New Metering Solution Controls Condensate in HRSG Systems

Water in steam tubes can lead to trouble. However, a new solution, utilizing ultrasonic flowmeter technology, allows precise water detection in heat recovery steam generator (HRSG) systems, giving operators the opportunity to alleviate the problem before failure results.

Jack Sine

Many combined cycle and cogeneration plants with heat recovery steam generators (HRSGs) were originally intended as baseload power sources or steam producers. In recent years, however, some have been repurposed as backup power sources for wind and solar farms as well as for conventional and peaking power plants.

HRSG-equipped systems are designed to capture energy that would otherwise be wasted by a combustion gas turbine. Hot exhaust gas created by the gas turbine during operation is routed to a HRSG, where it generates steam that drives a steam turbine. The power generated by the steam turbine increases the total efficiency of the plant.

This design offers several advantages. For example, plants can be started quickly, they come in packaged modules with varying power outputs, and they have high efficiencies. However, problems can arise—specifically during startups—when the technology is used as an on-demand energy source.

A lot of water can condense in HRSG superheater and reheater sections, and it can be problematic to drain the water. If the water isn't drained, it can cause damage to the boiler's tubing, resulting in expensive repairs and major downtime. This has been a chronic issue with these boilers for many years. Now that they are being cycled more frequently, the problem has become even more critical.

Guidelines Lacking

Until recently, not much attention had been given to designing HRSGs for cyclic service. That is changing as plants have begun starting and stopping more often while backing up renewable power sources. According to a white paper titled "Cyclic Service Features for Heat Recovery Steam Generators," written by Lewis R. Douglas of Nooter/Eriksen Inc. and Samuel Perez of Iberdrola Generación, insufficient design codes have been another reason for the lack of attention to cyclic service.

"For the most part ASME Section I Power Boiler code and the British BS 1113 do not have rules or guidance for how to design boilers for cyclic service," the paper says. "This information is essential to operating boilers in ways that will improve life expectancy."

However, the authors point out that most major boiler manufacturers have learned much in the last 10 years about HRSG features that could help ensure the equipment will last its intended life. In addition to the design, there has been a lot discovered about boiler operation that is equally important to understand.

For HRSGs that are required to cycle daily, condensate management becomes a real challenge. How condensate is removed is important for boiler design and operation when cycling. Many manufacturers are including condensate pots with level sensors in their superheater designs.

“It is very difficult to tell when the water in the pipe has converted to steam. There are valves, of course, to drain excess water but you have to know when to let the water out and when to close the valve to keep the steam in,” said Robert Anderson, owner of Competitive Power Resources, a consulting firm specializing in HRSG systems.

“Water in the system will find its way to the tubing and cause serious damage. And if you open valves too long, steam escapes and that’s a waste of energy and, in some cases, can damage the boiler’s steam drum. Early in the startup on the vast majority of HRSG systems, there’s no really good way to tell what’s in the pipe,” Anderson added.

There are some ways to know, like collecting the water in a big vessel with level detectors, but it’s way too expensive and too large for most retrofit opportunities. Anderson said that he didn’t know of any applications where that solution had been successfully implemented.

A workable method is to put thermocouples on tubes inside the boiler, but that’s very expensive. Installing 50 or 100 thermocouples inside the boiler could cost a couple of hundred thousand dollars. It’s very time consuming too, so most operators resort to visual identification, risking damage. However, about five years ago, Anderson found what looked like an elegant solution.

An Ultrasonic Metering Solution

“The Electric Power Research Institute (EPRI) was looking into ultrasonic technology to control superheater drains,” he said. “I went to a trade show specifically looking for clamp-on ultrasonic flowmeters. I knew something of the technology, but not in depth. One of the companies I found was FLEXIM Americas, and the guys at the booth helped fill in my knowledge gaps.”

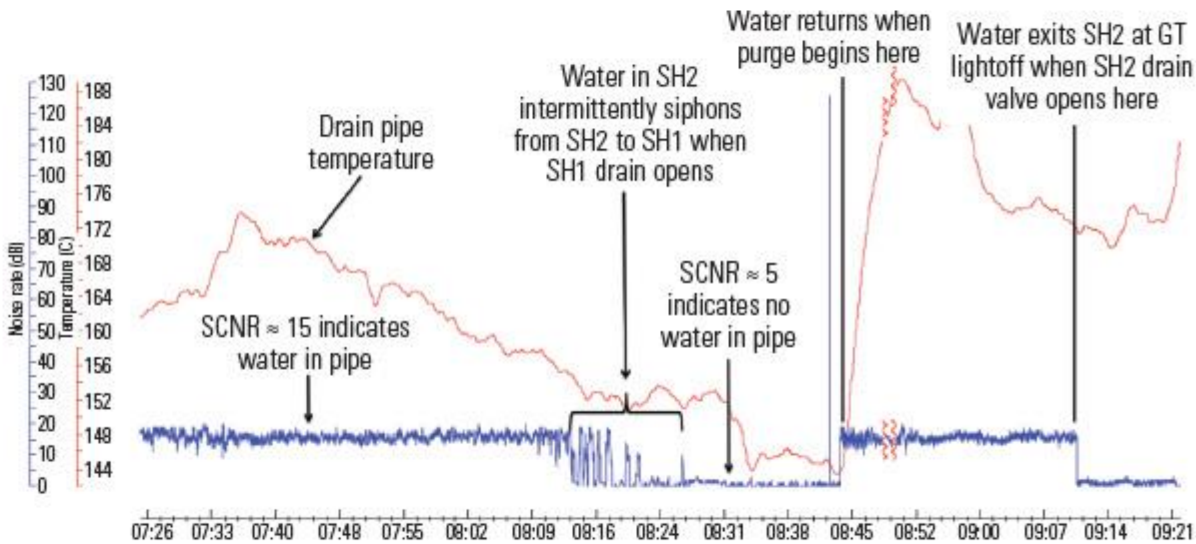
Ultrasonic flowmeters, unlike traditional meters, contain no moving parts and do not require frequent calibration or maintenance. Measurements are made using the transit-time difference method. This method exploits the fact that the transmission speed of an ultrasonic signal depends on the flow velocity of the carrier medium. An ultrasonic signal moves slower traveling against the flow direction of the medium and faster when it is traveling in the direction of flow.

“For the measurement, two ultrasonic pulses are sent through the medium, one in the flow direction and the second against it,” explained Frank Flow, FLEXIM Americas’ southeast regional manager. “The meter’s transducers work alternately as transmitter and receiver.”

The meter measures the transit time difference between the two signals and calculates the average flow velocity. Because the ultrasound signals propagate in solids, the meter can be mounted directly onto the exterior of the pipe noninvasively.

"FLEXIM ultrasonic flowmeters are not affected by density, which make them ideal for multiple applications from slurries to gas measurements," Flow said. "They can automatically compensate for variations in viscosity."

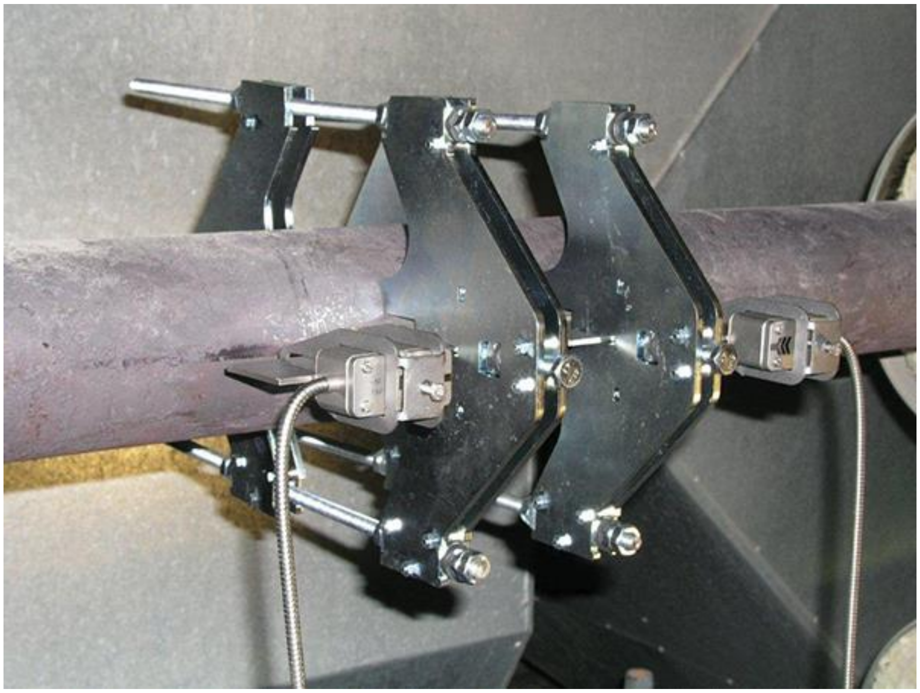
Using sound speed for information, the meters can also detect liquid type and density in an application where multiple products flow in the same pipe (Figure 1).



Steam or water? This graph shows activity inside the secondary superheater (SH2) drain pipe during a hot startup from 575 psig. The ultrasonic flowmeter equipment was monitoring but not controlling during this test. Source: FLEXIM Americas

"The ability of these meters to identify variations in viscosity and density really got my attention," said Anderson. "I asked Frank if ultrasonics could tell the difference between steam and water inside the pipe. He told me that through signal and sound speed diagnostics it would be easy to identify the differences between water and steam. I determined to try it out at my first chance."

But Anderson was also concerned about the high temperatures of the steam pipes and whether or not the meters could stand up to them. Flow assured him that FLEXIM's system could withstand a very broad range of temperatures. He noted that the standard meter is capable of accurate measurements in conditions up to 400F, and if temperatures are higher, then the company's patented WaveInjector mounting fixture (Figure 2) greatly increases the meter's range.



Innovative mounting feature. The WaveInjector fixture holds the ultrasonic flowmeter's transducers up to 4 inches off the pipe's surface, increasing the meter's operating temperature range to –260F to 750F. Courtesy: FLEXIM Americas

The WaveInjector attaches to the pipe and thermally separates the meter's transducers from the pipe, enabling it to accurately measure temperatures from –260F to 750F. The company also recently developed a new mounting procedure that greatly reduces installation time and increases accuracy. The biggest challenge would be the combination of high-temperature and small-diameter, thick-wall pipes. Flow knew they would need to have a clear and accurate distinction between the signal produced by water and that produced by steam.

EPRI Testing

Concluding that an ultrasonic flowmeter had good potential for detecting the transition from water to steam, EPRI initiated a research project to look into this new approach to condensate monitoring.

"The object was to find some kind of sensor that could tell us whether there was water or steam in the pipe," said Anderson. "Their funding allows them to sponsor or perform research that otherwise wouldn't be done. That's how this project is funded."

After successful initial testing to prove the concept, EPRI purchased a couple of the ultrasonic meters for further analysis. The management team at Oglethorpe Power Corp.'s 1,250-MW Thomas A. Smith Energy Facility near Dalton, Ga., agreed to use the meters on one of their HRSG systems.

"We put one meter on each of two drains of the HRSG superheater so the meter could identify the presence of water and initiate the draining of condensate during a startup," said Anderson. "If the water is not drained quickly enough, it finds its way into the tubes. The water quenches the hot tubes, causing high stresses at tube-to-header attachment welds, especially tubes with bends, so it's critical to make sure all of the water is drained."

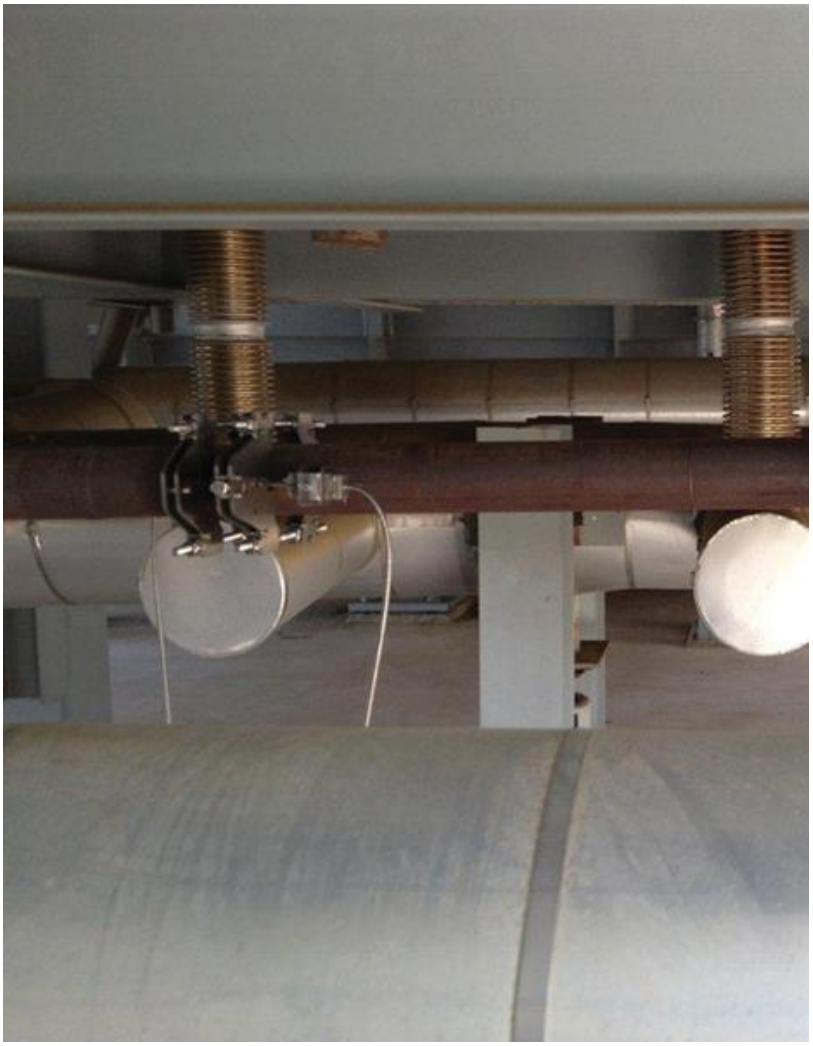
When tubes require repair, it can be very expensive. Any cracked welds have to be redone, and all repairs must pass quality control inspections. It can take a huge amount of time, and the HRSG system has to be down during the whole procedure.

"Initially, one of the two meters was working great, but the other did not work as well as we wanted. We found that a portion of the drain pipe was running slightly uphill to where the meter was mounted, so it didn't fill with water when the valve remained closed," Anderson said. "We moved the meter to a lower part of the pipe, so when water formed in the superheater, the meter could see the water in the pipe and then open the drain valve."

Size Matters

Another problem occurred on the 2-inch pipe. The walls have to be thick enough to handle the intense pressure, but with the small diameter it was difficult for the meter to distinguish between water and steam. However, FLEXIM's engineering team developed a rather novel solution.

Because the flow rate was not important in detecting the presence of water, the engineers came up with the idea of modifying the meter's firmware to use the signal-to-correlated-noise ratio in decibels (dB) to measure the water versus steam signal difference with better distinction. A low dB level indicated an empty pipe, and a high dB level indicated the presence of water (Figure 3).



Smaller does not mean easier. Engineers got creative and used noise levels to determine whether water or steam was passing through the 2-inch drain pipe. Courtesy: FLEXIM Americas

"The new firmware makes liquid detection in 2-inch pipe possible," said Anderson. "It also provides a wider, more consistent range between empty-pipe values and full-pipe values in all size pipes. So we finally have an economic solution for HRSG condensate removal."

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