WHITEPAPER

IMPROVE BOILER EFFICIENCY

Know your options when selecting the appropriate flowmeter technology to measure natural gas, water and steam in power generation

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In many chemical plants, the electricity the plant uses is derived from a natural gas power plant or a co-generation plant burning waste gas streams. In large boilers (Figure 1), power plants bring together air and fuel (natural gas, waste gas, oil or coal) for combustion, which creates heat. The heat boils the water, creating steam. The steam runs through a turbine, which causes the turbine to spin, thus generating electricity.

Measuring the flow energy — flows that cost money such as natural gas, waste gas, water and steam — in these boiler applications is critical for improving energy efficiency, identifying waste and minimizing the greenhouse gases going into atmosphere. Only with accurate flow measurement can you make informed decisions to improve energy efficiency.

"Engineers must measure the air and gas ratio accurately for efficient combustion in the boilers..."

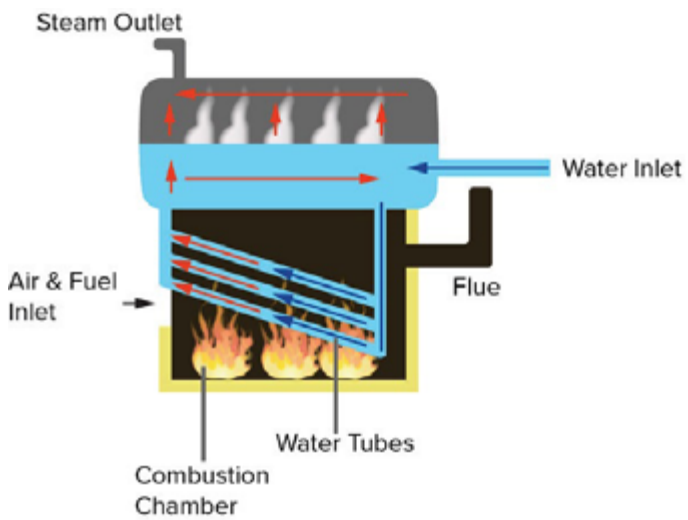

Figure 1: BOILER DIAGRAM
Typical boilers follow this process to generate electricity: Air and fuel are combined for combustion which creates heat, to boil the water, creating steam. The steam causes a turbine to spin, generating electricity.

BOILER EFFICIENCY CONSIDERATIONS

How do you decide which flowmeter technology is best to measure the gas, water and steam for boiler applications? Choosing the right flowmeters depends on the fluid being measured. When discussing boiler efficiency improvements, three primary applications are involved:

1. Accurate inlet air and fuel (natural gas, waste gas, oil or coal) measurement for efficient combustion;
2. Inlet feed water measurement to determine steam production efficiency and identify waste; and,
3. Measurement of outlet steam production.

INCREASE COMBUSTION WITH OPTIMAL FUEL-TO-AIR RATIO

Power generation requires inlet air and fuel (natural gas, waste gas, oil or coal) for combustion. Engineers must measure the air and gas ratio accurately for efficient combustion in the boilers. Too much gas is wasteful, dangerous and costly, and too little will create insufficient flame to boil the water efficiently.

Orifice and turbine meters. Monitoring fuel gas to boiler units traditionally is accomplished with an orifice or turbine meter. However, these are not the best measuring devices for this application because they both are subject to failure and require frequent skilled maintenance to provide an accurate and reliable measurement.

Constrained piping conditions also can give engineers headaches. For example, an orifice meter requires 10 to 50 diameters of upstream piping to eliminate the effect of flow disturbances. Because long straight pipe runs are hard to find, most flow measurement systems are affected adversely by varying flow profiles within the pipe.

The biggest cause for concern, however, is that orifice and turbine meters measure volumetric flow. Additional pressure, temperature and differential pressure sensors, as well as a flow computer, are required to calculate or infer mass flow (Figure 2). This not only degrades the flow measurement accuracy, but the installation and maintenance costs with this type of compensated measurement increase the cost of ownership.

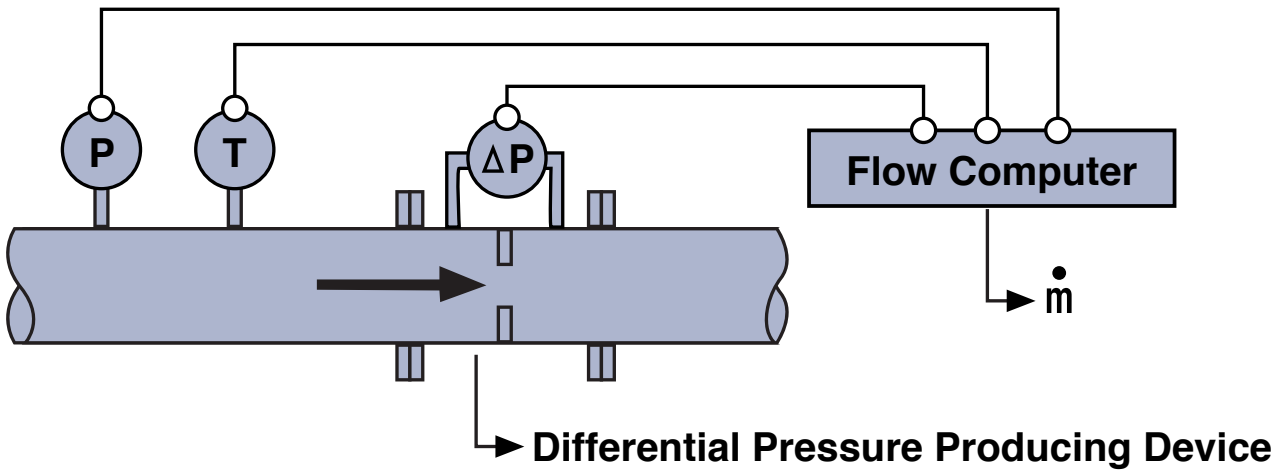

Figure 2. DIFFERENTIAL PRESSURE PRODUCING DEVICE
This is a typical differential pressure flow meter set up with additional pressure, temperature and differential sensors to infer mass flow.

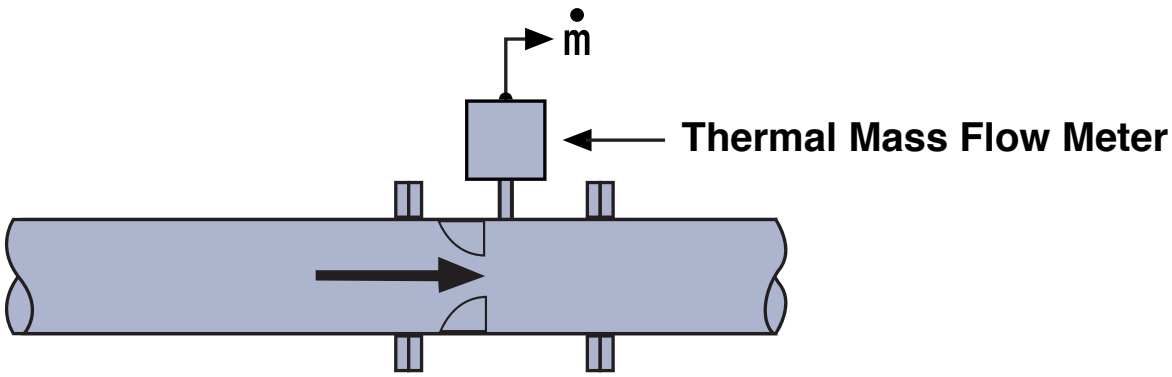

Figure 3. THERMAL MASS FLOWMETERS
This diagram demonstrates direct mass flow measurement using thermal mass flowmeters.

Thermal mass flowmeters. In contrast, thermal mass flowmeters are suitable for the direct mass flow measurement of gases, not volumetric flow. Because thermal mass flowmeters count the gas molecules, they are immune to changes in inlet temperature and pressure and measure mass flow directly without compensation. In inlet air and gas flow boiler applications, thermal flowmeters perform well because the optimal fuel-to-air ratio for efficient combustion in boilers is calculated on a mass basis, not volumetric (Figure 3).

In a thermal flowmeter's simplest working configuration, fluid flows past a heated thermal sensor and a temperature sensor. As the fluid's molecules flow past the heated thermal sensor, heat is lost to the flowing fluid. The thermal sensor cools down, while the temperature sensor continues to measure the flowing fluid's relatively constant temperature. The amount of heat lost depends on the fluid's thermal properties and its flowrate. Thus, by measuring the temperature difference between the thermal and temperature sensors, the flowrate can be determined (Figure 4).

New developments in four-sensor thermal technology coupled with stable "dry sense" sensor technology as well as advanced thermodynamic modeling algorithms enable some thermal flowmeters to attain ±0.5% reading accuracy, rivaling Coriolis flowmeter accuracy at less cost. On-board software apps also enable gas-mixing capability, in-situ validation, and dial-a-pipe.

"...thermal flowmeters perform well because the optimal fuel-to-air ratio for efficient combustion in boilers is calculated on a mass basis, not volumetric..."

MEASURE INLET FEED WATER ACCURATELY

Water also is an expensive flow energy and limited resource. In boiler applications, it's important to measure the inlet feed water flow to the boiler accurately because you need to measure the efficiency at which the boiler turns this feed water into steam (Figure 1).

Clamp-on ultrasonic flowmeters. While you could measure inlet water with a volumetric vortex flowmeter, clamp-on ultrasonic flowmeters are ideal for water flow applications due to their

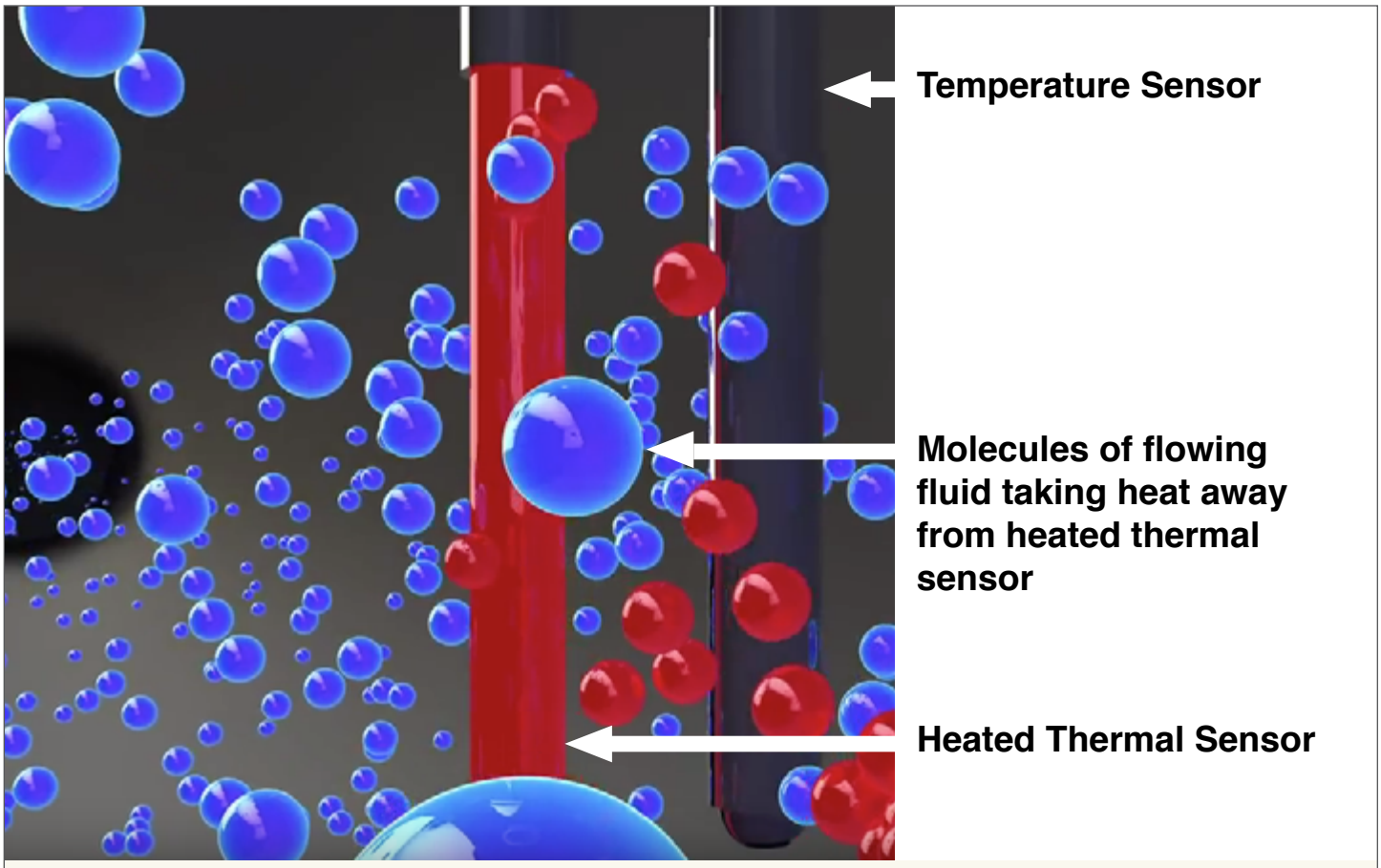

Figure 4. SENSING TEMPERATURE
A thermal flowmeter determines flowrate by measuring the temperature difference between the thermal and temperature sensors.

Figure 5: METER INSTALLATION
Sierra Instruments' InnovaSonic® 207i clamp-on ultrasonic flow meter offers ease of use and flexibility for water and liquid flow applications.

ease of use and application flexibility. They achieve high accuracy at low and high flows, save time with no pipe cutting or process shutdown and are not affected by external noise (Figure 5). Advancements in ultrasonic technology now have on-board software and apps that make the meter easy to install, providing a visual signal that it has been done correctly.

OPTIMIZE STEAM PRODUCTION

The boiler's steam must be measured accurately to determine whether your boiler is producing the expected amount of steam or needs to be tuned for increased efficiency (Figure 1). Traditionally, steam flow has been measured with a differential pressure device. This typically is an orifice plate.

However, such devices are inherently volumetric flow measurements. Changes in pressure and temperature will change the steam's mass flowrate. Even a "small" change of 10% in steam pressure will result in a 10% error in non-compensated mass flow. This means that, in a typical differential pressure measurement installation, the volumetric flowrate must be compensated by measuring temperature and pressure. These three measurements (ΔP, T and P) then are integrated with a flow computer to calculate mass flow.

Insertion multivariable vortex flowmeters.

Insertion multivariable vortex flowmeters measure steam output production from boilers more accurately (Figure 6). One insertion vortex flowmeter with one process connection measure mass flowrate, temperature, pressure, volumetric flowrate and fluid density simultaneously. Saturated steam's density varies with either temperature or pressure, while superheated steam varies with temperature and pressure, so multivariable vortex flowmeters assure the flowmeter's density calculations are correct, and therefore, the mass steam flow measurements are correct.

Multivariable vortex flowmeters provide steam accuracy of ±1% of reading, 30:1 turndown as well as pressure and temperature compensation. In addition, recent technology and sensor advancements account for external vibration, making the vortex flowmeter even more accurate and enhancing low flow measurement. New on-board software apps also allow easy setup, tuning, trouble shooting, in-situ calibration validation and data logging.

Figure 6:
METER INSTALLATION
Sierra Instruments' InnovaMass® 241i Insertion multivariable vortex mass flow meters measure steam – one process connection for mass flowrate, temperature, pressure, volumetric flowrate and fluid density simultaneously.

Figure 7: METER APPLICATION
Sierra Instruments' SteelMass® 640S thermal mass flowmeter was installed at a PTA chemical plant in China to measure methane waste gas.

CASE STUDY

Thermal Flowmeters Improve Boiler Efficiency at a Purified Terephthalic Acid Chemical Plant in China

Purified terephthalic acid (PTA) is the precursor to polyethylene terephthalate (PET), the ubiquitous material used worldwide in plastic bottles, textiles and elsewhere. A PTA chemical plant in China generated steam and electricity from its on-site power plant using coal as a fuel. It also had a wastewater treatment station that produced methane, which then was flared off. Both processes are major greenhouse gas emitters.

New government regulations required the company to reduce its CO_2 emissions. The plant decided to modify its four boilers to burn both coal and the previously flared-off waste gas (methane), estimating a savings of approximately $0.5 million in coal each year. Working with a single-source supplier, engineers reworked the boilers' designs and installed Sierra Instruments'

industrial insertion thermal flowmeters to measure its combustion air and waste gas fuel, ensuring optimal combustion (Figure 7).

One thermal flowmeter measures the waste gas flow, while the other four thermal flowmeters provide sub-metering of this gas stream to each boiler. Another four meters measure pre-heated (200°C, 392°F) combustion air to each boiler, allowing the boiler control system to optimize the fuel-to-air ratio. The Sierra flowmeters provided both precision flow data for complying with government regulations and helped the company reduce waste while increasing efficiency.

Other potential metering applications are under review, including:

- *Feed water to the boilers using clamp-on ultrasonic flow.* Because this is a pre-existing feed piping system, a clamp-on ultrasonic meter provides a flexible solution.
- *Steam flow measurement.* Measurement of steam flow delivered from the boilers to the turbine generator and sub-metering to the other plant processes.

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