The History & Evolution of Mass Flow Controllers

Considering the development of a popular solution for OEMs & system integrators

By Jesse Yoder, Ph.D.

The August 2013 issue of *Flow Control* magazine featured an article titled "The History and Evolution of Thermal Flowmeters" (pages 22–26), which examined the origins of thermal flowmeters in the 1970s, based on in-person interviews with the founders of Sierra Instruments (*sierrainstruments.com*), Fluid Components Int'l (*www.fluidcomponents.com*), and Kurz Instruments (*www.kurzinstruments.com*). Anyone who follows the flowmeter business is likely to know that many mass flow controllers (MFCs) also employ thermal technology. Should these devices also be included in any discussion of the history of thermal flowmeters, or should they be treated separately? As it turns out, the history of mass flow controllers is also very fascinating, but MFCs developed independently and somewhat in parallel to thermal dispersion flowmeters. MFCs are also particularly attractive solutions for many OEM and System Integrator applications where air, oxygen, and/or hydrogen flow is required.

In the fall of 1954, someone from Exxon approached Charlie Hawk, an engineer from Hastings Instrument Company (now Teledyne Hastings, *www.teledyne-hi.com*) at a trade show. He wanted an instrument that would measure the amount of waste gas flowing in a flare stack so he could better monitor how efficient his refining process was.

Hastings Introduces Air Flow Probe in 1955

In response to this inquiry, Hastings introduced what it called an "air flow probe" in 1955. This device contained small thermocouples in the flowstream, which measured the rate of cooling. Unfortunately, the Hastings air flow probe became covered with grime and could not survive the heat in this application. As a result, the instrument was withdrawn after several years.

Capillary Tubes Introduced by Hastings in the 1970s

In the early 1970s, Charlie Hawk and his colleagues decided to try again. Instead of putting the air flow probe directly into the flare stack, they put the probe into a capillary tube that had the sensors on the outside. This is essentially the principle that a mass flow controller uses to measure flow. This new device was more successful. While the tubes still became plugged, it was possible to clean them by purging them with a source of air.

This brief history shows that important developments in thermal metering were in fact occurring at about the same time that thermal flowmeters were being developed on the West Coast of the United States. In many ways the experiences were similar. The Hastings air flow probe, introduced in 1955, had to be withdrawn because it was not rugged enough for industrial flare stacks. This sounds very much like the anemometers from TSI in Minnesota that were used for research purposes. They were not industrial thermal flowmeters because they were not rugged enough, although industrial thermal flowmeters were developed from them. So if we consider the Hastings product a thermal flowmeter, then TSI's probes would have to be similarly classified.

Thermal Flowmeters and MFCs Take Independent Track

The Hastings instruments developed in the 1970s may have used a thermal principle, but the design is that of a mass flow controller. Because industrial thermal dispersion flowmeters and mass flow controllers are so different in type and application, it is probably best to consider them as independent instrument types and to describe their histories separately.

The Roots of Mass Flow Controllers

Some of the earliest ideas for a thermal mass flow controller go back as far as 1911, when C.C. Thomas described a flowmeter containing a heated element with two thermometers upstream and downstream of the heated element. However, this instrument was never put into production. In 1947, J.H. Laub proposed the idea of attaching the heater and the thermometers to the outside of the pipe. While this instrument seemed to give good results under ideal conditions, its readings became unstable when faced with the realities of gas viscosity, Reynolds number, and velocity profile.

Like industrial thermal dispersion flowmeters, mass flow controllers for industrial use appear to have developed mainly in the 1970s, although some sources credit Tylan General with introducing capillary tubes in the 1960s. Besides the advances made by Charlie Hawk and others at Hastings, others developed the mass flow controller technology independently during this time. One development involved a micro-machined silicon sensor with a very fast response time.

The Role of Sierra, Kurz, and Fluid Components Int'l

Industrial thermal dispersion flowmeters were developed in the mid-1970s by Sierra Instruments (*www.sierrainstruments.com*) and Kurz Instruments (*www.kurzinstruments.com*). The principals of both companies, Dr. John Olin and Dr. Jerry Kurz, had previously worked at TSI in Minneapolis, Minn. There they worked on anemometers designed to measure air flow. However, these were used for laboratory and research purposes and were not rugged enough for industrial applications. Fluid Components Int'l (*www.fluidcomponents.com*) also developed industrial thermal flowmeters in the same time period, although they approached the subject through switches rather than anemometers. These three companies are still among the leading suppliers of thermal dispersion flowmeters.

Mass Flow Controllers are used in a wide variety of OEM analytical systems. The analytical instrument shown here is designed to accurately detect carbon content in aqueous matrices down to the PPB level using a high temperature combustion furnace and a pressurized NDIR detector. (Photo courtesy of Teledyne Hastings)

It is safe to say that while industrial thermal dispersion flowmeters and mass flow controllers have similar roots, they were developed independently during the 1970s in the United States. While both devices have earlier predecessors, the 1970s is the timeframe when both instruments found their application for industrial purposes.

Mounting Types

There are a number of ways in which thermal flowmeters differ from mass flow controllers. One way is in mounting types. Mass flow controllers typically are made as inline devices, fitting into a relatively small gas flow line. Thermal dispersion flowmeters, by contrast, are divided between inline and insertion meters. About 65 percent of thermal dispersion flowmeters are of the insertion type, while the remaining 35 percent are inline. The bulk of these are single-point insertion, though some are multipoint insertion. Insertion thermal flowmeters can be used on large line sizes, including those above 20 inches.

Industries & Applications

Another important difference between mass flow controllers and thermal dispersion flowmeters is that a majority of mass flow controllers are used in the semiconductor industry. The remaining MFCs are divided between industrial and research/laboratory applications. The industrial applications are divided among a variety of industries and applications. Some of these include petrochemical, metals processing, food and beverage, solar/photovoltaic, fuel cells, and a number of others. Mass flow controllers are widely used to measure industrial gases, whether it is in semiconductor, industrial, or laboratory/research applications.

Vicki Tuck of Flow Research holding a Fluid Components International ST98 FlexMASSter thermal mass flowmeter for gas.

Thermal flowmeters, by contrast, are mainly used in the process industries. Leading industries for thermal flowmeters include power, water and wastewater, chemical, and oil and gas. Thermal flowmeters are used almost entirely for gas flow measurement in those industries, and they are used both to measure natural gas and industrial gases. Many thermal flowmeters are used for environmental applications. These include continuous emissions monitoring (CEM), flare and stack gas measurement, biogas, biomass, compressed air, boiler inlet, and many others. Multipoint thermal flowmeters were developed to provide higher accuracy in larger line sizes such as those above 30 inches.

An Attractive Solution for OEMs & System Integrators

The majority of thermal flowmeters are sold to end-users, with the balance being sold to OEMs, systems integrators, and engineering and consulting firms. However, a larger percentage of mass flow controllers are sold to OEMs and systems integrators. MFC OEM applications include solar energy and semiconductor equipment manufacturing. Other examples include biotechnology and pharmaceutical applications. These four industries have a high requirement for measuring air, oxygen, and hydrogen flow. MFCs fit well for these applications because they are small and economical, yet sufficiently accurate for the jobs they are required to perform in these environments.

A particularly common application of MFCs for OEM applications is in the pharmaceutical industry for dosing applications. Banks of MFCs are used to fill 15 or more ampoules at a time. In this case, the OEM sets up the groups of MFCs specifically for the purpose of filling the ampoules. Both repeatability and accuracy are important. The OEM sets up the equipment, which includes multiple MFCs, so that it is ready to be put into the dosing line.

OEMs play a vital role in the flow measurement market. A flowmeter, for example, may be ready to go out of the box, but it may also require other instruments, such as temperature sensors, pressure transmitters, or analytical equipment to serve a particular application. An OEM purchases the flowmeter and incorpo-

Mass Flow Controller Suppliers

Company	Website
Aalborg	www.aalborg.com
Alicat Scientific	www.alicat.com
Azbil (Yamatake)	www.azbil.com
Bronkhorst	www.bronkhorst.com
Brooks Instrument	www.brooksinstrument.com
Burkert	www.burkert.com
Hitachi Metals	www.hitachimetals.com
Horiba/STEC	www.horiba.com
KOFLOC/Kojima	www.kofloc.co.jp
MKS	www.mksinst.com
Parker Hannifin	www.parker.com
Pneucleus	www.pneucleus.com
Sensirion	www.sensirion.com
Sierra Instruments	www.sierrainstruments.com
Teledyne Hastings	www.teledyne.com
Tokyo Keiso	www.tokyokeiso.co.jp

rates it into an instrument assembly that is designed for a particular purpose. Another example is skids used in downstream custody-transfer applications for refined fuels. These typically incorporate positive-displacement or Coriolis flowmeters, along with many other devices. A different example is that of orifice meter runs, which incorporate an orifice fitting along with upstream and downstream meter runs.

Research Continues

In the case of mass flow controllers, a lot of attention is being paid to the industrial segment, in part to compensate for the cyclical nature of the semiconductor industry. In the case of thermal flowmeters, suppliers are working to increase their accuracy and to target specific new environmental applications.

The important thing to remember is that the flowmeter market is dynamic, not static, and that just as mergers and acquisitions can suddenly alter the landscape, so can the introduction of new flowmeter technologies. FC

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For more on Flow Research's work in the area of mass flow controllers, visit www.massflows.com.

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