Steam Turbines

This guide provides an overview of the control valve applications associated with steam turbines. Common applications are highlighted with typical process conditions, application challenges, and commonly used Fisher® valve solutions.

Process Overview

Steam Turbine

Steam turbines are utilized in a variety of industries to capture energy associated with the expansion of process-generated steam. While most commonly used in commercial power plants to drive electrical generators, steam turbines are also used in other industrial facilities such as refineries, pulp and paper mills, and chemical plants. Rated turbine output varies widely, with most turbines used in commercial power applications ranging from 30 MW to 1,000 MW in output. Steam turbines are commonly classified by the condition of the exhaust:

- **Non-Condensing Turbines**: Non-condensing or back pressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly used in refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are available.

- **Condensing Turbines**: Condensing turbines are most commonly found in commercial power plants. These turbines exhaust steam in a partially condensed state, typically of a quality near 90%, at a pressure well below atmospheric to a condenser.

- **Reheat Turbines**: Reheat turbines are also used almost exclusively in commercial power plants. In a reheat turbine, steam flow exits from a high pressure section of the turbine and is returned to the boiler where additional superheat is added. The steam then goes back into an intermediate pressure section of the turbine and continues its expansion.

- **Extraction Turbines**: Extracting type turbines are common in nearly all applications. In an extracting type turbine, steam is released from various stages of the turbine, and used for industrial process needs or sent to boiler feedwater heaters to improve overall cycle efficiency in commercial power plants. This is one arrangement of the regenerative rankine cycle used to improve the thermodynamic efficiency of a power plant.

Turbines can be configured in a variety of casing and shaft arrangements. These configurations include single casing, tandem compound, and cross compound turbines. Single casing configurations are the most basic style where a single casing and shaft are coupled to a generator (see figure 1). This style is commonly seen in industrial applications rather than in commercial power facilities.

Tandem compound configurations are primarily used in commercial power plants. A tandem compound steam turbine configuration is where two or more casings are directly coupled together to drive a single generator (see figure 2).

A cross compound turbine configuration features two or more shafts not in line driving two or more generators that often operate at different speeds (see figure 3). A cross compound turbine configuration is typically used in larger applications.

A steam turbine package is made up of several components/systems including the following: steam turbine, generator, gland steam seal system, lube oil system, shaft seal oil system, hydraulic system, and a control system. The three areas covered in this guide are the main steam turbine, the steam seal system, and the lube oil system.
Steam Seal System

When a condensing steam turbine is first started up and in a low-load condition, steam from the inlet (HP) end will leak from the outboard gland - even though labyrinth seals are installed to minimize the leakage (see figure 4). Superheated steam is invisible and, due to its high temperature, can be very dangerous. Leakage of steam also impacts the overall plant efficiency and is not desirable.

Conversely, under the same low-load conditions, the LP packing glands will be under the vacuum of the downstream surface condenser. This vacuum will tend to pull in cold atmospheric air through the seals along the shaft (see figure 5). Unless it is prevented, the air drawn into the condenser through the packing glands can cause a reduction in vacuum in the condenser and ultimately a turbine trip. In order to minimize these problems, a controlled supply of low pressure steam is piped to a common line feeding the respective packing glands of the turbine. This pressure prevents the ingress of air at the LP packing glands and ensures a positive pressure at the IP and HP glands during start-up.

When the turbine load is increased, the leakage flow of steam into the seal-steam header from the IP and HP packing glands will be great enough that the turbine becomes “self-sealing” and the steam seal regulator valve will start to close. The leakage from the higher pressure sections of the turbine provides the seal steam flow to the LP packing glands. At 40-50% turbine load the steam seal supply valve will be fully closed and the system pressure will be maintained at 3-5 psi by the steam seal dump valve. The dump valve diverts excess seal steam to the condenser.
Figure 4. Typical Steam Seal HP Packing Gland

Figure 5. Typical Steam Seal LP Packing Gland
Application Review

While GE, Siemens, Mitsubishi, and Alstom have historically been some of the largest steam turbine manufacturers, the market for steam turbines is quite fragmented. There is also a very large pool of smaller manufacturers that have an offering. While differences do exist in the design of systems amongst these manufacturers, the valve application requirements tend to be quite similar. Though certain designs may contain more or fewer valves, the applications described within this guide are common to nearly all designs used in industry.

1. Main Steam Control Valve

The main steam control valve modulates flow of admission steam to the HP turbine from the HRSG or boiler. There is typically a main stop valve and a control valve in series. These valves may be part of the turbine casing itself. They are usually designed and manufactured by the steam turbine OEM. The application requires a very large high pressure valve with a pilot plug and hydraulic actuation. The OEM manufacturer may use a labyrinth valve stem packing with a leak-off to the condenser.

2. LP Induction Admission Steam Valve(s)

The admission steam valves are located by the crossover piping on the low pressure side of the steam turbine. There may be two valves in series: a stop valve and a control valve. On some OEM designs these are a matched set, others may use two different types or manufacturer’s valves. The stop valve is an on/off configuration used to quickly shut off steam to the turbine. The control valve is used to modulate the amount of steam entering the LP turbine. Hydraulic actuators are typically used on both of these valves.

- Typical Process Conditions:
  - Fluid = Steam
  - $P_1 = 50 – 150$ psig
  - $T = 500 - 700 \, ^\circ F$
  - $Q = 0 – 120,000 \, lb/hr$ or higher

- Typical Valve Selection:
  - NPS 16 – 24 ANSI 150-300 Butterfly
  - Carbon or Stainless Steel
  - 17-4 or Nitronic 50 shaft

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and maintenance.
  - Is the shaft material appropriate for the current actuator forces?
    - The actuators are typically mounted at and serviced by a hydraulic actuator manufacturer. Recheck the torques now being applied to the shaft and evaluate if it is necessary to upgrade the valve shaft material.
3. Combined Reheat Intercept Valve

The combined reheat intercept valve controls the hot reheat admission steam from the HRSG or boiler to the IP section of the turbine. There may be two parallel lines with each, including a stop valve and an intercept (control) valve. These valves may be designed and manufactured by the steam turbine manufacturer and contain either unbalanced or pilot trim.

- **Typical Process Conditions:**
  - Fluid = Steam
  - $P_1 = 500 - 600$ psia
  - $T = 950 - 1050$ °F

- **Typical Valve Selection:**
  - NPS 16-20 ANSI 600-900 large e-body
  - C12A
  - Bore Seal
  - ANSI Class V Shutoff

- **What to look for:**
  - Review process conditions and maintenance practices.
  - Is this a candidate for a Fisher valve?
  - Have the valves been inspected in the last two years?
  - If no, perform routine valve inspection and maintenance.

4. Reverse Flow Valve

A reverse flow valve is used to quickly unload or slow down the turbine during a turbine trip. When a turbine trips, both the stop valves and intercept valves will shut, trapping high pressure main steam in the boiler and HP turbine. There is a flow path through the packing between the HP and IP turbines. The high pressure “bottled up” steam will flow from the HP turbine through the packing and into the IP turbine causing the turbine to spin. If this flow is not diverted, it can cause the turbine to spin to the point of overspeed, which can cause a catastrophic turbine/generator failure. During trip or load rejection these valves would open to divert this steam away from the IP turbine and prevent an overspeed situation from occurring. There may be more than one of these valves on the IP turbine or a second valve may be located on the header.

This valve may also be referred to as the packing blowdown valve.

- **Typical Process Conditions:**
  - Fluid = Steam
  - $P_1 = 400 - 700$ psig
  - $T = 650 - 950$ °F

- **Typical Valve Selection:**
  - NPS 3 - 6 ANSI 600 or 1500 e-body or HPD with BWE
  - WC9
  - Linear Cage
  - ANSI Class V Shutoff

- **What to look for:**
  - Have the valves been inspected in the last two years?
  - If no, perform routine valve inspection and
maintenance.

— Does the valve provide sufficient shutoff?
  • Use Fisher Instrument & Valve Services (IVS) ultrasonic testing to check for leakage as this valve is typically closed.
  • Some valves installed in this application were originally specified with ANSI Class IV shutoff.
  • Upgrade to Class V shutoff if demonstrated shutoff is not acceptable to the customer.
— Is the customer familiar with the benefits of the FIELDVUE™ DVC6200 positioner?
  • Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
  • Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

5. Drain Valves

Drain valves will be located throughout the system. These will be small valves used to remove any water from the turbine and steam system. These may be hydraulic or pneumatically actuated. In some cases, metal seated ball valves are used if this application is purely used for on-off. In throttling applications, Fisher control valves are an option, but it is recommended the control valve be used for throttling and that a metal seated ball valve or other on-off valve be installed to insure tight shutoff.

- Typical Process Conditions:
  — Fluid = Water/Condensate
  — P1 = 500 – 3000 psia
  — P2 = Condenser Pressure
  — T = 300 – 1050 °F

- Typical Valve Selection:
  — NPS 1 - 2 ANSI 600 – 2500+ Globe with BWE
  — WCC/WC9/C12 body, 316SST / CoCr-A trim
  — Quick Opening
  — ANSI Class V Shutoff

- What to look for:
  — Have the valves been inspected in the last two years?
    • If no, perform routine valve inspection and maintenance.
  — Does the valve provide sufficient shutoff?
    • Use Fisher IVS ultrasonic testing to check for leakage as this valve is typically closed.
  — Is the customer familiar with the benefits of the DVC6200 positioner?
    • Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    • Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

Steam Seal System

The majority of control valve applications associated with a steam turbine are found within the steam seal system. Collectively, these valves condition the seal-steam, regulate its flow to the respective turbine packing glands, and provide pressure relief in emergency scenarios. The reliability of these valves is critical to the operation of the steam seal system, which is necessary to maintain high turbine availability.

6. Steam Seal Regulator (SSR) Valve

The steam seal regulator valve throttles the flow of steam into the steam seal system. This valve may also be referred to as the steam seal feed valve. During startup, this valve will flow up to 50,000 lb/hr of steam which is used to prevent the ingress of air through the LP packing and maintain positive pressure at the HP packing. As the turbine load increases, this valve will gradually close as the leakage from the HP packing reaches a sufficient level to provide seal steam to the IP and LP packing. During normal operation, this valve will typically remain closed.

It should also be noted that turbines built prior to the mid-1970’s may have an OEM-manufactured steam seal regulator used in lieu of control valves.

- Typical Process Conditions:
  — Fluid = Steam
  — P1 = Main Steam Pressure
  — P2 = 3 - 5 psig
  — T = 650 - 1050°F
  — Q = 0 - 50,000 lb/hr

- Typical Valve Selection:
  — NPS 1 - 6 ANSI 600 - 2500 Globe
  — WCC/WC9/C12 body, 316SST / CoCr-A trim
  — MicroForm or Standard Trim
    • May have a standard trim with a diffuser or Whisper Trim™ III with a diffuser for high pressure drop applications.
  — ANSI Class IV or V Shutoff

- What to look for:
  — Have the valves been inspected in the last two years?
    • If no, perform routine valve inspection and maintenance.
  — Is the customer familiar with the benefits of the DVC6200 positioner?
    • Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    • Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.
  — Does the valve provide sufficient shutoff?
    • Use Fisher IVS ultrasonic testing to check for leakage
as this valve is typically closed.
• Some valves installed in this application were originally specified with ANSI Class IV shutoff.
• Upgrade to Class V shutoff if demonstrated shutoff is not acceptable to the customer.

7. **Auxiliary Steam Seal Feed (ASSF) Valve**

Some turbine designs add a second valve called the auxiliary steam seal feed valve. It supplies steam from a secondary source, usually the cold reheat header, allowing for greater operational flexibility. This is also an energy saving upgrade using the lower enthalpy cold reheat steam when it is available rather than using the main header steam. The set point of this optional valve is between those of the steam seal regulator and the dump valve.

In practice, the SSR valve is open upon turbine startup using main header steam. The ASSF would open as well and the dump valve would remain closed. As the cold reheat pressure builds up, it will satisfy the header pressure and the SSR valve would close, leaving only the ASSF valve open. Once the steam seal system is self-sealed, this valve closes.

Set point control can become a challenge when an ASSF valve is added to the process.

- Typical Process Conditions:
  - Fluid = Steam
- P1 = 600-700 psig
- P2 = 3-5 psig
- T = 400-700°F

- Typical Valve Selection:
  - NPS 4 - 10 ANSI 600 Globe
  - WCC/WC9/C12 body, 316SST / CoCr-A trim
  - Standard Trim
  - ANSI Class IV or V Shutoff

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and maintenance.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
    - Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    - Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.
  - Does the valve provide sufficient shutoff?
    - Use Fisher IVS ultrasonic testing to check for leakage as this valve is typically closed.
    - Some valves installed in this application were originally specified with ANSI Class IV shutoff.
8. Steam Seal HP Desuperheater

The HP desuperheater is used to reduce and regulate the temperature of seal steam entering the steam seal system. In most facilities, spraywater will be sourced from the condensate system at relatively low pressure and temperature (150-400 psig, 100°F). The valve construction details outlined below are typical for this configuration. In some instances, the spraywater will be sourced from the boiler feedwater supply. In those cases, the feedwater valve is typically required to be an ANSI 1500 construction due to the higher pressure and temperature conditions (2000-3500 psig, 300°F).

- Typical Spraywater Valve Process Conditions:
  - Fluid = Spraywater
  - $P_1 = 150 - 400$ psig
  - $P_2 = 75$ psig
  - $T = 100°F$

- Typical Spraywater Valve Selection:
  - NPS 1 ANSI 600 Globe
  - WCC body, 17-4SST cage, 416SST plug
  - MicroForm trim
  - ANSI Class V Shutoff

- Typical Desuperheater Process Conditions:
  - Fluid = Spraywater
  - $P_1 = 75$ psig
  - $P_2 = 3 - 5$ psig
  - $T = 100°F$

- Typical Desuperheater Selection:
  - DVI / DMA
  - WCC construction

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and maintenance.
    - If BFW is used as the spraywater supply, check the shutoff performance and look for potential damage to the plug and seat.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
  - Legacy spraywater valves in this application are likely to have an older digital positioner or analog positioner installed.
  - Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

- Is the attemperator providing sufficient desuperheating performance?
  - Utilize the nozzle replacement program to improve desuperheater performance.

9. Steam Seal LP Desuperheater

The LP desuperheater is used to reduce and regulate the temperature of seal steam entering the steam seal system. In most facilities, spraywater will be sourced from the condensate system at relatively low pressure and temperature (150-400 psig, 100°F). The valve construction details outlined below are typical for this configuration. In some instances, the spraywater will be sourced from the boiler feedwater supply. In those cases, the feedwater valve is typically required to be an ANSI 1500 construction due to the higher pressure and temperature conditions (2000-3500 psig, 300°F).

- Typical Spraywater Valve Process Conditions:
  - Fluid = Spraywater
  - $P_1 = 150 - 400$ psig
  - $P_2 = 75$ psig
  - $T = 100°F$

- Typical Spraywater Valve Selection:
  - NPS 1 ANSI 600 Globe
  - WCC body, 17-4SST cage, 416SST plug
  - Micro-Form trim
  - ANSI Class V Shutoff

- Typical Desuperheater Process Conditions:
  - Fluid = Spraywater
  - $P_1 = 75$ psig
  - $P_2 = 3 - 5$ psig
  - $T = 100°F$

- Typical Desuperheater Selection:
  - DVI / DMA
  - WCC construction

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and maintenance.
    - If BFW is used as the spraywater supply, check the shutoff performance and look for potential damage to the plug and seat.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
  - Legacy spraywater valves in this application are likely to have an older digital positioner or analog positioner installed.
  - Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.
— Is the attemperator providing sufficient desuperheating performance?
  • Utilize the nozzle replacement program to improve desuperheater performance.

### 10a. Steam Seal Regulator Dump Valve

The steam seal regulator dump valve maintains the pressure of the steam seal system by regulating the flow of excess steam that is discharged to the plant’s condenser. This valve will typically remain closed throughout startup. As the turbine load increases and steam leakage from the HP packing increases, this valve is opened to allow excess seal steam to exit to the condenser.

This application may also be referred to as the Spillover Valve.

- **Typical Process Conditions:**
  - Fluid = Steam
  - P1 = 3 - 5 psig
  - P2 = Condenser Pressure (1 psia)
  - T = 500 – 600°F
  - Q = 0 - 50,000 lb/hr

- **Typical Valve Selection:**
  - Vee-Ball™ rotary control valve, Globe
  - WCC, Stainless Steel
  - Equal Percentage
  - ANSI Class II Shutoff

- **What to look for:**
  - Have the valves been inspected in the last two years?
    • If no, perform routine valve inspection and maintenance.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
    • Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    • Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

### 10b. Steam Seal Diverter Valve

The steam seal diverter valves help improve overall turbine and plant efficiency by changing the discharge location of the excess seal steam that is discharged from the system. In many plants, a tandem-linkage butterfly assembly is used to provide the same functionality as a three-way valve and directs the discharge steam to the condenser or the feedwater heater. When the steam is dumped to the condenser, turbine efficiency will decrease. By dumping the steam to a heat exchanger, much of that heat can be recaptured in the condensate system which improves turbine and plant efficiency. Utilizing a diverter valve assembly in this application rather than a dump valve allows for greater operational flexibility and can also lead to greater efficiency when steam is diverted to the feedwater heater. At full or near full load, this valve may operate at a partial open position where some steam is diverted to a feedwater heater or other heat exchanger and some diverted to the condenser. Operation is dependent upon how much flow the feedwater heater can accept.

- **Typical Process Conditions:**
  - Fluid = Steam
  - P1 = 3 - 5 psig
  - P2 = Condenser Pressure (1 psia)
  - T = 500 - 600°F
  - Q = 0 – 50,000 lb/hr

- **Typical Valve Selection:**
  - Butterfly tandem linkage with open/closed actuators
  - SST
  - Quick Opening
  - ANSI Class IV Shutoff (not critical)

- **What to look for:**
  - Have the valves been inspected in the last two years?
    • If no, perform routine valve inspection and maintenance.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
    • Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    • Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

### Lube Oil System

The lube oil system provides proper lubrication and cooling to the bearings in the steam turbine as well as other rotating equipment included in the package. The primary valves in any lube oil system are the back pressure control valve, the lube oil pressure control valve, and the temperature control valve.

### 11. Back Pressure Control Valve

This application controls how much lube oil is dumping back into the oil reservoir. Either a control valve or a regulator may be used, depending on process conditions and skid-builder preference and travel requirements.

- **Typical Process Conditions:**
  - Fluid = Oil
  - P1 = 100 - 400 psig
  - P2 = 25 - 30 psig
  - T = 70 - 160 °F
— Q = 60 - 700 lb/hr

- Typical Valve Selection:
  - Up to NPS 3 ED ANSI 150-300
  - WCC body
  - Standard Trim

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and maintenance.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
    - Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    - Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

12. **Lube Oil Pressure Control Valve**

The flow of the lube oil needs to change based on turbine speed. The Lube Oil Pressure Control Valve is a self-operating valve that regulates the flow by monitoring the downstream pressure of the valve.

- Typical Process Conditions:
  - Fluid = Oil
  - P1 = 100 - 400 psig
  - P2 = 25 - 30 psig
  - T = 50 - 160 °F
  - Q = 60 - 700 lb/hr

- Typical Valve Selection:
  - NPS 2 - 4 e-body ANSI 150-300 (655ED)
  - WCC body
  - Standard Trim

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and maintenance.
  - Is the customer familiar with the benefits of the DVC6200 positioner?
    - Legacy valves in this application are likely to have an older digital positioner or analog positioner installed.
    - Sell the benefits of an upgrade to the DVC6200 positioner: non-contact feedback, diagnostics, superior throttling performance, etc.

13. **Temperature Control Valve**

The temperature of the lubricant affects the bearing system reliability and must be monitored. If the temperature is too high or too low, a phenomena called “oil whip” can occur.
which can cause severe vibration issues. Additionally, if the
temperature is too high the rate of oxidation is accelerated
which can create sludge in the lubricant that will compromise
the hydrodynamic clearance. A three-way valve is used
in this application to control the cooling water through a
heat exchanger in an effort to maintain the appropriate
temperature of the oil lubricant.

- Typical Process Conditions:
  - Fluid = Cooling Water
  - P1 = 150 psig
  - P2 = 135 psig
  - T = 70 - 150 °F

- Typical Valve Selection:
  - NPS 1 - 6 GX 3-Way or YD, ANSI 125 - 600

  - Cast Iron or WCC Body / SST trim
  - Standard Trim
  - ANSI Class IV Shutoff

- What to look for:
  - Have the valves been inspected in the last two years?
    - If no, perform routine valve inspection and
      maintenance.
  - Is the customer familiar with the benefits of the
    DVC6200 positioner?
    - Legacy valves in this application are likely to have an
      older digital positioner or analog positioner installed.
    - Sell the benefits of an upgrade to the DVC6200
      positioner: non-contact feedback, diagnostics,
      superior throttling performance, etc.