Technical Publication

Utilizing Thermal Mass Flow Meters To Optimize Thermal Oxidizer Performance and Reduce HAP/VOC Emissions

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Many processes in the oil/gas refining, specialty chemical production, solvents, paint, coatings and photoelectric industries generate hazardous air pollutants (HAPs) and volatile organic chemicals (VOCs), which need to be removed from waste, flue and tail gases before emission into the environment to meet clean air regulations around the world. In addition to removing problematic greenhouse gases, emphasis is placed on eliminating toxins that can be harmful to industrial workers and the environment.

The various types of oxidizer system designs all rely on accurate and repeatable mass flow measurements. Knowing the amount of VOCs entering the system, combustion air and natural gas feeds to the burner for efficient waste processing and measuring the amount of emissions in order to meet governmental reporting requirements related to clean air regulations are common system requirements.

Thermal Oxidizer Basics

Oxidation is a process used in the destruction of HAPs and VOCs; using heat to convert them into carbon dioxide and water prior to being emitted into the atmosphere *(Figure 1)*. Depending upon the composition and volume of the waste-laden air stream, several different types of Catalytic and Thermal oxidizer designs exist to achieve 95% to 99% destruction efficiencies:

- Regenerative Thermal Oxidizer (RTO)
- Regenerative Catalytic Oxidizer (RCO)
- Catalytic Recuperative Oxidizer (CATOX)
- Thermal Recuperative Oxidizer
- Direct Fired Thermal Oxidizer (DFTO/Afterburner)
- Vapor Combustion Unit (VCU)
- Rotor Concentrator

Three primary factors are associated with the effective design and operation of an oxidizer system: retention time, turbulence (mixing) and process temperature. Depending upon the HAPs/VOCs being oxidized, the waste gas must be retained within the system for a sufficient duration of time and at a temperature that is sufficient for combustion to occur. In many cases, the internal temperature of the oxidizer is in excess of 1,000 °F [538 °C]. Systems utilizing a catalyst in the oxidation process will typically operate at lower temperatures.

Flow Measurement and Control

Accurate and repeatable flow readings are required for the efficient operation of an oxidizer system. Depending upon the type of oxidizer and site requirements, typical air flow rates can range from 100 to 500,000 SCFM. Starting with the solvent laden air (SLA), it is important to know the mass flow of the gas feed so excessive loading, which could lower the destruction efficiency or allow unsafe levels of explosive media to buildup. In some cases, it might be necessary to utilize makeup air to keep the ratio of VOCs within acceptable Lower Explosive Limit (LEL) percentages for the type of system being used.

For systems utilizing a burner to start and/or maintain combustion of the VOCs, ensuring a proper fuel gas to air ratio prevents additional waste gas bleeding into the emission stream. Monitoring the gas flow as it circulates between stages of an oxidation process and the exhaust of treated air further prevents unsafe conditions and inefficiencies.

When a heat recovery system is utilized in conjunction with an oxidizer, the amount of purified air needs to be measured and accounted for in the total emissions of the system. Finally, stack measurements are common in order to report actual emissions to regulatory agencies.

Given that gases are compressible, the actual mass can vary with changes in process pressures and temperatures. Therefore, it is important to utilize a technology that accounts for density changes and provides a mass flow output. Accuracy and repeatability, operation at higher temperatures, wide variations in flow rates, low flow conditions, response time and compliance

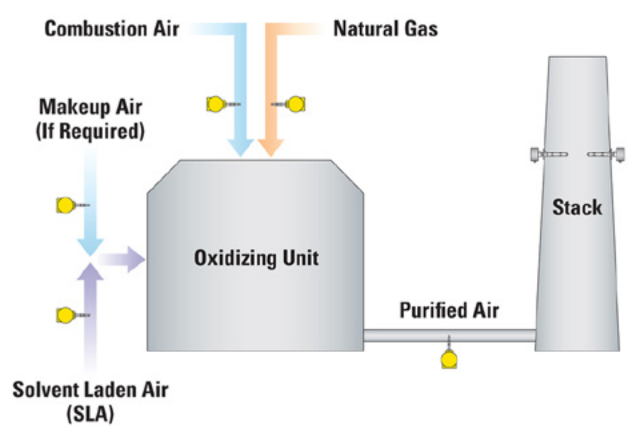

Figure 1: Thermal oxidizer process

to global safety standards for equipment used in hazardous areas are other factors to consider when establishing a flow measurement technology preference.

The types of processes emitting HAPs and VOCs are environments that require industrial grade instrumentation and controls. Not only is it necessary for the instruments to provide the desired measurements, they must also have a safety pedigree often associated with these processes.

Only a few of the primary flow measuring technologies can meet the demanding requirements and operate effectively in these applications. For example, a few flow meter designs tend to plug and foul in dirty gas environments, leading to accuracy issues and/or frequent preventative maintenance cycles, which can be costly with regards to man-hours and idle production. Some flow sensors are better suited to liquid flow measurement. Others have moving parts that can degrade and fail over time due to less than ideal gas stream conditions, especially when those streams contain particulate or small amounts of liquid.

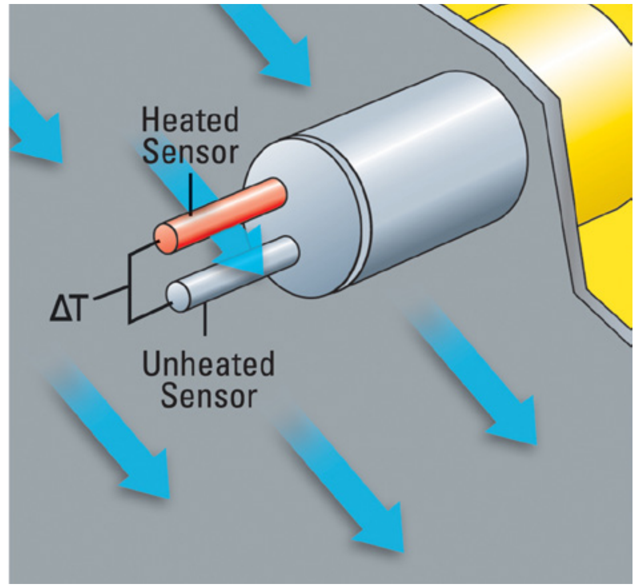

Figure 2: Thermal dispersion principle of operation

Thermal Dispersion Mass Flow Measurement

The simplicity and robustness of a thermal sensor *(Figure 2)* addresses many of these technology concerns. The sensor is comprised of two platinum RTDs that are protected within thermowells. These sensors are typically fully welded to prevent migration of the measured gases into the instrument. One RTD is heated while the other provides a reference by measuring the process temperature. This temperature differential is directly proportional to the mass flow measurement of the process.

The gas composition, density, velocity and cross sectional area of the pipe/duct are accounted for in factory calibration. Additional steps can be taken to ensure repeatability of the flow readings over a broad process temperature range. With no moving parts or orifices to plug or foul, thermal mass flow meters are less likely to be affected by particulate matter contained in the waste gas.

Thermal gas flow meter technology provides superior performance with regards to the accuracy, repeatability, turndown ratio, ease of installation and maintenance requirements of a thermal oxidizer system. As one of the two recognized mass flow technologies, the need for additional temperature and pressure sensors, as well as flow computers, to account for changes in gas density required by volumetric flow meters is eliminated; removing complexity, more points of potential failure and additional maintenance from the ownership costs.

Common baseline accuracies published by manufacturers of thermal mass flow meters can range as low as ±0.75% to ±1.75% of reading with an additional ±0.5% of full scale. We must be mindful that published accuracies are based on ideal calibration conditions in which fully developed flow profiles exist. Inherently, permanent pressure losses associated with thermal sensors are negligible. This is important for processes operating at very low pressures. A 100:1 turndown ratio is often achieved and there are some cases in which 1000:1 is feasible. This capability coupled with the ability to measure very low flows from 0.25 SFPS (0.8 Nm/sec) to higher flows up to 1,000 SFPS (300 Nm/sec) makes thermal the first technology to consider and evaluate for any of gas flow measurements.

Other features such as fast response times, sensor designs suitable for process temperatures up to 850°F (454°C), various wetted materials for chemical corrosion resistance, packing glands suitable for use with isolation ball valves in hot-tap installations, global agency approvals for use in hazardous areas and failure rate data for safety instrumented system evaluation ensure suitability for use in the varied applications associated with a thermal oxidizer system. Some instruments include optional diagnostics in compliance with the US Environmental Protection Agency's (EPA) 40 CFR Parts 60 and 75 requirements for Continuous Emissions Monitoring System (CEMS) and Continuous Emissions Remote Monitoring System (CERMS); They provide automated calibration drift tests of low and high span points and a sensor interference check every 24-hours.

More capable self-diagnostics and a variety of analog outputs and digital communication protocols are available in today's "smart" thermal flow meters. These instruments are often designed to meet the needs of both legacy (analog or HART) and future control system platforms (PROFIBUS, Foundation Fieldbus, etc.), as well as provide more visual information regarding the process measurements and health of the device.

Application Driven Solutions

Proper selection and factory calibration of a thermal mass flow meter starts with a thorough evaluation of the application and an understanding of performance criteria. Factors such as line size and upstream/downstream conditions for the meter run could impact the decision to utilize single point meters, possibly with flow conditioning, or multipoint configurations in order to meet accuracy requirements *(Figure 3)*.

Single point meter solutions are most economical when dealing with gas measurements in 20-inch or smaller line sizes. The addition of a flow conditioner may be necessary to achieve the desired accuracy when straight-run is limited. Larger lines up to 48-inches can benefit from a dual-point averaging system; while even larger ducts can require multipoint configurations placing two to eight sensors in the flow stream to meet the measurement objectives.

These applications are often difficult for other flow meter technologies because of distorted flow profiles associated with inadequate straight-run and larger cross-sectional measurement areas, which can lead to inaccurate flow readings when using a single point meter design. The use of multiple sensors addresses this by breaking a large cross-section down into smaller measurement areas and averaging them to provide a more accurate reading.

Figure 3: FCI Model ST100, ST102 and MT100 flow meters

Conclusions

Given the various gas flow measurements associated with an oxidizer system, Thermal mass flow meters have many advantages over other technologies and should be your first consideration. Regardless the oxidizer type, each requires accurate, responsive and dependable flow measurement to help ensure the efficient destruction of HAPs and VOCs. ■