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PREVENTING CAVITATION REQUIRES PROPER DESIGN AND OPERATION OF FEED-WATER VALVES

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It takes a large number of control valves to run a power plant, and while some valves are more critical to plant operations than others, it always follows that when a severe service valve fails, the plant goes off line. Feed-water level control valves fall within this severe service category. These valves are of particular importance since they often fall victim to cavitation, with resulting damage to the valve trim. When this occurs it causes leakage at shutoff, lack of control during startup, and high and/or low drum level alarms.

The operating sequence of a feed-water level system during startup requires that the control valve immediately downstream of the feed-pump have a high inlet pressure and a low downstream pressure. Under these conditions, the flow pressure can drop below the vapor pressure of the liquid. As the flow pressure drops, cavitation occurs and subsequently there is a high potential for cavitation-caused damage. The cure is to take the pressure drop in stages to keep flowing pressure above the liquid's vapor pressure. This is the theory of operation used by anti-cavitation valve trims.

While use of anti-cavitation valve trim would seem to be an obvious answer to the feed-water level control problem, it usually takes additional measures to ensure continued and proper valve operation.

Figure 1. Anti-cavitation trim valve plug showing low-flow erosion damage. Photo courtesy of Fisher Controls International, LLC.

BASELOAD FEED-WATER LEVEL CONTROL

Baseload plants use one of two configurations to regulate feed-water flow. One method is to utilize a small startup valve in combination with a large main valve. The second approach is to utilize a single valve to address both startup and normal operating functions.

In either configuration, the potential for cavitation in a baseload plant is slight during startup because the pressure drop across the valve decreases rapidly as the plant comes online. As a result, cavitation damage to the valve's trim occurs slowly, thus extending the time between a trim rebuild or trim replacement. Installing anti-cavitation trim will extend the life of the valve and reduce the cost of maintenance.

Market conditions have changed dramatically since most of the baseload plants entered operation. Today's trend is to utilize combined-cycle power plants in peaking situations with daily start/stop modes. The frequent start/stop operation typically leads to feed-water valve failure due to cavitation in a matter of months, if not weeks.

Determining just how much cavitation protection is needed requires an understanding of the entire range of operating conditions. For instance, after addressing startup conditions it is important to look at the feed-pump characteristics in combination with the pressure ramping that occurs in the boiler.

As pump pressure decays and downstream pressure increases, the need for cavitation protection becomes less. By understanding the relationship between decaying feed-pump pressure and increasing drum pressure, a characterized anti-cavita-

Figure 2. In detail, erosion and cavitation damage due to low-flow erosion. Photo courtesy of Fisher Controls International, LLC.

tion solution can be developed. "Characterized" refers to a trim that at startup provides the anti-cavitation protection needed during the low flow and high-pressure drop conditions. It then follows by providing reduced cavitation protection as flow and downstream pressure increase.

Minimum Operating Point

Many anti-cavitation trims are cage-style and feature either drilled holes through the cage wall or a series of flow passages with right angle turns. Both of these approaches provide independent pressure staging with a downstream recovery area.

With either trim style a certain amount of the flow passage needs to be open in order to realize the anti-cavitation benefits. If the valve is throttled below this minimum operating point, the pressure drop will not be gradual through the trim. Instead it will be taken directly across the seating surface of the valve plug and seat ring. While all control valves have a minimum operating point, which a rule of thumb sets at 10 percent open, for valves with anti-cavitation trim the minimum operating point can vary.

It is easy to identify the damage resulting from throttling below the minimum operating point. Figure 1 shows a valve plug from an anti-cavitation trim set that was throttled below the minimum operating point for an extended period. The damaged area around the circumference of the plug has a gear tooth appearance.

Trim damage will be exacerbated when the valve goes to the closed position against full pump pressure. If the valve remains closed for a long period, the pressure differential will cut a similar wear pattern into the seat ring. This type of damage also is common on boiler feed-pump recirculation valves caused by similar conditions.

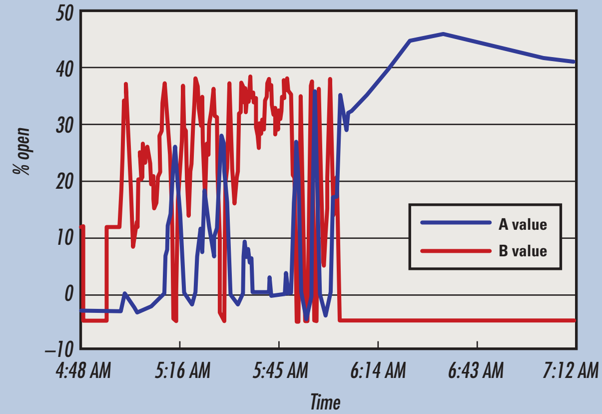
Two-valve System Operation

A common practice to circumvent cavitation, and the low-flow problems encountered with a single feed-water valve, is to separate startup from normal operating functions. One valve equipped with anti-cavitation trim is used at startup to withstand the high-pressure drops and the possibility of cavitation. A second valve equipped with standard trim is used to control normal operating conditions.

Transitioning control from the startup valve to the main valve becomes the tricky part of the operation. The startup valve typically is sized so that when it reaches 80 percent of its travel, it controls 20 percent of the unit's capacity. At this point the main valve opens to flow 20 percent of the unit's capacity and the startup valve closes. The main valve continues to control the drum level through the rest of startup and during normal plant operation.

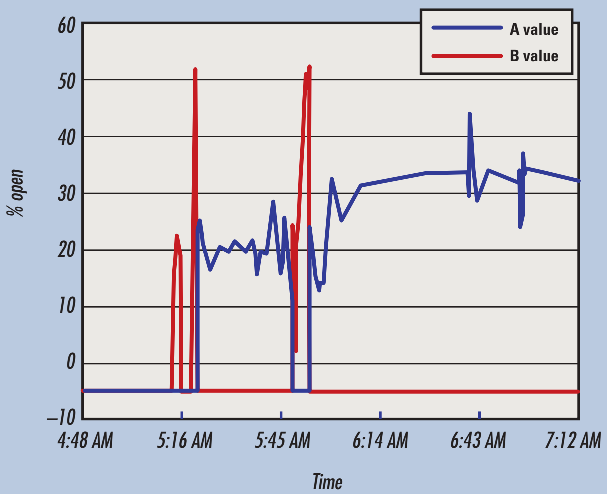
Programming this transition is the most problematic issue in two-valve arrangements. The typical error is to instruct the startup valve to go to 100 percent open, and then as the drum level demand requires more flow, program the main valve to open. However, with the startup valve remaining fully open, the main valve is required to operate with a

FIGURE 3
IMPROPER OPERATION OF TWO-VALVE FEED-WATER SYSTEM



Source: Fisher Controls International, LLC

FIGURE 4
TWO-VALVE OPERATION WITH RE-CONFIGURED DCS LOGIC



Source: Fisher Controls International, LLC minimal input signal, just off of its seating surface. Figure 2 shows erosion and cavitation damage around the lower portion of a valve plug that operated in this manner for three months.

When the main valve is closed, the erosion damage allows leakage past the plug tip and seat line, which in turn results in cavitation damage to the bottom edge of the valve plug. As the damage increases, the leakage rate of the valve similarly increases, which then causes drum level control problems during startup.

CROSSOVER POINT VERSUS CROSSOVER RANGE

Another situation to avoid is having the crossover point become a crossover range. A range will cause both valves to operate at the same time, which can expose the main valve to low-flow erosion. Even if the main valve is not operated below its minimum operating point, continual valve cycling from closed to partially open can lead to premature wear.

Figure 3 shows a two-valve system that operated in this manner during a typical startup. In this figure the B valve is the startup valve, and the A valve is the main valve. The A valve is subjected to repeated open/close cycles. Continual operation in this mode can lead to the premature degradation of the trim in the main valve.

However, a number of safeguards can be implemented into the system to prevent this type of operation. While controlling the valves in the correct manner is important, it is imperative that this does not impact the startup cycle of the unit.

Because of the performance shown in Figure 3, locking circuits were programmed into the DCS to ensure that both valves were not operated below their minimum operating points. The valve positioners were given a zero signal until a certain controller output signal was received. In this specific situation, the startup valve operated until reaching approximately 55 percent open. At this point, the control signal to the startup valve was removed, and the main valve was set to 20 percent open. This operation prevented the main valve from continually operating near the seating surface.

Another issue in this case was that the valves were somewhat oversized. Because startup times can vary depending on load demand, it was important to prevent the valves from switching back and forth. Logic was programmed into the DCS that allowed the main valve to control down to 10 percent before switching back to the startup valve. Figure 4 shows the same system with reconfigured DCS logic.

With the improved DCS logic, the valves are not continuously cycled during the initial phase of the start up. With the proper dampening and gain settings, the transition between the valves becomes much smoother, leading to a smoother startup.

Even with the changes implemented into the system, there is still the possibility that an operator will override the controls and use the main valve during startup conditions. While this may save time, it can cause the effects previously discussed.

To provide further protection against this type of operation, the valves can be equipped with a digital valve controller that incorporates a low travel cutoff feature. This feature ensures that the valve will not open unless a minimum drive signal is received. While this can be overridden in the DCS in certain cases, it cannot be changed in the digital controller without the use of a handheld communicator or online software system.

ENSURING PROPER OPERATION

There are several steps that can be taken to ensure the proper operation of a power plant's feed-water control valves:

- *Review the valve operating information that's collected by the data historian in the DCS. Make certain that all valves are operating above their minimum operating point and make sure that each valve's cavitation protection meets the conditions seen.*
- *Check the transition point between the startup and main valves and make sure that the main valve is not operating near its seat. Operation in this zone can lead to premature trim degradation and issues with level control.*

It is important that the valves have ANSI Class V shutoff capability, otherwise isolation valves should be utilized. Leakage past the valves can lead to premature trim failure similar to that shown in Figure 2. In addition, it is recommended that the boiler feed-water pump only be started when the unit is brought on line and shut it down as soon as possible after the unit is taken off line. PE

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