Deliberation of Heat meters Measurement and Testing Technology In District Heating

Zhu Jiguang
(Harbin Institute of Metrological Verification and Testing, Harbin 150036 China.)

Abstrct: The essay combines the experiences of the testing practice and analyses the practical applied effect, aims at the various big-bore heat meters and heat metric equipments which were largely applied in the concentrated heat-supply pipe networks of urban areas. Meanwhile, it probes detailed in the component verification/calibration methods of heat meters and their relative equipments, such as flow sensor, transforming unit and the secondly calculated meters, etc.
Keywords: Heat meters; Big-bore; The component verification methods;

1. Introduction

The centralized heat-supply of Harbin developed rapidly along with the reform of heat-supply system within urban areas. The state-owned, private and co-operated enterprises positively participate in the building, rebuilding and management of heating source and heat-pipe networks. Statistic shows that the new heating sources are increased by 1300MW, heat-supply pipes are newly laid by 200 km and that is the main construction of the past 10 years, which is unimaginable as before. Harbin is located in the northeast part of China, and its heat-supply period lasts 180 days in the cold season, also its unit area heat-supply is about 75W, which is on the top in the northern part of China. The high coverage of centralized heat-supply will bring us many advantages definitely, such as reducing the cost of heat-supply, decreasing the pollution of environment, improving the quality of atmosphere and the level of people's life. In recent years, the heat-supply departments invested a lot in the monitor system technology and equipments for enhancing the scientific management level of heat pipe networks, monitor and measure the heat- net's balance, in order to have accurately heat metric trade. The sticking points of influence on operating quality of heat pipe networks monitor system are not computer and communication technology but flow quantity metric technology. Almost all kinds of industrial flow meters were applied in some area, but quite a lot cannot guarantee the measurement accuracy and were taken down because of various reasons. Especially in recent years, disputes caused by heat measurement inaccuracy happened from time to time in the constantly increased district heat-supply trade. Point to this situation and in order to measure scientifically and impartially, maintenance the bilateral economic benefit of the heat trade parties, our colleagues engaged in metric technological institutes often went to the scene to test the flow measurement and solve the problems which caused by misusing the heat flow meters. We also are accumulating the experiences in order to fit the development of heat metrics testing work.

As we all know, that heat meters can be divided as integer style and fission style. Most heat-meters used for district heat connected measurement. Combined this character and the verification regulation of JJG225-2001 heat-meter, we can implement component verification. More to emphasize is that the construction of heat-meter and equipments on the scene are different, and the output signals

of the flow sensor and the flow quantity of secondly calculating (including calculator), also the calculated method are different, we should treat them separately while component verificated that the metrological capability of the heat-meters can be reflected accurately. The more we gain the aim, the better we can exert the adaptability of the verification regulation of JJG225-2001 heat-meter, so the more convenient for the operation by the base metric departments, the more heat measure problems can be solved in the scene. In the following paragraph, it will briefly introduce that several styles of the district heat meters and their relative equipments which were commonly used in the heat networks, and give the suggestions on realizing the component verification.

2 Flow sensor

The flow sensor in the real measure occasion is various. Using the method of different principles to measure flow, real flow measure range, specification choose, the manufacture of flow meter and adjust quality, install terms and maintenance management, etc. factor. They are all the indispensable condition that guarantees its realization accuracy.

2.1 Standard Orifice plate flow sensor

The advantages of the orifice plate flow meters have simple structure and the throttling component and computing technology have already been standardized. Its assays generally do not need to demarcate in the real flow condition. As we know, the principle of orifice plate flow meter is: according to the continuity of flowing fluid and the law of conservation of energy learn: when fluid is flowing through throttling component, there will be some shrink of flow bunch when the goes through, thus in the cross section, this make velocity the velocity of flow increase, static pressure reduce, produce static pressure bad and then figure out the flow by the static different pressure before and after the throttling component. With a large number of popularizing differential pressure transmitters with high accuracy in recent years and computer technology application of showing instruments, the calculating precision has improved constantly, the actual span ratio of orifice plate has been raised notably, and adjust diameter ratio can reduce pressure loss, the application of its prospect is very considerable. This kind of flow meter is not only suitable for hot water measure, but also better in high-temperature vapor heating measure. What deserves to be mentioned is, measure the field in the hot water and steam of big-bore (DN300-1000mm), because the standard accorded with by it is regular, geometry method is adopted, district and city level measure organizations are getting easier to launch in verification and calibration work. Compared with flow meter of other types, the cost of verification is very low, and in arbitrating measure it is easy to operate, and have made the good social effects in the work of the spreading value of quantity.

2.2 Ultrasonic flow sensor

Ultrasonic flow meters measure the flow utilizing ultrasonic wave's sound velocity change in positive and negative speed of flow and gets the fluid velocity. Such advantages as it has bigger dynamic measurement ranges, no wearing and tearing, high accuracy. Its supreme medium can be measured up to 130 degrees Centigrade. Some controlled ultrasonic type flow meters that the urban hot network installed online have run through several heating periods. Till now managing datum show and indicate in China and abroad that some better brand ultrasonic type flow meter have stable accuracy, the safeguarding amount is small, suitable for the hot network..

2.3 Electromagnetic flow sensor

The measurement principle of the electromagnetic flow meter is base on

Faraday's electromagnetic induction law, namely: the conductive liquid produced the voltage of reaction in the conductor while cutting the magnetic line in the magnetic field. While measuring the flow, it flows through the vertical magnetic field electric conductivity flow reaction of fluid produce a voltage which is in direct radio of average voltage (namely the accumulating flow), so require the conductance rate with minimum limit of flow liquid examined. Its induction signal of voltage can be examined out through two electrodes that contact the fluid directly, and convey to the amplifier through the cable, then change into a output signal. The flow meter has high to measure precision, wide range ratio, measure medium temperature can up to 140 degrees Centigrade, widely used in the hot network.

2.4. Impeller flow sensor

The principle of impeller flow meter is: impeller that put in fluid according to with flow quick angular speed of direct radio whirling, the velocity of flow can be got by the whirling angular speed of the impeller, and the fluid will rotate the number of times to try to get from the impeller. The flow of the impeller has various forms. Impeller flow meters used in industry are mostly Turbine Flow Meter, they are high accuracy, wide flow range, high enduring pressure, wide temperature range, easy maintain, digital signal output, etc. It is one of the ideal sensors for the heat measuring.

2.5. Vortex flow sensor

Vortex Flow Meter, according to the hydro mechanical principle, if we put the object, such as a cylinder or a block of board, etc. vertically installed in the flowing pipe, thereafter swirl will appear. It sends out from both sides alternatively and formed two vortexes side by side of the form just likes saw tooth, called Karmen Vortex. The frequency of swirl is direct proportion to the fluid velocity in a certain range of Reynolds Number. Through measuring and calculating the swirl figures we can get the velocity of flow. This kind of instrument called Eddy Meter. The advantages are: It has no moving part, simple structure, long performance life, wide measuring range; The flow is not be influenced by the parameters, such as temperature, pressure, density or viscidity of the examining fluid, etc.; Pressure losses are relatively little. The shortcomings are :Anti-seismic performance bad, the straight length of the pipe expect much, poor performance in enduring the high temperature. The quantity is less used in the field of heat network at present.

2.6. Elbow flow sensor

Elbow flow meter is used as its advantages: pressure lose less, measure precision high, easy maintain and low fault rate . It begins to get application in some steam water trade measure field. The principle of siphon flow sensor is: When the fluid flows through the crooked pipeline, because of the centrifugation based on inertia principle, will cause the change of the pressure on the inside and outside of it. namely the pressure outside increasing, interior lateral pressure reducing. Through people a large amount of theory with experiment research, it derives that: while meeting certain condition, the average velocity of the fluid in the pipe and the internal and external differential pressure have the following relational expression:

$$V = \alpha \cdot \sqrt{\frac{R}{D}} \cdot \sqrt{\frac{P_1 - P_2}{\rho}}$$

Where:

V- the average velocity of fluid, m/s;

D- the internal diameter of the elbow, m;

R-elbow conduit's; axis curvature radius, m;

P_1- the pressure outside of the elbow, Pa;

P_2- the lateral pressure in the elbow, Pa;

ρ-Density of operating mode of the fluid

medium, kg/m^3

β-Index;

α-Comprehensive flow coefficient.

Therefore, to specific pipeline measurement parameter, medium situation and working conditions, the internal and external lateral pressure difference of the elbow and the flows through it has definite functional relation. Through measuring differential pressure we can realize that the flow can be measured.

3 Heat calculating and showing instrument and device

3.1. Real-time heat measuring device on the computer

The real-time heat measuring device on the computer uses computer according to the measuring parameter in real time (the temperature, pressure and flow signal), to calculate and accumulate thermal, it includes input unit, monitor, printer, keyboard and host computer, etc. The device can accept the thermal technology signal in multi-pipeline, deal with and show.

Its characteristics are: Absorb ISO5167-1991-2 relevant contents, according to the measured medium actual parameter (the pressure, temperature and differential of pressure) that operating mode change, work out the calculated process, follow and calculate all variables while the line is real, the density of the medium ρ, medium viscidity η, coefficient of discharge C, expansibility factor ε, diameter ratio β, Reynolds Number ReD, hot enthalpy value h introduce formula and calculate actual flow and heat after carry more parameters and carry on the online real-time calculation, therefore expanding measure range ratio, overcoming the classical orifice plate shortcomings for the small range ratio. It has certain practicability and realizes that the collector and line-four RTD are made and compounded , reduce the measurement error greatly that the wire brings, make the class A Pt100 sensor interchangeable, guarantee the precision of heat measure.

The main technical targets of the device are:

（1） The device relative error of software result of instantaneous heat :≤±0.1%;

（2）he device fiducial error of instantaneous heat: ≤±0.4%;

（3）The device error of cumulating heat: ≤±0.4%;

（4）The fiducial error of temperature: ≤±0.2%.

3.2. The elbow integrating instrument of heat flow

The elbow integrating instrument of heat flow is an instrument which is used to measure and display parameters, such as the liquid flow, the quantity of heat, the instantaneous pressure, the instantaneous temperature, the instantaneous heat, and so on. Generally, there are many suitable sensors, such as the standard orifice plate sensor, the turbine sensor, the vortex sensor, the ultrasonic sensor, the resistance thermometer sensor, the thermocouple and so on. The pressure transmitter, the differential pressure transmitter and the temperature transmitter are the transmitters connected with the integrating instrument. People can enter the set state after corresponding password posting, set some parameters such as suitable sensor form, the measure range, and so on; which have the functions of power down holding.

It is generally composed of the single chip, the operating key, the monitor, and the communications interface and process channels. The input analogue signals are (0-10)mA，(4-20)mA, (0-10)V, (1-5)V. The frequency of pulse signal is no more than 10kHz usually; for voltage pulse, its low level is no more than 2V, the high level is no less than 4.5V.

The class of precision is usually 0.5 for the familiar smart integrating instrument of heat flow.

3.3. The smart elbow integrating instrument of heat flow

The hardware configuration of smart elbow integrating instrument of heat flow is about the same with the smart integrating instrument of heat flow. While there have some differences, it is specially used with elbow flow sensor, its inner design formulas of flow is designed for elbow, it has the functions for measuring instantaneous flow, instantaneous heat, temperature, pressure, displaying and accumulation. In order to ensure the high measuring precision, the instrument pressure, not only uses real time compensation method to compensate the temperature and pressure for flow measurement, but also uses the method to correct the thermal expansion of pipe diameter; the corrected value is figured out by actual temperature measured and the linear expansion coefficient of actual elbow sensor medium. The measuring precision of instrument is reliable because of the compensating and correcting.

All of the input signals are analog quantity (4-20) mA DC, the precision of instrument is: 0.2%FS.

3.4. Power calculator

Manufacturers call the power calculator as power meter, which has the same function with defined calculator in rules, and the power is provided by lithium cell mostly. The calculator can receive the pulse signal from flow meter, measure the water magnitude; the power measurements include: the measurement of water-supply temperature and backwater temperature, the correction of water density and enthalpy value, and work out the gross of heat energy. This calculator can be connected with most pulse-type flow sensors with different measuring principles, has wide flow range, some type's top flow are about $3000m^3/h$. The calculation is suited for the calculation of large heat energy, and it is satisfied the requirements of commercial services site and industry consumer.

The pulse input methods have two ways: the mechanical switch or the trigger of triode opened and the trigger of electronic pulse signal. The temperature-measuring sensor has two connection methods, which are two-line and three-line method, the last one is more exact.

The precision accords with the verification regulations of components.

4 The discussion of verification method

4. 1 he verification and calibration of flow sensor

4.1.1 The standard orifice plate

The standard orifice plate is classical flow sensor, the function relation is defined clearly by international standard ISO5167, which is the relation of the pattern, size, the process measuring parameter and the flow ; The influence quantity for hot water and steam medium can be corrected, which are the inside diameter of orifice plate, the outside diameter of pipe, viscosity, and the expansibility factor. We know that the orifice plate and ring chamber, flange, straight length and pressure-pipe, differential pressure transmitter, which compose the sensor equipment; usually, it is difficult to take the real fluid verification. The geometric method is put forward in the verification regulations for JJG640-1994 differential pressure flow. The main technical targets are :the throttle aperture, the acutance of entrance edge, the upper planarity, the surface roughness, and the thickness of orifice plate; the geometric method is effective. What must to be noticed is the disturbance by the orifice plate installation, such as the straight length, concentricity, perpendicularity, the pressure point and the temperature-measuring point; we should control it according to the standard strictly, once departure, the additive uncertainty is considered.

4.1.2 The Ultrasonic Flow Meter, Electromagnetic Flow Meter, Turbine Flow Meter, and Vortex Flow Meter

These flow meters have the same operation principle, which is to measure the flow rate of full pipe in closed conduits. The Verification Regulation of JJG198-1994 rate flow meter is suited the verification of flow meters above, the main verification targets are: the intrinsic error, the repeatability, the instrument coefficients, and the linearity. Presently, the verification medium is mostly normal temperature water in the flow standard equipment of measure section; these flow meters apply to the measurement of (40-90)° C water, the change tendency of veracity what we know is very little, the report about this way is difficult to search in literatures in recent years. In the following period, the sections that can equip the experiment equipments of hot energy meter verification mostly localizes the small caliber verification, while the verification equipments above DN50 and even until DN1000 are not reach. If the error variety curve of various flow meters can be mastered in the contrast experiment between the conditions of cold and hot water, so the thermal measure sensor can be verified under the normal conditions, and affirm the measure characters. The verification cost can be reduced mostly, and provide the safeguard for thermal trade. Therefore, we advise that relative domestic institutions push for the conditions to develop the thermal measure verification and research on the large flow sensor, in order to support the operation of skeleton departments.

4.1.3 The elbow sensor

Through theoretical derivations and experiments, the elbow R/D is the only geometric characteristic parameter in theoretical model, which has the important function for flow measurement. R/D is the ratio of elbow conduits curvature radius to conduit diameter. The elbow conduit curvature radius R is a intangible space curve which could not be measured exactly by a simple method straightly. Therefore, the ratio measurement must be confirmed through indirect way. At present, the special measuring instruments can exactly measure the elbow diameter ratio by the equal string geometry measurement. If the measured value can be controlled in proper range ,that can be showed the comparability of its geometry. The relative standard uncertainty can be controlled within 0.5%. Through the real-fluid verification, it can be realized to the 1.0 level precision by using the secondary instrument.

4.2 Verification and calibration of the instrument and the device of the heat calculation and display

4.2.1 Real-time heating measuring device on computer

This apparatus is mostly used for hot measurement of the heavy-caliber pipeline and the flow sensor is standard orifice plate. According to the measurement performance request, the measuring electricity instrument with corresponding precision, multi-way standard direct current signal source, DC resistance box, standard ammeter, electronic timer are chosen. The major indicator needing examining includes: instantaneous flow, instantaneous heat, temperature, pressure, accumulation, sample cycle and so on.. The specific and detailed operation methods are neglected for the limited spacing and the calculation methods of theory value in the processing of verification are introduced as follows calculation formula:

$$q = 3600\frac{\pi}{4}\cdot\frac{c}{\sqrt{1+\beta^4}}\cdot\varepsilon\cdot d_t^{\,3}\sqrt{2\Delta P\cdot\rho}$$

where q: instantaneous flow, kg/h;

C: coefficient of discharge;

ε: expansibility factor;

d_t: the diameter of opening of

throttling component in working temperature, m;

ρ: the density of fluid, kg/m^3;

ΔP: differential pressure between the front and back of the throttling component, Pa;

β: diameter ratio;

It belongs to steam heat-supply for the pipeline that has the flow pipe without the return pipe, the heat computational formula:

$$Q = q_f (h_f - h_n);$$

the pipeline which has the flow pipe and return pipe belongs to hot water supply, considered losing water, the heat computational formula:

$$Q = q_f h_f - q_r h_r - (q_f - q_r) h_n$$

where

Q: instantaneous quantity of heat, kJ;

h: enthalpy value, $h=f(p, t)$, kJ/kg;

q: flow, kg/h;

the subscripts: 'f' is the water supply pipe, 'r' is the water return pipe, and 'n' is the nature water.

The resistance emulate method is used to adjust the temperature value displayed by computer, when the each value is no more than the maximum permissible error, that is up to grade. For the partnership temperature sensor, the class A resistant of Pt100 is used to verification solely. During the process of flow verification, the range of working conditions should be considered; to set some temperature and pressure points, and check the ability of dynamic correction.

4.2.2 Smart integrating instrument of flow

The input signals of the integrating instrument mainly has two common styles: current source and impulse. The JJG225-1992 heat meter has been abolished and taken place of by JJG225-2001, whose measure apparatus emphasize particularly on heat meter for industry. And some items about the measure method of temperature, pressure and instantaneous flow, still practical .in my opinion, they can be considered.

Current source (4-20) mA DC signal are mostly standard orifice-plate sensor signal with compensatory function for temperature and pressure. Numerical value of instantaneous flow can be calculated according to the formula in the item 2.1.Pay attention to the expansibility factor $\varepsilon=1$ in the formula; in the certain range of flow, the coefficient of discharge C is influenced slightly by pipeline Reynolds Number, so the modification is not needed. Usually the cut-off points of small flow signal is under below 5% of the flow range according to the measure precision of differential pressure transmitter.

In practical use, there is only one flow meter in pipeline for providing water or withdrawing water and usually we do not consider the lost water of pipeline and apparatus. The formula for instantaneous kinetic energy theory value is as follows:

$Q=q_m(h_f-h_r)$ (heat water for heating supply)

$Q= q_m h_f$ (steam for heating supply)

The impulse signal can be classified into ultrasonic, rotor, vortex or electromagnetic flow sensor, and we can choose highly accurate frequency signal generator to input pulse signal of standard flow to get instantaneous flow, instantaneous heat, accumulation. The formula for instantaneous flow is as follows:

$$q_m = 3600 \frac{f}{k} \cdot \rho$$

where q_m: mass flow, kg/h;

f: frequency of input signal, Hz;

ρ: density of the fluid, kg/m^3;

K: instrument coefficient;

In the condition of inputting pulse, the calculating method of instantaneous kinetic energy accords with that of current source

4.2.3 Smart elbow-flow heat integrating instrument of flow

The signal of this instrument is current source (4-20) mA DC signal, whose measuring quality is nearly the same as integrating instrument except that the method of mass flow is different. Here the formula for theory calculation of instantaneous flow:

$$q_m = 3.6\frac{\pi}{4} D_t^{\,2} \alpha \sqrt{\frac{R}{D}} \sqrt{\Delta P \rho}$$

where

q_m: mass flow, t/h;

D_t: internal diameter of the pipe after modifying the temperature, mm;

α : synthetical flow coefficient.

4.2.4 Power calculator

The verification of power calculator should be done strictly according to the component verification method in the regulation. In the procession formula the heat conventional true value can be calculated as follows:

$$Q = \frac{N}{1000K} \cdot (h_f - h_r) \cdot \rho$$

where Q: heat energy, MJ;

N: number of pulse;

K: instrument coefficient;

h: enthalpy of water in the current temperature, kJ/kg;

Most of the energy calculators can display the heat power, and in practical use this function considered to be an important parameter in watching heat supply is always asked to be measured. Because there is not any specific verification method in the verification regulation of the heat meter, the calibration can be taken in practical use and the theory value can be calculated according to the following formula:

$$P = \frac{f}{1000K} \cdot (h_f - h_r) \cdot \rho$$

where f: frequency of pulse, Hz;

K: instrument coefficient, pulse/l;

ρ: density of water in operating mode, kg/m^3

h: enthalpy of water in the current temperature, kJ/kg;

P: heat power, MW;

As some calculator-temperature sensors have three-wire connection, the consistency of the resistance of the three-wire connection should be pay attention to with the heat-meter's verification to avoid errors.

5.Conclusions and Suggestions

It should be emphasized that the above mentioned component verification methods have their inherent limitations. Though all the parts of the heat-meter are calibrated, the wiring style of the signal transmission between the sensor and the meters, also the electro-magnetic interference on the scene and other factors can occasionally cause the unconformity of the entirely operating quality and the results of the component verification, and even cause serious influence. The practices proved that the combination of laboratory component verification and the electrical voltage simulate test on the scene are effective when the entire verification can not be completed. How can the results of the component verification precisely describe the entire metric capability of the heat meters and the equipments, that is what we need research in the testing works later on.

Reference

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