How to avoid, fix problems with boiler feedwater valves

By **John Wilson,** Fisher Controls International LLC

Combined-cycle powerplants offer a great deal of operating flexibility, typically having the ability to respond to changing load demands much faster than large fossil-fired steam stations. So it is not surprising that in competitive power markets combined-cycle facilities are experiencing more operating cycles than owners planned for at the design stage.

While the ability to cycle a large combined-cycle plant is ideal for fleet flexibility, frequent startups and shutdowns strain many critical components and limit their effective lifetimes. Witness the relatively common boiler tube failures caused by flow-accelerated corrosion (FAC) and the premature failure of steam-turbine bypass valves. Such problems can bring a plant down for extended periods, often without warning.

Another maintenance issue, one that has not received much publicity to date, has to do with valves in the boiler feedwater system. The design of boiler feedwater systems varies somewhat from plant to plant, but the valves used are fairly repeatable.

The number of valves depends on the design of the steam turbine and the heat-recovery steam generator (HRSG). If the turbine and HRSG are of the multi-pressure type, the number of valves increases. To illustrate: For multi-pressure HRSGs, drum level may be controlled by a one-valve or two-valve arrangement. Depending on plant design, there may be between two and six drum-level control valves. In addition, for each boiler feedpump (most plants have two per HRSG), there is a recirculation valve that recycles a portion of feedwater flow back to the low-pressure (l-p) drum or deaerator to prevent the boiler feedpump from overheating and potentially cavitating.

Similar problems with feedwater valves have been experienced at several combined-cycle plants with different types of steam turbines and HRSGs. The most common issue noted is excessive leakage. With leakage comes damage to the internal throttling and seating surfaces of the valve. This damage often is incorrectly attributed to faulty design or misapplication. In many cases the resultant leakage damage can be traced to frequent cycling of the unit. It is not uncommon for a combined-cycle plant to experience over 250 starts per year. This is more than the number of starts that most large coal-fired plants experience in a lifetime.

Given that there are up to eight critical boiler feedwater valves per HRSG, maintenance or replacement of these valves can be very expensive. The cost of feedwater valves for a two-on-one combined cycle can run more than $100,000. While many problems can be traced to frequent cycling, there are other reasons for valve damage as detailed below. It is important to understand the type of damage and its cause before the proper replacement or fix can be applied.

What causes feedwater valves to leak? The first indication of leaking feedwater valves normally is an increase in drum water level. After you determine which valves leak, they must be opened for inspection to determine the root cause. Below are six reasons for leakage and what to do when you isolate the problem.

1. Insufficient information to guide valve selection

Valve leakage often can be traced back to the engineering and design phase of the project. It is at this time that operating data are specified and equipment is selected based on preliminary heat-balance information. Only two or three operating conditions normally are provided and these are intended to encompass the entire range of conditions that the valves will experience. Many times operating conditions are specified before the feedwater pumps have been purchased, making it very difficult to predict the output-pressure and flow data needed for proper valve selection.

Note that for a grassroots combined-cycle plant using F-Class combustion-turbine (CT) technology and supplemental duct firing, feedwater pressures can be as high as 3000 psig. If newer steam-cooled CTs are specified, feedwater pressures can climb to 3500 psig. Repowering projects present a wide array of feedwater pressures with some climbing above 4000 psig.

It is important to know pump performance details before selecting a control valve. Reason is that with such high feedwater pressures comes the potential for valve cavitation. If the pump characteristics of head loss with increasing flow are not properly understood

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during the selection phase, it is likely that the control valves will experience cavitation damage. This occurs at the plug and seating surfaces of the valve and results in subsequent leakage.

The bottom line: Because pump characteristics usually are not available during the valve selection phase, the valves selected may not have been properly sized for startup conditions or other limitations imposed by the pump manufacturer.

Solution. Before repairing, upgrading, or replacing any existing feedwater valve, review pump design parameters and plant operating data. A pump curve can be used to ensure that the valves properly match the pump characteristic and have the necessary anti-cavitation trim to protect against damaging effects. Information on pump pressure, drum pressure, and feedwater flow and temperature can be retrieved from the data historian provided with most plant control systems.

If an upgrade is required, usually it is not necessary to remove the existing valves.. A simple trim change often fixes the problem. However, if your recirculation valves were not supplied with anti-cavitation trim, larger valves are likely needed.

Comparing leakage rates for various classes of valves

ANSI/FCI 70-2 leakage class	Leakage rate, 3-in. valve, gpm	Leakage rate, 4-in. valve, gpm
Class II (0.5% of valve capacity)	4.653	40.00
Class IV (0.01% of valve capacity)	0.08	1.086
Class V (0.0005 ml/psi/mm)	0.0015	0.0370

2. Oversizing valves to meet maximum conditions

Designing for maximum conditions can lead to some of the operating and leakage problems with feedwater valves. The valves normally are sized to accommodate an operating condition that occurs when the safety valves open during a unit trip. It is critical not to allow the HRSG to “dry out,” which can cause severe thermal damage to the boiler tubes and the drums.

To protect against this, the feedwater valves are sized for minimal pressure drop, allowing the maximum amount of water to flow to the drum. At this point, the normal feedwater inlet pressure to the high-pressure (h-p) drum-level control valve is nearly 2400 psig. The valve is sized to take a 20- to 30-psi pressure drop, which increases the required capacity to nearly twice that needed for normal operation. This means that the valve must operate at lower lifts (30%-40% open) than intended during normal operating conditions, thereby exposing seating surfaces to premature erosion during startup.

Since the maximum operating pressure of a combined-cycle plant is around 1850 psig with supplemental firing, and the safety valves normally lift at approximately 2000 or 2100 psig, the valves are being sized to supply a much higher feedwater pressure to the drum. If the allowable pressure drop across the valve were increased to approximately 100 psi, valve size would decrease and it would operate at 50% to 70% open during normal operating conditions.

Solution. To prevent oversizing your feedwater valves, it is necessary to understand the impact of valve capacity on protecting the HRSG from drying out. As previously stated, slightly increasing the pressure drop across the valve will prevent the valve from being oversized. Retrofit trim packages that alter the performance characteristic of the valve can be supplied. Again, this can be done without removal of the valves. If a change is made, it is important to ensure that a revised valve characteristic does not interfere with any DCS logic.

3. Failure to specify tight shutoff

Another problem often introduced during the engineering phase of the project is that of not requiring tight shutoff for some of the feedwater valves. ANSI (American National Standards Institute) and FCI (Flow Control Institute) have established criteria to denote leakage classes for control valves. Class V shutoff is the typical recommendation for feedwater valves exposed to cavitating conditions. However, numerous drum-level valves have been specified by engineering contractors and HRSG OEMs with Class IV shutoff or less. While it doesn’t appear to make much difference on the surface because the valve does not experience cavitating conditions on paper, not selecting a valve with Class V shutoff has significant impact on valve leakage. Table shows the corresponding leakage of 3- and 4-in. feedwater valves with varying shutoff classes.

The need for tight shutoff becomes apparent during unit startup. While the CT is generating electricity and the steam system is warming up, the feedpumps are operating. At this time, flow is being recycled around the pump via the recirculation valves. Since the drum-level control valves are located just downstream of the feedpumps, they are exposed to the high inlet pressures that the recirculation valve experiences.

Looking at the table, it’s easy to understand what can happen to the drum-level valves if they are not Class V. Flow that leaks past the seating surface will cavitate, damaging the seating surfaces of the plug and the seat ring and exposing the valve to further damage. If the drum-level valves are less than Class V, it is possible to protect them during startup. One way is to install a motorized isolation valve between the drum-level and recirc valves. While such valves are installed in many plants, often they are not used.

Solution. Specify all feedwater valves with Class V shutoff. For existing valves, this may require a trim change and likely will require a change in the actuator and some additional accessories to attain the required seat load for adequate shutoff. If not already included, a digital valve controller should be added to the system. The diagnostic information available in this device can determine the seat load supplied by the actuator, which allows the user to ensure that the valve has adequate seat load for proper shutoff performance.

4. Improper operation

Not all problems can be attributed to a lack of information at the selection phase or to a lack of tight shutoff. Sometimes problems are introduced by the way the valves are operated.

All control valves have a minimum operating point which, if observed, helps protect against the effects of what is called "low-flow erosion." If the valve is opened only a minute amount off of the seating surface, the plug and seating surfaces can experience erosion. A rule of thumb that applies to most types of control valves: Do not operate your valves below 10% open. This ensures that the pressure drop occurs in the valve trim, not across the seating surface.

Valves supplied with anti-cavitation trim can have other than a 10% minimum throttling flow requirement and may be an exception to the rule. So are valves that eliminate the formation of damaging cavitation by staging the pressure drop through the valve trim. In essence, this is similar to placing a number of orifice plates or elbows into a valve to reduce the pressure in a small amount of space.

To gain the anti-cavitation effect, a certain number of flow passages must be exposed. If they are not, all of the pressure drop will occur across the last stage of the trim and the seating surfaces, creating high, local velocities that will erode the plug and seat ring. To protect against this effect, the valve manufacturer should provide the minimum travel point to the user.

Photo shows a valve plug that has been operated too close to the seating surface. The "gear-tooth" damage at the bottom of the plug is what is commonly found in valves that have operated below or right at the minimum operating point for extended periods of time. This plug was removed from an h-p drum level valve and was in operation for six months. After reviewing the operating data, it was determined that this valve was operated below the minimum operating point for nearly an hour during each plant startup.

Gear-tooth damage to feedwater startup valve is attributed to operating at minimum flow for extended periods. Valve plug shown is only six months old

Damage did not occur only during plant startup. Because the seating surface had been damaged, any leakage through the valve only exacerbated the problem. This is most commonly experienced before the valve is operated during startup when the recirculation valve is bypassing feedpump flow as discussed in point 3.

Similar damage can occur in the main drum-level valve when two valves are being used for level control. The cause of damage to the main drum level in a two-valve arrangement is either by a lack of tight shutoff or by improper transition from the startup valve.

Solution. There are several ways to ensure that the feedwater valves do not operate below the minimum operating point. One is to put a hard lock in the DCS logic to prevent the valves from operating below a certain input signal. However, this still allows the operator to override the system when cavitation can be occurring.

The other approach is to use a digital valve controller. This smart valve positioner can be programmed with a low travel cutoff feature to protect the valve from operating below a certain setpoint. If the signal supplied to the valve is less than required for operation, the actuator will remain completely saturated ensuring maximum seat load supplied to the valve.

5. Poor control arrangement

Two-valve arrangements for drum level control usually are specified for several reasons. One is financial. Typically it is less expensive to buy a small valve with anti-cavitation trim and large valve with standard trim than it is to buy one valve that incorporates a characterized trim—one that incorporates the cavitation protection and the high capacity required in feedwater applications.

In two-valve arrangements, it is important that a smooth transition occur between the startup and the main drum-level valves that will protect both valves from low-flow damage. Programming of this transition is one of the most common problems facing operators of combined-cycle plants today.

Perhaps the best two-valve setup is one where the smaller valve—the so-called startup valve—has sufficient cavitation protection for startup and is capable of handling about 20% of unit flow and the main valve is used for normal throttling control. The transition between the two valves follows what is referred to as the 80/20 rule. The capacity of the startup valve at 80% open should match that of the main valve at 20% open. Transfer between the two valves occurs when the startup valve is 80% open. At this time, the smaller valve closes and remains that way until the next startup. It is important that a smooth transition occur between the two valves to protect both from low flow damage. Programming of this transition is a problem faced by many operators of combined-cycle plants.

Often feedwater valves are of the correct size, but have not been set up properly in the field. The most common error is to allow the startup valve go to 100% open and then to open the main valve to match flow demand. This exposes the main valve to low-flow erosion effects and subsequent leakage. Over time, the leakage passing through the main valve can exceed the capacity of the startup valve, making startup of the unit difficult at best.

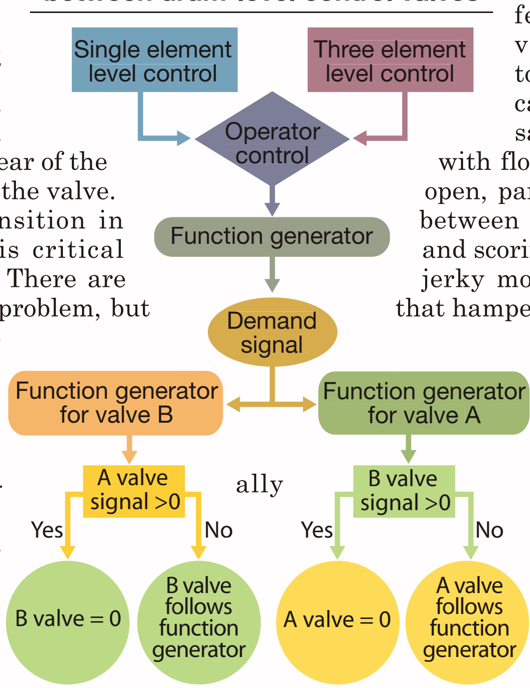
Another problem might be that the gain settings of the feedwater valves are tuned much too aggressively. This means that the valves will try to react to the slightest change in drum level, which can cause repeated on/off cycling of the valves. One example: At an Oklahoma four-on-one combined-cycle plant, the drum level valves were cycled on/off 35,000 times in less than six months. This repeated cycling caused premature wear of the shutoff and sealing areas of the valve.

Solution. Smooth transition in two-valve arrangements is critical to proper plant operation. There are several ways to tackle this problem, but the one that works best is to define a crossover range between the two valves. Rigid transition points work well, but only if the two valves are not continually fighting one another for control. Experience has shown that during a typical startup using a rigid transition point, the two valves can switch between one another up to 20 times. This repeated operation exposes the valves to the potential for premature erosion.

The control diagram illustrates the DCS logic used to solve several feedwater control issues. This arrangement ensures that the two valves are not continually throttling back and forth between one another as plant load is increased. In this case, valve B is the startup valve and valve A the main valve. The function generators are set, depending on the capacity of both valves, to ensure a smooth transition between the two.

Table (right) shows an example of the controller output and valve position. This arrangement prevents the valves from switching back and forth between one another if the controller output varies right at the transition point. After the transition occurs, the startup valve remains closed unless the controller demand falls off substantially.

DCS logic for proper crossover between drum-level control valves



Controller output versus valve position for successful operation of a two-valve arrangement

Controller A output	Valve A position	Controller B output	Valve B position
0.00	-5.00	0.00	-5.00
4.99	-5.00	2.99	-5.00
5.00	10.0	3.00	15.0
10.0	17.0	5.00	23.0
15.0	22.0	10.0	29.0
15.1	22.1	15.0	55.0
40.0	60.0	15.1	-5.00
100	100	40.0	-5.00
		100	-5.00

6. Entrained particulates

All the problems discussed previously have been experienced across the industry in different types of plants. However, entrained particulate matter has been linked largely to startup and operation of combined-cycle plants. It causes a great deal damage to all types of valves, and other equipment as well. Much of the particulate matter can be linked to FAC or inadequate pipe blow down during plant startup and commissioning.

Inadequate pipe blows have caused the failure of many valves, not just feedwater valves. But feedwater valves are particularly susceptible to particulate damage because crud can become lodged in the flow passages and reduce capacity. In valves with flow passages large enough to remain open, particulate matter can become lodged between the plug and cage causing galling and scoring of those surfaces. This can cause jerky motion of the valves, a phenomenon that hampers control. Worst case is that it renders the valve completely useless if the plug becomes stuck.

FAC occurs when the HRSG is operated at reduced loads for extended periods. What happens is that high-velocity flow in the preheater tubes removes material from the boiler tubes. The liberated material has to go somewhere and it often finds its way directly to the feedwater system. One plant in Texas removed nearly 50 pounds of fine particulates from the l-p drum during a scheduled outage. Fine particulate matter is not captured by the strainers typically installed in many new plants and it essentially “grit blasts” critical surfaces. Erosion of the valve plug can lead to the plug wedging into the seat ring and to leakage and additional valve damage.

Solution. There are several ways to deal with entrained particulate matter. The first is to ensure that proper piping blows are conducted. Prior to a pipe blow, it is necessary to remove the normal operating trim from the valve and install sacrificial trim. This will protect the finished surfaces from damage while also acting to either catch the particulates passing through the valve or to let them pass through without obstruction.

Entrained fine particulates removed from the boiler tubes are not so easy to deal with. Over time fine particulates will be expelled through continuous and intermittent blowdown operations, but it can take several years to complete the process.

Protected seats are available for control-valve trims that also provide anti-cavitation benefits. These solutions either remove the shutoff areas of the trim away from the flowing particulates or the seating surfaces are located away from any areas where a pressure drop may be taken. By ensuring that a pressure drop does not occur across the seating surface, the high-velocity sandblasting effect can not occur and the trim is protected against premature erosion. Research is ongoing to identify erosion-resistant materials that do not require the use of elaborate valve trims. CCJ