Reflections on compensating for expanded uncertainty by decreasing the maximum permissible error in initial verifications of oil flow measurement systems

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Abstract: The objective of this work is to bring reflections on the reductions of the maximum permissible error to the detriment of a non-conform expanded uncertainty in initial verifications of oil flow measurement systems, according to the metrological technical regulation in force in Brazil. The research used calculations to estimate the State's governmental participation, in oil production, to facilitate the reflections, as well as calculations to reduce the maximum permissible error proposed by international recommendation. In the end, it was possible to verify that the change in the maximum permissible error criteria in the initial verification of flow measurement systems could have consequences in the measurement of oil and that such change must be preceded by a cautions impact analysis.

1. Introduction

Brazil, like the rest of the world, still shows great dependence on oil for energy generation, fact easily observed by the economic impact generated by repeated tensions involving this matrix, such as the world oil crisis of 1973, the strong deficit in the distribution of the energy matrix in the strike started by truck drivers in 2018 in Brazil, with consequences for the prices of food and other consumer goods and the drop in the price of oil barrel in the financial market in the first quarter of 2020.

In order to regulate the construction and the minimum metrological performance that the Flow Measurement System (FMS) applied in the extraction and in other important activities with regard to oil and in conformity with the Joint Ordinance ANP-Inmetro n° 001 of June 19, 2000 [1] the then National Institute of Metrology, Standardization and Industrial Quality - current National Institute of Metrology, Quality and Technology (Inmetro) - published Metrological Technical Regulation (MTR), granted by Ordinance Inmetro n° 64 of April 11, 2003 (hereinafter, Ordinance 64/2003).

In July 2021, Inmetro revised the MTR that accompanied the aforementioned Ordinance, issuing the Ordinance 291 of July 7, 2021 (hereinafter, Ordinance 291/2021) – approving the consolidated Metrological Technical Regulation for dynamic measurement systems equipped with meters for the quantity of liquids [2].

However, Ordinance 291/2021 does not consider the most recent edition, of the international recommendation IR (International Recommendation) OIML (International Organization of legal

Metrology) R-117, a document that lists suggestions for the elaboration of regulations for liquid flow measurement systems, except water, which dates from 2019, and which served as the basis for the elaboration of the MTR of Ordinance 64/2003.

Among the MTR and the IR requirements and suggestions, respectively, there are technical and metrological guidelines for the FMS operation, but also for its legal control, including model evaluation criteria and initial verification. According to the International Vocabulary of Legal Metrology Terms verification of a measuring instrument is the “conformity assessment procedure (different from model assessment) that results in the affixing of the verifications mark and/or the issuance of a verification certificate” [3] and initial verification is the “verification of a measuring instrument that has not been previously verified” [3].

The checks carried out on measuring instruments, subject to legal metrological control, include physical inspections and performance analyses, especially to assess measurement errors, in order to ensure that the reproduction of the approved model complies with the relevant technical regulations. Below is a table that demonstrates the Maximum Permissible Error (MPE) of an FMS according to its accuracy classes.

Table 1. MPE according to accuracy classes [2]

Accuracy classes	0.3	0.5	1.0	1.5
A (%)	0.3	0.5	1.0	1.5
B (%)	0.2	0.3	0.6	1.0

In time, the values in line A of Table 1 represent the MPE assigned to the already constituted FMS, while the values in line B represent the MPE of an isolated flow meter. From the comparison between the MTR that accompanies Ordinance 291/2021 and IR OIML R117/2019, it was found that one of the suggestions, proposed by the international recommendation, was not fully adopted by the list of requirements of the technical regulation.

According to item 4.2.1 of the international recommendation “when a test is conducted, the expanded uncertainty of the determination of errors on indications of volume or mass shall be less than one-fifth of the maximum permissible error applicable for that test during type evaluation and one-third of the maximum permissible error applicable for that test during other verifications” [5]. Still, the suggestion not fully used by the technical regulation, contained in 4.2.2 of the recommendation, says that “[...] if it is technically or economically impractical to reach an uncertainty of 1/5 and 1/3 of the MPE, a “reduced MPE = (6/5 × MPE – U)” and a “reduced MPE = (4/3 × MPE – U)” respectively may be used” [5].

Where:

- Reduced MPE is the Reduced Maximum Permissible Error;
- MPE is the Maximum Permissible Error;
- U is the expanded uncertainty.

In other hand, requirement 5.2.1 of the MTR that accompanies Ordinance 291/2021 determines that when an initial verification test is carried out, the expanded uncertainty of the measurements used in the determination of errors in the indications of volume or mass must be less than one-third of the maximum permissible error [2].

As can be seen from the previous citations, IR OIML R-117/2019, unlike the MTR in force, admits that, when carrying out an initial verification, instruments associated with an FMS that do not have expanded uncertainty between the ± 1/3 MPE interval, may comply with metrological effectiveness criteria if the maximum error of the instrument under analysis is within the range of a reduced maximum permissible error, according to the equations.

In Brazil, Inmetro is responsible for complying with legal metrology, which is in a way, operationalizes […] through checks and inspections […] [6].

As an example, considering that an FMS, accuracy class 0.3 was subjected to the tests of an initial verification, it has a flow meter with an expanded uncertainty of 0.2% and maximum error of 0.2%, determined during the tests. If requirement 5.2.1 of the MTR were applied, the FMS in question would not be approved in the initial verification, since 0.2% is greater than 0.1%. However, if the MPE reduction equation is applied, we have:

$$MPE_{reduced} = \frac{4}{3} \cdot 0.3 - 0.2 \quad (1)$$
$$MPE_{reduced} = 0.2$$

The equation demonstrates that, for the proposed case, if the alternative suggested by the IR were adopted, the MPE for class 0.3 would no longer be 0.3% and would fall to 0.2%, as a measure of compensation for the non-conformity expanded uncertainty of the meter. Therefore, the nonconformity for this parameter of the initial verification would no longer exist.

2. Literature review

2.1. Metrological Technical Regulation

According to the Guide to Good Regulatory Practices, a Technical regulation is "a document that sets out the characteristics of a product or the processes and production methods related to it, including the applicable administrative provisions, whose compliance is mandatory" [7].

In Brazil, the Metrological Technical Regulation is a mandatory document in the national territory, under the responsibility of Inmetro, applied to those who wish to import, produce, build, market, distribute or operate measuring instruments or any other device that influences measurements, within legal metrological control of measuring instruments contemplated by Conmetro resolution nº 08, of December 22, 2016, which describes in which applications such control must be carried out.

An MTR can also refer to labelling and quantitative control of pre-measured products.

2.2. Flow Measurement System

A measurement system is the set of one more measuring instruments and often other devices, comprising, if necessary, reagents and inputs, assembled and adopted to provide information aimed at obtaining the measured values, within specified intervals for quantities of specified natures [8].

A flow measurement system is an association of measuring instruments and other equipment, dedicated to quantifying the dynamic volume of one or more fluids. The oil and natural gas measurement system includes the meter itself, and all auxiliary and additional devices, and associated measurement instruments, applied to a measurement point [9].

It is important to note that there are two types of flow measurement systems: fixed and compact and mobile. Their technical and metrological characteristics and MPE limits must satisfy the same criteria, differing only with regard to their respective model evaluation processes, as well as their mobility.

2.3. International Recommendation IR OIML R-117

Before briefly approaching the recommendation itself, it is important to briefly explain what it is and what is the main function of the OIML. The International Organization of Legal Metrology is a worldwide and intergovernmental organization whose primary objective is to harmonize the regulations and metrological controls applied by the national services, or related organizations, of its Member States [4]. In other words, this organization comprises countries that seek to harmonize their metrology laws with each other, through technical recommendations. Thus, the requirements for conformity of products and services are minimally standardizes and technical barriers to foreign trade are mitigated.

IR OIML R-117 sets out numerous suggestions that may become regulatory requirements related to the conformity of flow measurement systems for liquids other than water. This reference document brings its suggestions separated into 3 distinct parts:

- Part 1: Technical and metrological requirements;
- Part 2: Metrological control and performance tests;
- Part 3: Test report format.

2.4. Government participation or royalties

Under Resolution 01/2013, government participation is understood to be the effective cost of compensation related to oil extraction, more popularly known as royalties and are applied to the fiscal measurement points of oil. Royalties correspond to the compensation due to the Union, the States, the Federal District and the Municipalities for the exploration and production of oil, natural gas and other fluid hydrocarbons [9]. One of the reasons for charging this indemnity is related to the fact of exploiting a limited resource, although still abundant. The calculation that quantifies government participation, for a giver period, represented by:

$$Production\ value = (V_{oil} \cdot P_{oil}) + \left(V_{ng} \cdot P_{ng}\right) \text{ [11]} \quad (2)$$

$$Royalty = Rate \cdot Production\ value \text{ [11]} \quad (3)$$

Where:

- Royalty is the amount resulting from field production in the calculation month, in BRL;
- V oil is the oil production volume of the field in the calculation month in m 3 ;
- P oil is the reference price for oil produced in the field in the month of calculation, in BRL/m3 ;
- V ng is the natural gas production volume of the field in the calculation month, in m^3;
- P ng is the reference price of natural gas produced in the field in the month of calculation, in BRL/m^3. That is, these equations indicate the need for a dynamic measurement of the volume of hydrocarbons traceable to the best metrological standards.
- Rate is the percentage, owed to the State, of the production value of oil, natural gas and other hydrocarbons, generated in the reference month, provided for in the concession contract for a given field;
- Production value is the value corresponding to the gross collection for the production of oil, natural gas and other hydrocarbons by the field.

2.5. Measurement uncertainty

It is known that, for any measurements performed, the measurement process is influenced by other external quantities, which makes the measurement result an estimate of the true value (which is also estimated).

The result of a measurement will always present a doubt associated with the measurement, a doubt that we consider the measurement uncertainty. What is sough in a measurement with metrological reliability is to estimate the results and their associated uncertainty as faithfully as possible. Measurement uncertainty will always exist and will never be eliminated [...] [12].

Expanded uncertainty is defined by the International Vocabulary of Metrology as the product of a standard uncertainty combined with a factor greater than the number one [8].

3. Discussion

IR's suggestion, if the associated measurement instrument subjected to initial verification tests of an FMS, does not obtain an expanded uncertainty of less than one third of the MPE needs to be approached with great care.

It should be taken into account that a technical regulation, even those that consider international guidelines and regardless of the scope or area of application addressed, is an adapted document that seeks to discipline economic agents with contours adequate to the reality of the country that developed it, at the same time that it seeks to resolve the effects of technical barriers to foreign trade.

It is important to note that the MTR that accompanies Ordinance 291/2021 is used in order to standardize and discipline minimum criteria to be met by FMS used in the production and operation of oil, that is, these measurement systems are directly involved in the calculation of government participations, more commonly called royalties, owed to the government.

According to the monthly oil and natural gas production bulletin, issued by the ANP, in March 2023, the field with the highest oil production was Tupi, in the Santos Basin, with 135 202 951 L of hydrocarbon extracted, on average, daily [13]. Assuming that all FMS installed at the field measurement point have the lowest maximum error permissible for an FMS (± 0.3%), established by Ordinance 291/2021, a product of ± 405 608.85 L is obtained, as:

$$135\ 202\ 951\ (L) \cdot 0.003 = 405\ 608.85\ L \quad (4)$$

Converting the volume supposedly not totalized, due to the summed average errors of the FMS in operation in the Tupi field, to the current national monetary value (real), by multiplying the volume supposedly not totalized by the field and the price of a liter of oil (R$ 2.30 on 05/14/2023), we obtain ± R$ 932 900.36, in approximate value.

The last calculated value (± R$ 932 900.36) represents the maximum daily amount that, for this hypothetical case, can be legally not accounted for the interference of disturbances in the Tupi field. The amount of daily monetary compensation due to the treasury, considering the 15% rate established by law, for the example suggested above, is calculated using the equations in (2) and (3).

$$Production\ value = 135\ 202\ 951 \cdot 2.30 \quad (5)$$
$$Production\ value = R\$\ 310\ 966\ 787$$
$$Royaltie = 0.15 \cdot R\$\ 310\ 966\ 787 \quad (6)$$
$$Royaltie = R\$\ 46\ 645\ 018.10$$

Substituting the average daily production volume of the field, of 135 202 951 L, by the average measurement error, of ± 405 608.85 L, in the royalty determination calculation, we have:

$$Production\ value = 405\ 608.85 \cdot 2.30 \quad (7)$$
$$Production\ value = R\$\ 932\ 900.36$$
$$Royaltie = 0.15 \cdot R\$\ 310\ 966\ 787 \quad (8)$$
$$Royaltie = R\$\ 46\ 645\ 018.10$$

In this case, it is observed that the average daily values of royalties from the Tupi field can legally vary within the range of ± R$ 139 935.05, an amount equivalent to ±0.3% of the total amount under ideal conditions.

Thus if the error of a FMS interferes in the capture of indemnities due to the treasury and there is a criterion for this error to be evaluated, the change of this criterion must be carefully treated. As attractive path may seem, changing the MPE of the FMS could have significant consequences for capturing royalties, even if the reduction in the MPE compensates for an expanded non-conform uncertainty.

In addition to the totalization of volume in fiscal measurements, a significant change such as the MPE could have implications for foreign trade, if the metrological guidelines for these applications in the international field are not observed, which, ultimately, could be a source of technical barriers to export and import.

A multidisciplinary analysis of regulatory impact in which, mainly, data is collected form countries that adhered to the proposal so that measurements could be accessed in a reproducible condition could be a relevant option to evaluate the alternative suggested by the IR.

4. Conclusions

This work presents reflections on a possible adoption of the suggestion of a reduction of the MPE at the expense of an expanded non-conform measurement uncertainty in initial FMS verifications, proposed by IR OIML R-117/2019.

Through the analysis of hypothetical examples, it was observed that the measurement error of an FMS used in oil explorations has a direct effect on raising funds for the treasury.

It was even possible to establish that the adoption of the aforementioned suggestion, even with a deep debate between the various actors in the oil production and operation market could generate sensitive effects on volume measurement, since it concerns evaluation criteria of the metrological performance of flow measurement systems used in oil capture.

It is noticed that, in the case of a measurement process involving significantly high flows, any alteration could be observed, even if in relative numbers they are not very representative, that is, if a change in the evaluation criteria of the MPE and expanded measurement uncertainty of any components of an FMS is adopted, in the initial verifications, it must be preceded by a deep analysis of regulatory impact.

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