Turbine Bypass Condenser Dump Applications

Figure 1. LP Turbine Bypass Condenser Dump Applications
Figure 2. Typical IP (HRH) / LP Turbine Bypass Dump to Condenser Arrangement

Dumping Steam into the Condenser

For some turbine bypass applications, in particular the intermediate-pressure (also known as the Hot Reheat Bypass) and low-pressure turbines, it is common for the bypass steam to be dumped directly into the condenser. This application is more sensitive than other turbine bypass applications because the dump to condenser has a number of elements that must be properly considered during the design stage.

The condenser is a very costly component of the steam system that is sensitive to both pressure and heat. The responsibility of the turbine bypass valves for this application is to protect the condenser and associated piping against excessive pressure, temperature, and enthalpy excursions during bypass operation. Also, due to the limited space typically allowed for these applications, it is important that the correct strategy is implemented for controlling the injected cooling water. A final factor that must be considered is the noise that is generated by dumping high-energy steam into a thin-walled, low pressure condenser (or condenser duct) area that is prone to high levels of noise. These considerations vary depending on whether the condenser is a water-cooled design or an air-cooled model.

Condenser Dump Turbine Bypass Application

The typical pressure and temperature controlled bypassing of the IP/LP turbines to condenser is shown in figure 2. The turbine bypass valves in this application are used to both control pressure in the boiler re-heat section and also protect the downstream equipment from the severe pressure and thermal transients. This application is also necessary to prevent condensate losses during turbine trips due to the lifting of safety valves.
Steam Conditioning

The primary function of a turbine bypass valve is steam conditioning, which is defined as combining a pressure reduction valve with a desuperheater to simultaneously control or reduce both the pressure and temperature of steam. The key component to steam conditioning in the IP / LP bypass to condenser application is the water injection. A steam-conditioning valve must have the capacity to spray enough water to cool all steam upon a turbine trip and also spray it effectively so that it will result in rapid vaporization and mixing.

A second requirement of the steam conditioning is to provide tight shutoff to prevent high temperature steam from leaking into the condenser. This can be done either with the steam-conditioning valve or with a block valve.

Backpressure Spargers

The backpressure sparger is installed to provide backpressure for a turbine bypass valve, to limit steam line velocity, to protect condenser tubes, and to reduce overall turbine bypass system noise. The sparger can be specified in either the condenser or the turbine bypass manufacturers’ scope of supply. In either case, it is highly recommended that the layout and installation be coordinated by the two suppliers for optimization and cost reduction of the system.

The sparger is custom designed to match the turbine bypass valve outlet steam piping and be inserted into the condenser or turbine bypass duct. The sparger is designed to provide the required drilled flow area to take the final pressure drop from the turbine bypass valve outlet to the condenser and minimize the pipe size based on the velocity resulting from the lower pressure. This pressure drop across the sparger is optimized with the drop across the turbine bypass valve to limit the total installed cost of the steam conditioning valve, downstream piping, and the sparger.

Once the sparger flow area is determined, the next task is to determine the geometry available for installation. The sparger should be designed to distribute steam flow with respect to the condenser’s structural layout and heat sensitive surfaces. This prevents the possible spray of the steam and water directly onto the condenser tubes, thus extending the life and limiting maintenance on the condenser. Flow area is designed to either inject steam out of the end as shown in figure 4, or spray out the sides as shown in figures 5 and 6.
Figure 5. Low Pressure Bypass Condenser Dump with Water Cooled Condenser

Figure 6. Low Pressure Bypass Condenser Dump with Air Cooled Condenser
Insertions / Installation

The IP/LP condenser dump steam-conditioning valve is designed for an optional installation that is close-coupled to the condenser as shown in figure 7. These installations do not allow for long distances between the steam-conditioning valve and the condenser for the cooling water to mix.

The structure of the condenser is a key element in this stage of the design. After the drilled holes of the sparger are aligned to face away from the condenser tubes, the next step is to find the proper installation design for the sparger. Insertion of the sparger in an inappropriate position could affect the turbine exhaust pattern, thus leading to decreased efficiency from the turbine. Fisher offers both an insertion model sparger and also a branch connection approach to avoid wasting valuable space inside the condenser duct. These options are shown in figures 5 and 6.

Control Strategy

Because of this close-coupled installation, temperature sensor feedback control is not possible.

A more accurate method for this application is a feedforward control strategy. Other turbine bypass applications may use a downstream temperature sensor for feedback control to determine the exact amount of water that is required for desuperheating. This option is usually not possible due to the short distances after the spray nozzle in most plants and the time it takes for the water to fully vaporize in the steam due to the extreme volume of water addition (often in excess of 500 GPM).

Feedforward control is accomplished using an algorithm supplied by Fisher that is characterized specifically to the valve and sparger installed in the application. The algorithm is programmed into the Distributed Control System to provide an accurate calculation of the spraywater that is required to reduce the steam enthalpy and temperature prior to admittance into the condenser. The algorithm requires input of upstream temperature and pressure as well as the position of the valve. Upstream enthalpy and spraywater enthalpy are then determined using steam property tables within the DCS. The total spraywater required is calculated from a heat balance using the final enthalpy into the condenser.
Noise Control

The sparger is an essential element to noise control for high velocity dumps into low pressure, thin walled condensers. Application noise limits vary depending on the required level at condenser duct, bypass downstream piping, or the plant fence line. The “system noise” (valve, piping, sparger, and transmission outside of the system) is an important consideration for the bypass design. The sparger design employs two methods to lower the noise generated by the bypass valve and noise generated by flow into the condenser duct. First, by providing the proper backpressure to the bypass valve, velocities in the bypass line are kept within an appropriate limit. Second, by separating the bypass flow into numerous jets through the sparger by means of an engineered hole pattern, the generated frequencies can be shifted out of the audible range. Selection of the correct spacing of flow exit holes is crucial to eliminate jet interaction between the individual flow streams. The prevention of jet recombination keeps the peak frequency of the noise spectrum above the audible range. Also, by maintaining the higher frequencies, the amount of energy that is effective in exciting pipe vibrations is reduced. This results in reduced radiated noise. As an illustration, the shadowgraphs in figure 8 show the importance of maintaining jet separation. Note the jets recombining as the pressure drop is increased while the hole spacing is kept constant. It is evident that the desired frequency shift present in the 40 psi case has been lost in the higher drop cases, as the flow through the three holes has recombined to produce lower noise spectrum peak frequencies. Consideration of space limitations is crucial to the design of the spargers where the tradeoff between hole spacing and space limitation is concerned. Maximizing hole spacing provides the most noise reduction, but results in increased sparger size that may exceed space limitations. Noise calculations can be provided for each application and can include customized drilled hole spacing patterns to allow for recovery and low noise generation.

The pressure drop ratio must be established to optimize the hole spacing and assure that jet independence will exist. High pressure drop ratios will result in the jets recombining into one larger jet in the outlet of the sparger unless the proper hole spacing is applied. This scenario is common for the bypass to condenser application since the condenser pressure is typically about 3 inches of Hg (approximately 1 to 2 PSIA). The high pressure drop ratios associated with spargers often require baffles to be added to the sparger. The baffle’s responsibility is to diffuse the flow and reduce noise levels by maintaining steam jet independence.
For multiple bypass dumps to the same condenser, spargers must be separated by an appropriate spacing ratio. The Fisher noise research team should be consulted for the appropriate spacing in order to assure that the steam jets exiting the spargers don’t combine to create a higher level of noise. Recommended sparger spacing will vary depending on the range of operating conditions and the geometry of the condenser duct.

Now, more than ever, it is critical that this application is carefully engineered to assure protection of the condenser duct or tubes, low noise levels, and low total installed cost. It is important that the turbine bypass system is designed considering all variables to assure smooth and continuous operation. These considerations should all be evaluated during the design stage as the engineering firms work closely with the turbine bypass manufacturers. It is also highly recommended for the plant to consult with an experienced equipment supplier who can provide startup service during this phase of plant commissioning.

Summary of Application

It has been common in North America over the past decades to supply water-cooled condensers with most power plants. In recent years this trend has changed to more frequent use of air-cooled condensers. This change has been driven by the fact that the current sites for these plants don’t have access to the water source that is required to operate a water-cooled condenser.

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