Low-pressure Steam System
Start-up and Commissioning

Knowing what goes on inside a low-pressure steam system is key to understanding the consequences of improper installation and operation.

BY CAREY MERRITT

Despite the fact that a significant number of low-pressure steam systems are modified and operating in the United States, this type of experience is dwindling. Consequently, any retrofit or new installation of a low-pressure system can present challenges; and once operational, an incorrect installation can lead to a number of problems, including nuisance low-water shut downs, poor steam quality, water-logged mains and boiler water-level fluctuations.

To fully understand the consequences of improper installation and operation, it is important to know what occurs inside the boiler and piping when various system parameters change. How these parameters affect steam generation and delivery, and the importance of an operational strategy all help minimize problems associated with start-up and commissioning.

Boiling and boiler operation
An understanding of the challenges of low-pressure steam system design and operation begins with the boiling process. Energy is transferred from the combustion chamber, through the pressure vessel wall and into the water, bringing the water to a boil. During this relatively simple process, the formation of steam bubbles and the size of these bubbles are critical, and depend upon both pressure and surface tension.

Bubble size is inversely related to pressure: the higher the pressure, the smaller the bubbles. Steam bubbles produced in a high-pressure boiler are much smaller than bubbles produced in a low-pressure boiler. Figure 1 shows that an increase in pressure results in a decrease in steam volume. As a result, the same mass of saturated steam will occupy a larger volume at lower pressure. Consequently, low-pressure steam systems require larger boiler steam nozzles and piping than high-pressure systems.

Surface tension also influences the size of steam bubbles. Water-dissolved solids, alkalinity and other impurities in a boiler increase the water-surface tension, which in turn produces larger bubbles. So, the higher the surface tension, the larger the bubbles become before they collapse.

Why is bubble size important? Simply put, the larger the bubble, the thicker the foam layer that forms on the water surface inside the boiler. Thick foam layers result in carryover and poor steam quality, which can lead to pressure fluctuations and nuisance low-water shutdown. In a high-pressure boiler, the foam layer may only be 1-in. thick, while it maybe several inches thicker in a low-pressure boiler. Mitigating some of the challenges associated with start-up and commissioning a low-pressure steam system relies heavily on controlling the size of this foam layer through the control of steam pressure and chemistry.

System-design considerations
The efficiency of any steam system depends upon the design of the components that deliver and control the steam throughout the system. Much like brakes preventing a car from moving too fast and protecting the driver from danger, the steam delivery system prevents the boiler from operating erratically and helps maintain a safe water level. A well-designed system controls steam velocity, mass flow and pressure. It also avoids erratic boiler level and pressure fluctuations, load starving, steam whistling and water hammer. [Editor’s Note: Water hammer, or hydraulic hammer effect, is defined as a phenomenon in which a pressure concession occurs by suddenly stopping the flow of liquids in a closed container.]

Additional design and installation features critical to the
efficient operation of a low-pressure steam delivery system include pipe sizing, control-valve selection, steam-trap locations and header draining design. Pipes should be sized so that steam velocity is <6,000 fpm. Figure 2 on pg. 26 serves as a guide to header sizes. As the chart indicates, retrofitting a high-pressure system to operate at lower steam pressure will most likely require under-sized headers, which can produce a whistling noise and allow steam to carry more entrained water because of the associated increase in steam velocity. Consequently, most retrofits will require a piping-size change in the field. [Editor's Note: Entrained water is a process in which the liquid boils so violently that suspended droplets of liquid are carried in the escaping vapor.]

Often overlooked, control-valve selection is just as important as proper pipe sizing. Control valves—whether direct-acting, pilot-operated or pneumatic—regulate steam flow and pressure. The price and degree of control vary tremendously according to the application.

A pneumatic-operated steam-control valve offers the most precise control, particularly in process applications; however, it also is the most costly. Direct-acting control valves are the least expensive and also the least accurate, taking several seconds to respond to a need to open or close the valve. A good compromise is a pilot-operated valve. These valves typically offer response rates between those of pneumatic and direct-acting valves, and are reasonably priced. Accuracy is good, and they enable the use of different types of pilots, including pressure or temperature.

System commissioners must ensure slow opening times, or rapid boiler depressurization can occur. When a valve

\[\text{Steam Volume vs. Pressure Curve}\]

\[\text{Figure 1} \text{This graph shows steam volume versus pressure. As the pressure increases, volume decreases. Chart courtesy of the author.}\]
Low-pressure steam controls

A well-designed boiler and steam-delivery system must be complemented with a good control strategy to ensure proper low-pressure steam system function. Controls help match system load to steam production and help prevent conditions that cause poor steam quality. Pressure control, level control and lead lag control must be matched to the application to keep the boiler(s) in sync with the steam demand.

The most frequently overlooked control is the basic pressure control. The boiler response to system pressure can be controlled either by pressure switches or by a pressure integral differential, or PID, system. Although pressure switches are reliable and less expensive, the accuracy of these switches at low pressure is marginal. Additionally, pressure switches experience setpoint differentials equally above and below the setpoint, allowing the boiler to start and stop based on an equal differential. The combination of poor accuracy and the pressure switch's lack of differential flexibility challenges the ability to maintain constant pressure in the system.

The alternative to pressure switches, a PID control system uses a pressure sensor and programmable logic controller to control pressure. The PID control limits the boiler firing rate; varies the differential pressure above and below setpoint; and provides much greater accuracy than pressure switches. PID controllers also feature remote setpoint manipulation and can be integrated into a local building-management system. Another advantage of this type of system is the ability to have multiple pressure setpoints, which helps to limit system pressure during off-peak periods.
Low-water shutdowns are a common nuisance in low-pressure steam systems, especially during start-up from a cold condition. The cause of these shutdowns is generally a consequence of poor level control of the boiler water. During high demand loads, the water level in the boiler drops quickly, and the feed water pump energizes and temporarily quenches the boiling, which causes the water to dip below the low-water cutoff. One way to mitigate this problem is to optimize the level-control system. Time delay (up to 10–15 seconds) in the low-water cutoff circuitry will help alleviate the consequences of bouncing water levels. Regulating the feed water-flow rate to minimize the quenching also will help reduce low-water shutdowns.

When multiple boilers are designed into the steam system, a good lead lag system will help stage and rotate the boilers to ensure long life. Another benefit of a good lead lag controller is the ability to limit boiler output during high demand start-up loads. Any low-pressure steam system experiences massive start-up loads due to cold piping that must be heated. Limiting output for 10–15 minutes during this period will prevent erratic boiling in the boiler(s) and stabilize the boiling process. A lead lag controller can maintain each boiler firing rate within its optimum range, generally 25%–75% output. Keeping the boilers operating in this range will help ensure steam quality and level stability.

**Boiling it down**

Low-pressure steam systems can be a challenge to start-up and operate. A properly designed and operated system will reduce the magnitude of that challenge. The following points should be considered when designing a new system or retrofitting an existing one:

- Maintain constant controlled boiling conditions in the boiler by using control valves that mitigate large pressure swings;
- Minimize foam layer height by maintaining good boiler water chemistry;
- Eliminate water from the steam piping by correctly sizing headers, traps and drip legs;
- Reduce quenching and low-water shutdowns with good level control strategy;
- Manage high start-up demand loads via good boiler controls and restricting orifices; and
- Use a good lead lag controller to keep boilers operating in the optimal firing range.

Keeping these concepts in mind during the design and installation of the system will pay dividends during start-up and commissioning.

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