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**BACKGROUND REPORT FOR  
THE PREPARATION OF A CANADIAN  
STANDARD ON THERMAL ENERGY METERS  
FOR HYDRONIC HEATING/COOLING SYSTEMS**

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# **BACKGROUND REPORT FOR THE PREPARATION OF A CANADIAN STANDARD ON THERMAL ENERGY METERS FOR HYDRONIC HEATING/COOLING SYSTEMS**

## **1 Summary**

The district heating/cooling industry is new in Canada but is rapidly expanding. Currently, no Canadian standard exists for meters used to record the accumulated thermal energy supplied by a district heating (DH) utility to a customer. As a result, the application of metering for revenue billing has been problematic due to non-certified equipment and lack of standardized installations. Errors in recorded energy values and lack of reliability have occurred leading to decreased confidence in the viability of metering. Two heat metering installations in remote communities have been abandoned because of obvious inconsistencies in the data.

New thermal energy meters have improved performance and the old international documents have become obsolete. Recent European standards and international recommendations have been developed. It is an appropriate time to evaluate Canadian requirements for standards and compare these to work that has been done in other countries.

With fully certified metering, the concept of "user pays" will become widely accepted in space heating, cooling and consumption of domestic hot water. Based on the European experience this will lead to reduced consumption and slower depletion of fossil fuels. Some Canadian applications of thermal energy metering include high rise condominium buildings as well as the potential for sub-metering in apartment buildings.

## **Sommaire**

L'industrie canadienne de la distribution urbaine de chaleur et de froid est encore jeune mais croît rapidement. Présentement, aucune norme canadienne ne couvre les compteurs utilisés pour le mesurage de l'énergie thermique fournie par un système urbain à un usager donné. Ainsi des installations non standardisées de même que l'usage de compteurs non certifiés dans un contexte de facturation est problématique. La confiance dans les systèmes de mesures actuelles s'en trouve d'autant diminuée que des erreurs ont été décelées dans le mesurage d'énergie de certains systèmes ; en particulier deux systèmes de chauffage urbain dans des communautés éloignées ont été abandonnés dû à des incohérences flagrantes dans les données énergétiques.

De nouveaux compteurs d'énergie thermiques démontrent maintenant une performance accrue, rendant du même coup certains documents internationaux obsolètes. Aussi, de nouvelles normes européennes et recommandations internationales ont ainsi été développées. À ce moment, il s'avère donc approprié d'évaluer les exigences canadiennes et de les comparer avec celles développées par d'autres pays.

Le mesurage par des installations certifiées rendra le concept d'« utilisateur-payeur » de plus en plus acceptable dans les domaines de chauffage et de climatisation d'espace ainsi que pour la consommation d'eau chaude domestique. Suivant l'expérience européenne, cela mènera également à une consommation réduite et une certaine préservation des ressources d'énergie fossile. Les applications canadiennes du mesurage d'énergie thermique incluent les bâtiments en hauteur du type condominium de même que le potentiel pour le mesurage à l'échelle des utilisateurs dans les édifices à logements.

## **2 Background**

### **2.1 Evolution of district heating systems in Canada**

Until the 1980's most of the district heating in Canada consisted of steam distribution systems. Usually these were on government building complexes, including military bases, or university campuses. Due to the common ownership of the buildings, there was no need for accurate metering for revenue billing purposes.

In the meantime, northern Europe evolved rapidly to hot-water based district heating systems. Cities such as Helsinki presently obtain over 80% of their heat from large, multi-fuel power plants which often combine electric power generation (cogeneration) with waste heat extraction for district heating.

There is currently a rapid expansion of new, hydronic district heating/cooling systems in Canada. At least nine systems of the megawatt size exist and a number of others are in the planning stages. Six of these have cogeneration plants. Others utilize a renewable biomass fuel, reducing greenhouse gasses and creating local employment.

Hydronic heating/cooling systems lend themselves to accurate metering. Promotion of economical, low-grade energy can be marketed to a variety of customers, if there is an acceptance of accurate metering methods.

### **2.2 Description of hydronic thermal energy meters**

Thermal energy meters measure the supply and return temperatures at the load and the volume flow rate of the liquid. In certified measurement systems water is generally used, with additives for water quality control.

The thermal power being transported by the liquid is proportional to the product of temperature difference and the flow rate. A microprocessor computes these quantities and applies corrections to compensate for water density and specific heat changes with temperature and for non-linearities in sensors. The values of instantaneous power are accumulated to memory registers that can only be reset by pass-codes. Most thermal energy meters have options to transmit data via remote readout equipment.

### **2.2.1 Potential for errors due to low temperature difference**

Often when a load is connected to a DH system it is difficult to accurately predict the peak loads and the statistics on load variations. This is especially true when aging buildings are connected to the system. In some older systems loads are connected to a nominally constant flow loop. This results in temperature difference proportional to power being extracted from the fluid. The problem is particularly acute in cooling systems, some of which have been observed to operate at temperature differences below 2 °C for a large part of the time. The international standard for thermal energy meters specifies 3 °C as the minimum operating temperature difference.

### **2.2.2 Potential for errors due to low liquid flow rate**

Depending on the design, in a hydronic heating system there can be significant variations in flow levels and it is important to have a large “turn-down ratio” in the flow sensor. Some flow sensors can operate to below 3% of peak flow before the relative error begins to exceed specification. Other sensors have much lower turn-down capability. An example is the orifice plate, which has a differential pressure output proportional to the square of flow rate. This approach is typically limited to a turn-down ratio of about five.

### **2.2.3 Difficulty of correcting errors in accumulated energy**

As a result of the multiplication of the two variables of flow and temperature difference the thermal energy meter is prone to error if either of the quantities is low while a high value of thermal power is being transported. Consequently, it is impossible to fully correct for errors that are identified after an extended period of operation. For example, a common source of error in differential temperature measurements is an offset error. Even if this error were to stay nominally constant, when the magnitude of differential temperature varies down to low values the relative error will vary in a nonlinear manner. The effects of offset error can only be corrected if the time series values of both flow and temperature difference are available for analysis.

## **2.3 Need for standards in the Canadian district energy industry**

It is estimated that slightly over 1,000 thermal energy meters are currently used in Canada for revenue billing. At present there is no Canadian standard to define the accuracy and operational characteristics of thermal energy meters. Often there is a simple contractual agreement between the energy supplier and consumer to pay whatever the energy meter registers. Since there is usually no prior agreement between the parties involved regarding a definition of accuracy, the lack of standards has the potential for legal problems if significant errors are found after an extended period of operation.

A number of problems have been observed with older thermal metering installations in Canada due to the lack of a standard, including:

- 2.3.1 Lack of water density and specific heat correction. This can cause over one percent added error, depending on the operating temperature levels.
- 2.3.2 Use of temperature sensors designed to be mounted on the surface of pipes instead of in thermal wells or directly immersed in the flow. Large errors occur due to loose mounting and insufficient insulation.
- 2.3.3 Potential for errors due to use of semiconductor temperature sensors at low levels of temperature difference. Some meters use thermistors and other semiconductor devices instead of the platinum RTDs (resistance temperature detectors) which are matched to 0.05 °C in certified meters. The new international standards state the "Maximum Permissible Error (MPE)" must be less than 0.1 °C even after years of operation.
- 2.3.4 Lack of points to attach seals on critical parts of the installation, making it easy to tamper with the accuracy.
- 2.3.5 Data transfer to external systems is not standardized.
- 2.3.6 Errors due to use of non-standard hardware and one-off software incorporated in building monitoring/control systems. In a large system a cumulative error was identified when compared to a newly installed heat meter. This was due to rounding errors in the building monitoring software, as a result of resetting some accumulators each midnight.
- 2.3.7 Lack of confidence by sellers and buyers of heat energy due to lack of standards. There have been cases where potential users of thermal energy metering have lost interest when they found there is no standard. Concern over potential liability was stated as one of the reasons for not applying this technology.

## **2.4 Impact of certified meters on energy conservation**

As indicated in 2.3.7, the lack of a standard has been a barrier to the acceptance of heat metering in Canada and impacts negatively on Canada's energy conservation. Other countries have found a reduction of 20 to 30% in energy consumption for heating and cooling and 30 to 50% reduction in consumption of hot water<sup>i</sup> once energy charges were implemented<sup>1</sup>.

## **2.5 Recommended technical features in modern thermal energy meters**

Modern thermal energy meters avoid the problems discussed in 2.3. In order to make a meter fully functional for both revenue billing and diagnostic purposes a number of features are necessary:

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<sup>i</sup> (marketing document from SVM Sweden, based on more than 25 reports by independent energy authorities, encompassing six northern European countries)

- Accumulated values should include water volume as well as the standard energy quantity. The water volume, together with energy, allows calculation of “flow-weighted average temperature difference”, which will indicate if water flow has been excessive. A number of instances have been seen where the supply to the domestic hot water heat exchanger goes into a high flow condition due to improper control and is not detected for extended periods.
- Instantaneous values of flow and temperatures as well as error indicators.
- The ability to switch the unit into fast response outputs for testing and calibration.

### **3 Proposed terms of reference**

#### **3.1 Standards for both heating and cooling systems**

Both heating and cooling will be included in the standard, as many new Canadian buildings are now air conditioned from a central source. Both four-pipe and two-pipe systems are used. At least one European manufacturer of thermal energy meters has recently begun production of a unit designed for two pipe heating/cooling systems. This meter computes two values of energy based on both positive and negative temperature difference. Energy is accumulated into separate registers, allowing different tariffs to be applied for heating and cooling.

#### **3.2 Steam systems**

It is assumed that no standard will be developed at this time on steam systems. Steam energy flow is difficult to measure to a high accuracy and the use of steam systems is in decline.

#### **3.3 Use of semiconductor sensors for temperature measurements**

In principle, any temperature sensor that meets the accuracy specification of the standard should be considered acceptable. However, the question of long-term stability in diverse environments is more complex and difficult to specify. The current practice in certified thermal energy meters is to use platinum temperature sensors, which have a proven track record for extended periods of operation. As background there is need to obtain expert input regarding certification test procedures that may involve accelerated life-cycle tests specific to potential modes of accuracy deterioration in semiconductor sensors.

#### **3.4 Provincial boiler pressure codes**

Due to historical considerations carried over from steam systems, flowmeters fall under the boiler code. Since the boiler pressure code is a provincial jurisdiction, consideration may need to be given to the certification procedure for flowmeters in the provinces. Possibly the most stringent provincial boiler codes will need to be identified and used as the overall standard.

Flowmeters that meet a provincial pressure code are assigned a CRN number. There is some uncertainty regarding the implications of this pressure code. When flowmeters are used directly on the high temperature/high pressure part of a district heating system the need for certification under the boiler code is important. Since larger district heating distribution systems are often designed to operate up to 120 °C or higher there is serious danger of steam generation if a line is broken.

A different situation exists in a local heat distribution system inside a building either isolated from a district heating system by a heat exchanger, or supplied by a local boiler. This will typically operate at a lower pressure and at a temperature below the boiling point<sup>ii</sup>. The building distribution system will be protected by over-temperature and over-pressure relief valves in case there is a loss of temperature control. This is similar to the protection on a domestic hot water tank for residential hot water. In spite of this protection, the code states that plumbing components used above 65 °C and 16 bar pressure must have a CRN certification number. The meters being manufactured in Europe are certified at these levels.

CRN certification is a complex procedure. It requires:

- Submission of the detailed production drawings for a full design review (to evaluate wall thickness, etc)
- Materials evaluation to compare to materials that have been previously certified under CRN– tensile tests, over-pressure testing
- Quality control during manufacturing – ISO 9001

As a result most European meters are not certified under the Canadian provincial pressure codes.

There is a need to establish if the certification procedures can be linked to the European certifications.

### **3.5 Communication protocols for remote readout of energy meter data**

Consideration needs to be given to three commonly used standards:

- M-bus - allows multiple meters to be addressed from a master controller, with requests to transmit data.
- Lonworks - this system can be set up for repetitive transmission of data, allowing the data to be used for control applications.
- RS 232 - allows direct connection to a modem for automatic dialup from a computer.

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<sup>ii</sup> An example is sub-metering in an apartment building.

### **3.6 Sub-metering of domestic hot water to estimate energy consumption**

In modern, well-insulated residential buildings the consumption of domestic hot water (DHW) is often a significant part of the energy load. In some applications, such as apartment buildings, low-cost, simplified methods of sub-metering for DHW consumption are used. This is often done by using water volume only and assuming constant delivered hot water temperature. Currently there appear to be no standards for this methodology, but some consideration could be given to future addition of this capability. There would need to be standards for these flowmeters and the software used to compute the DHW energy equivalent to the water volume. Accuracy will be improved by proposed changes to the National Building Code that will limit the delivered DHW temperature of new installations to 49 °C by use of a fixed tempering valve. As a minimum any new standard for DHW metering should state that the flowmeter must be located after a tempering valve.

## **4 Procedures to define standards**

Steps in the procedure:

- Background work by NRCan, to supply information to the Standards Committee
- Nomination of committee members to draft the technical standard
- Nomination of advisory members to supply comments on policy questions
- Development of a draft standard.
- Comments on the draft standard by the district heating industry, solar energy industry, and companies involved in high-rise sub-metering
- Preliminary evaluation of the specification of thermal energy meters being sold in Canada to evaluate compliance to the standard
- Discussions with Industry Canada to obtain information on procedures that will be implemented to evaluate meters for compliance to the standard

### **4.1 Background work by NRCan, including review of currently applicable recommendations and standards**

#### **4.1.1 *Organisation Internationale de Métrologie Légale (OIML)*<sup>2</sup>**

OIML is the main international agency dealing with metrology and Canada is a member of this organization. The main reference for accuracy specifications could be OIML R 75, which addresses thermal energy meters. This document is defined as an “International Recommendation”. They are “model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for

checking their conformity; the OIML Member States shall implement these Recommendations to the greatest possible extent". As stated in its introduction, the OIML R 75 was developed on the basis of 1997 European Standard EN 1434<sup>3</sup>, which is discussed next in 4.1.2.

OIML R 75 is available in English and French and can be down-loaded free at:  
<http://www.oiml.org/publications>

This recommendation will be in at least three parts:

- |             |             |   |
|-------------|-------------|---|
| OIML R 75-1 | Heat meters | Part 1: General requirements (17 pages). Based on EN 1434 part 1                                  |
| OIML R 75-2 | Heat meters | Part 2: Type approval tests and initial verification tests (20 pages). Based on EN 1434 parts 4,5 |
| OIML R 75-3 | Heat meters | Part 3: Test report format (to be published in at a later stage, superceding the 1988 edition)    |

The OIML R 75 recommendation currently refers only to heat meters and it can not be applied directly to cooling systems, by simply reversing the definition of supply and return temperature measurements. The test procedures for temperature sensors specifies a minimum temperature of 5 °C and the lowest temperature for the flow sensor is specified as not less than 10 °C. Some cooling systems operate at temperatures below 5 °C. The environmental conditions specify the relative humidity as less than 93%. This could be a problem, since the flowmeter in a cooling application could have condensing conditions on its surface.

Since OIML R 75 is a new document and is still under development, it does not encompass the full scope of the requirements that were addressed in more detail by the European standard EN 1434 (1997). In particular, the important area of communication protocols is not covered although these are mentioned in the references.

A possible approach would be to use OIML R 75 as the starting point, with modifications and additions as required to meet the needs of the Canadian industry.

An example of a potential variance for Canada is the two standards for platinum alloys used in the temperature sensors. The European standard has a factor of 0.385% per °C, while the North American standard is 0.3915% per °C. Both are equally accurate, but the European thermal metering standard only defines the linearization equation for the 0.385 factor. If it is decided to permit both standards in Canada, as a minimum it should be mandatory to define the temperature sensor factor on the meter faceplate.

#### **4.1.2 Comité Européen de Normalisation (CEN) or European Committee for Standardization**

CEN developed the European Standard, EN 1434 (1997) and the EN 1434 specifies requirements in detail. Until such time as OIML R 75 is as complete as EN 1434, the latter standard will need to be used as reference material for the Canadian standard.

In 2002 EN 1434 was amended (A1) to include cooling applications.

EN 1434 (1997) is currently in six parts:

- Part 1: Heat Meters - General Requirements (24 pages)
- Part 2: Heat Meters - Constructional Requirements (29 pages)
- Part 3: Heat Meters - Data Exchange and Interfaces (53 pages)
- Part 4: Heat Meters - Pattern Approval Tests (22 pages)
- Part 5: Heat Meters - Initial Verification Tests (7 pages)
- Part 6: Heat Meters - Installations, Commissioning, Operational Monitoring and Maintenance (13 pages)

#### **4.1.3 European Union Measurement Instrument Directive (Doc.9681/4/03 REV 4)**

This directive was accepted early in 2004. The section of the document referencing heat meters is a seven page summary listing the main accuracy specifications of OIML R 75 and EN 1434.

#### **4.1.4 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)**

A preliminary search of the ASHRAE standards<sup>4</sup> has identified a test procedure for thermal energy meters:

Standard 125-1992 (RA 2000)—Method of Testing Thermal Energy Meters for Liquid Streams in HVAC Systems (ANSI approved)

“The purpose of this standard is to provide a method of testing factory-assembled thermal energy meters used to measure the thermal energy added to or extracted from a liquid stream supplying an HVAC system”.

## **4.2 Technical support**

### **4.2.1 National Research Council – Institute for National Measurement Standards (INMS)**

To address the concerns regarding the long-term stability of thermistors and the guaranteed accuracy with which their exponential characteristic can be mathematically linearized, contact will be made with NRC - INMS. They are responsible for national standards on temperature

measurements and have a number of experts in this field. Their input will also be requested on other semiconductor temperature sensors.

#### **4.2.2 International Energy Agency (IEA)<sup>5</sup>**

Previous work by IEA examined accuracy and reliability considerations in detail. Testing was done on the newest technologies being used in thermal energy meters, and recommendations made regarding standards. This work was done in the period 1988-1990<sup>6 7 8 9 10</sup> and is partly out of date. Some of the information on test procedures and field testing is still relevant.

Recent IEA work<sup>11</sup> has emphasized usage of the communication features of modern thermal energy meters to supply information for demand side management. Since district heating systems are even more prone to overload at peak conditions in comparison to electric utilities, there is the potential to make significant improvements in the overall efficiency of the energy supply system by controlling peak demand.

### **5 Input from district heating industry**

Contact will be made with Industry Canada, manufacturers of heat meters, retailers, installers and calibration facilities.

### **6 Evaluation of new standards by comparison to current equipment**

After a draft standard is issued an evaluation of specifications will be done of heat metering equipment currently or potentially available in Canada. The objective will be to establish whether most of the equipment from serious manufacturers can fit into a specific class within the standard.

### **7 Certification process for thermal energy meters**

After a standard has been issued a process will need to be set up to certify whether a given meter can be sold in Canada with a compliance certificate. If the Canadian standard has a well established relationship with reference to the OIML R 75 and EN 1434 documents this could be a fairly simple process.

### **8 Recommendations for installation procedures**

Due to the relative complexity of heat meters and the lack of installation experience in Canada, it may be necessary to define basic installation considerations that could be overlooked in the manufacturer's installation instructions. For example, the EN 1434 includes specifications for maximum wire lengths for two-conductor cable of various wire gauges that are permissible for use with platinum temperature sensors.

## References

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- <sup>2</sup> Organisation Internationale de Métrologie Légale, 11 rue Turgot - 75009 Paris - France.
- <sup>3</sup> Comité Européen de Normalisation (CEN). Central Secretariat: rue de Stassart 36, B-1050-Brussels.
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<http://resourcecenter.ashrae.org/store/ashrae/newstore.cgi?itemid=6893&view=item&page>
- <sup>5</sup> IEA Secretariat, Mr. Hans Nilsson, 9 Rue de la Federation, F-75139 Paris, Cedex 15, France.
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