Standing the Test of Time: Ultrasonic heat meters prove their durability

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For measuring the flow of water as the carrier of heat energy, the ultrasonic meter has proved to be the unbeatable method in terms of precision and service life. Although ultrasonic metering may still be considered a relatively new technology, compared to mechanical measurement, it has been in use now for 20 years or more. Over that time, a clearer picture of the ultrasonic heat meter's durability has also emerged. Methods of testing flow sensors have been developed and employed in Europe to assess the ultrasonic meter's measurement stability. Denmark has played a special role in this development.

Today, 60 percent of all households in Denmark are supplied with district heating. For district heating utilities, the main buyers of ultrasonic meters, the decisive selection criterion is durability, or measurement stability over the meter's service life. District heating customers expect accuracy in billing – especially in energy-conscious times. Thus, if the utilities are to maintain customer confidence, both they and the manufacturers of measuring solutions must pay attention to the service life and continued functionality of their meters. Utilities have an additional interest in measurement stability because long-term meter stability translates to lower maintenance costs.

Unlike most consumer goods, energy has the annoying characteristics of being transient and elusive. To demonstrate the quality and quantity of their product, district heating suppliers must therefore provide some form of verification of their services, such as approvals, certification or test results. This obligation falls back on the energy meter suppliers who thus carry out tests and verification of their products in close cooperation with the utilities.

Not only is it important for a meter to be precise, but it’s also important for this precision to be demonstrable. General manufacturing standards ensure consistency at the beginning of operations but do not take into account the drifting of devices over a longer period of time.

Since releasing its first heat meter in 1959, Danish meter manufacturer Kamstrup has developed measuring solutions in close cooperation with district heating utilities to meet the evolving needs of Denmark's district heating industry. The world’s largest manufacturer of ultrasonic heat meters, the company established a facility at its headquarters in Skanderborg, Denmark, that today is Europe’s largest accredited laboratory for “pattern approval” testing and random sample testing of flow sensors.

The pattern approval test complies with the European Committee for Standardization's EN 1434-4, the national standard governing flow sensor durability in all 27 European Union member states as well as in Croatia, Norway, Iceland and Switzerland. (Other parts of EN 1434 govern other aspects of heat meter construction and operation.) The pattern approval test verifies that the flow sensor meets a set of minimum durability requirements and is allowed to be sold in the aforementioned countries.

To supplement the requirements of EN 1434-4, several heat meter manufacturers voluntarily submit their flow sensors to an additional durability test performed by AGFW, the
German Energy Efficiency Association for District Heating, Cooling and CHP. AGFW developed this test to set an even higher standard for flow sensors for the German district heating industry. While fulfillment of the EN 1434-4 requirements suffices for heat meters marketed in Germany, utilities both within and outside Germany may prefer meters that have passed the AGFW test.

In Denmark, heat meters also are subject to random sample testing after six years in operation, as required by DANAK, the national body for accreditation. This supplements the initial pattern approval, which declares the heat meter as measuring stable for five years. These three steps – the pattern approval test, the AGFW durability test and random sample testing – help the Danish district heating industry ensure the long-term measurement stability of ultrasonic heat meters.

**Pattern Approval Testing**

The pattern approval test has been a European standard for more than a decade, but its development began in the 1980s. At that time, after receiving reports of defective heat meters from district heating utilities, AGFW instituted a number of tests to establish a minimum requirement for heat meters used in Germany. Around the same time, a standard for measurement stability was being discussed at the EU level. These organizations combined forces, and cooperation between AGFW and the European Committee for Standardization eventually resulted in the durability test included in 1434-4 in 1997.

The pattern approval test is a 2,400-hour accelerated test performed in a specially designed facility that corresponds to five years’ operation time. In principle, a ‘pattern-approved’ meter has thus already been through five years of operation time and is considered to be reliable and to measure precisely.

In relation to passing the durability test, EN 1434-4 requires that “no significant fault shall occur after the test” and, in addition, that the test facility “shall suit the purpose, be traceable to more precise standards and be part of a reliable calibration programme.”

To receive the pattern approval, the new meter must be tested in an accredited test facility. Kamstrup’s accredited test facility is one of only three in Europe and the only one belonging to a private heat meter manufacturer. The other two facilities are located in Vienna and Berlin, at the national metrology organizations of Austria and Germany, respectively. These organizations also carry out testing for third parties; due to its accreditation, Kamstrup is obliged to test competitors’ products as well (something that in reality never occurs). The company’s test facility is a sealed-off room containing the test rig. Monitored by DANAK, the facility is off-limits to company personnel once the flow sensor testing is under way, per accreditation requirements. Up to 12 flow sensors can be tested simultaneously, with three different sizes handled at the same time. The sensors are mounted in three ‘strings,’ or trains, each with four test specimens. The facility is formed as a closed system consisting of an automatic water refill system, a circulating pump and a heater.

The water temperatures can be regulated up to 150 degrees C (302 F) and the flow up to 40 cu m/hr (10,567 gal/hr). The flow of each sensor is logged. A reference meter documents the test procedure while the logging of the test specimens verifies the test procedure of all three trains. The complete durability test comprises a basic wear test of 100 identical cycles of 24 hours’ duration each (fig. 1, fig. 2) and an optional endurance test for long-life flow sensors consisting of an additional 300 hours at maximum flow. Both the types of tests are carried out at 130 C (266 F), the upper temperature range limit specified in EN 1434-4.

**Figure 1.** Heat Meter Basic Wear Test: 2,400 Hours. This test is based on a continuous series of 100 24-hour cycles, each at three different flow rates: minimum (Qmin), nominal (Qnom) and maximum (Qmax).

**Figure 2.** Detail of a 24-Hour Test Cycle. The high-load phase lasts 18 hours – 16 hours at nominal flow (Qnom), one hour in which the flow rate is raised to maximum flow (Qmax), plus a total of one hour transition time between the changing flow rates. The high-load phase is followed by a low-load phase, lasting six hours, at 1.5 times the minimum flow (Qmin).
The additional endurance test at maximum flow rate is voluntary for manufacturers who believe that their flow sensor is capable of lasting more than five years in a real installation. As the flow sensor is subjected to extra wear during the endurance test, the accuracy (or inaccuracy) will show when measuring low flow rates because these are generally more difficult to register.

Some manufacturers of mechanical meters have strongly opposed both of these durability tests; and some are trying in creative ways to circumvent even the basic wear test.

**AGFW’s Durability Test Program**

As mentioned, in addition to obtaining the EU-stipulated pattern approvals, meter manufacturers may voluntarily submit meters to AGFW for durability testing, which assigns the meters a designation of “measuring stable” or “not measuring stable” in the final report. The AGFW test program includes six phases totalling 4,800 hours at various temperatures and flow rates. This means that AGFW is the authority with the highest standards in the field of flow sensor testing as its durability test program goes far beyond the government-regulated criteria.

In the initial test phase, two curves showing the measurement deviations of the new flow sensor at 25 C (77 F) and 55 C (131 F), respectively, are recorded. Then the first continuous-load phase is carried out prescribing 2,400 hours at 90 C (194 F) and a nominal flow rate. Once a day, the load is increased to double the level of the nominal flow rate for one hour. The second load phase prescribes 1,800 hours at 90 C (194 F) and nominal flow rate. Here, too, the load is increased once a day to double the level of the flow rate for one hour. The next two phases are endurance tests, each lasting 300 hours at double flow. Finally, an optical analysis is carried out in which the test specimens are dismantled for determining particular changes.

A simple and clear record is generated to document the test results for each flow sensor. A mid-test report is produced in addition to the final report. The sensors receive a rating of from one to five points in each of the categories of measurement precision, measurement stability, and restorability.

In a November 2006 report on its durability test program, AGFW states that a “clear distinction between good and bad heat meters” becomes evident after 2,400 hours of performance testing – the duration of the government-regulated pattern approval testing. AGFW therefore concludes that the EN 1434-4 standard for pattern approval and verification for flow meters is inadequate and that only its own testing program can ensure heat meter durability.

Only few mechanical flow sensors are submitted for testing at AGFW. The 2006 program report showed 39 ultrasonic meters evaluated that year, of which five (13 percent) did not pass the durability test. (The failed ultrasonic meters came from only two manufacturers.)

**Reality Test: Random Sampling**

Nearly 100 percent of Denmark’s meter inventory currently consists of ultrasonic meters, and they are strictly monitored. The Danish authorities require that random sample testing be carried out at an accredited test lab to measure the stability of heat meters after six years in operation. With its long history of random sample tests, Denmark has accumulated a great deal of knowledge about flow sensor quality.

For more than 10 years, Kamstrup has performed this obligatory evaluation for about 80 district heating utilities and issued an annual report with test results. Since most heat meters used in Denmark are the company’s own, it rarely receives meters from other manufacturers for re-verification.

Utilities have a major interest in having the measurement stability confirmed. For this purpose, each utility divides its meter inventory into “lots” from which 10 percent to 15 percent are removed and submitted to the test lab. An additional six years of operation are granted if the test results are within the original calibration error margins. If the results do not exceed the maximum errors permitted, the period is extended by three years. If the maximum errors permitted are exceeded, the entire lot must be exchanged.

As shown in Kamstrup’s 2009 annual report on its random sample testing program, the company’s flow lab tested 2,293 ultrasonic meters that year from a total of 122 lots (fig. 3); all were Kamstrup meters. Fifty-nine mechanical meters (three lots) from other manufacturers were also tested. Ninety-three

![Figure 3. Kamstrup’s Random Sample Tests, 2009. Measurement deviation for 2,293 randomly sampled ultrasonic heat meters after six or 12 years’ operation time.](source: Kamstrup A/S.)
percent of the ultrasonic meters were within the strict threshold values. Based on lots, the results clearly illustrate the long-term stability of ultrasonic meters, as 78 percent of the lots containing ultrasonic meters were extended by six years as compared to none containing mechanical meters.

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Several of the ultrasonic heat meters tested in 2009 have now been subject to their second random sampling and, based on their test results permitting service life extension, are on their way to 15 or 18 years of installation time.

A clear picture is now emerging: On the basis of pattern approvals, AGFW’s advanced test program and the already 20 years of actual operation, the ultrasonic meter has proved to be the most durable heat meter technology. These comprehensive and demanding tests are important both because the energy medium is transient and because the relationship between district heating utilities and their customers is based on trust. Since the heat meter is the only common reference point for controlling and billing for energy consumption, the demonstrability of a high degree of measurement stability is essential.

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