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# Comparative Analysis on the Electromagnetic Flowmeters Standards for Water Flow Measurement in closed conduits at Home and Abroad

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**Abstract**

The electromagnetic flowmeter is one of the most important hydraulic structures to measure the water flow in closed conduits. Based on the collected current and latest electromagnetic flowmeter standards at home and abroad, this paper gives a comparative analysis of the technical parameters of electromagnetic flowmeters, including product parameters, measurement parameters and metrological parameters, classified by product standards, measurement standards and metrological standards. The results show that there are some differences among the technical parameters of these standards at home and abroad. It provides helpful and reference value for understanding the requirements of revising standards.

## 1. Introduction

Electromagnetic flowmeter based on Faraday's law developed in the 1950s and 1960s. With the development of modern electronic technology, different forms of electromagnetic flowmeter are widely used in flow measurement. The large diameter electromagnetic flowmeters are widely used in China's South-to-North Water Transfer Project, the Three Gorges of the Yangtze River and other large-scale hydropower projects to trade water flow measurement of irrigation and water transferring. It plays an increasingly important role in the national economy.

The standards of electromagnetic flowmeter are an important technical basis for flow measurement. They include product standards, metrological (verification/calibration) standards and measurement method standards. In order to study the standards of electromagnetic flowmeter at home and abroad, this paper deals with a comparative analysis on related technical parameters of affecting the performance of electromagnetic flowmeter.

## 2. Main technical standards

### *2.1 Current standards*

11 current standards of electromagnetic flowmeter are collected totally at home and abroad, including 1 international standard, that is ISO 20456:2017. 1 American standard, that is ASME MFC-16-2014. 1 British standard, that is BS EN ISO 20456: 2019. 1 German standard, that is DIN EN ISO 20456: 2020. 1 Japan standard, that is JIS B 7554-2017. 6 Chinese standards, that is GB/T 18660-2002, GB/T 18659-2002, GB/T 20729-2006, JJG 1033-2007, CJ/T 364-2011 and JB/T 9248-2015. The list of technical standards is shown in Table 1.

***Table 1.*** List of main technical standards for electromagnetic flowmeter at home and abroad

| Number of standard | Name of technical standard |
|---|---|
| ISO 20456:2017 | Measurement of fluid flow in closed conduits. Guidance for the use of electromagnetic flowmeters for conductive liquids |
| ASME MFC-16-2014 | Measurement of Liquid Flow in Closed Conduits with Electromagnetic Flowmeters |
| BS EN ISO 20456: 2019 | Measurement of fluid flow in closed conduits. Guidance for the use of electromagnetic flowmeters for conductive liquids |
| DIN EN ISO 20456: 2020 | Measurement of fluid flow in closed conduits - Guidance for the use of electromagnetic flowmeters for conductive liquids |
| JIS B 7554-2017 | Electromagnetic Flowmeters |
| GB/T 18660-2002（idt ISO 6817:1992） | Measurement of conductive liquid flow in closed conduits; method using electromagnetic flowmeters |
| GB/T 18659-2002（idt ISO 9104:1991） | Measurement of fluid flow on closed conduits; methods of evaluating the performance of electromagnetic flow-meters for liquids |
| GB/T 20729-2006（idt ISO 13359-1998） | Measurement of conductive liquid flow in closed conduits - Flanged electromagnetic flowmeters - Overall length |

| Number of standard | Name of technical standard |
|---|---|
| JJG 1033-2007 | Electromagnetic flowmeters |
| CJ/T 364-2011 | Online calibration requirement for piping electromagnetic flowmeter |
| JB/T 9248-2015 | Electromagnetic flowmeter |

### *2.2 International standard*

ISO 20456:2017 replaces ISO 6817:1992, ISO 9104:1991 and ISO 13359:1998. In addition to structural adjustment and editorial changes, ISO 20456:2017 main technical changes compared with withdraw standard including:

1) In terms of product performance, ISO 20456:2017 only specifies the qualitative technical requirements of performance evaluation, and does not specify the specific evaluation performance index, which simplifies the detailed and operable performance in evaluating method in ISO 9104:1991.

2) In terms of calibration, ISO 20456:2017 deletes the nominal calibration conditions, interpretation of results and pressure testing offered in ISO 6817:1992. The requirement of flowmeter verification (in-situ electronic verification) is added, and the uncertainty analysis is altered.

3) In terms of measurement method, ISO 20456:2017 adds the requirement for effecting of non-ideal flow conditions and the sensors of buried and submerged. The general technical requirements for potential equalization is added as well. The accessing for maintenance and cleaning of sensors is simplified, which is detailed introduction in ISO 6817:1992.

### 2.3 *Standards of major developed countries*

British standard and German standard are equivalent international standard ISO 20456:2017, which adopted in 2019 and 2020 respectively. The Japan standard does not reflect the relationship with international standards.

### 2.4 *Chinese standard*

China has issued six standards, among which three standards GB/T 18660-2002, GB/T 18659-2002 and GB/T 20729-2006 are identical to ISO 6817:1992, ISO 9104:1991 and ISO 13359:1998, but these three international standards have been withdrawn by ISO 20456:2017. The electromagnetic flowmeter standards issued by China involve the product standards, verification/calibration standards and measurement method standards respectively.

## 3. Comparative analysis on the parameters

### 3.1 *The product parameters*

3.1.1 *Scope*

The most standards are applicable to industrial electromagnetic flowmeters used for measurement of flowrate of a conductive liquid in a closed conduit running full. And they are not applicable to insertion-type flowmeters or electromagnetic flowmeters designed to work in open channels or pipes running partially full, nor do they apply to the measurement of magnetically permeable slurries or liquid metal applications.

ASME MFC-16–2014 is applicable in electrically conductive and electrically homogeneous liquids or slurries flowing in a completely filled, closed conduit.

3.1.2 *The conductive liquid*

Based on the basic theory of electromagnetic flowmeter, the measured liquid must be conductive medium, which is the most fundamental prerequisite for using electromagnetic flowmeter.

The specific value of liquid conductivity is not given in ISO 20456:2017. ASME MFC -16-2014 stipulates that when the conductivity of liquid is (5 ~20) μS/cm, the measurement result of the flowmeter will not be affected. The range of liquid conductivity specified in Chinese standards GB/T 18659-2002 and JJG 1033-2007 is (50 ~5000) μS/cm, or according to the technical indicators given by the flowmeter manufacturer.

### 3.2 *The metrological parameters*

3.2.1 *Accuracy of electromagnetic flowmeter*

ISO 20456:2017 and ASME MFC -16-2014 specify four basic types of accuracy. See Table 2 for details. JJG 1033-2007 gives seven accuracy class, which are 0.2, (0.25), (0.3), 0.5, 1.0, 1.5, 2.5 respectively, and the accuracy class without brackets are preferred, and the maximum allowable errors correspond to ± 0.2% (± 0.25%) (± 0.3%) ± 0.5% ± 1.0% ± 1.5% ± 2.5% respectively.

***Table 2.*** accuracy specifications

| Type of Accuracy Specification | Accuracy Statement |
|---|---|
| % of reading | ± 0.X% of reading |
| % of full scale | ± 0.X% of full scale |
| Combination | ± 0.X% of reading ± 0.X% of full scale<br>± 0.X% of reading ± 0.X ft/sec |
| Divided range | ± 0.X% of reading (> X ft/sec)<br>± 0.XX ft/sec (0.X–X ft/sec)<br>Undefined < 0.X ft/sec |

3.2.2 *Liquid flow rate*

The increase of flow rate will lead to the synchronous increase of measurement background noise, which will greatly reduce the measurement accuracy.

CJ/T 364-2011 has made technical provisions on the flow rate of the calibrated liquid: the actual flow rate of the liquid should not be less than 0.3m/s, and there are no specific provisions on the technical indicators of this parameter in other technical standards.

3.2.3 *Accuracy of transfer measurement device*
The transfer measurement device is used to reproduce and transmit the flow value. ISO 20456 :2017 does not refer the relevant accuracy requirements of the flow standard device. American and Chinese standards specify that the accuracy level of reference measurement standard should be at least three times higher than that of the tested electromagnetic flowmeter.

**3.3 *The measurement parameters***

3.3.1 *Rated ambient condition*
When the ambient temperature changes, the cross-sectional area of the flow measurement pipe will also change accordingly, resulting in changes in the distribution of the fluid velocity field, so that the flowmeter can not accurately measure the flow rate. ISO 20456-2017 and ASME MFC-16-2014 do not give specific values of environmental conditions of electromagnetic flowmeter. According to GB/T 18659-2002 and JJG 1033-2007, the test environmental conditions of electromagnetic flowmeter are (4 ~ 35) ℃, the relative humidity is 15% ~ 85%, and the atmospheric pressure is (86 ~ 106)kPa. The working conditions of electromagnetic flowmeter are generally (-10~55) ℃, and the verification environmental conditions are generally (5 ~ 35) ℃.

3.3.2 *Length of straight pipe*
When installing electromagnetic flowmeters in practical applications, it is often necessary to install pipe fittings (bends, valves, reducers, etc.) placed upstream, which will cause flow distortion in velocity profiles. To restore the axisymmetric velocity distribution of the fluid, a certain length of straight pipe is required.

ISO 20456:2017 requires the length of the straight pipe is at least 5 times length of the pipe diameter placed upstream and at least 2 times length of the pipe diameter placed downstream. ASME MFC-16-2014 only emphasizes that the straight pipe length should be set according to the manufacturer's regulations when installing the electromagnetic flowmeter, but it does not give a specific value. GB/T 18659-2002 stipulates that the length of the upstream straight pipe of the electromagnetic flowmeter shall be at least 10 times the length of the pipe diameter or specified by the manufacturer, but there is no specific requirement for the length of the downstream straight pipe. The requirements of GB/T 18660-2002 and JJG1033-2007 for the length of straight pipe is at least 10 times length of the pipe diameter placed upstream and at least 5 times length of the pipe diameter placed downstream.

3.3.3 *Connection pipe size*
To minimize pressure loss in cases where a sensor with a smaller nominal bore than the connecting pipe is installed, it is advisable to connect the sensor into the pipe work by means of shallow tapered cone pieces.
ISO 20456:2017 recommends a maximum included angle is $16^0$, and GB/T 18660-2002 recommends a maximum included angle is $15^0$.

**4. Conclusions**

(1) Chinese standards GB/T 18660-2002, GB/T 18659-2002 and GB/T 20729-2006 are identical to ISO 6817:1992, ISO 9104:1991 and ISO 13359:1998, but these three international standards have been replaced by ISO 20456:2017. China urgently needs to revise these three national standards.
(2) In the product parameters, ASME MFC-16–2014 is applicable in electrically conductive and electrically homogeneous liquids or slurries flowing in a completely filled, closed conduit. the standard scope is wider than ISO standard and other countries' standards of electromagnetic flowmeters. It stipulates that the conductivity of liquid is (5 ~20) μS/cm, which range is lower than the range of liquid conductivity (50 ~5000) μS/cm specified in Chinese standards GB/T 18659-2002 and JJG 1033-2007.
(3) In the metrological parameters, International, American, British and German standards have consistent provisions on accuracy, but Chinese standard adopts accuracy class and the maximum allowable errors. Chinese standard specifies the actual calibrated flow rate of the liquid should not be less than 0.3m/s
(4) In the measurement parameters, ISO 20456-2017 and ASME MFC-16-2014 do not give but Chinese standard gives the specific values of environmental conditions of electromagnetic flowmeter. Length of straight pipe placed upstream and downstream are different specified in ISO and Chinese standard. To minimize pressure loss caused by a sensor with a smaller nominal bore than the connecting pipe, the maximum included angle between International standards and Chinese standard are basically consistent.

**References**

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