class VIII Shutoff pays for itself in saved maintenance and energy.



LESLIE CONTROLS, INC.
A subsidiary of CIRCOR International, Inc.

APPLICATION GUIDE

Control Valve Selection Chart

APPLICATION	ANSI Class	Body Mat'l.			Fail		Plug Style					Characteristic			Shut-Off	POS	SOV	Notes
		WCB	WC9	316SS	Open	Closed	UBP	BH	BL	PB	T^2	L	EP	QP				
Feedwater Control Valve	600-2500	■	■		■	■			■			■	■		IV,V	■		1
Boiler Feedwater Startup Valve	600-2500	■	■		■				■			■	■		IV,V	■		1,2
Boiler Feedwater Recirc. CV	600-2500	■	■		■					■		■			ZERO	■	■	1,3,6,7
Superheat Spray Control	600-2500	■	■			■					■	■			ZERO	■		1
Reheat Spray Control	600-2500	■	■			■	■				■	■			ZERO	■		1,3
Turbine Bypass	900-4500		■	■	■	■				■		■			ZERO	■		4,6
Heater Drain	600-1500	■	■		■					■		■		■	ZERO	■	■	4,7
Auxiliary Steam Extraction	900-4500	■	■	■		■	■			■		■	■		ZERO	■		6
Soot Blower PRV	900-4500		■	■		■				■	■	■			ZERO	■		
Steam Header Drain	900-4500		■	■		■				■		■		■	ZERO		■	7
Gland Seal Steam Control Valve	900-4500	■	■	■	■		■			■		■			ZERO	■		
Header Condensate Drain	600-2500	■	■			■	■			■				■	ZERO		■	1,6

NOTES:
1. Above 20-25 Ft/Sec use C9
2. Can use C3 Cage in FWCV and Eliminate
3. Cavitation trim is usually required
4. May need expander and plate to keep velocities < .5 Sonic
5. Possible Les-Sonic Trim
6. Could be angle body
7. Integral Cage strainer may be required

APPENDIX

ASME B16.34-1996 TABLE 2-1.1
RATINGS FOR WCB - A216

TABLE 2-1.1A STANDARD CLASS

	Working Pressure by Classes, psig						
Temperature, ºF	**150**	**300**	**600**	**900**	**1500**	**2500**	**4500**
-20 to 100	285	740	1480	2220	3705	6170	11110
200	260	675	1350	2025	3375	5625	10120
300	230	655	1315	1970	3280	5470	9845
400	200	635	1270	1900	3170	5280	9505
500	170	600	1200	1795	2995	4990	8980
600	140	550	1095	1640	2735	4560	8210
650	125	535	1075	1610	2685	4475	8055
700	110	535	1065	1600	2665	4440	7990
750	95	505	1010	1510	2520	4200	7560
800	80	410	825	1235	2060	3430	6170
850	65	270	535	805	1340	2230	4010
900	50	170	345	515	860	1430	2570
950	35	105	205	310	515	860	1545
1000	20	50	105	155	260	430	770

Not recommended for prolonged usage above about 800ºF

TABLE 2-1.1B SPECIAL CLASS

	Working Pressure by Classes, psig						
Temperature, ºF	**150**	**300**	**600**	**900**	**1500**	**2500**	**4500**
-20 to 100	290	750	1500	2250	3750	6250	11250
200	290	750	1500	2250	3750	6250	11250
300	290	750	1500	2250	3750	6250	11250
400	290	750	1500	2250	3750	6250	11250
500	290	750	1500	2250	3750	6250	11250
600	275	715	1425	2140	3565	5940	10690
650	270	700	1400	2100	3495	5825	10485
700	265	695	1390	2080	3470	5780	10405
750	240	630	1260	1890	3150	5250	9450
800	200	515	1030	1545	2570	4285	7715
850	130	335	670	1005	1670	2785	5015
900	85	215	430	645	1070	1785	3215
950	50	130	260	385	645	1070	1930
1000	25	65	130	195	320	535	965

Not recommended for prolonged usage above about 800ºF

ASME B16.34-1996 TABLE 2-1.10 RATINGS FOR WC9 - A217

TABLE 2-1.10A STANDARD CLASS

	Working Pressure by Classes, psig						
Temperature, ºF	150	300	600	900	1500	2500	4500
-20 to 100	290	750	1500	2250	3750	6250	11250
200	260	750	1500	2250	3750	6250	11250
300	230	730	1455	2185	3640	6070	10925
400	200	705	1410	2115	3530	5880	10585
500	170	665	1330	1995	3325	5540	9965
600	140	605	1210	1815	3025	5040	9070
650	125	590	1175	1765	2940	4905	8825
700	110	570	1135	1705	2840	4730	8515
750	95	530	1065	1595	2660	4430	7970
800	80	510	1015	1525	2540	4230	7610
850	65	485	975	1460	2435	4060	7305
900	50	450	900	1350	2245	3745	6740
950	35	375	755	1130	1885	3145	5665
1000	20	260	620	780	1305	2170	3910
1050	20(1)	175	350	525	875	1455	2625
1100	20(1)	110	220	330	550	915	1645
1150	20(1)	70	135	205	345	570	1030
1200	20(1)	40	80	125	205	345	615

NOTE: (1) For welding end valves only. Flanged end ratings terminate at 1000ºF.

TABLE 2-1.10B SPECIAL CLASS

	Working Pressure by Classes, psig						
Temperature, ºF	150	300	600	900	1500	2500	4500
-20 to 100	290	750	1500	2250	3750	6250	11250
200	290	750	1500	2250	3750	6250	11250
300	285	740	1485	2225	3705	6180	11120
400	280	725	1450	2175	3620	6035	10866
500	275	720	1440	2160	3600	6000	10800
600	275	720	1440	2160	3600	6000	10800
650	275	715	1430	2145	3580	5965	10735
700	275	710	1425	2135	3555	5930	10670
750	265	690	1380	2070	3450	5750	10350
800	260	675	1345	2160	3365	5605	10095
850	245	645	1285	1930	3215	5355	9645
900	230	600	1200	1800	3000	5000	9000
950	180	470	945	1415	2355	3930	7070
1000	125	325	650	975	1630	2715	4885
1050	85	220	435	655	1095	1820	3280
1100	55	135	275	410	685	1145	2055
1150	35	85	170	255	430	705	1285
1200	25	50	105	155	255	430	770

NOTE: (1) For welding end valves only. Flanged end ratings terminate at 1000ºF.

ASME B16.34-1996 TABLE 2-2.2
RATINGS FOR CF8M - 316SS

TABLE 2-1.10A STANDARD CLASS

	Working Pressure by Classes, psig						
Temperature, ºF	150	300	600	900	1500	2500	4500
-20 to 100	275	720	1440	2160	3600	6000	10800
200	240	620	1240	1860	3095	5160	9290
300	215	560	1120	1680	2795	4660	8390
400	195	515	1030	1540	2570	4280	7705
500	170	480	955	1435	2390	3980	7165
600	140	450	905	1355	2255	3760	6770
650	125	445	890	1330	2220	3700	6660
700	110	430	865	1295	2160	3600	6480
750	95	425	845	1270	2110	3520	6335
800	80	415	830	1245	2075	3460	6230
850	65	405	810	1215	2030	3380	6085
900	50	395	790	1180	1970	3280	5905
950	35	385	775	1160	1930	3220	5795
1000	20	365	725	1090	1820	3030	5450
1050	20(1)	360	720	1080	1800	3000	5400
1100	20(1)	325	645	965	1610	2685	4835
1150	20(1)	275	550	825	1370	2285	4115
1200	20(1)	205	410	620	1030	1715	3085
1250	20(1)	180	365	545	910	1515	2725
1300	20(1)	140	275	410	685	1145	2060
1350	20(1)	105	205	310	515	860	1545
1400	20(1)	75	150	225	380	630	1130
1450	20(1)	60	115	175	290	485	875
1500	15(1)	40	85	125	205	345	620

(1) For welding end valves only. Flanged ratings terminate at 1000ºF

TABLE 2-1.10B SPECIAL CLASS

	Working Pressure by Classes, psig						
Temperature, ºF	150	300	600	900	1500	2500	4500
-20 to 100	290	750	1500	2250	3750	6250	11250
200	260	680	1365	2045	3410	5680	10220
300	235	610	1220	1825	3045	5070	9130
400	220	570	1140	1710	2850	4750	8550
500	205	530	1065	1595	2660	4430	7790
600	195	505	1010	1510	2520	4195	7555
650	190	495	985	1480	2465	4110	7395
700	185	485	970	1455	2420	4035	7265
750	180	470	945	1415	2360	3930	7070
800	180	465	925	1390	2320	3860	6950
850	175	455	905	1360	2265	3775	6790
900	170	440	880	1320	2195	3660	6590
950	165	430	865	1295	2155	3595	6470
1000	160	420	840	1260	2105	3505	6310
1050	160	420	840	1260	2105	3505	6310
1100	155	405	805	1210	2015	3360	6045
1150	130	345	685	1030	1715	2860	5145
1200	100	260	515	770	1285	2145	3860
1250	90	230	455	680	1135	1895	3410
1300	65	170	345	515	860	1430	2570
1350	50	130	260	385	645	1070	1930
1400	35	95	190	285	470	785	1415
1450	30	75	145	200	365	610	1095
1500	20	50	105	155	260	430	770

(1) For welding end valves only. Flanged ratings terminate at 1000ºF

FCI 70-2 SEAT LEAKAGE

Class II =	.5% Valve Rated Capacity Differential of 45 to 60 psi Test Medium Water		
Class III =	.1% Valve Rated Capacity Differential of 45 to 60 psi Test Medium Water		
Class IV =	01% Valve Rated Capacity Differential of 45 to 60 psi Test Medium Water		
Class V =	5 x 10-4 ml / min of water / in. seat diameter / psi DP Tested @ Rated Differential Test Medium Water		
Class VI =	1”	.15 ml/min.	1 bubble/min.
	1.5”	.30 ml/min.	2 bubble/min.
	2”	.45 ml/min.	3 bubble/min.
	2.5”	.60 ml/min.	4 bubble/min.
	3”	.90 ml/min.	6 bubble/min.
	4”	1.7 ml/min.	11 bubble/min.
	6”	4 ml/min.	27 bubble/min
	8”	6.75 ml.min.	45 bubble/min.
	Differential of 50 psi Test Medium Air or Nitrogen		
Leslie “ZERO”	Less than one drop per minute, Tested @ Rated Differential Test Medium Water		

LIQUID BODY VELOCITY LIMITATION

Carbon Steel (WCB)

Continuously Modulating or DP > 500 psi	20 ft/sec
Intermittent Modulating or DP < 500 psi	30 ft/sec
2% Intermittent Flow	40 ft/sec

Alloy or Stainless Steel

Continuously Modulating or DP > 500 psi	45 ft/sec
Intermittent Modulating or DP < 500 psi	60 ft/sec
2% Intermittent Flow	90 ft/sec

Notes: Use Alloy or SS if flashing or cavitation exists
Body erosion and noise will occur above these limits

Compressible Velocity

Noise cannot be predicted >=Mach .5
Carbon Steel Limit is .35 Mach
Alloy or SS Limit is .9 Mach

INSULATION DECIBEL REDUCTION

Thickness	Type	Decibel Reduction
1"	Thermal	-4
2"	Thermal	-8
3.5"	Thermal	-10.5
5"	Thermal	-13
	Cladding	add -5

NOISE ATTENUATION

PIPE SIZE	PIPE SCHEDULE											
	10	20	30	40	60	80	100	120	140	160	STD	XS	XXS
1	—	—	—	0	—	-3	—	—	—	-6	0	-3	—
1.5	—	—	—	0	—	-3	—	—	—	-6	0	-3	-9
2	—	—	—	0	—	-3	—	—	—	-7	0	-3	-9
3	—	—	—	0	—	-3	—	—	—	-9	0	-3	-9
4	—	—	—	0	—	-5	—	-6	—	-7	0	-6	-9
6	—	—	—	0	—	-4	—	-6	—	-8	0	-6	-10
8	—	+2	+1	0	-2	-4	-6	-7	-8	-9	0	-34	-9
10	—	+3	+1	0	-3	-4	-6	-8	-9	-10	0	-3	—
12	—	+3	+1	-1	-3	-5	-7	-9	-10	-11	0	-3	—
14	+3	+1	0	-2	-4	-6	-8	-10	-11	-12	0	-3	—
16	+3	+1	0	-3	-5	-7	-9	-10	-12	-13	0	-3	—
18	+3	+1	-2	-4	-6	-8	-10	-11	-13	-14	0	-3	—
20	+3	0	-3	-4	-7	-9	-10	-12	-14	-15	0	-3	—
24	+3	0	-4	-6	-9	-10	-12	-14	-15	-16	0	-3	—
30	+1	-3	-5	—	—	—	—	—	—	—	0	-3	—

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