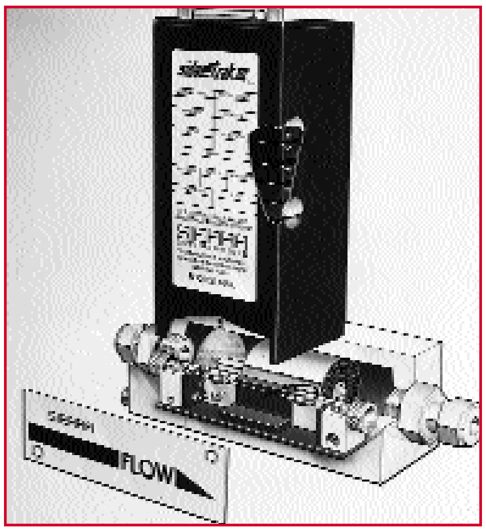
The Evolution of Thermal Mass Flow Meters

John Olin, founder and CEO of Sierra Instruments, Inc., in Monterey, California, provides a historical perspective on the development of thermal mass flow measurement.

Q. Who were some of the pioneers in thermal mass flow technology?

A. Thermo-Systems, Inc. (TSI) began in its founder's basement in 1959, with a cooled-film anemometer designed for transient measurements in high temperature fluid flows. This led to TSI's hot-film and hot-wire anemometers, the first commercial products of this type. These immersion-type devices were used mainly as research instruments, many related to environmental pollution.



Tylan Instruments was another pioneer in thermal flow technology. In the early 1960's, Tylan developed the first capillary-type thermal instrument to regulate gases used for chemical vapor deposition in the semiconductor industry. These mass flow controllers (MFCs) utilize two resistance temperature (RTD) coils around a capillary sensing tube to measure mass flow, and an integral control valve to regulate the flow.

Both instrument types use the thermal principle, but most manufacturers have concentrated on development of either the immersion-type or the capillary-type device. Sierra enjoys a unique position in the thermal technology field, because the company has been designing and manufacturing both types of instrument for the last thirty years.

Q. What are some of the major innovations you've seen in capillary-type MFC design?

A. One of the most significant developments was the introduction of ultra-clean mass flow controllers. Driven by the microelectronic industry's demand for particulate reduction in processing equipment, those manufacturers who served the semiconductor industry brought dozens of new ultra-clean MFCs to market in the late 1980's.

During the mid-1980's John Olin delivered training seminars on mass flow measurement to promote understanding of this technology and advance its application in the semiconductor, automotive, pharmaceutical, and gas manufacturing/distribution industries.

The microprocessor has also expanded the functionality and improved the performance of MFCs. The early instruments were gas-specific, and required calibration on actual or equivalent gases, under specified calibration conditions. The latest generation of mass flow controllers utilizes digital bridge technology and incorporates algorithms for several gases. This allows the end-user to change gases, flow rates, setpoints, response characteristics, and other critical flow parameters – without the nuisance and expense associated with returning the instrument to the factory for re-calibration.

Smaller footprints, integrated displays, waterproof enclosures, and higher flow capacity are some of the other features that have helped to advance this technology.

Q. What are some of the most recent developments in immersion-type thermal flow technology?

A. One of the major problems with early thermal mass flow meters was that they could not be re-ranged in the field. Quite often, the device was replacing an older volumetric technology that could not provide the same level of accuracy or turndown, and customers found that the flow rate they had specified – based on the reading of the prior device – was not, in fact, the actual mass flow rate. This often meant that they had to send the mass flow meter back to the factory for re-calibration.

New "smart" mass flow meters utilize microprocessor technology to solve this problem – by allowing the operator to change the instrument's full scale, as well as alarm settings, time response, totalizer, and other flow parameters. Additionally, because the instrument's electronics stores calibration data, these devices can be "field-validated" to ensure accuracy.

Q. How has the application of thermal mass flow meter technology changed or grown?

A. Over the last thirty years, thermal mass flow meters have gained wide acceptance in industrial flow monitoring installations. Their ability to measure mass flow directly and provide an accurate measurement at low and varying flow rates has made them the instrument of choice in many critical gas flow applications. These include combustion control, custody transfer, chemical batching, pneumatic power, heating, cooling, and drying, just to name a few.

As I mentioned earlier, the first applications of TSI's hot-wire and hot-film technology were found primarily in the research community, such as environmental and micrometeorological measurements, flow and turbulence studies, etc. The first light-duty industrial versions of the hot-wire anemometer were introduced by TSI in the late 1960's and by Sierra Instruments in the early 70's. These glass-coated sensors were used primarily in HVAC applications.

In a parallel development, Fluid Components, Inc. (FCI) utilized another variation of the thermal technique – the constant current method – to develop a stainless steel thermal flow meter in the early 1960's. Their line of air and gas flow meters, flow switches, and liquid level switches further expanded market awareness and acceptance of thermal flow technology.

In the late 1970's Kurz Instruments introduced the first stainless steel thermal sensor based on the constant temperature method – which provides faster response time to changes in flow rate – and the technology began to find use in more demanding applications.

The form factor evolution of the technology, such as multi-point systems, in-line flow meters, built-in flow conditioning, and ultra-clean construction has had a considerable effect on the application of these instruments. The earliest flow meters were simple, single-point insertion meters that were inserted into the centerline of a pipe to measure point mass velocity. These evolved into in-line meters that incorporate a section of pipe or tubing, the mass flow sensor, transducer, and process fittings. These devices deliver a direct reading of gas mass flow in the pipe, and are intrinsically more accurate than the insertion meter.

Q. What are some of the industry requirements that have affected the evolution of thermal mass flow meters?

A. Multi-point flow averaging systems are an example of how these instruments have been adapted to suit specific applications. In the early 1990's, the EPA issued requirements under the Clean Air Act for CEMS (Continuous Emissions Monitoring Systems) on coal-fired power plants, and thermal flow meters were specified as an appropriate measurement technology. In response, several thermal flow meter manufacturers introduced "systems" that use one or more probes, each with several sensors, to measure the non-uniform flow rates found in large ducts and stacks. Although new non-invasive technologies, such as ultrasonic flow meters, have since become popular, multi-point technology remains in wide use in the power-generation industry.

Q. What future developments might you predict for thermal mass flow measurement technology?

A. Developments in gas correlations and microprocessor technology will help manufacturers reduce their cost to produce the instrument, and provide more field-adjustable functions.

Another emerging trend is adding multivariable capability to the instrument. Multivariable flowmeters are one of the fastest-growing segments of the flowmeter market. End-users like them because they provide more information about the process, at less cost than buying comparable components separately. Because the thermal meter uses a temperature sensor to measure flow, it is fairly simple to output a temperature reading in addition to the mass flow reading.

Sierra Instruments' first immersion-type meters were designed for duct monitoring.

I expect thermal flow meter manufacturers will continue to add sensors and make more information available to the end-user through this multivariable approach.