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# WELMEC Guide 10.15

## Process range of liquid flow meters

### Extension of the measuring range

## Version 2021

*For information:*
This Guide is available for the Working Group Measurement Instruments
For future reference on the Europa Website.

WELMEC is a cooperation between the legal metrology authorities of the Member States of the European Union and EFTA.

This document is one of a number of Guides published by WELMEC to provide guidance to manufacturers of measuring instruments and to Notified Bodies responsible for conformity assessment of their products.

The Guides are purely advisory and do not themselves impose any restrictions or additional technical requirements beyond those contained in relevant EU Directives.

Alternative approaches may be acceptable, but the guidance provided in this document represents the considered view of WELMEC as to the best practice to be followed.

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# Contents

# 1 Introduction

The measuring conditions of liquid flow meters for industrial application can have a larger operating range than usually applied in fuel dispensers with respect to flow rate, viscosity range, density range etc.. Calibration facilities do not exist for some of these extended conditions and therefore the test procedures “Accuracy at the limits of the working range” according to OIML R117-2 cannot always be exactly followed.

Liquid flow meters are a component of a measuring system. In some cases, submitted documents (e.g. PC or EC) that are accepted by one Notified Body (NoBo) for Module B are not accepted by another Notified Body for Module B.
The reason for not accepting documents (that one NoBo for module B accepts and another NoBo does not accept) is the lack of accepted standards, as there is no prescribed test procedure for the conformity assessment required by MID. Therefore, also no test procedure for subsequent calibration for such special applications is available.
A pragmatic harmonized approach should be established to avoid that module B documents submitted by the manufacturer and which have already been accepted by a Notified Body are rejected by another Notified Body of module B.

# 2 Scope

As far as possible the test procedures mentioned in OIML R117 should always be followed.

In case of extended operating range and measuring conditions for which test facilities are not (yet) available in the world, the scope of this document is to give guidance for type evaluation of liquid flow meters according to module B or H1 for Notified Bodies and manufacturers about the possibilities for testing, evaluating and extrapolating.”
Extension of the operating ranges and measuring conditions shall always be based on test results. Proof by technical documentation justification alone is not sufficient. The manufacturer is responsible for the supporting evidence which shall be reliable and suitable for extension of the operating ranges and measuring conditions. The Notified Body shall:

- examine the proposal for the supporting evidence.
- determine if an appropriate test plan is made for the extension of the operating ranges and measuring conditions. If this test plan is not considered to be sufficient for the metrologically justified assumption that the meter measures correctly in the extended measuring ranges, additional tests are necessary in order to achieve reliable results.; and
- carry out appropriate examinations and tests according to the test plan, or have them carried out, to check whether, where the manufacturer has chosen to apply the solutions have been applied correctly.

The supporting evidence and test plan shall be in line with chapter 6 of this guide. As for other type examination activities, these test results fall under the responsibility of the Notified Body.

This document cannot describe in detail all possibilities, but one should act in the spirit of this document as long as the chosen method is justified.
Note: This is on basis of MID Module B (EU-type examination) articles 3e and 4.4 and Module H1 (Conformity based on full quality assurance plus design examination) articles 3.2b and 4.2d. These articles state that appropriate examinations and tests shall be carried out when the solutions in the relevant harmonised standards and/or normative documents have not been applied in full.

# 3 Definitions, abbreviations and symbols

The definitions of OIML R117-1 edition 2019 apply to this guide.

Abbreviations:

| | |
|---|---|
| MID | Measuring Instruments Directive |
| NoBo | Notified Body |
| EU-TEC | EU-Type examination certificate |
| EC | Evaluation Certificate as defined in WELMEC guide 8.8 |
| PC | Parts Certificate as defined in WELMEC guide 8.8 |
| MPE | Maximum Permissible Error |
| MMQ | Minimum Measured Quantity |
| EUT | Equipment under tests |

# 4 Conformity assessment Module F and G

For conformity assessment MID module F or G, it is always preferred to calibrate the flow meter on the actual liquid product for which the measuring system is going to be used. If it can be proven during type evaluation that for the flow meter some effects of the temperature, pressure, density and/or viscosity do not affect the metrological behaviour of the measuring principle, the calibration of the flow meter can be done with conditions that are different to the conditions of later use. In that case these effects shall be investigated and guidance shall be given about the use of alternative calibration of the flow meter as a substitution of on-site calibration in the EU-TEC of the measuring system. In addition, the flow meter shall always be tested at least on the accuracy at the flow rate range.
A product can be considered similar to the actual product if the difference in properties lay within the limits as stated in OIML R117-1:2007 §B.A.6.2 or R117-2:2019 §X.5.3.3.

# 5 Method

The manufacturer shall provide information regarding the operating ranges of the measuring device. These operating ranges can be accepted if this information is based on already certified flow meters (by e.g. EU-TEC, EC or PC) or by tests results according to OIML R117-2 (“Accuracy at the limits of the working range”) issued by a Notified Body for MID Annex VII (MI-005).
In the event that no test equipment is available for the required accuracy for obtaining such test results, reliable supporting evidence must be provided that the accuracy requirements of the measuring device can be met.

The supporting evidence can be based on an investigation of meters from the same family by using other test results which can be extrapolated to the required operating conditions.

The Notified Body issuing the (type) evaluation report shall clearly state in the report whether an extrapolation from testing to operating range in the report is carried out (e.g. technical background and information on the extrapolation) and specify an alternative evidence, to prove, that the meter will also work as intended in the extrapolated range.

This information is needed for the NoBo module B to check the implementation for the full operating ranges specified in the evaluation report before issuing the EU-TEC. It is also possible for the NoBo issuing the EU-TEC to extrapolate any operating ranges, and if so it has to be explained in the Evaluation Report appertaining to the EU-TEC.

# 6 Guidance for supporting evidence

In the table below the availability of accessible test facilities are mentioned and for these ranges the tests shall be performed according to OIML R117-2 (“Accuracy at the limits of the working range”).

In the case no test facility is available (outside the ranges for accessible test facilities as mentioned in the table below), the supporting evidence for the extended range can be used for proving that the accuracy requirements of the measuring device are met. Other supporting evidence can be based on information which is mentioned below, in the table. If simulated test results are used, the simulation model shall be verified and supported by actual flow testing.

If tests are performed at the facilities of a manufacturer or laboratory, it must be ensured that the test procedures are comparable with the requirements of ISO/IEC 17025. A documented assessment must be carried out that the requirements for carrying out the tests are met (i.a. personnel, facilities, environmental conditions, equipment, metrological traceability, validation of methods, handling of test and evaluation of measurement uncertainty). This documentation together with the test report is part of the evaluation report. Reference is then made to this evaluation report (or EC/PC) in the EU-TEC of the measuring system.

If an extrapolation of the test results is used, this shall be on based on reliable test results of at least one representative meter of a meter family. Depending on which metrological characteristics are to be extrapolated, the size of the meter should be selected in such a way that it best enables an evaluation of the test results in terms of the characteristics to be extrapolated. If it is considered necessary that the test results of the meter are not sufficient to ensure the extrapolation of the characteristic data, further measurements are to be carried out on equal meters to confirm the assumptions made regarding the extrapolation of the characteristic data. The range of the extrapolation should be restricted based on the test results and other physical parameters that could have influence to the meter performance.

The Notified Body can consult any third party (e.g. academia, specialized companies or institutes) for support, provided that the manufacturer permits so.

No significant influence on the metrological behaviour of the measuring principle can be considered, if the influence is smaller than the significant fault as defined in OIML R117-1:2007 §2.5.4 or OIML R117-1:2019 §2.5.4.

| Operating range | Accessible test facilities | Extended range supporting evidence |
|---|---|---|
| Flow rate | Up till 5.000 $m^3$/h | All flow meter sizes according to the family of meter approach shall be tested on at least one liquid product.<br><br>A higher flow rate range, where at least up to 50% of $Q_{max}$ is covered by accuracy flow testing, can be covered by proof of linear result at high flow rate with smaller sized meters of the meter family, which in this case have to be tested up to 100% of Qmax (instead of at least 80% Qmax), and on the basis of linear behaviour as a function of flow velocity. |

| Operating range | Accessible test facilities | Extended range supporting evidence |
|---|---|---|
| Temperature | Minimum: -200 °C<br>Maximum: +85 °C | At least one meter of choice (most sensitive) shall be tested with flow at the limits of the temperature. Special attention is needed regarding the maximum permissible errors at the temperatures below –10 ºC or above +50 ºC (see OIML R 117-1:2019, section 2.4).<br><br>An extended temperature range can be covered by proof that the temperature effect at this extended range has no influence on metrological behaviour of the measuring principle. These influences can be for example:<br>- Meter body change.<br>- Ultrasonic transducer signal path change.<br>- Stiffness change for Coriolis meter.<br><br>This proof can be covered by a combination of dynamic flow measurements and static measurements or simulation modelling. Static measurements can be done in a climate chamber and a flow meter filled with liquid at zero flow rate. If simulation modelling is used, the model shall be verified based on actual test results and taken into account the limits of the model. |
| Pressure | Up till 80 bar(g) | At least one meter of choice (most sensitive) shall be tested with flow at the limits of the pressure.<br><br>A higher pressure range can be covered by proof that the pressure effect at this extended range has no influence on metrological behaviour of the measuring principle. These influences can be for example:<br>- Meter body change.<br>- Ultrasonic transducer signal path change.<br>- Stiffness change for Coriolis meter.<br><br>This proof can be covered by a combination of dynamic flow measurements and static measurements or simulation modelling. Static measurements can be done using a flow meter filled with liquid and pressurising the meter. |
| Density | Low density e.g. with LPG or a gas<br><br>High density e.g. with sodium tungstate solution | At least one meter of choice (most sensitive) shall be tested with flow at the limits of the density. |

| Operating range | Accessible test facilities | Extended range supporting evidence |
|---|---|---|
| Viscosity | Low viscosity e.g. with LPG or a gas.<br><br>High viscosity up to approximately 1000 mPa·s. | At least one meter of choice (most sensitive) shall be tested with flow at the limits of the viscosity.<br><br>An extended viscosity range can be covered by:<br>1) Several liquid products shall be tested with the same flow meter to approve the viscosity behaviour and extend this range.<br>2) Based on investigation on the effect on Reynolds numbers (combination of flow range and viscosity at measuring conditions), so that tests can be performed based on same Reynolds number with lower or higher viscosities. The viscosity limits shall not be extended by more than 20 % than which have been tested. |
| Reynolds number | Reynolds ranges laminar, transient and turbulent can be covered depending on flow rate, diameter of the flow meter and liquid viscosity. | Specifically, flow meters that are sensitive to the flow profile (especially turbine and ultrasonic) shall be tested on the complete Reynolds ranges for each size, according to the ‘family of meters’ approach. Where the Reynolds range includes the transition and laminar flow regime, special care shall be taken for the transition area as flow profiles are very unstable. |

The supporting evidence should be made available to the national market surveillance authorities upon request. This is necessary in order to make it possible for the market surveillance authorities to assess whether the requirements for testability according to MID annex 1, article 7.6 after the instrument is put into use, is fulfilled.

# 7 Risk assessment table

This chapter handles the risks associated with “not all combinations of density; temperature; pressure and viscosity” are tested.

The manufacturer shall assess the need for testing each combination of density; temperature; pressure and viscosity. The manufacturer shall justify the arguments for testing not conforming with OIML R117 requirements and how the risks are reduced for exceeding the maximum permissible errors.

| **EVAL** | Flowrate | Density | Temperature | Pressure | Viscosity |
|---|---|---|---|---|---|
| Flowrate | X | TC1 | TC2 | TC3 | TC4 |
| Density | TNC1 | X | TC5 | TC6 | TC7 |
| Temperature | TNC2 | TNC5 | X | TC8 | TC9 |
| Pressure | TNC3 | TNC6 | TNC8 | X | TC10 |
| Viscosity | TNC4 | TNC7 | TNC9 | TNC10 | X |

TC = Testing compliance via calibration and is without any risk.
TNC = Testing that does not (directly) prove compliance with OIML R 117.
The manufacturer should justify the particular TNC cases and describe how this can be covered by an alternative method and how the risk for exceeding the MPE can be reduced. This alternative method shall be on well-founded arguments and be in line with this document.

# Annex: Measuring principle risk knowledge (Informative)

The information stated in the tables below can be used to determine the required supporting evidence (investigation and/or test results) which could be used to extrapolate to the required operating conditions. This chapter could also be used to get knowledge and guidance regarding the measuring principles.

Test quantities shall always be considered in line with MMQ specifications, and the test quantities are advised to be at least 5 times the MMQ.

Note: Consider any influence of high pressure drop on the accuracy.

**Build of instrument – Compliance to OIML R117-1: 2019 requirements, and also secure "intent of use" (as per EU Blue Guide) and choice of MMQ (versus capacity to execute subsequent verifications):**

| Meter technology | Sensitive to | Other risks to consider |
|---|---|---|
| PD (Positive Displacement)<br>E.g. piston, rotor or slidig vane. | Temperature: Moderate<br>Pressure: Moderate<br>Density: Moderate<br>Viscosity: Moderate<br><br>Flow profile: No<br>Zero-offset influence: No<br>Cavitation: High<br>Bubble trapping: High<br>Particles/dirt: Moderate | • Temperature: For piston meters, the expansion (contraction) of fluid due to a temperature increase (decrease) may be partially compensated by a corresponding change in size and travel distance of the pistons. Difference between the expansion coefficient of the measurement chamber and that of the piston may cause problems.<br>• Temperature: For rotor meters a difference in expansion coefficient of the measurement chamber and the rotor may cause problems.<br>• Pressure variations (start/stop): Check "inflating" parts and bubble traps.<br>• Viscosity: Possible internal leak (with error) at low viscosity.<br>• Sensitive to flow rate overloading.<br>• Dissolved gases or air in the liquid.<br>• Cavitation: Special consideration for possible cavitation before and inside meter, and bubble trap. |
| Turbine | Temperature: Moderate<br>Pressure: Low<br>Density: Moderate<br>Viscosity: High<br><br>Flow profile: Yes<br>Zero-offset influence: Yes<br>Cavitation: High<br>Bubble trapping: No<br>Particles/dirt: Moderate | • Temperature: Difference in expansion coefficient of the measurement chamber and the rotor can cause problems.<br>• Flow profile: Turbine meter shall be calibrated over the expected Reynolds range in which the meter is going to be used. Some calibration facilities report the measurement error against $Q/\nu$ (differs from Re only by a constant factor).<br>• Viscosity: Turbine meters are highly sensitive to viscosity, unless special construction of rotor.<br>• Sensitive to flow rate overloading.<br>• Sensitive to cavitation, unless sufficient back pressure. |

| Meter technology | Sensitive to | Other risks to consider |
|---|---|---|
| Electromagnetic | Temperature: Moderate<br>Pressure: Low<br>Density: Low<br>Viscosity: Low<br><br>Flow profile: Moderate<br>Zero-offset influence: Yes<br>Cavitation: Moderate<br>Bubble trapping: Moderate<br>Particles/dirt: Moderate | • Temperature: A temperature change of the liquid has an impact on the meter body and so the meter performance.<br>• For measuring a minimum conductivity of the liquid is needed. |
| Ultrasonic | Temperature: Moderate<br>Pressure: Low<br>Density: Low<br>Viscosity: Moderate<br><br>Flow profile: High<br>Zero-offset influence: Yes<br>Cavitation: High<br>Bubble trapping: High<br>Particles/dirt: Moderate | • Temperature: A temperature change of the liquid has an impact on the meter body and so the meter performance.<br>• Ultrasonic meters are very sensitive to gas bubbles being present in the liquid. If this is the case, the acoustic sound signal is scattered by those bubbles and cannot be detected anymore.<br>• The transition area from turbulent to laminar flow are a challenge for an ultrasonic meter due to the very unstable flow profiles. |
| Coriolis | Temperature: Moderate<br>Pressure: Low<br>Density: Moderate<br>Viscosity: High<br><br>Flow profile: Low<br>Zero-offset influence: Yes<br>Cavitation: Moderate<br>Bubble trapping: Moderate<br>Particles/dirt: Moderate | • Sensitive when improperly installed, this can be verified by checking for an offset at zero flow rate and comparing the shift in the zero point with the factory zero point. Large differences indicate improper installation of the meter.<br>• Option for mass, volume and/or density measurements.<br>• The temperature and pressure effects on a Coriolis meter are not independent of each other. Therefore, the single effect (temperature or pressure) as well as the combined effect shall be investigated.<br>• Coriolis meters are not insensitive to viscosity. The degree of the sensitivity depends on dimensional characteristics of the sensor tubes (e.g. large size Coriolis meters are more sensitive to the viscosity of the product) [1]. For these larger sizes at least the minimum, middle and maximum viscosity of the flow meter shall be performed on the sizes according to the ‘family of meters’ approach.<br><br>[1] Public domain article from 2006 in Flow Measurement and Instrumentation: Velocity profile effects in Coriolis mass flowmeters 2006 article in: Recent findings and open questions by J. Kutin, G. Bobovnik, J. Hemp and I. Bajsić. |

**Reference equipment - Compliance for type examination and initial verification tests:**

| Reference equipment technology | Sensitive to | Comment on risks to consider, where focus needed on understanding and assessing influence |
|---|---|---|
| Weighing | Temperature: Low<br>Viscosity: None<br>Ambient conditions: High<br>Evaporation: Moderate<br>Misting: Moderate<br>Wetting: None | • Wind can have a large influence on the stability of the scale if used in open conditions. High wind conditions shall be avoided and testing shall be postponed if wind prevents stable readings.<br>• Evaporation can be an issue in case open tanks are used to collect the product.<br>• Buoyancy correction (according OIML D28) is only needed in case of open tanks. Scale interval of the scale can be an issue, especially the case for weighing bridges. If needed, additional weights can be added up to the next step in indication.<br>• To calculate the volume, the density of the liquid is needed to be determined over the temperature range which is tested. In this case, the liquid temperature has more influence to the measurements.<br>• Difference in temperature of tank surface and surrounding air will cause rising of falling air stream along the tank surface, influencing the weighing. |
| Vessels | Temperature: Moderate<br>Viscosity: Low<br>Ambient conditions: Low<br>Evaporation: Low<br>Misting: Moderate<br>Wetting: Significant | • Temperature: Variation of size vessel and size of liquid between measuring time (at instrument) and time where vessel level is read.<br>• Viscosity: Influence possible on wetting result (and versus calibration initial process). Also influence with temperature.<br>• If instrument with temperature correction, process of check has to be adjusted accordingly.<br>• Evaporation: During fill, part of misting and instant evaporation is dragged out of vessel.<br>• Process shall be constant and prevent trapped vapours (design of vessel has influence).<br>• Reading: Might create extra error/uncertainty. Design of vessels and flatness of floor are also influence factors. |

| Reference equipment technology | Sensitive to | Comment on risks to consider, where focus needed on understanding and assessing influence |
|---|---|---|
| Small volume prover | Temperature: Moderate<br>Viscosity: Low<br>Ambient conditions: Low<br>Evaporation: None<br>Misting: None<br>Wetting: None | • Small volume provers typically have a measurement time of less than 0,5 second at the maximum flowrate and collect less than 10 000 pulses for the EUT.<br>• Pulse interpolation has to be used, but often this is standard in the provers control computer.<br>• Temperature and pressure difference between EUT and prover shall be taken into account.<br>• Care is to be taken if pure electronic measuring principles (Coriolis, electromagnetic and ultrasonic) are tested due to the delay between change in flow rate and response of the EUT.<br>• May not be suitable for electromagnetic or ultrasonic meters, check repeatability. |
| Large volume prover | Temperature: Moderate<br>Viscosity: Low<br>Ambient conditions: Low<br>Evaporation: None<br>Misting: None<br>Wetting: None | • Pulse interpolation shall be used if less than 10 000 pulses are collected from the EUT.<br>• Temperature and pressure difference between EUT and prover shall be taken into account.<br>• Small flow rates can be unstable in flow rate and pressure in the case of ball provers with one or more bends in the proving section. |
| Master meter | Temperature: Moderate<br>Viscosity: Low<br>Ambient conditions: Low<br>Evaporation: None<br>Misting: None<br>Wetting: None | • Temperature: In case of volumetric measurements, the temperature (and pressure) difference between EUT and master meter shall be taken into account.<br>• Reading: Small volume proving runs shall be avoided as they normally lead to large uncertainties. Or pulse interpolation shall be used. |
| Combination of instruments | Temperature: Moderate<br>Viscosity: Low<br>Ambient conditions: Low<br>Evaporation: None<br>Misting: None<br>Wetting: None | • A combination could be a small volume prover combined with a master turbine meter. Low flow rates are calibrated with the small volume prover only, higher flowrates are calibrated using the turbine meter, which in turn is calibrated before and after using the small volume prover.<br>• In such cases, the risk of each individual proving instrument shall be assessed. In addition, the uncertainty of the complete calibration method is to be evaluated. |