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TECHNICAL BULLETIN

Prepared By:	**Adrian Croft**	Issue Date:	**01 /09 / 2005**
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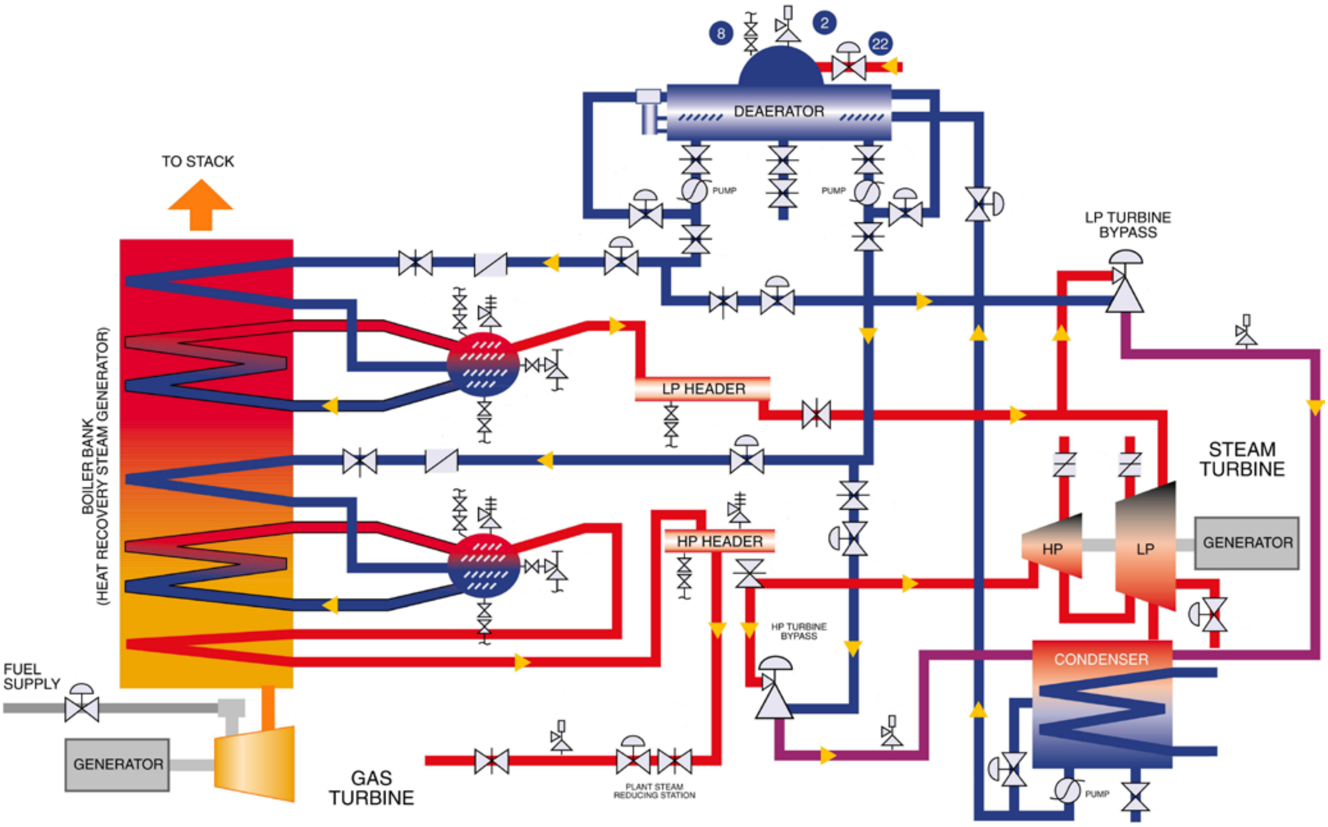
Subject: **Turbine Bypass Valves and their Application**

Introduction

Turbine Bypass control valves have long been associated with arduous process conditions. In controlling high temperature steam they are often required to open in seconds, while maintaining a high degree of closure, often to Class V.

Under normal operation the turbine bypass valve is used to reduce the pressure and temperature of the superheated steam before it enters the condenser. The valves are critical to the safe operation of the plant and must open very fast in the event of a turbine failure.

The diagram below shows a typical combine cycle power plant. The location of the HP and LP turbine bypass valves can clearly be seen.



Brief History of Turbine Bypass Valves

Traditionally turbine bypass valves were only occasionally used on power plants. The potential to cause serious damage to the condenser and other equipment now means that it is unusual to build new plants without fitting this type of valve.

The first generation of turbine bypass valves, simply bypassed the turbine on a short term emergency basis until the source of the steam could be isolated. The drive to reduce costs and to save space in modern plants has meant that condenser designers have been required to make internal provisions for equipment such as feed heaters and bled steam systems. Condensers and their associated systems were identified as an ideal location to make such savings by returning steam back into the overall cycle. In addition the condenser was identified as the best place to dump emergency and by-pass steam flows. These factors led to the growth in the use and criticality of the turbine bypass valves in the condensate system.

As the use of early turbine bypass systems increased several problems were encountered. Broadly speaking these problems fell into the following areas:

- Mechanical failure of the internal piping due to incorrect piping design or thermal expansion.
- Erosion of the internals of the condenser due to the location of the discharge.
- Tube damage from discharged steam due to incorrectly located lines.
- Overheating of the condenser internals due to improperly conditioned steam.
- Mechanical damage to the condenser due to water hammer from improperly drained pipes.
- Turbine damage due to impingement from improperly directed steam.

In the modern power station designers have largely solved these problems by the correct design of the bypass system and turbine bypass valves.

Turbine Bypass Valve Applications

In a power plant using a fired boiler with re-heater, the high pressure (HP) bypass valve controls the letdown of steam from the live steam line to the cold reheat line. The low pressure (LP) bypass valve controls the letdown of steam from the hot reheat line into the condenser.

Where there is a none fired boiler or Heat Recovery Steam Boiler (HRSB) as used in a gas fired combined cycle plant then the HP valve either discharges into the cold reheat system or into the condenser depending on the plant configuration. The LP valves are a separate system and will discharge into the condenser.

In power plants designed in accordance with the German TRD codes, the HP valves can also be used to provide over pressure protection for the superheater and live steam lines. This is a recognised practise and it is also accepted that the drum/superheater safety valves are not required.

In power plants designed in accordance with the ASME codes, boiler drum and superheater safety valves are still compulsory, although it is becoming more recognised that better use of the HP turbine bypass valves can minimise the costly lifting of the safety valves in an overpressure situation. There is also a noise consideration in trying to prevent the safety valves lifting.

Overall Design Principles

Fundamentally the turbine bypass valve fulfils two principle functions. Firstly as the steam enters the valve pressure is controlled by a fully active variable orifice (the valve trim). Secondly, as the steam passes towards the valve outlet then spraywater is injected into the valve to desuperheat the steam to the required temperature.

The valves can be globe or angle designs, but the requirements of the turbine bypass system often mean that angle valves are preferred. In recent years the bypass system design and the constraints of space have often meant that angle valves are laid on their sides so the valve is functioning in a horizontal motion.

When designing a turbine bypass system the engineer should ensure that the valve is located in a straight run of pipe after the desuperheating section. This prevents body wall erosion due to the impingement of water droplets.

Usually the high steam pressures and the required pressure reduction at the valve dictates that the valve trim should be a cage guided type. In a number of cases multi stage trims are required. The cage guided trim, being a low recovery design, ensures that the levels of jet impingement and turbulence are controlled by the cage. The jet separation produced by the cage produces a more stable downstream flow while reducing the acoustic efficiency of the power spectrum, ultimately reducing the generated noise at the valve outlet.

Depending on the valve size, the required Cv and the superior water pressure, water injection can performed by either a fixed area nozzle or variable orifice desuperheater. On a fixed area arrangement water is injected into the steam through a series of radial holes. The spray water pressure is controlled by a separate control valve. When a variable orifice desuperheater is used the water is injected directly into the centre of the pipe ensuring efficient atomisation of the water into the steam flow.

Turbine Bypass Valve & Spraywater Control Valve Fitted at Didcot B Power Station. The Valve is Mounted on its Side

After the water injection point, turbine bypass valves are often fitted with baffle plates. These baffle plates help to mix the water and the steam, by creating turbulent flow. They also help to reduce the noise levels of the steam. The number of baffle plates, the position of the baffle plates and the hole sizes in the plates depends on the sizing calculations for the valve in question. All turbine bypass valves are therefore unique and designed specifically for the application.

Pressure reducing and desuperheating valves are unique in that they are the only type of valve that can fulfil two control functions, in controlling pressure and temperature. The turbine bypass system relies on two independent measurements of pressure and temperature to control the pressure letdown and the desuperheating. The locations of the sensing elements are critical to achieving accurate process control, and they should be situated away from bends or sections of abnormal velocity, and located in a straight run of pipe. In cases where the sensing elements have been improperly located, such as on bends, then water separation can take place which leads to incorrect temperature readings.

One of the major differences between the US and European market is that in Europe, turbine bypass systems are predominantly actuated by hydraulic power units and cylinders. In the US combined cycle market, pneumatic actuation is preferred due to its relatively low cost.

Required Design Features

The turbine bypass system requires that the turbine bypass valves are designed with several special features.

Tight Shut Off – Traditionally the turbine bypass valves were designed as a temporary solution for controlling emergency steam dumps into the condenser. They used to be associated with an isolation valve which would isolate the steam flow on a longer term basis. To reduce the costs of the system design, designers have identified that control and isolation can be performed by one valve. This now means that turbine bypass valves are specified with Class V leakage. In view of the high temperatures associated with the steam, then this can prove problematic for the valve designer. The high temperature steam basically means that resilient seals cannot be used, so the valve designer must rely on metal to metal sealing or some form of special carbon steel.

Turbine Bypass Valves for Lost Pines Power Station

In the past many valve companies have addressed the problem of Class V seating by using pilot balanced plugs. These have often proved to be problematic due to the transient effects of the steam flow which have caused the two plug heads to become unstable and 'chatter'. This has caused the valve to become unstable and has ultimately induced hunting and vibration. Many companies have now stopped supplying pilot balanced trims for turbine bypass applications.

Recent developments in turbine bypass valve design has seen some of the major control valve companies release a balanced design valve with a special carbon seal to eliminate annular leakage between the plug and cage.

Valve Orientation - As previously stated, many turbine bypass valves are fitted on their side. This can cause problems in terms of stability, seat leakage, and gland leakage. On large bypass valves the weight of the plug can be in excess of one tonne. This means when the valve is laid on it side there is a huge load pushing the plug onto one side of the valve cage. This load can be significantly increased due to the inlet pressure of the steam. Ultimately the valve design engineer must consider the friction generated by the rubbing of the plug and cage due to the weight of the plug and the pressure exerted by the valve inlet pressure. The actuator size and stability can often be affected.

As a consequence of plug deflection, the plug does not run completely true in the valve. When the plug is seated this can mean that the plug does not fully contact the seating face of the seat, hence causing seat leakage.

Side loading of the plug can cause increased leakage through the valve gland. This is because the stem is loaded against one side of the packing.

The valve design engineer must ensure that the valves are substantially guided when they are laid on their sides, and ensure that the plug/cage clearance is minimised to prevent deflection of the plug and stem.

Fast Stroke Speeds – During emergency conditions turbine bypass valves are required to open within seconds, while under modulating conditions the valve must be stable and accurately respond to the control signal relatively quickly. Using electro hydraulic actuators can be a solution for this requirement. In addition the forces that can be generated by an electro hydraulic actuator can be beneficial. However, the relative cost of an electro hydraulic actuator can often mean that the preferred method of actuation is a pneumatic piston.

As the sizes and stroke lengths of turbine bypass valves increase, then the relative air volume to be ejected from the actuator in is consequently increased. This can prove challenging for the instrument engineer, especially during modulation. Large volume boosters and dump valves must be fitted, the size and quantity established by the required stroke speed of the valve.

To ensure maximum stability when fitting a pneumatic piston actuator, the actuator should be a double acting design. Air pressure above and below the piston regulated by the positioner, ensures maximum stability of the valve.

Conclusion

As discussed turbine bypass valves are unique in their design and application. There is no such thing as a valve.

When Class IV leakage is specified by the end user then the selection of a balanced design trim with carbon seals is preferred. When class V leakage is specified by the end user then special consideration must be made of the trim. If the valve is small enough and a suitable actuator is available then an unbalanced trim is preferred. If an unbalanced valve is not suitable then the valve trim design should be specially considered.

Instrument selection for fast stroke speeds for both the modulating and quick open conditions should be carefully considered.