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New Developments in Flow Sensors for Industrial Furnaces

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(Vortex and thermal flowmeters)

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Abstract

Flowmeters are used in industrial furnace applications for metering
– fuel (both liquid and gaseous),
– combustion air,
– flue gas and
– the heat on the water or steam side.

Recent years have seen important improvements being made in all application fields through multivariable measurements:
– New Coriolis flowmeters provide not only the mass flow, but also various diagnostic parameters such as density and viscosity of oils, thus enabling improvement of combustion, e.g. in support burners.
– New ultrasonic flowmeters used in biogas applications analyze methane content helping to determine calorific value in situ.
– New vortex flowmeters are able to determine the dryness fraction of steam, helping to improve safety, efficiency and accuracy in measurement.
– Devices now are available developed per IEC 61508 in compliance with SIL (safety integrity level) requirements including new verification concepts that provides longer proof test intervals.

Applications of the above-mentioned recent developments in a variety of industries will be presented.

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1. Introduction

This paper addresses new developments in the flow-metering of fuels, oxidizers, and energy that influence the design and operation of furnaces and boilers, and pointing out recent developments in metering technology that give rise to optimum process and combustion control and efficiency, with resulting reductions of pollutant emissions.

Four examples of superior flow-metering technologies that are applied to fuels and their oxidizers to enable optimum burner control and performance are described in detail. These technologies are now accepted in a wide range of industrial commercial processes.

2. Flow metering issues

In high-temperature applications – such as in metallurgy (blast furnaces, reheating, annealing, smelting), glass production, ceramics, cement, refractory materials, iron and steel, and other non-ferrous metals –, oxygen, compared to combustion air, has become increasingly used as an oxidizer. A defined ratio of fuel, primarily natural gas (also CNG, LNG, LPG, biomass gas) and oxygen must be made to achieve optimum combustion. If too little oxygen is used, soot and toxic carbon monoxide can occur and thus worsen the efficiency of combustion. If too much oxygen is used, this also diminishes the efficiency of combustion and oxygen is wasted. Both the fuel and oxygen must be measured with high accuracy and, if possible, with diverse and redundant flow monitoring.

Traditional tried and trusted flowmeters, such as orifice plates (ISO 5167) in burner combustion air and fuel systems, have very limited dynamic ranges (turndown) and cannot accurately measure both high and low flow rates. Therefore, in order to guarantee full combustion excess, oxidizer – usually air – is often maintained above the stoichiometric value. This results in lower efficiency. Reduction of NO_x, increased safe, and reliable burner combustion also require accurate and repeatable mass flow measurement of the burner fuel and oxidizer, rather than using fan current, damper positions, and low pressure differentials to estimate flows. Orifice plate calibration, which requires temperature and pressure compensation with long, clean pipework for accurate measurement, degrades over time through corrosion, erosion and contamination. This is particularly bad in steam flow.

3. New developments

As an alternative to the low rangeability orifice plate flowmeter, four different and technically superior flow measurement technologies for burner oxidizer and fuel flow are described in this paper, all of which are commercially available and are being used successfully in the industries mentioned above:

- *Coriolis flowmeters:* The pressure loss is comparable to orifice plates. Measurement uncertainty: max. ±0.35% in gas applications. They can be used in IEC 61508 SIL 2 applications. Highly accurate density and viscosity measurements of liquid fuels are available concurrently as additional outputs.

- *Vortex flowmeters:* Thousands are in use in oxygen applications and hundreds of thousands in steam applications. Vortex flowmeters have extremely high long-term stability, are accurate, robust, but require pressure and temperature compensation to accurately measure mass flow rate. This technology is also available with on-line real-time steam dryness fraction measurement. Therefore, they can operate autonomously in wet, dry and superheated steam regions. Steam distribution and energy balances are now accurate and reliable using this technology. SAGD (steam assisted gravity drainage) and EOR (enhanced oil recovery) applications exploit this vortex technology with its associated life-time calibration and measuring element inspection capability. It can output velocity directly to check compliance with IGC Doc/13/12/E. Vortex flowmeters with dual sensors and electronics can be used in IEC 61508 SIL 3 applications.

- *Thermal mass flowmeters:* These are routinely used for oxygen, air and natural gas flow measurement. They require no external pressure or temperature compensation and have a measurement uncertainty of max. ±1.5%. Pressure loss is negligible and the dynamic measuring range is enormous. Thermal mass flowmeters can be programmed for gas mixtures of up to eight separate gas components and can accept a chromatograph input in case of varying fuel-gas quality.

- *Ultrasonic flowmeters:* No pressure drop. High measuring dynamics. Good accuracy in gas (max. uncertainty of ±1.5%). Modern ultrasonic flowmeters can also output in biogas applications, even when wet: corrected volume methane, energy, Wobbe index (correct representation of the heating value of natural gas), gross calorific value, and net calorific value.