

Establishment of Traceability System for Hydrocarbon Flow in Japan

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Abstract: Generally the construction costs of a calibration facility for hydrocarbons are very high and it is difficult to cover every kind of hydrocarbon and all flow rate ranges required at industry. So far, at the primary standard in Japan, the calibration liquids are limited to kerosene and light oil, in spite of the demands from the industry for other hydrocarbons such as gasoline and heavy oil. Therefore the expansion techniques from the present primary standard to other liquids such as gasoline and heavy oil using flowmeters have been developed. Furthermore the standard flow has expanded to large flow rate range using flowmeters as accurately as possible at calibration laboratories. Consequently the traceability system for hydrocarbon flow using flow standard has been established.

Keyword: Traceability system, Hydrocarbon flow, Primary standard

1. Introduction

The measurement of hydrocarbon flow is important as a basis of quantity for the trade and taxation of petroleum products, and for the production control at the petrochemical plants. The accuracy of the flowmeter used in flow measurement is influenced by the property of liquids, the condition of flowmeter installation, and the condition of the flow. Therefore, to operate the flowmeter in a condition that ensures high accuracy, it is necessary to calibrate the flowmeter by standard flow. Also, periodical calibration is necessary to guarantee the performance of the flowmeter currently used.

The annual petroleum trade in Japan is approximately 29 trillion Japanese yen (290 billion USD)[1], and the merchandise value is said to be several times that amount. Tens of thousands of hydrocarbon flowmeters that provide the basis for the quantity entered on the trading certificates are in operation in the petrochemical complexes throughout Japan. Accurate measurement using the hydrocarbon flowmeter is in demand by industry and society. The range of flow measurement is mostly 1~1000 m³/h, and particularly the measurement of several hundred m³/h used for tanker truck is most frequently used. There are many types of petroleum, including gasoline, kerosene, light oil, heavy oil, and crude oil. Positive displacement flowmeter and turbine flowmeter are used most frequently. Currently, the precision demanded of flowmeters is very strict, and the level of uncertainty required for hydrocarbon flow standard is high.

On the other hand, with the advance in measurement technology, there has been a recent increase in the demand for high accurate flow measurement, as well as for measurement of more types of petroleum products and wider flow range, so that the companies can perform voluntary high accurate quality control on their own. Moreover, with the internationalization of economic and production activities, the international trade of the Japanese petroleum products is increasing, and it is mandatory to guarantee the integrity of the international flow measurement values. Therefore, there is a demand to provide a standard with international integrity to the users and to also offer

choices of maintaining the metrological traceability in accordance to the international system. However, calibration liquids and flow rate range at the primary standard in Japan are limited. Also, since the definition of metrological traceability was scientifically established, the metrological traceability could no longer be maintained with the conventional system that did not address uncertainty ^[2].

AIST newly constructed the national standard facility for large hydrocarbon flow in 2001, and after conducting the uncertainty evaluation and building up the quality system, it was designated as the primary standard for hydrocarbon flow according to the Measurement Law of Japan in 2005. Furthermore the national standard at the middle range of flow rate was established in 2008. Since the range of the primary standard for hydrocarbon flow was limited, under a government-supported research project and with cooperation from private petroleum companies, the technologies to expand the range of liquid types and flow range were developed at the level of secondary standards that were in possession of the calibration laboratories. This completed the traceability system of measurement in Japan, and the Japan Calibration Service System (JCSS) for hydrocarbon flow was established utilizing the capabilities of the accredited laboratories.

2. Traceability System for Hydrocarbon Flow in Japan

In the actual on-site measurement of the hydrocarbon flow, it is necessary to conduct the flow measurements with minimum uncertainty using minimum resources (cost, time, etc.), and the reliability must be guaranteed. Since the flow standard is set up using other physical quantities such as mass, volume, time, density, temperature, and pressure, it is necessary to clarify “who and where” the set up of the standard flow from other standards will be done in providing the national standard. Since there was no calibration device for hydrocarbon flow that could be used as a national standard in Japan, the work of setting up the flow rate from other physical quantities was left to the flowmeter manufacturers and users, and the reliability was unknown. The provision of the flow standard can be categorized roughly into the following three ^[3]:

(1) Method where the NMI provides the flow standard

If the national metrology institute (NMI) sets up the flow standard as a national standard, it will be highly reliable, and an ideal traceability system could be constructed. However, there is a diversity of petroleum products and the range of flow rate is extremely wide, and it is not realistic to create and provide the flow standards for all liquid types and flow ranges used in society. Even if all flow standards with small uncertainties at a national standard level can be provided to fulfill the diverse flow measurement conditions actually used, such systems will be extremely expensive. As a result, the user who pursues a balance of uncertainty and cost will most likely select the service of the calibration laboratory described in (2).

(2) Method where the calibration lab calibrates the flowmeter using the standards for other physical quantities (such as volume)

This is a method where the calibration laboratory conducts the calibration of flowmeters using not the national flow standard, but instead, for example, the mass and density standards. In this method, even in a case where the calibration lab uses the mass and density standards, if the calibration of the flowmeter is done using inappropriate combinations, it may lead to problems such as missing an important correction value or underestimating the uncertainty. It is generally said that kinds of liquid and flow rate are unconditionally extensible using a prover or a volume tank. However, an unexpectedly large uncertainty may occur by this method. Also, establishing

the technology to achieve small uncertainty is a great burden on individual calibration labs, and it may result in increased social cost of measurement control. It is also difficult to guarantee reliability, and this may be a disadvantage to the users. On the other hand, this method is highly expandable, and the calibration lab can adapt this method to diverse liquid types and flow rates.

(3) Method of using the flow standard provided by overseas institutes

Although the flow standard is employed in many countries, this method will force dependence on foreign standards, and it is difficult to achieve small uncertainty required in Japan. Also, the flowmeter must be transported abroad for calibration, and the reliability decreases in that process.

Since there was no national standard for hydrocarbon flow in Japan, method (2) was employed using a standard established by the law for the calibration and testing of specified measurement devices for trade. However, it became necessary to establish a national flow standard due to the recent increasing demand for the calibration of devices that cannot be covered by method (2), including high accurate flow measurement, measurement of diverse liquid types and flow ranges, and measurement that guarantees international integrity. Therefore, the combination of method (1) that achieves reliability and (2) that focuses on expandability was selected. This is a method where AIST provides the flow standard with high accuracy (small uncertainty) for core flow rates and liquid types, and the calibration lab extends the ranges of standard flow rates and expands the liquid types using the calibration device it already owns, by utilizing the JCSS. Fig. 1 shows details of the division of labor between AIST and the calibration lab for the liquid types and flow ranges. Assuming the flow ranges of the flowmeter used for tanker shipment, 300 m³/h was set as the maximum flow rate in this national standard, and the liquid type was set as kerosene and light oil because their viscosity is of medium level.

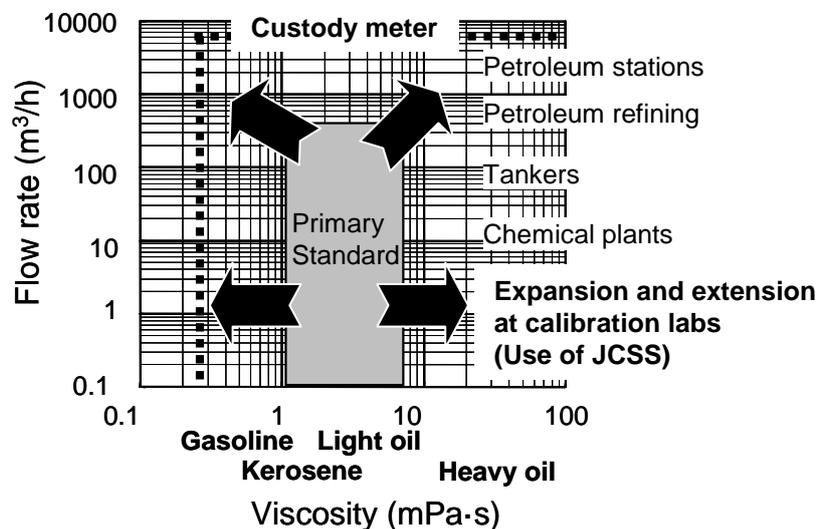


Fig. 1 Diagram for the work division according to liquid types and flow ranges between the national standard and the calibration labs.

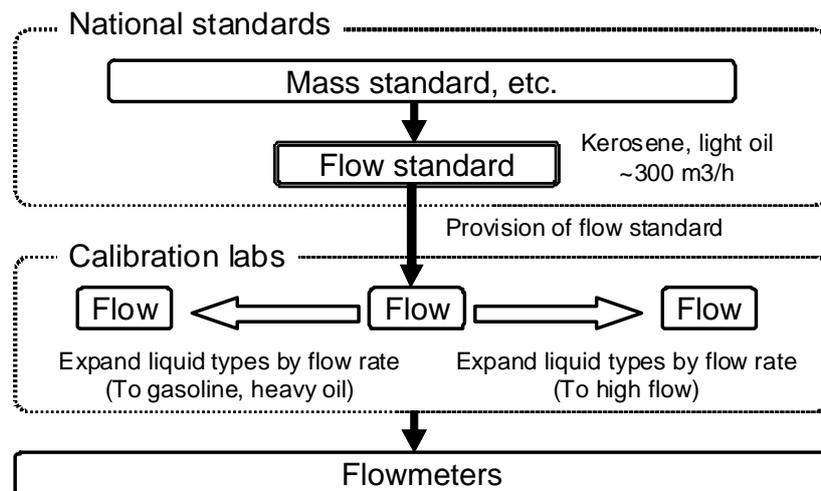


Fig. 2 Outline of the traceability system for hydrocarbon flow.

3. National Standard for Hydrocarbon Flow in Japan

A specification of national standards for hydrocarbon flow in Japan is shown in Table 1^{[4]-[7]}. Light oil and kerosene are used as the working liquids; each oil has a separate test line at the large calibration facility. The flow rate range is from 3 to 300 m³/h. Although the kerosene and light oil test rigs are isolated, both test rigs cannot work simultaneously since a common chiller unit to control the liquid temperature is used. The calibration method adopted as the national standard for measuring hydrocarbon flow is a static and gravimetric method with a flying start and finish using a diverting system. In this method, liquid (kerosene or light oil) passing through the flowmeter via a nozzle of the diverter is collected in a weighing tank on a weighing scale for a given time, and then the standard mass flow rate is obtained by dividing the total mass of liquid, which is measured by the weighing scale, by the collection time. Furthermore, the volumetric flow rate is calculated by dividing the mass flow rate by the liquid density. The calibrations are carried out by comparison between the standard flow rates and those indicated by the calibrated flowmeter. One of the characteristics of the calibration method using a diverter is the small changing flow during measurement in comparison with the flow-switching method using valves.

Table 1 Specifications of national standards for hydrocarbon flow in Japan.

	Large flow rate range	Middle flow rate range
Flow rate range	3 ~ 300 m ³ /h	0.1 ~ 15 m ³ /h
Liquid	Kerosene, Light oil	Kerosene, Light oil
Temperature	15 ~ 35	10 ~ 35
Uncertainty (Mass flowmeter)	0.020 %	0.020 %
Uncertainty (Volumetric flowmeter)	0.030 %	0.030 %

4. Efficient JCSS Traceability System

To respond to the demands of industry that uses the flowmeter for diverse petroleum products at wide flow range, it is necessary to expand the flow range and the range of liquid types from the national standard through the Japan Calibration Service System (JCSS). Therefore, in a government-supported research project^[8], we developed the technology to enable easy expansion to different liquid types by adding an advanced analysis to the characteristic of the flowmeter that is dependent on the liquid viscosity, and the technology to extend the flow range by the parallelization of the flowmeters^[8]. Fig. 3 shows cases where the calibration capacity of Japanese calibration laboratories was surveyed to verify the adequacy of these new calibration technologies^[3]. As shown in the result for 2005, the calibration facility that originally had deviations of $-0.05\% \sim +0.10\%$ from the national standard significantly improved the calibration capacity to match within $\pm 0.03\%$ of the national standard, by calibrating its facility using the flowmeter calibrated by the national standard. Moreover, the values for heavy oil that is out of the range of calibration using the AIST national standard matched $\pm 0.03\%$ of the values of the overseas calibration institutes, and this implies that the method for expanding the liquid types, developed for the project, was adequate.

We also drafted the Guidelines on the Technological Requirement^[9] to technologically support the National Institute of Technology and Evaluation (NITE) that accredits the calibration labs that receive the national standard. As a result, the number of accredited and registered calibration labs are increasing as a new business.

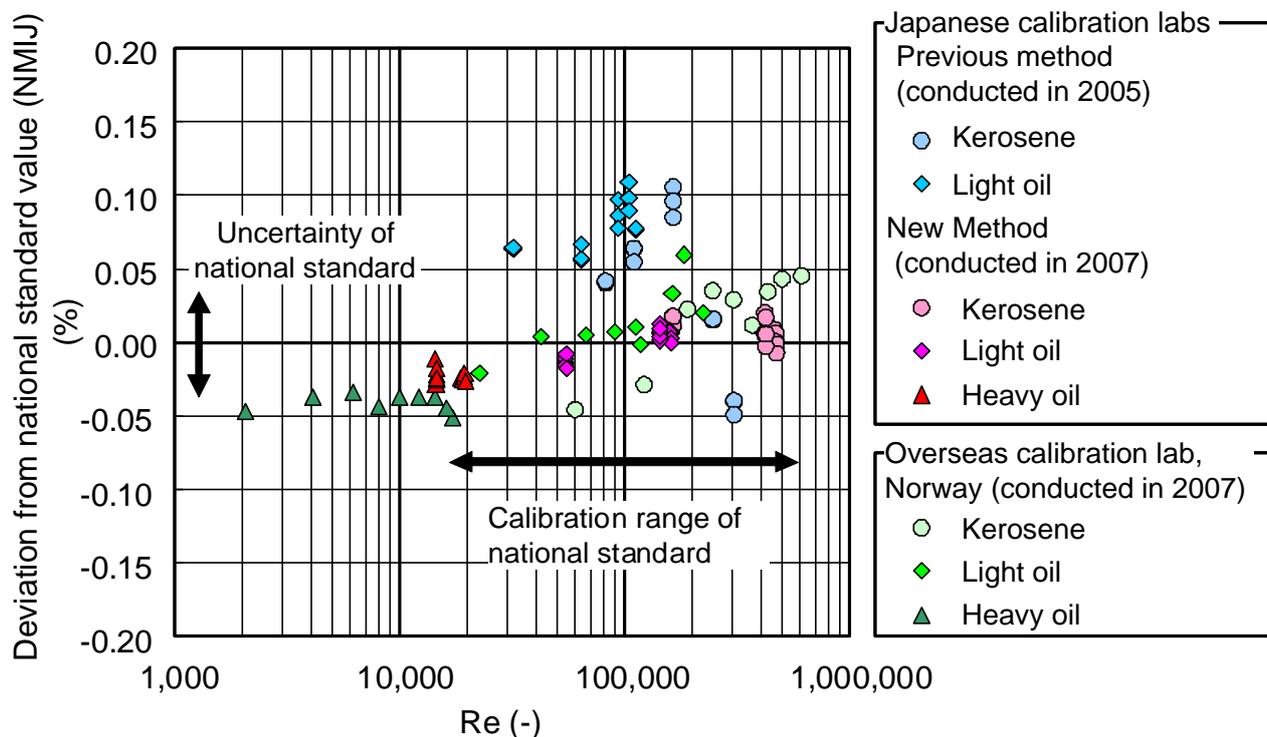


Fig. 3 Deviation from the national standard value (NMIJ). The Re number do not match since the flowmeters used in 2005 and 2007 were different. The calibration range of the national standards is provided as reference.

5. Conclusion

In this paper, we reported on the adequacy of the national standard and the construction of the traceability system that could be used by the user. Currently, we are providing technical support to calibration labs that wish to be accredited under the JCSS, to achieve efficiency of the precision management of the flowmeters used in practice. In the future, there are necessities for the establishment of new technological standards, the technological advices for changed regulations, and the improvement of the traceability systems to meet the social demands.

Acknowledgment

The surveys of the technological trend among the flowmeter calibration laboratories and the NMIs of various countries played important roles in this research. These were obtained as the research results of the Hydrocarbon Flow Research Consortium Session, in which the petroleum companies and the flowmeter manufacturers participated, organized by the Japan Measuring Instruments Federation.

References

- [1] Petroleum Association of Japan: *Konnichi No Sekiyu Sangyo (Today's Petroleum Industry)*, 2009 (in Japanese).
- [2] ISO/IEC, International vocabulary of metrology – Basic and general concepts and associated terms (VIM), GUIDE 99:2007.
- [3] T. Shimada, R. Doihara, Y. Terao, M. Takamoto, Development of primary standard for hydrocarbon flow and traceability system of measurement in Japan, 2010, Vol.3, 1, 53-63
- [4] R. Doihara, T. Shimada, Y. Terao, M. Takamoto, Development of the national standard facility for hydrocarbon flow at 0.1 to 15m³/h, FLOMEKO 2007.
- [5] T. Shimada, R. Doihara, Y. Terao, M. Takamoto, K. Stolt, A. Andersson, New primary standard for hydrocarbon flowmeters at NMIJ - International comparison between NMIJ and SP - , The 11th International Conference on Flow Measurement 2003, Netherlands, 2003.
- [6] T. Shimada, R. Doihara, Y. Terao, M. Takamoto, Uncertainty Analysis of Primary Standard for Hydrocarbon Flow at NMIJ , The 12th International Conference on Flow Measurement 2004, China, 2004.
- [7] T. Shimada, R. Doihara, Y. Terao, M. Takamoto, Development of hydrocarbon flow calibration facility as a national standard, *J. Fluid Science and Technology*, 2007, 2: 23-34.
- [8] National Institute of Advanced Industrial Science and Technology: Research on the flowmeter quality control technology for the rationalization of hydrocarbon distribution, *METI Subcontract Funds FY 2007 Result Report*, 2008 (in Japanese).
- [9] National Institute of Technology and Evaluation: Guideline for the technical required items – Category for registration: Category (designations) of calibration method for flow volume and flow rate, *Liquid Flowmeter (Hydrocarbon Flowmeter)* (7th ed.) JCT20830-07, 2009 (in Japanese).