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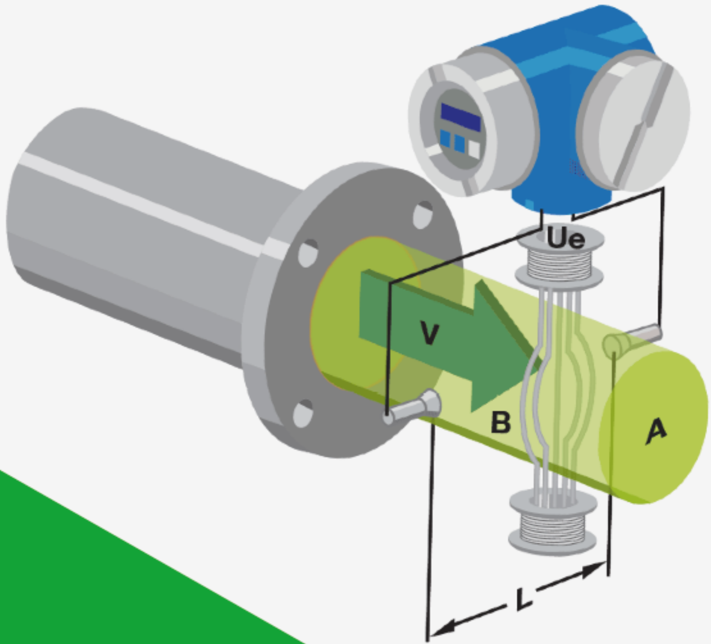

GUIDELINES ON CALIBRATION OF FLOW METERS

WAQSP Funded by European Union | West Africa Quality System Programme

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ORIGINAL VERSION

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Contents

1 INTRODUCTION

Throughout industry, flowmeter accuracy and repeatability are scrutinized with different criteria to ensure confidence in a particular application. In utility environments, for example, a government body may require a flowmeter to meet minimum accuracy and repeatability standards. In others, say private industry for example, in-house specifications are likely the source for accuracy and repeatability standards. Whatever the case, be it a government-mandated standard or an internal performance requirement, flowmeter accuracy and repeatability are of the utmost importance.

There are a variety of methods users can employ in an effort to ensure flowmeter performance, but the terminology for describing such practices is often used interchangeably despite the unique nature of different practices. In some applications, flowmeter verification will satisfy requirements for meter performance within a defined tolerance of the original manufactured state. In other applications, however, a traceable calibration is required to fulfill this requirement. And some other scenarios may require in-field proving of the meter to instill confidence in its performance in a specific system. These techniques, which are the most prominent methods for ensuring flowmeter accuracy and repeatability, have inherent differences and can be a good fit in many environments, depending on the requirements of the application.

2 STANDARDS

Fluid flow rate standards could be significantly simplified if the fundamental bases of these measurements were as simple as those for mass, length and so on. These systems of measurement are based upon discrete standards or artifacts. These artifacts can be considered identity standards.

The mass and length artifacts can be considered identity standards because under the appropriate conditions of use they define the basic quantity in their respective measurement Systems.
However, the flow rate measurement of fluids does not exist as an identity standard such as gallons/minute, m^3/hr, gm/sec, etc. To supply the fundamental basis upon which to establish a flow measurement system, a derived standard is required.

For fluid flow rate measurements, as needed to form the basis of a reference system, the laboratory is maintained for use by industries and others with respect to:

- Calibration by Master Meter Method
- Calibration by Volumetric Method

Such laboratory generally consists of:

- A source of flow, generally a pump, a blower or a constant head tank with appropriate auxiliary equipment.
- A test section into which the meter and its adjacent piping can be installed so that the flow and fluid conditions into it duplicate those expected where the meter will actually be used; and

– A flow determination system having a specified level of performance and appropriate proof of traceability to specify and assure the desired metering performance of the devices in question.

The heart of the fluid flow meter calibration facility is the flow determination system. This generally uses a timed collection of the fluid that flows through the meter being calibrated. This collected fluid is converted to flow rate using the collection time, the volumetric flow rate through the meter can be determined via the corresponding temperature and density. The system can be operated with suitable means at a high-level performance to determine the bulk flow of the fluid.

3 CALIBRATION

Calibration is a comparison between the reading of a device and that of a standard. The process which establishes this relationship is a set of interrelated measurements and operations which provide the comparison. Flow measurement does not rely on a single operation and so neither does a flow-based calibration.
Measurement of the quantity of fluid depends on establishing the basic quantity and a number of influence factors. The quantity of fluid may be expressed as a volume or a mass. The measurand may be the quantity or the 'rate' i.e. the quantity per unit time. The quantity measured by the standard may be different from the quantity passed through the test device due to changes in volume or even mass between the meter and the standard. Changes are usually related to the influence factors such as temperature, pressure, viscosity and expansion. This combination of fluid, influence factors, the standard and the device come together to define a set of operations which is to provide the calibration.

As the fluid and influence factors all affect the meter performance, the calibration is carried out 'under specified conditions' and these must be defined.

A calibration is not an absolute operation. It is a comparison between the measuring instrument, in this case the device under test or flow meter, and the standard. Through this comparison, a relationship between the quantity measured by the device under test and the measurement of the same quantity derived from the standard is established. This is expressed in some way which gives a meaningful expectation of how the device will perform in use.

The comparison during a calibration is against a standard. The standard comprises the system of pumps, pipes, fluids, instrumentation, quantity reference measurement, calculations and operators. These all combined provide a measure of the quantity of fluid passing through the device or flow meter being calibrated.

The measurement of fluid flow is dynamic and all measurement devices are affected in some way by the conditions of use. It will be impossible to have a standard which fully reproduces the conditions under which the meter will be used in practice. Flow devices are affected by temperature, viscosity, flow profile, flow rate fluctuations and pulsations. They are also affected by the external environment, vibration, stress and temperature, etc. Different devices are affected in different ways. Similarly the standard will also be susceptible to these same influences.

Since a calibration is a comparison between the measurement made by the device under test and that realised by the standard, the resultant relationship will be for the specified conditions; therefore a further assessment of the relevance to the final application must be carried out. Selecting the standard will be a compromise to best replicate the conditions of use while providing a suitable reference standard measurement. The standard must also be compatible with the performance and characteristics of the meter to be tested and the result desired.

The extent to which a flow measurement device is affected by the conditions of use is most often a function of the flowrate. It is therefore important that calibration takes place across a range of flowrates to establish this relationship.

4 RATE, QUANTITY AND TIME

The mechanism by which a flow measurement device gives a reading of flow is dynamic. The sensor reacts to the flow of fluid through it or past it to realise an output related to the flowrate or the quantity passing.

Measurement of flowrate and quantity are related through the time interval across which the quantity is measured. In practice, the end user of the device has different expectations for the behaviour and hence the calibration. In establishing this relationship, it is vital to relate the response time of the device to the calibration method. Again, the current and older generic definitions of response times are given.

The interpretation of response time is reasonably straightforward for mechanical meters. The mechanical interface between the fluid and the indicator can be explained and defined in terms of momentum and drag affecting the meter when the flow changes. With the advent of electronics this has become more difficult to establish. For example, a positive displacement meter in liquid responds very quickly to changes in flowrate even very abrupt changes; the flow stops, the rotor stops and the register stops. If a pulse generator is fitted, the generated pulses stop when the flow stops. A frequency counter will not reflect this until it completes its measurement cycle which may be some seconds later. During that time, a totalizer or register will correctly indicate quantity, but the flowrate indicator will not be showing the correct (instantaneous) flowrate. If however the mechanism in the meter has play or is loose, stopping the rotor may allow the output register to run on after the rotor stops hence generating additional quantity or pulses.

A different type of meter may of course not respond to an immediate change in flow. A turbine rotor will have significant momentum and, although speeding up quickly, may take time to slow down when subjected to a change in flow, particularly in gas measurement. Meters based on non-mechanical sensing techniques e.g. electro-magnetic, Coriolis or ultrasonic meters, have different response characteristics. For example, an electromagnetic meter may take some time to establish and measure a change in the generated voltage after a change in flow, while an ultrasonic meter output is the average of a number of measurement cycles and this averaging may take appreciable time to complete.

Most meters based on non-mechanical sensing, and some mechanical meters, have a microprocessor which calculates the output quantity from the sensor signal. For some meter types this is an additional capability while others require this processing to convert the sensor signal and correct for influence factors before calculating and generating an output signal. The output signal can be a pulse frequency or a current (mA) output generated from this calculation process.

A digital display may be added to show the required output value and many modern meters have digital outputs to transmit the chosen measurement(s) to a remote readout or computer. All these outputs will have a different response times delaying the raw sensor response by the signal processing and calculation time.

An example of a processed output signal comes from a vortex meter with a signal processor designed to smooth any pulses missed by the sensor and to increase the resolution of the output. Such a device may have output response times of many seconds even though the sensor itself has responded in under a second.

Modern flow meter types such as Coriolis, electromagnetic, or ultrasonic meters are totally dependent on microprocessor-based output, and the variety of settings to average, damp or cut-off low flowrates must be understood and selected to ensure the response time matches the limitations of a calibration method. Matching the response time of a device to the chosen calibration method is a vital part of the process. If the device response time does not match the time within which a calibration test point is taken, poor repeatability or calibration offsets may be observed. This response time may however be perfectly adequate or even advantageous when the meter is in service.

5 REPEATABILITY AND REPRODUCIBILITY

To obtain confidence in a measurement it is expected that the measurement should be able to be repeated and give the same result. In practice measurements only repeat to within a certain band over a short time and a (probably) wider band over a long time period or under different circumstances. It is generally expected that a calibration should give some indication of the repeatability of an instrument; however it is not likely that one calibration will show the reproducibility. Repeated calibration may of course be carried out perhaps over many years to show this parameter.

A measurement standard should have determined repeatability and reproducibility figures which will have been included in the uncertainty determination. The repeatability of a calibration will of course include the repeatability of the standard, but also the repeatability of the device under test. A large part of the repeatability will be the resolution of both the device and the standard.

It is interesting to note that a device or flow meter may be believed to have better repeatability than that of the standard. This belief is based on history, behaviour in other calibrations and service etc. The repeatability cannot however be proved to be better as it can only be demonstrated through repeated calibrations against the standard.

6 FLUID PROPERTIES

All flow meters interact in some way with the flowing fluid. The nature of this interaction is affected by the properties of the fluid or the velocity distribution of the fluid passing through the device. Changes in this interaction alter the ability of the device to give an accurate representation of the quantity. The magnitude of the error is different for different meter types and fluids.

For this reason it is desirable to calibrate using the same fluid and pipework configuration within which the meter will normally operate. This is clearly not often possible; the meter has to be installed in a test laboratory, or the calibration standard has to be installed in the same pipework as the flow metre under test. In either case some degree of disturbance to the meter is inevitable. The best economic compromise must be established in choosing the calibration. This will be based on the final duty of the meter, the required uncertainty and knowledge of the meter performance. For some meters, for example orifice plates, the performance can be related to Reynolds numbers. This allows a calibration to be carried out in a fluid different to the meter‘s operating fluid. The relationship may even allow a liquid calibration to be applied to a meter for a gas duty by matching Reynolds numbers.

For other meter types, such as turbine meters, the choice of calibration fluid is particularly important. Turbine meters are viscosity sensitive, and the figure opposite shows some typical calibration results from a turbine meter using water and three petroleum products. Because of this sensitivity to viscosity it is important to calibrate these meters using a fluid as close to the viscosity of working fluid as is practicable. For this reason, among others, fiscal meters for oil are often calibrated on site using a dedicated pipe prover.

For gas meters, air is often used as the calibration fluid for safety reasons. When used with other gases the performance related to Reynolds number provides a good relationship for turbine and ultrasonic meters. Coriolis, and positive displacement meters do not follow this relationship. For variable area meters it is important to correct the gas density to a standard condition to match the scale. Gas pressure is probably the most important influence factor as this affects the density and hence many aspects of a meter performance.

Properties of the fluid such as density, temperature, conductivity, pressure may also have to be considered when replicating the use of the meter in a calibration.

7 FLOW PROFILE

When a fluid passes through a pipe, the distribution of velocity across the pipe alters to approach a fully developed profile which is dependent on the pipe internal diameter, roughness and fluid Reynolds number. The presence of any change from a straight pipe will alter the profile drastically. Bends, double bends, valves, etc. all introduce asymmetry to the velocity distribution and some introduce swirl or rotation. As the way the fluid interacts with the sensor can be highly dependent on the velocity profile, these effects must be considered in the calibration. Most calibration facilities allow adequate straight pipe lengths and the use of flow conditioners to establish predictable and reproducible flow profiles close to an ideal profile. It should be noted however that care has to be taken to ensure pipes upstream of the meter have the same internal diameter as the meter inlet and step changes or misalignment of joints and gaskets do not introduce irregular profiles.

8 TRACEABILITY, ACCURACY AND UNCERTAINTY

Since a calibration is a comparison between the reading taken from a device under test and that of a standard, it is necessary to consider what properties are required from a standard. Firstly and most importantly, the standard should measure the same quantity as the device. There is little value in comparing a mass meter output with that of a volume tank without a measure of density to allow conversion between mass and volume. For flow measurement, the standard is a system comprising of a measure of quantity and the subsidiary measurements to determine the fluid conditions, properties and influence factors.

Another feature of the standard is that there must be confidence that the measurement taken by the standard is accurate. To achieve this all the measurements in the system have to show traceability to higher level measurements and ultimately to National and International standards.

The definition of traceability provided expresses the process by which a measurement can be related through an unbroken chain of comparisons to national/international standards. It must be noted that each step of the chain will have an uncertainty becoming smaller at each step. It must be noted that providing or claiming traceability alone makes no statement regarding the quality or uncertainty of the result; this requires an uncertainty value. Traceability must also be through comparisons to other/better calibrations and NOT TO an accreditation body. It is contentious to use the term 'accuracy' in relation to calibration work. Accuracy does not have the rigour or precision required to describe a scientific process. In practice however accuracy, when used correctly, is the term to which users relate and can usefully be employed to express expectation and general specification. Accuracy is a qualitative term and therefore the number associated with it should be used for indicative purposes.

To correctly express the accuracy of a standard or a calibration, the uncertainty must be determined and quoted. Uncertainty provides confidence that the determination of the value lies within the stated value. For flow measurement, the confidence in the result lying within the uncertainty is normally quoted with a coverage factor of k=2, which is approximately 95% confidence level. A full explanation is given in the Guide to Measurement of Uncertainty (GUM) or ISO 5168.

Every standard must be assessed for the uncertainty in the determination of its measured quantity, as indeed must the result of a calibration.

The uncertainty quoted for a calibration or a standard will be estimated from a detailed examination of all the components within the system, the use of the system and its history. It will specifically state for what parameter the uncertainty applies to. This parameter may be the quantity measured by the standard or the quantity passed through the device under test. The latter is the uncertainty which is needed initially. It is stressed that this is not the uncertainty of the calibration result. The resolution of the meter, the influence factors and finally the repeatability and linearity of the calibration results must all be included to provide the uncertainty of the calibration result.

The purpose of a calibration is to estimate the uncertainty associated with measurements from the meter in its final application. It is clear that the calibration will only provide a component of this final measurement uncertainty. A responsibility remains with the end user to use the calibration uncertainty along with an understanding of the use of the meter compared with the calibration conditions to provide this final result.

All calibration results should have a stated uncertainty and this should be stated clearly on the calibration report or certificate. The uncertainty statement should be clear and unambiguous as to what is included and which quantity it refers to. Uncertainty can be expressed on the certificate as being the uncertainty of the measured quantity (flow, volume or mass) or uncertainty of the device under test during calibration.

An equation fitted to the data, if provided, should also have a stated uncertainty estimated. The uncertainty will not include the estimate of uncertainty at different time or conditions. Any estimate at a different time or condition is an estimate (or speculation) and could only be advisory and not part of the calibration.

It is also worth noting that uncertainty may vary across the flow range of the meter. The quantity of fluid collected by the standard may contribute to different uncertainties, or the meter performance may vary.

In specifying the required uncertainty of a standard relative to that of a meter, it is good practice that the standard should have an uncertainty 10 times smaller than that of the requirement of the device to be calibrated. Although this is a good principle, in flow measurement it is often not achievable due to the high expectations of flow meters and the applications for them. A standard with an uncertainty of a factor of three lower than the requirement of the application is often all that can be achieved.

In some situations, especially in field testing, the uncertainty of the standard may be higher than the expected uncertainty of the meter. This applies when some methods of in-situ calibrations are called for. When this occurs the achieved uncertainty of the calibration must be larger than that of the standard, hence increasing the uncertainty of the final measurement.

When this situation is encountered, verification rather than a calibration is often specified. The result is used to provide increased confidence that the meter is operating correctly but not used to make corrections to the meter or as the primary assessment of its uncertainty.

It is to be noted that uncertainty should not be confused with error. Error expresses how far away from the true value the reading is; however, this value may be known to have a much smaller uncertainty. Knowing the error may allow a correction to be made to the reading.

9 ACCREDITATION

Accreditation is the process that a calibration laboratory or service provider undergoes to give confidence that the results provided to their clients meets the expectations stated in the scope of the work.

It is a process by which the equipment, technical methods, contractual arrangements, and quality of the results are examined to give confidence to the client in the delivery of the service. A third party, or indeed the client, accredits an organization, hence giving confidence in future works without individual inspection. This process ensures that traceability has been established, an uncertainty budget produced, and procedures are sound.

To avoid multiple client accreditations, and to provide commonality, accreditation is provided by a National accreditation body and subject to meeting international agreements on the standards for inspection. Most developed countries have their own accreditation body and it is now recommended that only one body should be appointed in each country.

10 CALIBRATION TECHNIQUE OF LIQUID FLOW METER

One characteristic of a liquid is that it can be contained in an open vessel and several liquid flow standards make use of this by causing the liquid to flow throughout t h e meter to be calibrated into a collecting vessel, master meter, and then determining the mass or volume of the liquid collected, when at rest. Types of calibrators used:

- Volumetric calibrators
- Gravimetric calibrators
- On site calibrators

10.1 Volumetric calibrators

The measurement of the quantity of liquid collected may be carried out volumetrically by collecting a known volume of liquid in a container. In the volumetric method the standard vessel takes the form of a container with a calibrated volume. Normally this will be a vessel with conical ends to facilitate drainage and to reduce the risk of air entrapment. The neck of the vessel is normally fitted with a sight glass and a scale marked in volumetric units. A typical volumetric tank is shown below. Various shapes of vessel are used. Inclined cylindrical vessels with necks at opposite ends are one design, as are simple cans with no bottom drain and the level being established at the top brim. This latter type is used for the calibration of fuel dispensers.

The tank volume must be determined by calibration of the vessel. This can be carried out by weighing the water contained in the vessel, or, for larger vessels, carried out using smaller volumetric measures which are themselves traceable to national standards by weighing methods. Calibration is usually done by filling the vessel with a measured weight of water, or by emptying the vessel into a weighing tank.

Volumetric systems are normally used with standing start and finish methods due to the difficulty of diverting flow into the tank and controlling the finish of the fill. The technique gives a very high level of repeatability. Drainage time (after the tank is empty) is vitally important. Liquid clinging to the wall can account for a significant part of the volume and takes appreciable time to drain down. It is normal practice therefore to calibrate the tank (including drainage pipework) and establish a consistent drainage time for the calibration. The tank has this drain time defined and marked on the calibration plate and certificate. For this reason higher viscosity liquids (above 10 cSt) start to give problems of both accuracy and repeatability due to the unpredictable quantity of liquid left attached to the walls of the tank.

For all volumetric methods, a number of corrections and conventions have to be observed due to the expansion and contraction of both the standard, and the device being calibrated. The expansion and contraction of the fluid between the standard and the flow meter has to be recognized. Expansion due to temperature is the most important, but expansion in a pressurized system must also be accounted for.

Reference volume tanks, and pipe provers, have their volume defined at a stated reference temperature (and pressure). Normal reference temperatures are 15 °C or 20 °C. Other references can be defined for special purposes to minimize the size of corrections. Similarly reference pressure is normally atmospheric pressure (1.01325 bar(a)).

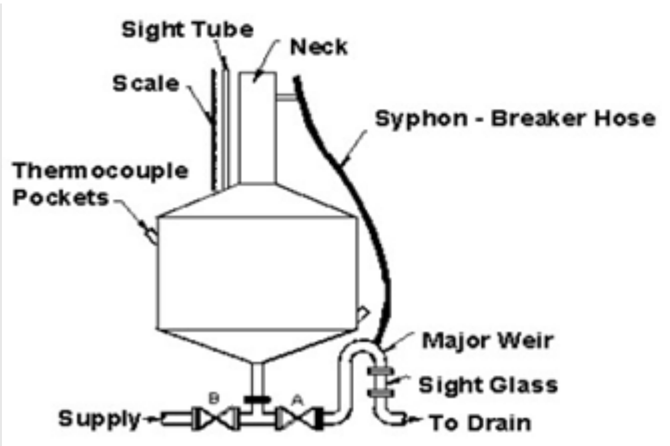


Fig. Volumetric Prover

The volume contained in the standard during use is the base volume corrected for the expansion, or contraction of the vessel if the temperature is different from the base temperature. As the container makes up a volume, it is the cubical expansion of the material used (three times the linear expansion of the material is assumed). The equation is:

$$V_S = V_b \cdot (1 + 3\alpha_s(t_S - t_R)$$

Where Vs is the volume contained

α is the linear expansion of the material of construction of the standard (prover or tank),

t_s is the temperature of the standard

t_R is the defined reference temperature (base)

To define the volume of fluid which has passed through the flow meter into the standard, the expansion of the fluid due to the temperature difference has to be calculated

$$V = V_S \cdot (1 + \alpha(t_M - t_S)$$

Where
V = volume passed through the meter,
α is the cubical expansion of the fluid
t_M the temperature of the meter
t_S the temperature of the standard

Similar corrections have to be applied due to pressure (compressibility of the fluid) if it changes from the meter to the vessel.

It is sometimes found more practical to reduce all volumes to base conditions rather than correcting to actual conditions and then calculating the error or K-factor. Both approaches should give the same answer.

In the oil industry, these corrections are calculated individually in a formulaic manner and are given Correction factor nomenclature:

Ctsp = temperature expansion correction for the steel of the prover
Cpsp = pressure expansion correction for the steel of the prover
Ctlp = temperature expansion correction of the liquid for the prover to standard conditions
Cplp = pressure expansion correction of the liquid for the prover to standard conditions

Corrections may be calculated by referring everything to a reference condition rather than the difference in conditions. Tables and algorithms are available to provide these corrections for hydrocarbon liquids.

The correction of the flow meter to a reference condition is contentious. The difficulty is defining the expansion coefficients (temperature and pressure) for a flow meter. Flow meters are complex devices and as such a simple volume correction factor will not be accurate. For this reason, it is not normally advised to apply corrections to the flow meter during calibration, but quote the result at actual conditions. Some industry practice does however demand these corrections are made, in which case the assumptions must be stated on the certificate.

Note: Different conventions are used as the base or reference conditions of temperature and pressure, e.g. for temperature, 20 °C, 15 °C, 60 °F are all commonly used.

The reference conditions used must be stated on any report or certificate.

10.2 Gravimetric calibrators (Static/Dynamic)

A flow meter can be calibrated gravimetrically by weighing the quantity of liquid collected in a vessel. The vessel is weighed empty, then full and the difference calculated. This gives the weight of the fluid collected.

Since the quantity has to be mass (and probably converted to volume) the weight collected needs to be corrected for the effect of air buoyancy. A weighing machine is calibrated using weights with a conventional density of 8,000 kg/m3. The fluid collected will have a significantly different density from the weights and hence will be subject to significantly different up-thrust from the air. This difference is significant and amounts to around 0.1 per cent for water. The formula to calculate the mass is given below.

$$M = W \cdot \left\{ \left(1 + \rho_{air} \cdot \left(\frac{1}{\rho_f} - \frac{1}{\rho_w} \right) \right) \right\}$$

Where M is the mass (kg)
W is the measured weight (kg)
ρ_{air} is the density of air (kg/m3)
ρ_f is the density of the fluid (kg/m3)
ρ_w is the density of the calibration weights (8000 kg/m3)

The increase in weight in the tank starts a timer and pulse counter at a predetermined volume. When a second predetermined volume/weight are reached, the timer and the counter are stopped. The dump valve is then opened and the tank is allowed to drain. This method if particularly suitable for low flow rates. At higher flow rates larger errors may be introduced because of the inertia effects on the weighing system. There are two ways of doing this:

i) Standing start and stop method: This method is generally preferred for quantity meters. In this method the flow through the meter is accelerated as quickly as possible from rest to the full test flow rate. At the end of the test, the flow is rapidly stopped; provided the test time is sufficiently long in comparison with the acceleration and deceleration periods, the accuracy of the method is not affected.

ii) Flying start and stop method: In this method a diverter system is used in conjunction with a sump/reservoir into which the liquid flows when the meter is not being calibrated; when being calibrated, the liquid flows to a measuring vessel. That is to say that the flow is always "on' through the meter. This technique is generally preferred for flow rate meters, such as differential pressure meters.

10.3 On-site Calibrators

The technique described above refer to calibration systems which are generally suitable for use in laboratory. Tank provers are also used at site to prove the flow meters at site, but becomes impractical for higher size flow meters. In many cases, it is either physically impossible or economically impractical to take the meter to the laboratory. In such cases, there are two alternative methods:

– A reference flow meter (Master meter) with sufficiently good accuracy calibrated in the laboratory may be used to do the secondary calibration of the meter at site.

– Another method is to use provers.

10.3.1 Provers

Since the late nineteenth century, the device used for establishing the accuracy of oil meter - meter proving or calibration - was the volumetric proving tank, which is still ideal for small positive displacement meters. However, the use of volumetric proving tank was not practical for large sized positive displacement meters used for custody transfer applications. Also, there was a need for a new method of proving custody transfer meters when normal metering was in progress, so as to prove the meters at normal operating flow rate and to avoid errors due to starting up and shutting down the flow at the beginning and end of the proving run.

The first step in this direction was made by "Shell', using a one-mile long pipe with a piston inside and tracking the movement of the piston. In this method, the piston had to be removed at the end, transported back to the starting point by vehicle and reinserted into the pipe. This was also creating problems due to the temperature variation along the pipe length. In another method, a piston was made to shuttle to and from along a short distance by the operation of a four-way flow reversing valve. This method was called standing start and finish mode with no flow through the meter at the beginning and end of the proving run. Neither of these methods was suitable for proving large custody transfer turbine flow meters.

In the family of modern pipe provers, the first was by R.H. Pfrehm. This consists of electro-mechanical piston detectors at points spaced well apart on a fairly short length of pipe. This method enjoys almost all advantages of the modern pipe provers. In another design by M.L. Barratt, the piston was replaced by an inflated-elastic sphere forming an interference fit inside the pipe. This reduced the piping works and flow reversing valves. With the developments in electronics, compact provers came into existence that needed much less space as compared to conventional provers employing optical techniques for measuring displacement of piston.

10.3.2 Operating principle

The flow of fluid that passes through the meter pushes a solid body known as displacer along a calibrated length of pipe. The displacers may be a piston or sphere, but seals positively against the inside wall of the pipe so that no fluid can leak past the piston. As the displacer enters the calibrated length, its proximity is sensed by a detector and admits the flow meter pulses to an electronic counter and starts counting.

As it leaves the calibrated length, a second detector sends a signal which stops counting. After correction for pressure and temperature effects, the accurate known volume of the prover is compared with the number of meter pulses counted, providing an accurate method for proving the meter. The major problems in the design of pipe prover are:

- Method of starting the displacer on its journey when it is desired to initiate a proving operation and stopping the same at the end of the operation.
- After a proving pass, the displacer is to be returned to its starting point.
- Valves incorporated in the prover and those between the prover and meter being proved are to be fully leak proof during the proving operation.

10.3.3 Classification

Pipe provers can be broadly classified as conventional pipe provers and compact pipe provers. The conventional pipe provers, the only kind available in the early days have a commo n feature of large size due to the use of electro-mechanical detectors. The positioning accuracy being ±1mm, the calibrated length of conventional provers will be of the order 10 meters to 20 meters, to reduce the error to ± 0.01%. This was also to reduce the rounding off error of ± 1 pulse by employing large calibrated volume. As the name implies, the compact pipe provers are used where saving of space is required. The length of calibrated portion is smaller than that of conventional pipe prover for same duty. Compact prover employs electronic detectors with greater accuracy than the electro-mechanical detectors employed in conventional prover. This also employs new methods of pulse interpolation so that rounding off error can be reduced with smaller number of pulses. This enables the calibrated volume to be reduced by a factor of ten.

10.3.4 Calibration of meters using Pipe provers

There are four different ways of proving meters using pipe provers. Depending on their intended manner of use as mobile provers, dedicated provers, central provers and laboratory provers.

10.3.4.1 Mobile Provers

Mobile provers are used for proving meters that need calibration regularly but not frequently. The metering system is to be designed so as to accommodate the prover through branch pipes with stop valves terminating flanges and block and bleed valve in the metering line to divert the flow. A mobile prover will be provided with flexible hoses to facilitate connection to a metering system. The mobile provers may be mounted on a truck or trailer. Majority of mobile provers are bi-directional provers.

10.3.4.2 Dedicated Prover

Here the prover will be permanently connected to the oil metering system and form part of the metering system. The system is designed in such a way that it is possible to enable the flow from one meter at a time to be diverted through the prover. Both unidirectional and bi-directional provers can be used as dedicated provers.

Compact provers are also being used. Dedicated proving systems will be normally employed for crude oil fiscal metering stations, large custody transfer metering stations, marine tanker loading stations, etc. Normally dedicated provers are provided with pressure relief valves in a void pressure build in the prover due to increase in oil temperature.

10.3.4.3 Central Provers

The concept of central prover is opposite in that of mobile prover. Here the meter is transferred to a central proving system and taken back after calibration. This is a cheaper alternative of using dedicated provers at large fiscal and custody transfer metering installations. Turbine meters used with this technique will have good repeatability and long-term stability with lower sensitivity to viscosity changes. In such metering stations, two turbine meters will be employed and output of the two will be compared. If the ratio exceeds the permitted limits, one of the meters will be dismantled and sent to central proving station for calibration. Central proving systems will be provided with oils having different viscosities. Here a pair of meters carried the entire throughput of a major metering station. These meters are normally larger in size.

10.3.4.4 Laboratory provers

Laboratory provers generally employ gravimetric calibration system. They can employ water/oil as the working fluid.

10.4 Calibration by master meter method

When one meter is selected to serve as the reference for proving of another meter the reference meter is called master meter and a comparison of the two outputs is the basis of the master meter proving method. Usually the master meter accuracy should be higher than the accuracy of the meter to be calibrated. This is an indirect method of proving. Either the ‘standing start’ or ‘running start’ method may be used for the proving.

The meter that is selected from a battery of meters as m aster meter or portable meter should be known from experience to be reliable, consistent and well maintained. The meter factor for the master meter shall be established for the same liquid and for virtually the same rates as will hold for the proving of the meter to be proven against it.

A complete record of the master meter proofs are to be kept so that the trustworthiness of the meter can be established to all parties involved in a transaction.

The master meter and the meter to be proved is connected in series and be sufficiently close so that the line-fill between them will not change during the period of proof, either in temperature, type of liquid or volume at reference conditions. Before the actual proof is made the meters are run at a desired flow rate for a period of time sufficient to purge the system and to achieve stability of temperature and pressure. If they are not operating at identical temperature and pressure, suitable corrections are to be applied to the readings. The master meter shall be normally placed downstream of the meter to be proved.

The purpose of proving/calibrating a meter is to determine its meter factor — A number obtained by dividing the actual volume of liquid passed through a meter during proving by the volume registered by the meter. The purpose of a meter factor is to correct a meter's indicated volume as it pertains to a particular measurement, at a particular rate (or narrow range of rates), in a particular petroleum liquid so that the indicated volume becomes a gross volume. Therefore, obtaining a meter factor is the first step in calculating the net standard volume o f a receipt or delivery of Oil.

11 REPORTING THE RESULT – PERFORMANCE INDICATORS

To display the result of a calibration, the nature of the meter output has to be understood. Flow meters may indicate flowrate or quantity in a number of different ways. There may be a mechanical or electronic display indicating quantity or flowrate, or an electronic output based on pulses, frequency or current (mA). The output may be in the form of a differential pressure.

Where the output or display is based on the rate measurement (i.e. frequency, flowrate, differential pressure or mA), readings normally vary a little during a calibration test point. It is normal to average the readings taken at a controlled sample rate across each calibration determination.

If the output is based on quantity passed (i.e. total pulses or display of quantity) the reading of the display has to be compared with a quantity of fluid measured by the standard. If the display is a visual one, clearly the flow has to be stopped to read the display unless some form of photographic reading triggered from the calibration process is used. If the output is electrical, electronic gating can coincide with a trigger signal from the standard.

Where electronic digital outputs such as serial or field bus data transfer is used, rate measurements can be sampled or quantity can be read at the end of the calibration period. This type of output cannot normally be triggered electronically to synchronize with a calibration standard, therefore extreme care must be taken to recognize update and processing times if a dynamic calibration method is used.

The result of a calibration is normally given in tabular form listing the measurements from the standard and the device. Information on the influence factors and the amount of raw data given will vary depending on the calibration specification.

The presentation of meter and standard readings is not the most helpful to interpret the result of the calibration. It is therefore normal to calculate a performance indicator. A performance indicator can be used to display the result in a way which best displays the performance of the meter across the flow range. It will also allow the determination of a quantity when the meter is used in practice.

A number of different performance indicators are commonly used.

<u>K-factor:</u> Used for meters with pulsed outputs proportional to quantity passed. K-factor is expressed as <u>pulses per unit quantity</u> (e.g. pulses per m3 or pulses per kg)

<u>Meter factor:</u> The generic definition is "correction factor" in the VIM but in the flow meter industry the term "meter factor" is used. The meter factor is normally dimensionless and is calculated as the ratio of the meter output to value determined by the standard. This can be computed from rate measurements or quantity measurements. Units should be the same. Example:

$$F = \frac{Q_s}{Q_i}$$

$$or\ F = \frac{V_s}{V_i}$$

Where
F is the meter factor;
Q is flowrate;
V is volume;
i is indicated by the device and
s is the measured value from the standard.

As with the K-factor, this is the number which the output is multiplied to give the true reading.

<u>Error</u>: Error is the difference between the indicated value and the value determined by the standard. <u>Relative error</u> is the error divided by the value determined by the standard and is normally expressed as a percentage.

$$Error = \frac{Q_i - Q_s}{Q_s} * 100\%$$

It is important to always define this equation in a calibration report as some industries use a different convention. This is best described as the inverse or negative error and this is based on the standard minus the indicated value.

Error can also be defined for meters with electrical outputs of pulses, frequency, volts or mA. In this case the indicated value is calculated from the output reading and the predetermined relationship (normally linear) between the output value and the equivalent quantity or flowrate.

An example is if a meter is configured to provide 20 mA = 10 l/s and 4 mA = 0 l/s. The value of Q_{ind} would be the flowrate calculated from the measured current and the linear relationship derived from the maximum and minimum settings.

Discharge coefficient: For differential-pressure meters, such as orifice plates and nozzles, the performance indicator used is the discharge coefficient (C). This is effectively an expression of the ratio of the actual flow to the theoretical flow. The theoretical flow is however, defined in terms of the diameter of the throat of the device. C is given by the formula:

$$C = \frac{q_m\sqrt{1-\beta^4}}{\frac{\pi}{4}d^2\varepsilon\sqrt{2\Delta p\rho_1}}$$

Where :

d is the throat diameter (m)

β is the ratio of throat diameter to pipe diameter d/D

D is the internal pipe diameter

Δp is the measure differential pressure (bar)

ρ is the density (kg/m3)

q_m is the mass flow rate (kg/s)

ε is the expansibility [expansion] factor

The coefficient ϵ is used to take into account the compressibility of the fluid. For incompressible fluids (liquids) ϵ = 1; for compressible fluids (gas) the value for ϵ is calculated from formulae based on the properties of the fluids.

The numerical value of C will commonly vary depending on the device. Typical orifice plates have a C value of around 0.6 and nozzles between 0.9 and 1. Discharge coefficient is relatively constant for any particular device, only varying slightly over the working flow range of that device. For these devices, the flow range is most usefully expressed in terms of Reynolds number. Values of C derived from a liquid calibration may be used in gas applications with appropriate application of ϵ.

It is to be noted that when calibrating a device, the values chosen for the diameters must be recorded and quoted in the calibration certificate. If these values are subsequently used to determine the flowrate from the derived C, any inaccuracy or uncertainty in the diameter values does not contribute to the uncertainty of the flowrate. Changes in the diameter due to wear, fouling or indeed temperature will of course make a difference. Accurate dimensions are only required where the value of C is derived from theoretical equations rather than by calibration.

Flowrate: To express the overall performance of a device, its performance across its flow range has to be determined. The flowrate is normally expressed in terms of quantity per unit time with the units chosen to suit the application. Alternatively, a more complex flow-based parameter may be used such as Reynolds number which can add further dimensions to the performance curve by accounting for viscosity and density.

There is no correct answer to the question. In some applications an answer is apparently easy. An industry standard or third party (regulator or trading partner) dictates the calibration frequency. In this case the meter is calibrated whether it requires it or not and is often assumed accurate between calibrations. For most applications however, it is the user who must define the calibration interval and the policy to determine when to calibrate. The calibration interval should be chosen to minimize the risk of an incorrect meter reading making a significant impact on the process.

For example, high flowrates of oil attract huge tax liabilities. The product value is high, the risk of meter damage is high and so perhaps weekly in-situ calibrations of the meter, in the actual product, will be specified. Alternatively, metering waste water with a Venturi may only require annual inspections, irregular verification, and no flow calibration. The differential pressure measurement device will however be calibrated regularly. The risk of the pressure transducer being in error is reasonably high, the risk of the Venturi changing is low, and the product value is low.

Other factors affecting the decision are the history of the meter, when the process is closed for maintenance, or what checking and diagnostics are monitoring the meter.

It is always good practice to keep calibration graphs, and control charts of the meter performance. This will assist in selecting intervals and also show changes in performance indicating degradation of meter performance.

Below is a sample flow data sheet of a Turbine flow meter calibrated through its flow range

Sl. No.	Pup bar	W1 Kg	W2 kg	t s	T deg C	Density kg/m^3	Qa m^3/h.	V litres	N pulses	K ppl	F Hz.
1	1.60	77.75	1547.40	107.049642	31.08	995.210	49.714	1478.29	35799	**24.2165**	334.4149
2	1.60	74.40	1573.20	109.429019	31.18	995.170	49.599	1507.67	36496	**24.2069**	333.5130
3	1.60	75.00	1562.10	108.770138	31.19	995.170	49.510	1495.90	36209	**24.2055**	332.8947
4	1.60	73.00	1564.55	109.284205	31.19	995.170	49.425	1500.38	36317	**24.2052**	332.3170
5	1.60	74.30	1575.40	110.199445	31.23	995.160	49.329	1510.00	36550	**24.2053**	331.6714
6	1.60	101.35	1312.20	109.944386	31.23	995.160	39.883	1218.03	29626	**24.3229**	269.4635
7	1.60	100.65	1326.20	111.319607	31.25	995.150	39.869	1232.83	29979	**24.3173**	269.3057
8	1.60	102.40	1315.60	110.183288	31.25	995.150	39.874	1220.40	29680	**24.3198**	269.3693
9	1.60	98.30	1320.65	111.161673	31.26	995.150	39.821	1229.61	29904	**24.3199**	269.0136
10	1.60	100.55	1317.85	110.614150	31.26	995.150	39.853	1224.53	29784	**24.3228**	269.2603
11	1.60	108.40	1010.30	109.214620	31.29	995.140	29.906	907.27	22215	**24.4857**	203.4068
12	1.60	108.95	1019.90	110.421343	31.30	995.130	29.876	916.38	22439	**24.4866**	203.2125
13	1.60	108.55	1014.20	109.756309	31.30	995.130	29.882	911.05	22311	**24.4894**	203.2776
14	1.60	110.25	1021.55	110.481890	31.31	995.140	29.871	916.72	22445	**24.4840**	203.1555
15	1.60	101.55	1021.10	111.574730	31.30	995.130	29.846	925.03	22647	**24.4825**	202.9761
16	1.60	138.05	928.65	143.860927	31.34	995.120	19.902	795.32	19575	**24.6128**	136.0689
17	1.60	928.65	1720.35	144.682846	31.34	995.120	19.817	796.43	19597	**24.6062**	135.4480
18	1.60	133.10	917.55	143.599581	31.34	995.120	19.783	789.13	19427	**24.6182**	135.2859
19	1.60	119.80	926.05	147.708153	32.26	995.150	19.767	811.04	19953	**24.6018**	135.0839
20	1.60	926.05	1729.65	147.236719	31.19	995.170	19.765	808.36	19885	**24.5993**	135.0546
21	1.60	952.70	1755.95	268.460086	31.03	995.220	10.835	807.96	20059	**24.8266**	74.7187
22	1.60	88.15	889.60	268.605693	31.06	995.210	10.805	806.16	20023	**24.8375**	74.5442
23	1.60	889.60	1691.60	269.081739	31.13	995.190	10.793	806.73	20027	**24.8249**	74.4272
24	1.60	121.45	924.40	269.803638	31.21	995.160	10.777	807.71	20050	**24.8233**	74.3133
	1.60	537.95	1340.65	270.020565	32.22	995.160	10.765	807.46	20049	**24.8297**	74.2499

Average K-Factor = **24.490** ppl

% Repeatability = +/- **0.004** %

$$Q_a = \frac{(W_2 - W_1) \cdot 1.00106x3600}{tx\rho} m3/h$$

$$V = \frac{(W_2 - W_1) \cdot Bx1000}{\rho} litre$$

$$K - factor = \frac{N}{V} \ ppl$$

of 10m³/h to 50m³/h.

Pup-Pressure at the upstream of the test meter

W_1- Initial mass of the weigh tank

W_2- Final Mass of the weigh tank

B - Buoyancy correction factor

T - Time of collecting water

ρ - Water density at line temperature

N - Number pf pulses in 't' seconds **F** - Output Frequency of meter

K - Meter Factor

V - Volume of water collected in 't' seconds

Qa – Actual Flow rate obtained from gravimetric system

12 VERIFICATION OF FLOWMETERS

Flowmeter verification is often used as a confirmation of long-term sensor or transmitter stability. Verifications can be electronic simulation that do not involve actual flow or process comparisons under flowing conditions.

Electronic verification does not include a wet test of the process meter. The electronic verification device coupled with integral meter diagnostics can detect changes in the sensor geometry from coating, erosion, or corrosion for example. Component drift, transmitter or converter errors, or hardware failure tests can be confirmed or compared with the original manufacturer tolerances and specifications over the process meter lifecycle.

Verification devices can store past tests so they can be reviewed or compared over the flowmeter lifecycle. These tests can be stored as read-only electronic files or printed for hardcopy review. As an option, electronic flowmeter verification can be provided at the time of manufacturing to create a baseline analysis from which to judge the long-term changes that occur in a tested sensor or transmitter component. Repeat field verification tests can show long-term change in meter stability. In some government, or agency requirement, a field verification activity can be carried out in-situ or offline.

Electronic verification tools should be periodically returned to the original manufacturer or laboratory to ensure proper functioning and calibration of electrical components.

Another method for verifying flowmeter operability in-situ is by comparing an additional flowmeter or flowmeter technology. This can be an insertion meter, such as a hot-tap differential pressure, magnetic, or ultrasonic device. In many cases, however, a nonintrusive ultrasonic flowmeter is a better fit because no process interruption is necessary. Nonintrusive devices can be used when pipe diameter, pipe wall thickness, and sound velocity characteristics are known.

Typically, the manufacturer produces coefficients and values that relate to the pipe and fluid types for meter commissioning. For example, the speed of sound in a liquid to be evaluated for flow comparison is required for ultrasonic commissioning, but is not necessary for magnetic flowmetering. In addition, the fluid characteristics to be tested should remain somewhat constant during the time of comparison. These characteristics include, for example, fluid density, concentration of chemical solutions, and temperature.

13 CALCULATION OF METER ERROR

The value of the meter error is determined using the following equations:

$E = E' + Ea + E_\beta$

$E' = [(Vm - Vs) / Vs] \times 100$

$E_\alpha = \alpha\,(ts - tm) \times 100$

$E_\beta = ß(tr - ts) \times 100$

Where

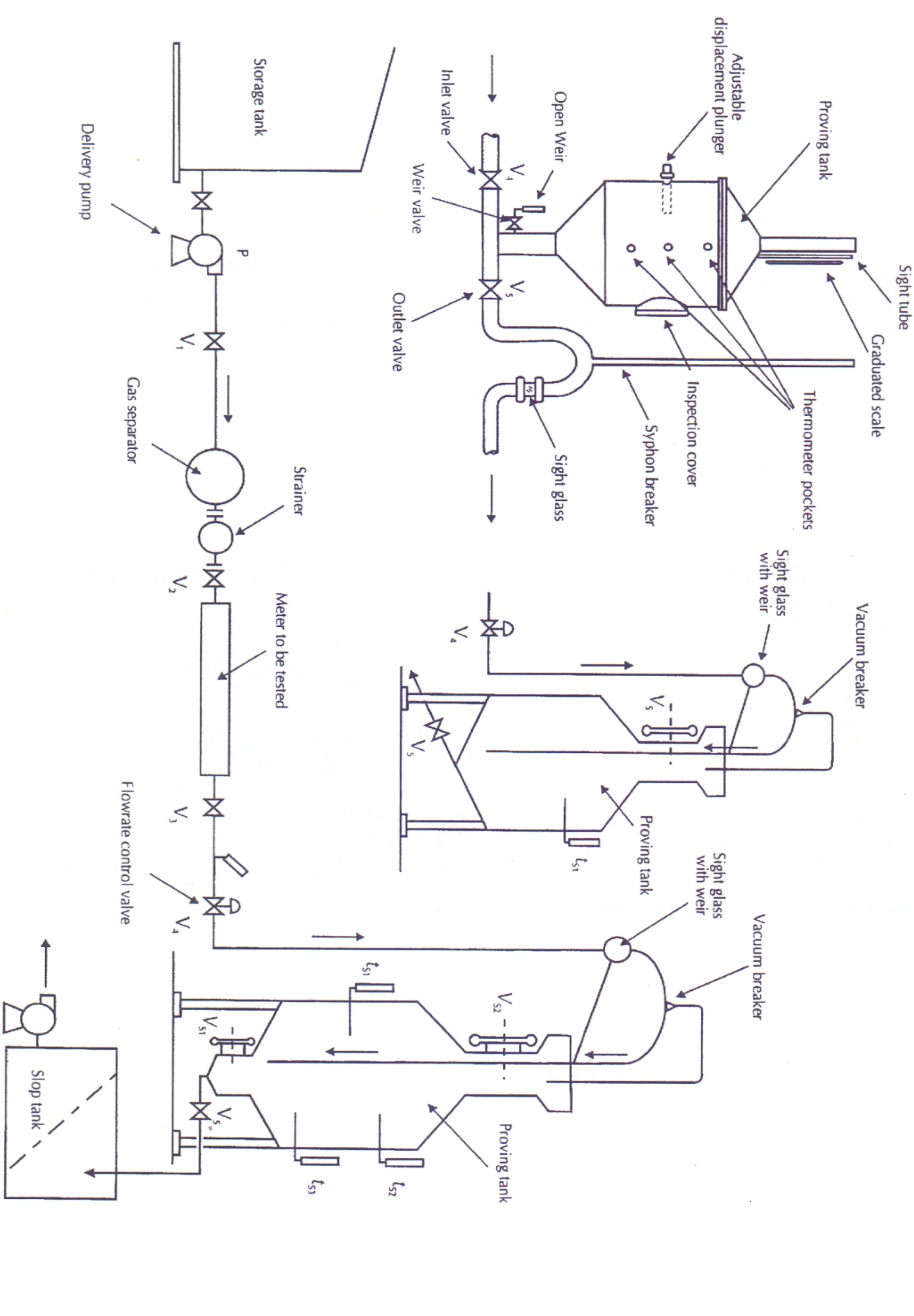
E is the meter error, in %
E' is the uncorrected error, in %
$E\alpha$ is the temperature correction for the test liquid, in %
E_β is the temperature correction for the standard capacity measure (%)
Vm is the volume indicated by the meter, in L
Vs is the volume measured in the standard capacity measure, in °C
ts is the average liquid temperature in the standard capacity measure, in °C
tm is the average liquid temperature in the meter, in °C
tr is the reference temperature of the standard capacity measure, in °C
α is the cubic expansion coefficient of the test liquid due to temperature, in $°C^{-1}$
ß is the cubic expansion coefficient of the standard capacity measure due to temperature, in $°C^{-1}$

Notes: α: Refer to OIML R 63 or ISO 91-1 for petroleum products; refer to ISO 8222 for water
ß: $33 \times 10^{-6}\ °C^{-1}$ for mild steel, $51 \times 10^{-6}\ °C^{-1}$ for stainless steel

ANNEX1: EXAMPLE OF A TEST REPORT

Test procedure for a meter on its own or fitted with ancillary devices

No	Procedure	P	V_1	V_2	V_3	V_4	V_5	Description
1	Before the test	x	x	x	x	x	x	(*)
2	Meter installation in the test line							
3	Preliminary run	O	O	O	O	O	O	Fill proving tank to V_{s2}
4	Proving tank draining	x	x	x	x	O	O	Drain to approx..zero (V_{s1}) (**)
5	Start reading	Observe and record V_{m1} and V_{s1} (***)						
6	Test run	o	o	o	o	o	o	Fill to V_{s2} (****)
		x	x	x	x	o	x	Keep closed
		Observe and record V_{m2} and V_{s2}						
		Observe and record t_{m^1}, t_{s1^1}, t_{s2^1} (*****)						
7	Proving tank draining	x	x	x	x	x	x	Drain to approx. zero (V_{s1})
8	Calculate uncorrected error E'(%)							
9	Calculate meter error E (%) ($E=E'+E_\alpha+E_\beta$) (*******)							


Proving tank
Adjustable displacement plunger
Sight tube
Graduated scale
Thermometer pockets
Inspection cover
Syphon breaker
Sight glass
Open Weir
Inlet valve
Weir valve
Outlet valve
Vacuum breaker
Sight glass with weir
Proving tank
Storage tank
Delivery pump
Gas separator
Strainer
Meter to be tested
Flowrate control valve
Vacuum breaker
Sight glass with weir
Proving tank
Slop tank

REFERENCES:

International vocabulary of metrology — Basic and general concepts and associated terms (VIM) BIPM 2008 {www.BIPM.org)

International Vocabulary of Basic and General Terms in Metrology (VIM). BIPM 1995 (BS PD6461, 1995)

Guide to the Expression of Uncertainty in Measurement 1995 (GUM). BIPM/ISO/OIML/IEC/IFCC/IUPAC/IUPAP. {www.BIPM.org}

ISO 5168:1998. Measurement of Fluid Flow -- Evaluation of Uncertainties.

ISO 4185:1980. Measurement of Liquid Flow in Closed Conduits – Weighing Method.

ISO 9368-1:1990. Measurement of Liquid Flow In Closed Conduits By The Weighing Method- Procedures For Checking Installations -- Part 1: Static Weighing Systems.

ISO 8316:1987. Measurement of Liquid Flow In Closed Conduits – Method By Collection of The Liquid In A Volumetric Tank.

ISO 12916. Liquid Hydrocarbons - Dynamic Measurement - Volumetric Proving Tanks Or Measures.

ISO 8222. Petroleum Measurement Systems - Calibration – Temperature Corrections For Use When Calibrating Volumetric Proving Tanks.

ISO 7278-2. Liquid Hydrocarbons - Dynamic Measurement - Proving Systems For Volumetric Meters - Methods For Design, Installation and Calibration of Pipe Provers.

ISO 7278-4. Liquid Hydrocarbons - Dynamic Measurement – Proving Systems For Volumetric Meters - Guide For Operators of Pipe Provers.

ANNEX 2: CLIENT CALIBRATION CHECK LIST

Contact Name:	
Company Name:	
Address:	
Tel:	
Email	
Type of meter Turbine/DP/Coriolis/Ultrasonic/etc.	
Make/Model	
Size of meter (Length, diameter,) (weight) (other size)	
Type Fluid to be Calibrated Water/Oil/Gas (air?) / Multiphase (get details i.e. what is the viscosity of liquid)	
Flowrate/Flowrange (remember to note Units!)	
Operating Pressure (especially for gas)	
Operating Temperature	
Signal Output: Pulsed/mAmps Pulsed = max frequency Resolution: is it a scale, pulses/unit	
K-factor (Check pulses required for calibration)	
Is pipework included. Are all electronics included	
What uncertainty is required	
What Flanges: screw etc. Are the flanges raised or RTJ Some standard fittings are ANSI 150 PN 10 BSP ANSI 600 PN 16	
Measured Points required g. (3 @ 5 flowrates) (1 at 10 flows)	
Timescale required	

Have you had the meter calibrated before	

WEST AFRICA QUALITY SYSTEM PROGRAMM (WAQSP)
SUPPORT TO THE IMPLEMENTATION OF THE ECOWAS QUALITY POLICY
PROJECT FUNDED BY THE EUROPEAN UNION

European Union

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