Academic Guru Publication House

Advances in Thermal Engineering : Emerging research and opportunities

Volume 1
Year: 2021

AG PH Books

A Review of Thermal Flow Measurement Using Flow Meter

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Abstract

For almost two decades, professionals have relied on Thermal Mass Flowmeters (TMFMs) for tasks as diverse as sweeping, gas injection and welding. Operators lack an adequate understanding of their operational actions. TMFMs are typically calibrated using nitrogen or air, although they may be utilised with a wide variety of process gases. Calibration using a surrogate gas necessitates the use of a correction factor (k-factor) to determine the actual flow rate of the process gas. These adjustment factors are often included in the user manual supplied by the product's manufacturer. The k-factor is crucial for accurate measurements in metrology and is used in the calibration process. Because of this, knowing whether the process gas or a surrogate gas with the suggested k-factor was utilised in calibration was crucial. The purpose of this research is to examine the implications of substituting the manufacturer's recommended k-factor for the actual process gas during calibration. This article presents test findings that are worrying in the discipline of metrology.

Keywords: Solar Absorption Chiller; Refrigiration;Cooling Systems; Heat Powered Absorption.

Introduction

In recent years, a variety of novel gas metering technologies have evolved, including vortex, Coriolis, ultrasonic, and thermal mass flowmeters. Thermal mass flow metres, in particular, show a lot of promise due to their numerous advantageous features such the lack of moving components, direct mass

* ISBN No. 978-81-955340-8-1

measurement, and digital output. A thermal mass flowmeter may be used to determine the overall mass flow rate via a pipe or channel as well as the local mass velocity of gas flow. The principle behind thermal mass flow metres is the correlation between the sensor's measured voltage output and the heat transfer rate caused by the sensor and the gas flow in the pipe. The thermos-physical parameters of the gas, such as its thermal conductivity, density, diffusivity, specific heat, and dynamic viscosity, do in fact affect the voltage output. The mass flow rate of a fluid is a crucial metric for controlling and monitoring a wide variety of manufacturing processes. Mass velocity may be measured at a spot or a small region of fluid flow with the use of a thermal anemometer. Fluid mass mass flow may be measured using either thermal dispersion mass flow metres (ITMF) or capillary thermal mass flow metres, both of which are based on different thermal measuring principles (CTMF). Specific guidelines for each have been released by the American Society of Mechanical Engineers (ASME). Both kinds use heat transfer from a heated surface to the moving fluid to determine the flow rate. Both insertion probe and in-line varieties of thermal dispersion mass flow metres exist. These flowmeters calculate the mass flowrate of a fluid travelling via a closed pipe. An in-flowing fluid runs across a heated velocity sensor. The thermal anemometer is unique among thermal mass flow metre devices in that it is designed to function when submerged in a flow channel or stream. The installation circumstances and process conditions, as well as the thermal flow sensor's internal construction, all have an impact on its performance. In this paper, we explore the theory and practise of dispersion thermal mass flow metres.

Analysis of the Recent Studies

Experimentation with a thermoanemometric flow-meter (TAF) included a study of the following techniques for measuring the velocity of air flow, gas, and liquid mixes. But the information regarding the research of the fuels-flow utilising rapeseed oil is almost lacking.

Because biofuels' physicochemical qualities vary so much from those of traditional motor fuels, this kind of study is necessary (petrol and diesel fuel). The dynamic mode of the flowmeter's functioning and its errors are both affected by the major changes in the way biofuels flow through it.

Research into the thermal TAF balancing experiment was therefore carried out. Cost estimates for seven different fueling scenarios were analysed, with motor fuel temperature field inaccuracies and approximation taken into account. The precision of measurements performed using computational methods has been enhanced.

Creating a working model of the main measuring converter, conducting experimental study on the thermoanemometric biofuels flowmeter, and putting it through its paces in automobiles powered by diesel internal combustion engines are all part of this project.

Dispersion thermal flowmeter theory Dispersion

Dispersion Heat transferred from an electrically heated sensing element or probe to the surrounding fluid is used to calculate the mass flow rate, making thermal mass flowmeters an ideal tool for studying fluid dynamics. The American Society of Mechanical Engineers (ASME) has released a new national standard for thermal dispersion mass flow metres in response to their widespread use in industrial settings.

Figure 1 shows the whole transduction chain for a heat flow metre that generates a voltage signal. Two different transduction processes are shown here: first, a mechanical signal (mass flow) is transformed into a thermal one (heat transfer), and then the resulting temperature differential is transformed into an electrical output signal (current or voltage). The rate of heat transfer between the sensor and the fluid is inversely proportional to the sensor's output voltage, which is the basis of the gas mass-flow measurement concept.

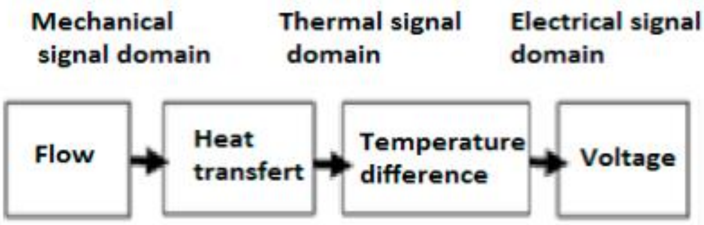

Fig.1. The three signal domains and the signal transfer process of a thermal flow sensor

Convective heat transmission from the thermal flow sensor to the fluid may be affected by the fluid's composition and type. L.V. King is credited with developing thermal mass flowmeters after publishing his now-famous King's Law in 1914, which describes how a heated wire submerged in a fluid flow may be used to determine the mass velocity of the flow at a certain location. King referred to his invention, a hot-wire anemometer, as such.

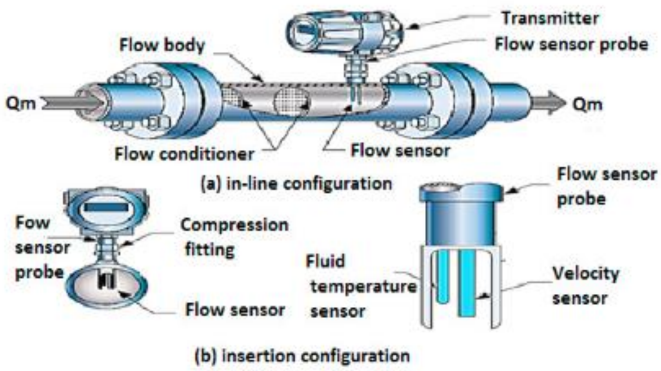

Fig.2. The two configurations of dispersion thermal mass flow meter

Dispersion thermal mass flow metres may be either installed in-line or with an insertion probe, and both designs and their main components are seen in Fig. 2. There is a similarity between the two setups in terms of their primary parts. Olin gave a talk on thermal dispersion mass flow metres in the industrial setting, including their operation, construction, and potential uses. The accuracy and reliability of thermal dispersion mass flow metres may be affected by factors such as the thermal flow sensor's design, the state of the installation, and the nature of the process being measured. The sensor structure, implications of insertion length, and construction details at the insertion point were all studied by Baker and Gimsonin. One of the best instruments required in flow metrology is the thermal mass flowmeter utilised in industry. These devices originated from hot-wire anemometers, which measure local velocity. With the use of sensors, a thermal anemometer can calculate the overall heat loss of a system consisting of heating components cooled by a fluid. Both constant temperature and constant current are the main modes of operation for a thermal anemometer. This study focuses on the constant temperature mode.

Operating principles ofThermal Mass Flow-Meters (TMFMs)

There is great potential for TMFMs to be used as flow rate metres. They're put to use all over the place to measure the movement of fluids (gases). Their primary benefit lies in the fact that, unlike volumetric flow metres, differential pressure metres, turbine flow metres, and ultrasonic flow metres, they directly measure mass flow.

TMFMs rely on the fluid being measured being heated as it flows through the device. All fluids will absorb heat as they move through a hotter medium. The flow metre has two temperature probes, one at the input and one at the discharge. The thermal power necessary to keep the temperature difference between the two probes at a constant value will be measured by the flowmeter. Mass flowrate is calculated from the temperature differential using the flow sensor. The following formulas may be used to explain this in terms of the first rule of thermodynamics (heat input Equals heat output, with no losses):

$$qm = \frac{(P - L) * f}{C_p * (\Delta T)}$$

In this equation, qm represents the mass flow rate in kilogrammes per second, Cp represents the specific heat in joules per kilogramme Kelvin, and T represents the temperature gradient in kelvin. P is the power input (in watts), L is the power lost in conduction (in watts), and is the meter's proportionality factor (dimensionless).

There are two main types of thermal flowmeters, and they operate on either the on-line or bypass basis. Bypass flowmeters are utilised in this discussion. This concept relies on the correlation between the heat transfer rate provided by the sensor and the gas flow in the pipe and the resulting voltage at the sensor's output (Fig.3). The thermo-physical parameters of the gas, such as diffusivity, thermal conductivity, density, specific heat, and dynamic viscosity, do in fact affect the voltage output. The characteristics of a gas are sensitive to its working conditions (temperature, pressure, and chemical make-up).

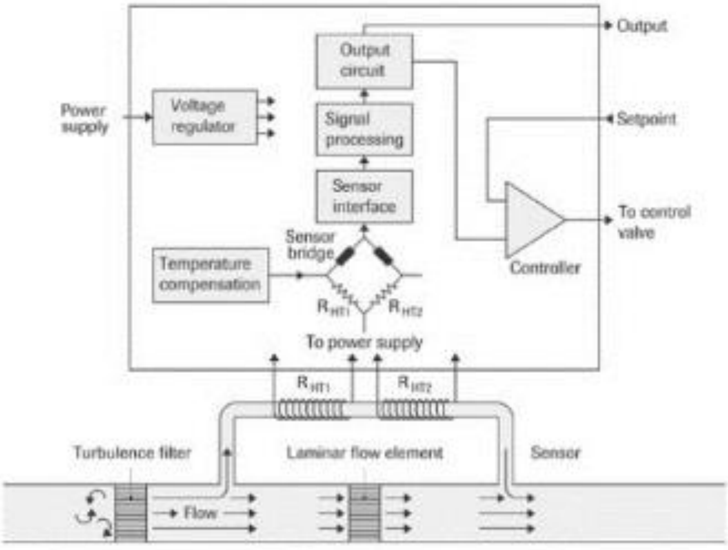

Fig. 3. Principle of Bypass Thermal Mass flowmeter

Thermal Flow Sensors

One way to measure the speed of a flow is by measuring how much heat is carried away from or redistributed to a heated temperature sensor. Thermal transport flow metres, also known as thermo-anemometers, are a kind of sensor that operates on the heat dissipation principle. As these flow metres have no moving parts, they can be used in situations where a narrow tube diameter is a necessity.

Thermal transport sensors have a wide dynamic range and high sensitivity, making them superior to other types of sensors. Two distinct categories exist for thermal flow sensors:

1. Hot-wire or Hot-film sensors: The flow's ability to cool a hot body is monitored by the sensor. The need for more energy to keep a given temperature constant, or a drop in temperature in response to a certain amount of energy input, are both indicators of this effect.
2. Calorimetric sensors:The temperature profile surrounding a heater is measured, and any changes caused by the fluid's motion are recorded by the sensor. Flow sensors that are micro-machined or use MEMS technology nearly always employ this method.

Literature Review

(Amina & Ahmed, 2017)Predicting flow behaviour and its consequences on the environment has relied heavily on measurements and models of flow. Production facilities, shipping companies, industrial plants, and government or public sellers all rely on flow measurement to do business with one another. Direct mass flow measurement of gases and vapours over a broad variety of process conditions without the requirement for density adjustments based on pressure and temperature may be made possible by thermal flowmeters, which might enhance transactional operation.

(Arevalo et al., 2013)For this simulation, we have used a length of 1.2mm and a channel height of 400m. Heat Transfer in Fluids, Laminar flow, and Joule heating interfaces were used in the modelling of the platinum heater element and two sensors. It is possible to sputter and pattern the three components with a thickness of 300nm in a functional device.

(et al., 2020)In order to quantify the quantity of fluid passing through a pipe at any one time, a metre called a "flow metre" is used. In this study, we will examine the many instruments used for measuring fluid flow, the sensors used for this purpose, their principles and operations, and the advantages of using sensors based on an Inertial Measurement Unit while doing so.

(ABBAS & Mouchel, 2019)Calibration using a surrogate gas necessitates the use of a correction factor (k-factor) to determine the actual flow rate of the process gas. These adjustment factors are often included in the user manual supplied by the product's manufacturer. The k-factor is crucial for accurate measurements in metrology and is used in the calibration process.

(Rotameter & Rotameter, n.d.)The thermal mass flowmeter of the BIMCO400 series uses the principle of thermal diffusion to determine the volumetric flow rate of a gas. It uses a pair of filmed resistance temperature detectors (RTDs) as its sensors; one of these detects the gas flow rate (RH), and the other detects any changes in temperature along the gas path.

(Yu et al., 2020)The fluid dynamics and heat transfer process are studied using a CFD model before the design is finalised. In order to validate the design and performance, experiments are conducted in a thermal vacuum chamber replicating the space environment.

(Khan et al., 2016)Hydrocephalus shunts and medication administration devices are only two examples of the many biological contexts in which thermal flow sensors may be useful. Infrared thermal sensing has several applications, including in preclinical breast cancer detection, in the identification of neurological illnesses, and in the monitoring of skeletal muscle activity. Methods for sensing and transducing thermal flow, and their various biomedical applications, are discussed.

(Igor Korobiichuk et al., 2015)Physically-informative models were used to realise all of the primary thermal techniques and the informational alternatives they provide, and then the outcomes of these approaches were compared to the tests. Costs were compared based on these parameters after a metrological assessment was performed, during which the sensitivity to gas and liquid consumption, as well as their static and dynamic mistakes, were identified..

(Tison, 1996)As there are many different TMFM manufacturers, each with their own ostensibly interchangeable instruments, TMFM use is made more difficult than it needs to be.

(Hylton, 1999)The mass flow rate or corresponding volume flow relative to some standard is often the quantity of interest (i.e. standard temperature and pressure). The mass flow rate cannot be directly measured by most gas flowmeters because of the effects of fluid density and other variables.

Conclusion

The microfabrication of thermal-flow sensors allows us to test out and refine emerging approaches. Various materials and transduction mechanisms may be employed for a variety of purposes. In order to diagnose and monitor fluid rates in the human body in order to intervene promptly, thermal sensing may be utilised. Compared to more complex sensor systems, a hot-film or hot-wire, which both use a resistive element to regulate current flow, are preferable due to their simplicity. The fluid velocity is connected to the output parameter like voltage. The benefits of thermal sensing are low power consumption, simple operation, and straightforward construction.

Without the need for density adjustments, thermal flowmeters can measure the mass flow of gases under a variety of process circumstances. If they are calibrated using the actual process gas, they can achieve high precision (1% or better). Theoretical gas conversion is very challenging, and even utilising the manufacturer-supplied conversion factors may lead to significant mistakes.

Even using computational fluid dynamics (CFD) models, hot-wire thermal flowmeter theoretical conversions are complicated. Inaccuracies of over a hundred percent (>100%) have been seen when determining gas properties using hot-wires correlated to literature. Similar inaccuracies may occur when using the conversion factors provided by the manufacturer. Within a few percentage points, conversion factors may be calculated using empirical heat transfer correlations provided that the correlations are suitable for the sensor's geometrical layout. Calibration on a small number of surrogate gases with thermal parameters (Prandtl Numbers) similar to the process gas yields a suitable correlation.

References

ABBAS, O., & Mouchel, F. (2019). *The influence of Gas Type on a Thermal Mass Flowmeter Calibration Results*. *21002*, 21002. https://doi.org/10.1051/metrology/201921002

Amina, B., & Ahmed, H. (2017). An Overview of Thermal Mass Flowmeters Applicability in Oil and Gas Industry. *Energy Procedia*, *141*(December 2017), 299–303. https://doi.org/10.1016/j.egypro.2017.11.109

Arevalo, A., Byas, E., & Foulds, I. G. (2013). Simulation of thermal transport based flow meter for microfluidics applications. *Comsol Conference*, *2*, 1–5.

Hylton, J. O. (1999). *Empirical Correlations for Thermal Flowmeters Covering a*.

Igor Korobiichuk, Shavursky Yurij, Michal Nowick, & Roman Szewczyk. (2015). Research of the Thermal Parameters and the Accuracy of Flow Measurement of the Biological Fuel. *Journal of Mechanics Engineering and Automation*, *5*(7), 415–419. https://doi.org/10.17265/2159-5275/2015.07.006

K L*, K., Rao, D. T. K., & math, P. (2020). Fluid Flow Measuring Devices used in an Inertial Measurement Unit Based on Different Flow Measurement Sensors. *International Journal of Recent Technology and Engineering (IJRTE)*, *8*(5), 555–558. https://doi.org/10.35940/ijrte.d4439.018520

Khan, B., Ahmed, S., & Kakkar, V. (2016). A Comparative Analysis of Thermal Flow Sensing in Biomedical Applications. *International Journal of Biomedical Engineering and Science*, *3*(3), 01–07. https://doi.org/10.5121/ijbes.2016.3301

Rotameter, C., & Rotameter, G. (n.d.). *Bombay instrument mfg. co .91*(022), 2389.

Tison, S. A. (1996). A critical evaluation of thermal mass flow meters. *Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films*, *14*(4), 2582–2591. https://doi.org/10.1116/1.579985

Yu, Y. M., He, Z. H., Roesler, H., Solano, C., & Zhang, Z. (2020). Design and application of thermal mass flow meter in space. *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *950*(October 2019). https://doi.org/10.1016/j.nima.2019.163003