The Quest for the Perfect Flowmeter

Gases & Instrumentation had the opportunity to speak with Dr. John G. Olin, Founder and Chairman of the Board of Sierra Instruments about the evolution of thermal mass flow meters and his latest product in this technology.

Gases & Instrumentation: You have been engaged in thermal mass flow technology for a number of years. You must have seen a lot of change.

Dr. John G. Olin: Yes, there have been tremendous changes in using thermal technology to measure flow. I started out 50 years ago, while I was working on my Ph.D. thesis at Stanford, where I majored in fluid mechanics and heat transfer. I was working with hot-wire anemometers. The principles involved then are the same basic ones that we still use. In thermal anemometers a resistance temperature detector (RTD) element immersed in the flow streamis self-heated with an electrical current to a fixed temperature above the temperature of the gas. The molecules of air or another gas get heated as they pass through the boundary layer around the heated element. Since it is the molecules of the gas that bear its mass, the amount of heat carried away by the molecules provides a measurement of the mass flow rate. I was using that technology back around 1964 to 1966. And then I joined a company called TSI, Inc., in Minnesota that manufactured thermal anemometers. But I was interested in getting into the industrial marketplace because it was much bigger. That's when I started Sierra Instruments, Inc. That was in 1973. We built an industrial sensor and placed the heated element inside a small diameter stainless steel tube. The tubular sheath is very strong. It can be inserted into any pipe of flowing gas and not be broken. That was a big big breakthrough. It occurred in the 1970s.

G&I: I understand there are two basic types of thermal mass flow meters.

JGO: Correct. One is an immersible thermal mass flow meter, sometimes termed thermal dispersion, and the other is the capillary-tube type. The one that I have been referring to so far is the thermal-dispersion type where the heated element is inserted in the flow, and the amount of heat loss is a measure of the mass flow rate. The capillary-tube is the same basic idea, but the flow goes through a small capillary tube, maybe with an internal diameter of ten thousandths of an inch. It has two identical heated platinum RTD wires wound around its outside diameter; the heat is again carried away by the flow; and again it measures mass flow rate. However, since it is just a small capillary tube, to handle larger flow rates you have to incorporate a bypass where most of the flow goes through the bypass and only a small fraction goes through the capillary tube.

G&I: How did you arrive at your current products, the QuadraTherm 640i and the 780i?

JGO: To start from the beginning, the traditional industrial thermal dispersion flow meter has two sensors immersed in the flow. Each one is encased in a stainless steel sheath. One measures the gas temperature, usually just a thin-film RTD. The other is a velocity sensor. They are usually located side-by-side such that they do not interfere with each other aerodynamically. The velocity sensor has a heated RTD element in it.

G&I: What are the drawbacks to this traditional design?

JGO: It suffers from two problems. These are skin resistance and stem conduction. The skin-resistance problem has to do with the fact that the typical construction of the velocity sensor uses takes a wire-wound platinum RTD that is shoved down into the tip of tubular sheath and is surrounded by ceramic cement or other potting compounds. Over a period of time, when there is temperature cycling, cracks can develop in the cement, and that causes a big change in the heat transfer characteristics of the velocity sensor, and you generate large errors over time.

G&I: How did you overcome this problem?

JGO: The solution to the skin-resistance problem is DrySense. The DrySense velocity sensor technology uses a proprietary swaging process that eliminates all air gaps between the heated velocity sensor and the tubular probe sheath eliminating the need for any potting compounds. There is no cement at all. This is why we call it "dry." No so-called "wet" potting compounds are used. We never have any drift in that sensor. As a result, it is extremely stable and why we issue a lifetime warranty.

G&I: But QuadraTherm has other major differences from the traditional configuration.

JGO: Well, this is where we tackle the second problem with thermal, stem conduction. The main difference between the QuadraTherm and traditional thermal mass flow meters is that instead of having two temperature sensors—one a temperature sensor in the temperature probe and the other self-heated temperature sensor in the velocity probe—there is an additional sensor in each, giving a total of 4 temperature sensors. The extra temperature sensor in the stem of each probe measures the stem conduction in each. And, if you don't account for that you are out of luck. First, stem conduction is a goodly function of the total heat transfer budget and must be accounted for. Second, stem conduction depends on the ambient temperature outside of the pipe. For example, the outside temperature gets cold at night and heats up when the sun comes out. The amount of that stem conduction varies all over the place.

G&I: So QuadraTherm solves the stem-conduction problem by measuring it?

JGO: Exactly. With the total of 4 sensors, two temperature sensors in the temperature probe, and a heated velocity sensor with additional temperature sensor in the velocity probe, we are able to solve that problem. When you have the two additional sensors you can measure the heat flux going down the stem. It more or less acts like a heat flux-gauge.

G&I: With other products, how do they account for stem conduction?

JGO: They don't and we didn't but we do now. What it amounts to, is that in the field application where the thermal dispersion mass flow meter is located, if the field conditions of temperature and pressure and outside temperature are exactly equal to those for which the sensor was calibrated in the lab, then it is OK. So, if the temperature doesn't vary too much and the pressure doesn't vary too much, you are fine, and that's where you get thermal mass instruments with 1% to 5 % of full scale accuracy.

G&I: There is also a lot of thermodynamic math going on, correct?

JGO: Yes, and that happens with our iTherm algorithm set found in the firmware. iTherm is the fourth pillar of our technology. The first pillar was the DrySense stable sensor. The second is the Aeromax aerodynamic design for the sensor head. And the third is QuadraTherm-- the physical layer with the 4 temperature sensors. iTherm solves the first law of thermodynamics for thermal technology very quickly. So, every fraction of a second you are getting updated values of the mass flow rate. It calculates the mass flow rate accurately even when the outside temperature changes plus or minus 50 degrees C. And the pressure of the gas can change, and all of these changes are taken into account through the math. For me, it is like a result of a lifetime of work that I have done, especially the last 5 years.

G&I: Why is an accuracy of 0.5% so important? That's just a half percent lower than some existing models.

JGO: Basically, the accuracy of the 640i QuadraTherm is a half percent of reading, that is, a half percent of reading when you are 50% to 100% of full scale, which is the range where most users operate. Note that this is "per cent of reading", a much tougher accuracy than traditional meters with their "per cent of full scale" spec. That half per cent is very important. (For more details on this, see G&I December 2012 eNewsletter at www.gasesmag.com). One of the big applications is custody transfer. A lot of custody transfer happens in the semiconductor industry. We have an ultra high purity version of QuadraTherm used where gas supply companies have tanks of gas outside fab areas delivering the big 5 gases—N_2, O_2, H_2, argon and helium. What the fab pays the gas supply company depends on the accuracy of the flow measurement. So, if the reading is high, the difference between 1% and 5% can amount to thousands of dollars over a period of months, or even weeks.

G&T: Are there other reasons?

JGO: Another, more abstract reason, is that the entire flow meter manufacturing industry is pushing for higher accuracy. It's just the world that we live in. Just as there are more and more apps for your iPhone, there's better and better accuracy for your flow meters. Sierra needs to be part of that. The other big driver is natural gas with the tremendous discoveries and resources that America has. This means we are going to be using a lot more natural gas. Thermal flow meters are perfect for that. They are perfect for measuring the custody transfer at the point where a distribution line splits off from a major natural gas pipe line. Then there is the quality issue. High accuracy is really important in the chemical processing, food processing, and numerous other industries where the products' quality gets better because the measurement of the ingredients that are going into that product are measured more accurately,

G&I: So it took a lot of years to arrive at the QuadraTherm.

JGO: For me this is my most satisfying accomplishment after working for so many years. The quest for the perfect sensor has always been my goal. The previous traditional sensor was not perfect, but it did satisfy an awful lot of need. The QuadraTherm, though, is "near" perfect, and satisfies a lot more.

For more information go to: *http://www.sierra instruments.com/products/quadratherm.html* .