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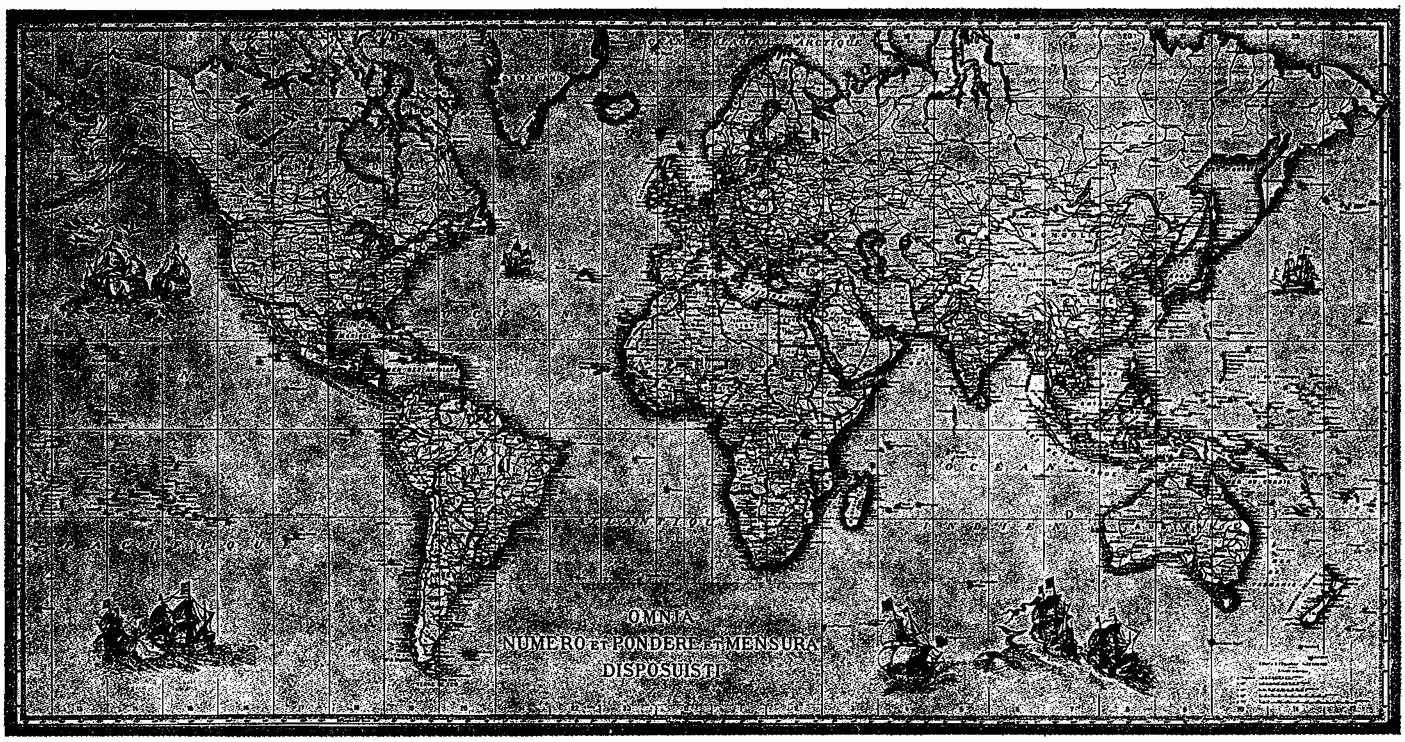

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STANDARDS for the CALIBRATION of GAS FLOWMETERS *

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SUMMARY — Specially manufactured measuring instruments and selected instruments of series production are used as standards in gas flow measurement technology. The requirements concerning uncertainty and ranges of measurement, which depend on the specific tasks of calibration, are decisive for which standard shall be used. It is also possible to use ordinary gas flowmeters as standards if the range of flowrates is considerably narrowed as compared to that of industrial use. This paper outlines the patterns of gas flowmeters which are mainly used as standard instruments and gives details of the practical experience gained by the ASMW concerning these instruments.

1. Introduction

As compared to other measurement techniques, the gas flow measurement technology is marked by a number of peculiarities which have to be taken into account by the use of standards. The first one is the fact that in general the gas is in a state of flow during its measurement. Secondly, a definite characterization of a gas volume requires knowing its thermodynamic state (pressure, temperature). Thirdly, when performing gas volume measurements of real gases, it is necessary to take account of the deviation from the ideal response, i.e. compressibility factor and possibly humidity of the gas.

Whereas the pressure in the town gas supply at households does not greatly exceed atmospheric pressure and the consumption is at a few cubic metres per hour, the gas pressure in industry of for the transport of (natural) gas in national or international gas pipe-lines attains 10 MPa (100 at) and the flowrate even exceeds 300 000 m^3/h, referred to standard reference conditions.

Gas flowmeters of very different design and functional principle have to be used to cover these large fields of application.

The standards to be used for calibration have consequently to be adapted for these conditions. In a number of defined cases it is in GDR necessary to perform a calibration of gas flowmeters according to the Decree on Metrology [1]. This calibration is then called verification.

In the GDR calibration, or verification, of gas flowmeters is at present almost exclusively performed with air at atmospheric pressure as fluid. The test results are evaluated for the standard reference conditions according to GDR Standard TGL 34 126 which are p_n = 101 325 Pa (760 torr), T_n = 273.15 K (t = 0 °C).

* English translation of a paper published in Metrologische Abhandlungen ASMW 3 (1983) 4.

2. Terminology

The term « gas flow » is used as a generic term for gas volume and gas mass. Typical gas volume meters are the bell prover, the drum-type gasmeter and the rotary displacement meter (see 4). In practical life the term « gas flowrate » is frequently used. The gas flow running through a pipe system in a given period of time is characterized as the volume flowrate $\dot{V} = \frac{V}{t}$ or mass flowrate $\dot{m} = \frac{m}{t}$. Gas flowrate meters are such measuring instruments as rotameters and vortex meters.

The results of gas flow measurements are primarily used for accounting and balancing purposes ; measurements of the (instantaneous) flowrate are mainly used for process control of plants.

As the mass and flowrate of a gas are interrelated in time and as, in general, sufficiently accurate measurements of time can be easily performed, it is possible to use both gas flowmeters and gas flowrate meters as standards for the measurement of gas flowrates.

3. General Requirements on Standards in Gas Flow Measurement Technology

During the calibration of gas flowmeters the meter to be tested and the standard instrument are connected in series and the indicated results are compared. In the majority of cases this standard does not consist of a single instrument, but it is a group of several inter-connected measuring devices, a supply system for the fluid and a defined procedure for evaluation. The term « standard » is applied in both cases.

The characteristics of standards have always to be « better » than those of the measuring instruments to be tested. It applies the principle [2] that the accuracy class of the standard should have at most 0.4 times the limits of error (or the accuracy class) of the flowmeter to be tested. Moreover, the standards have to meet the requirements given below :

- no or only negligibly small reactive effects on the metrological characteristics of the meter to be tested ;
- a low experimental standard deviation or good reproducibility of measured values ;
- a good long-term stability ;
- a wide measuring range over a wide range of flowrates ;
- a small mass.

However, experience shows that there does not exist any « ideal standard » which can be used for all tasks of testing. That is why the ASMW and industry employ different types and categories of standards according to the specific application.

4. Standards for Gas Flow Measurement Technology

To carry out calibration of gas flowmeters, there are, firstly, standards used, which have been specially designed for this purpose. Secondly, among the ordinary gas flowmeters such instruments are selected, whose metrological characteristics are good enough or can be adapted for use as standards.

The first group includes

- bell provers (floating bell measuring instruments) ;
- measuring devices with « critical » nozzles ;
- gravimetric measuring devices ;
- pipe provers (measuring devices with a sliding piston).

The second group includes measuring devices with

— CVM meters ;
— rotary displacement meters ;
— drum-type gasmeters ;
— turbine flowmeters ;
— differential pressure flowmeters ;
— vortex meters.

4.1. **Bell provers (floating bell measuring instrument)**

The bell prover [3] is one of the oldest devices to perform calibration or verification of gas flowmeters. The device which was at first designed in England about 1860 is still used in its original form. It consists of a vessel (the « tub ») filled with a confining liquid (water or oil) and the bell dipping into this confining liquid. Since the bell is filled with gas (fluid), it floats on the confining liquid. If the fluid is discharged, the bell immerses deeper into the confining liquid. The depth of immersion is a measure of the volume of the gas to be measured (fig. 1). It can be read from a calibrated scale with a pointer. After every discharge the bell has to be refilled with fluid, which leads to a periodic operation.

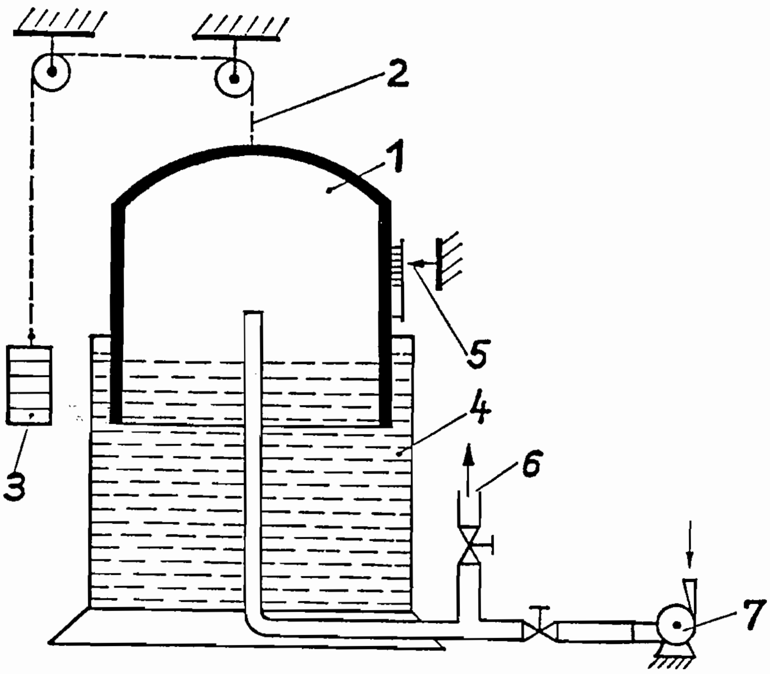


Fig. 1 — BELL PROVER

1 bell
2 chain
3 counter-weight
4 tub
5 read-out device
6 connection to meter under test
7 blower

The calibration of the bell prover [4] consists of a metrological examination and a functional test. The metrological examination includes a check of the geometrical dimensions so as to determine the volume of the bell versus the depth of its immersion. Bell provers are classified in the accuracy class 1.0.

Bell provers are used for verification of series-manufactured diaphragm gasmeters with a maximum flowrate of about 100 m^3/h. In general, the volume of the fluid V which has been discharged from the bell is used without correction to determine the error of the meter to be tested. It is not an economic procedure to calibrate series-manufactured gasmeters, due to its discontinuous operation (delays resulting from having the bell refilled and drained) as well as relatively large test volumes resulting from its metrological characteristics.

To reduce delays to a minimum two bell provers can be installed in a tandem arrangement [5]. This arrangement does, however, not prove useful in practical work since it requires a considerable amount of space and equipment.

The bell prover is still used as primary standard for the calibration of other standards [6]. These devices with a bell volume of 2 to 10 m^3 (exceptional case : 56 m^3) require a large amount of technical equipment for collecting measured values and influence quantities as well as for air conditioning in the room where they are installed and require also electronic data processing devices for evaluating the results. The relative uncertainty of these devices is 1 to $3 \cdot 10^{-3}$.

4.2. **Measuring devices with critical (sonic) nozzles**

The measurement procedure with « critical » nozzles [7] is a method of flowrate measurement which requires generation of a « super-critical » pressure ratio by a specially formed nozzle (fig. 2). In case of a large decompression, the expansibility factors (see 4.9.) only apply up to one expansion ratio, the « super-critical » ratio at which speed in the narrowest section of the nozzle is equal to sonic speed at a given thermodynamic state. A further reduction of pressure behind the nozzle or increase of pressure in front of it does no longer result in an enhancement of the flowrate. In the narrowest section of the nozzle the fluid continues to flow at the speed and to be in the thermodynamic state as is the case with the supercritical pressure ratio.

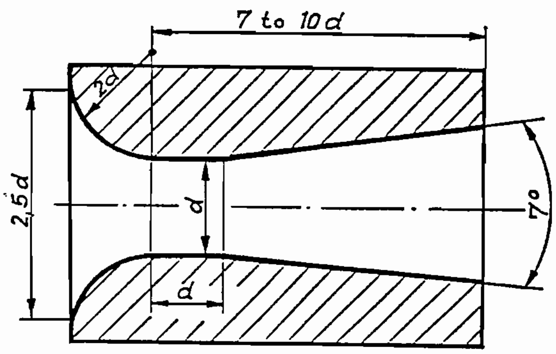


Fig. 2 — NOZZLE (modified Smith-Matz nozzle)

The volume of the fluid which has run through the measuring device V can be calculated by the equation*

$$V_N = \dot{V}_N \cdot t = \alpha \cdot c_d \cdot A_d \sqrt{T_1} \cdot t \qquad (1)$$

with

$$c_d = \left(\frac{2}{\varkappa + 1} \right)^{\frac{1}{\varkappa - 1}} \cdot \left(\frac{2\varkappa}{\varkappa - 1} \right)^{\frac{1}{2}} \cdot R^{-\frac{1}{2}} \qquad (2)$$

All terms in equation (1) and (2), except the flow coefficient, are measurable or calculable. $\varkappa$ is experimentally determined.

* The signification of the symbols used in the equations is given in the annex to this paper.

The measuring apparatus with five parallel-connected sonic nozzles which has been designed and constructed in the ASMW exhibits a relative uncertainty of $6 \cdot 10^{-3}$. The range of flowrates is from 0.01 to 30 m^3/h.

Measuring devices with sonic nozzles are increasingly used as standards for the calibration of gas meters. As compared to the testing procedure with the bell prover (see 4.1.), the measurement procedure with sonic nozzles exhibits the advantages given below :

— an improved accuracy of measurement for the measured quantity of volume with a high reproducibility of the volume flowrate values at the test points ;

— a high effectiveness of the testing procedure as a result of the elimination of delays, the reduction of volumes of the fluid and the shortening of times for testing ;

— possibilities of an automation of the test sequence.

The disadvantage resulting from the fact that it is possible to generate only one volume flowrate with one sonic nozzle is partly overcome by parallel connections.

4.3. Measuring devices operated according to the weighing method

Weighing methods are subdivided into « direct » and « indirect » methods. As far as gas flowmeters operated according to the direct weighing method are concerned, the mass of gas is directly determined with a weighing device. For this purpose the gas to be measured flows into an evacuated vessel with a constant volume (vacuum method) or is filled into the vessel under overpressure (overpressure method). The gasflow which is the measure of the volume of the fluid that has flown through the meter to be tested can be determined by the difference of weighings with the empty and filled vessel. With the indirect weighing method the gas to be measured at first displaces an equivalent volume of a liquid. The mass of the displaced liquid is determined by weighing and the result of it is used to calculate the gas volume which has flown through the meter to be tested.

4.3.1. Measuring devices using direct weighing

Figure 3 shows the diagram of a device operated under overpressure according to the direct weighing method [8, 9]. The vessel 2 hanging on the weighing device 1 completely dips into the water 3. The vacuum pump evacuates the vessel 2 and the secondary vessel 5. During calibration the fluid taken from the atmosphere at first flows through the meter to be tested 6 and then through nozzle 7 into the secondary vessel 5. A super-critical pressure ratio has to be maintained in nozzle 7 so as to ensure a constant flowrate of the fluid through the measuring device. When the constant flow regime has been attained, the direction of flow of the fluid is changed by means of the group of valves 8 with the timer so as to make the fluid flow into the vessel 2. Calibration has to be completed when the pressure of the fluid does no longer allow to keep up a super-critical pressure ratio. The difference of weighing results determined before and after vessel 2 has been filled is equivalent to the mass of the air quantity which has run through the meter to be tested 6. The volume of the fluid can be calculated by the equation :

$$V_N = (\Delta m + \Sigma m_i) \sqrt{\frac{T_1 \cdot T_N}{p_1 \, k_1^2 \left(p_1 - k_2 \cdot \varphi \cdot k_3 \cdot e^{\frac{-k_4}{T_1}}\right)}} \qquad (3)$$

The measuring device of this type in the Czechoslovak Metrology Institute has a vessel of a geometric volume of about 0.3 m^3. The range of flowrates is said to be from 0.7 to 40 m^3/h at standard reference conditions and the relative uncertainty is about $1 \cdot 10^{-3}$.

This measuring device operated according to the direct weighing method is exclusively used for the examination or calibration of standards.

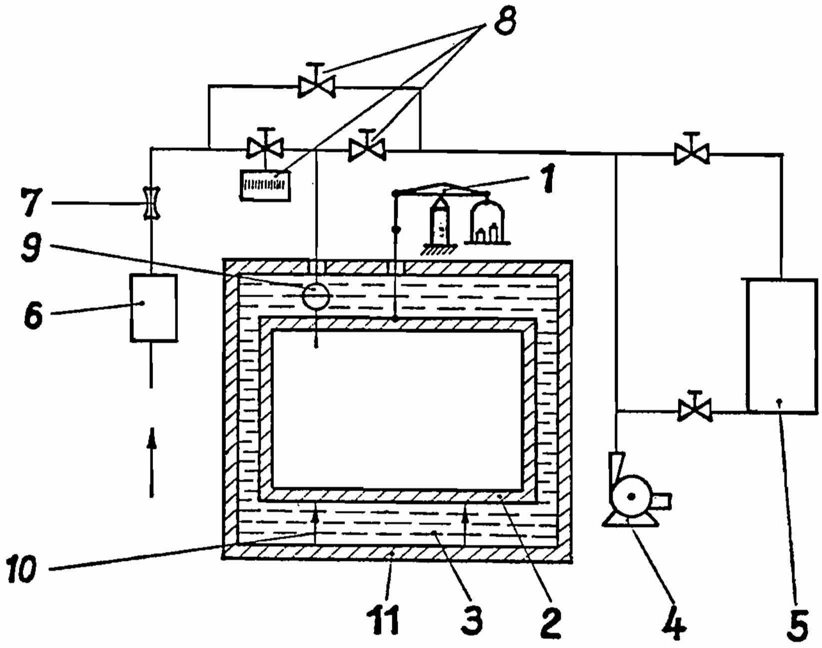


Fig. 3 — DIRECT WEIGHING METHOD

1 weighing device
2 vessel
3 water
4 vacuum pump
5 secondary vessel
6 meter under test
7 critical nozzle
8 group of valves and timer
9 special valve with coupling
10 blocking device
11 outside vessel

4.3.2. Measuring devices using indirect weighing

Fig. 4 shows the diagram of the measuring device built at the ASMW [10]. The fluid flows with a low and constant overpressure from the floating bell 1 (supply vessel, air) through the meter under test 2 into the air-filled section 3 of the vessel 4 while the indirect fluid — water — simultaneously flows out from the water-filled section 5 of vessel 4. This water flows either into the supply vessel 6 or into the vessel on the weighing device 7. The vessel 4 containing the fluid has been given a form which only causes a small lowering of the liquid level during calibration so that there exists an almost constant discharge rate for the indirect fluid (water) and thus also for the other fluid (air). At the beginning of calibration water at first flows into a supply vessel 6. When flow conditions in the measuring device have stabilized, the flow of the indirect fluid (water) is directed into the weighing vessel 7 through the two-way switch. The difference of the weighing results determined before and after the direction of flow has been changed is the mass of water which has been discharged from the vessel 4. The volume of this water mass is equivalent to the volume of the fluid which has flown into vessel 4. This volume can be calculated by the equation :

$$V_N = \frac{\Delta m + \Sigma m_i}{\rho_w} + \Sigma K\text{or} \qquad (4)$$

The testing plant which has been mounted in the ASMW is fitted with a 50 kg precision weighing device which enables to perform tests with volumes up to 50 dm^3. The range of flowrates can be varied from 0.04 to 6.5 m^3/h with the aid of 24 discharge nozzles. The relative uncertainty is equal to $1 \cdot 10^{-3}$.

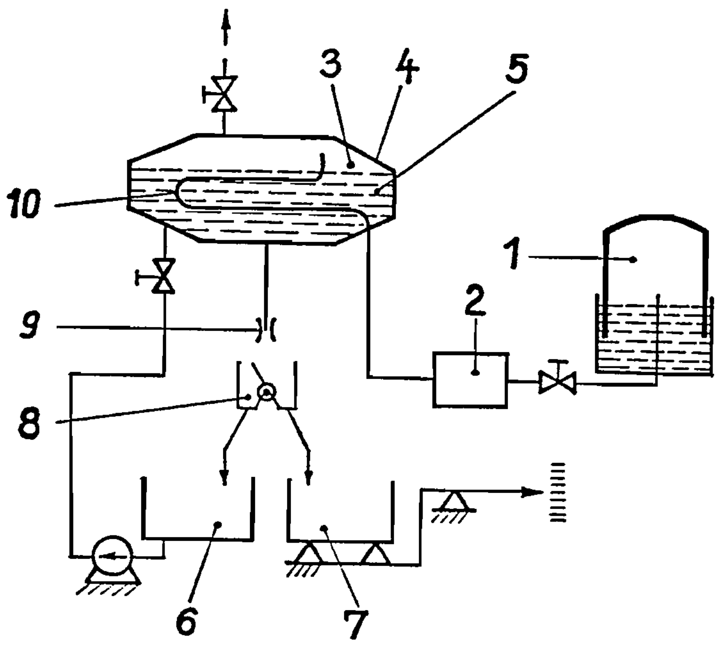


Fig. 4 — INDIRECT WEIGHING METHOD

1 floating bell (air-filled supply vessel)
2 meter under test
3 air-filled section of the vessel
4 vessel
5 water-filled section of the vessel
6 water-filled supply vessel
7 weighing device
8 change-over unit
9 water discharge nozzle
10 heat transfer unit

This measuring device operated according to the indirect weighing method is primarily used for the examination or calibration of standards. For this purpose the device has been fitted with an electric control system which actuates the change-over unit through incoming pulses from the meter under test. The change-over unit is connected to an electronic timing system.

4.4. **Pipe provers**

Figure 5 shows the functional diagram of a gas pipe prover. The gas flow makes the piston 4 slide in the pipe 5. On its way this piston passes the contacts 8 thus definitely fixing the beginning and the end of measurement and the volume of the fluid. Through a proper combination of valves the piston can move to and fro without changing the direction of flow in the meter to be tested. One forward and one backward motion of the piston are always used for the evaluation of results.

Pipe provers have since long been known as standards for liquid flowmeters [11], while they have been used for gas flowmeters for a few years only. The relative uncertainty of liquid pipe provers is said to be equal to $1 \cdot 10^{-3}$.

Account has to be taken of a number of special characteristics of pipe provers for gases as compared to those used for liquids.

These include :

— The fluid is compressible and has low density and bad lubricating properties. This may lead to the so-called « stick-slip effect », especially at low flowrates. This is a phenomenon resulting in a discontinuous motion and larger or smaller components of partial motion of the piston. The resulting differences in pressure in the fluid also effect the volume (referred to reference conditions).

— The section of the pipe in which the piston moves to and fro has a relatively large diameter. The variations within the tolerances in the pipe manufacture also create variations in volume of the fluid.

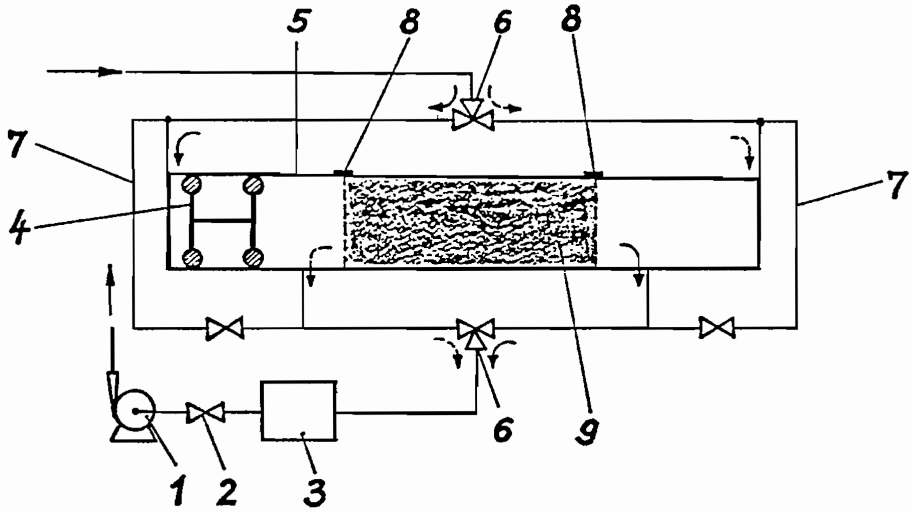


Fig. 5 — PIPE PROVER

1 blower
2 flowrate adjustment device
3 meter under test
4 piston
5 pipe
6 reverse valve
7 by-pass
8 contacts
9 standard volume

— The low density of the fluid results in the fact that there exists a large risk of internal and external leakages.

— It is necessary to use transportable standards with the required effective measurement range for the calibration of gas pipe provers with the fluid - gas. In general, these standards display a minimum uncertainty of $1 \cdot 10^{-2}$. If a liquid is used for calibration, the determination of volume can be performed with a considerably smaller uncertainty as can be done with gas, but it is not possible to cover specific components of error which occur during the operation with gas. This is why, the uncertainty of gas pipe provers is considerably larger than that of pipe provers for liquids. The relative uncertainty of gas pipe provers is expected to vary from $5 \cdot 10^{-3}$ to $1 \cdot 10^{-2}$.

One of the advantages of gas pipe provers lies in the fact that it is possible to perform the calibration of gas flowmeters with real fluids such as natural gas.

In the ASMW a gas pipe prover has been built, which can be used to carry out tests of gas flowmeters with air at low pressures in a range of flowrates from about 50 to 1 000 m³/h. The volume of the fluid which has been measured by the gas pipe prover — V_N — can be calculated with the formula :

$$V_N = \frac{D^2\pi}{4} \cdot L + \Sigma Kor \qquad (5)$$

To test this measuring device, comparative measurements were carried out with a NW 50 standard nozzle-flowmeter (see 4.9.). The set-up was analogous to that shown in fig. 5. During the test the air blower 1 sucked air through the standard nozzle-flowmeter and through the gas pipe prover. The comparative measurements showed that there existed an average systematic average deviation of — 0.5 % between the gas pipe prover and the standard nozzle-flowmeter at an experimental standard deviation of $1 \cdot 10^{-3}$. The discovered systematic variation is not significant since the comparative procedure exhibited a similar uncertainty.

4.5. **CVM meters**

The CVM meter is a new type of a flowmeter which separates and counts equal subvolumes of the flowing fluid by freely rotating blades. In every position these blades and a rotary slide valve shut the gas inlet against the gas outlet (fig. 6).

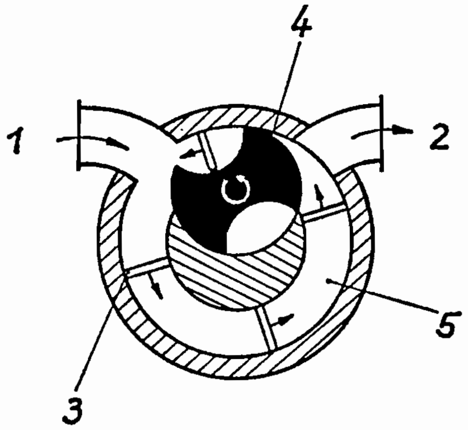


Fig. 6 — CVM METER

1 gas inlet
2 gas outlet
3 rotating blades
4 rotary slide valve
5 subvolume of the annular measuring chamber

If gas is discharged behind the meter, a pressure differential between inlet 1 and outlet 2 of the meter occurs. The gas with the higher pressure in inlet 1 of the meter applies a force to blade 3 and thus puts the blade mechanism as well as the connected rotary slide valve 4 into motion. The rotations of the blade mechanism are mechanically transferred to a counter with each rotation being equal to a given volume for actual values of pressure and temperature. In the range of low pressures the indicated volume can be converted into the state of the fluid in the meter under test by means of the perfect gas equation of state ; in case of tests performed under overpressure, it is necessary to take account of the compressibility of the fluid.

In the ASMW tests and examinations were performed on two CVM meters of the G 100 and G 650 types (8 to 160 m^3/h and 50 to 1 000 m^3/h). The measurements were carried out with the aid of the standard differential pressure measuring device of the ASMW (see 4.9.) using air and were repeated several times during a period of six years. The plotted measured values in Fig. 7 and Fig. 8 are mean values of several calibrations. The experimental standard deviations varied between

G 100 : $5 \cdot 10^{-4}$ and $8 \cdot 10^{-4}$

G 650 : $2 \cdot 10^{-4}$ and $4 \cdot 10^{-4}$

Fig. 7 and 8 show that the error distribution curves

— sharply decrease, display unsteadiness or are difficult to be reproduced at small volume flowrates ;

— vary in a range of about ± 0.5 % at $V \geqslant 0.25 \cdot V_{max}$ without revealing any systematic variations.

Unlike the other error distribution curves, the curve of the G 650 type of 1985 almost constantly runs at 0.15 % above the base line over a large range of flowrates. It is possible that this good result is due to a very purposeful installation of the counter.

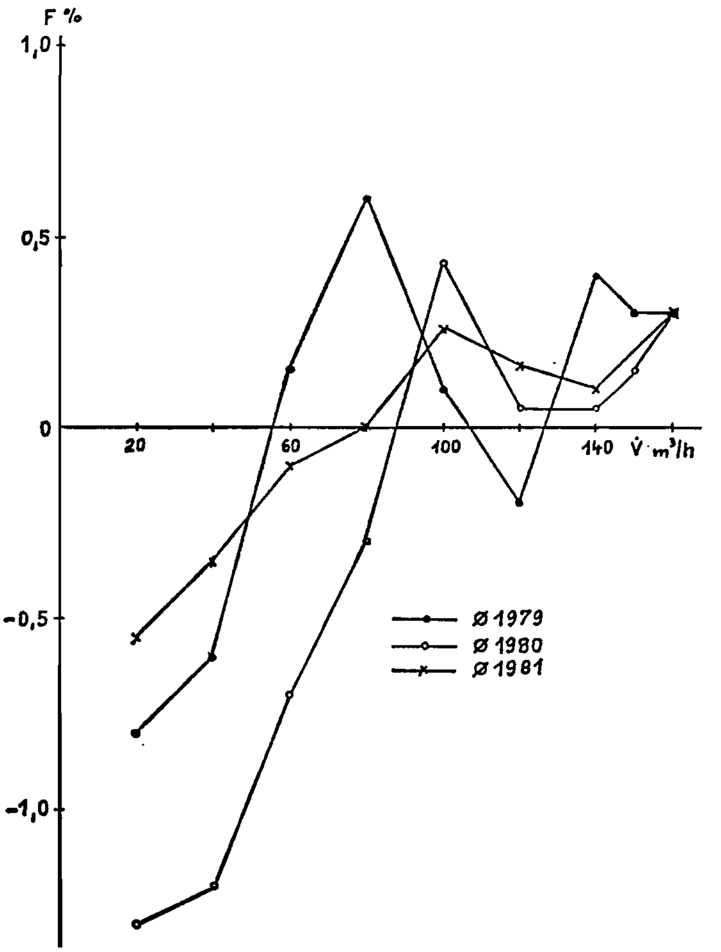


Fig. 7 — RESULTS OF CALIBRATIONS OF THE CVM PD METER OF THE G 100 TYPE

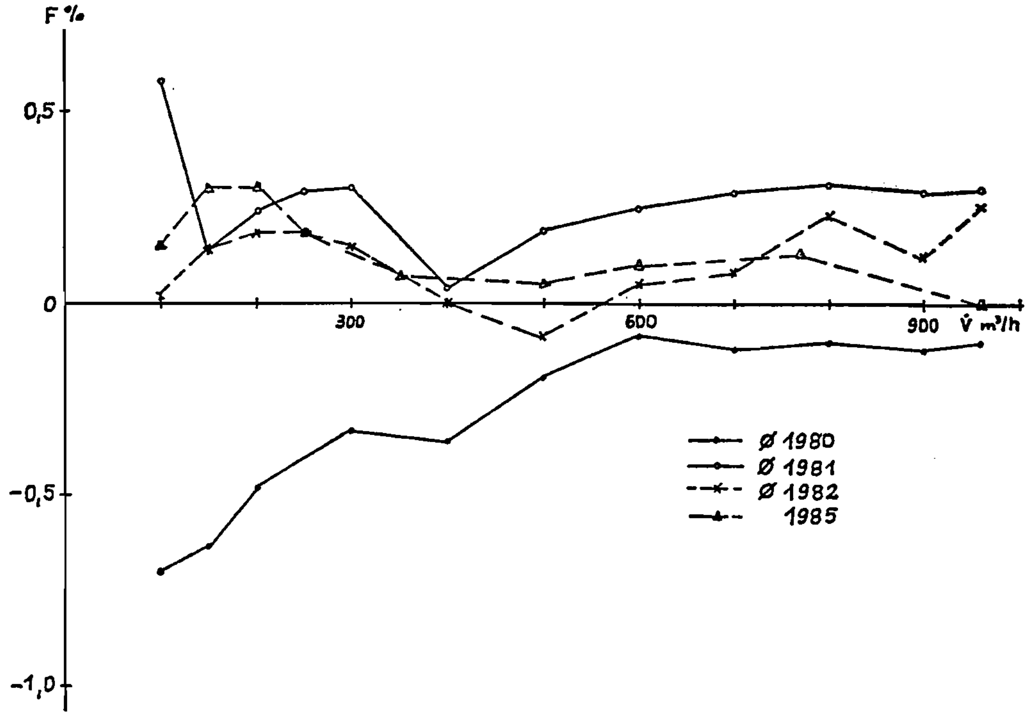


Fig. 8 — RESULTS OF CALIBRATIONS OF THE CVM PD METER OF THE G 650 TYPE

These measured results show that both CVM PD meters display a sufficient long-term stability and can be used as standards in a limited effective measurement range of about 25 to 100 %. They are also suitable to be used as transportable standards because of their relatively small mass.

4.6. **Rotary displacement meters**

The rotary displacement meter which has been known since the thirties is a volume flowmeter. The measuring mechanism consists of two rotating lobes with a lemniscate-like profile, which are interconnected through pairs of toothed gears. The lobes rotate in opposite directions in a cylinder without touching each other or the cylinder wall (fig. 9).

The gas enters the meter through inlet 1. As is the case with the CVM meter, the discharge of gas behind the meter leads to a pressure differential between inlet 1 and outlet 2 and thus applies a force to the flanks 4 of the rotating lobes 3. This applied force effects the rotation of the lobes. With each rotation the two lobes separate a given volume which in a first approximation is equal to the cylinder capacity minus the space occupied by the lobes. This geometric volume is falsified through gap flows which occur between the two lobes and between the lobe and cylinder wall with the intensity of the gap flows being dependent on the width of the gap and the intensity of the volume flowrate. The gas flow through the meter is not steady since the pressure of the separated fluid varies with the angle of rotation of the lobes, but it is a pulsating flow. This results from the fact that certain speeds of the lobes cause resonant vibrations for which mode, amplitude and frequency also depend on the conditions of installation.

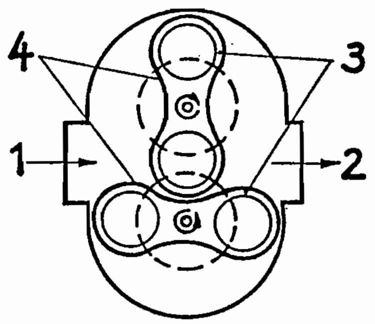


Fig. 9 — ROTARY DISPLACEMENT METER

1 gas inlet
2 gas outlet
3 rotating lobes
4 flanks of rotating lobes

In the ASMW metrological tests were performed with a number of rotary displacement meters of different types by using the standard differential pressure measuring device (see 4.9.). The error distribution curves of a rotary displacement meter for the range of flowrates from 50 to 600 m^3/h, plotted in fig. 10, are characteristic for all meters. The experimental standard deviations vary from $6 \cdot 10^{-4}$ to $8 \cdot 10^{-4}$. The measured results show that the error distribution curves

— run parallel to the base line in the greater part of the range of flowrates ;

— do not display any systematic variations but vary in the usual range of some 0.5 % ;

— are also within a range of 1 % at small volume flowrates up to a value of 20 m^3/h.

Rotary displacement meters can be used as standards by virtue of their error distribution curves and long-term stability. Because of their relatively large mass they are primarily used as stationary standards.

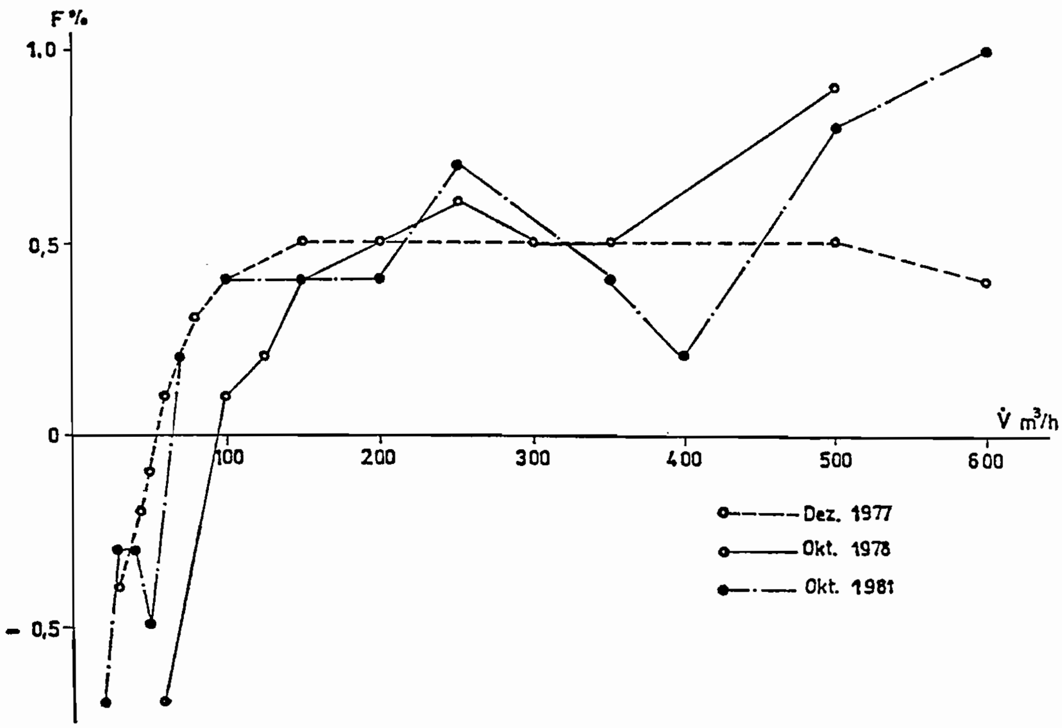


Fig. 10 — RESULTS OF CALIBRATIONS OF THE NB 500 ROTARY DISPLACEMENT METER

The error characteristics of a rotary displacement meter which has been used as a standard for a range of flowrates of 100 to 1 200 m³/h, could be observed over a period of 20 years. It appeared that

— the error distribution curves remained almost constant over this long period ;

— no systematic shift of the error distribution curves could be detected (long-term stability) ;

— the error values lie within a range of ⩽ 1 %.

4.7. Drum-type gasmeters

The drum-type gasmeter (wet gasmeter) is the oldest design of a gasmeter ; the measuring drum of the gasmeter was developed by CROSLEY in 1816. Fig. 11

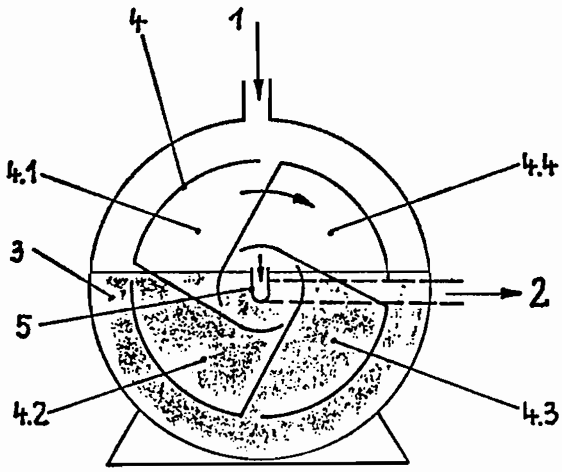


Fig. 11 — DRUM-TYPE GASMETER

1 gas inlet
2 gas outlet
3 confining liquid
4 measuring drum
4.1 to 4.4 measuring drum sections
5 hook pipe to gas outlet

shows the diagram of a drum-type gasmeter. The gas enters the meter through inlet 1 and fills the space above the confining liquid (oil or water) of the measuring chamber 4.1. The gas pressure puts the rotatable measuring drum 4 into motion. The measuring chamber 4.1 emerges higher from the confining liquid 3. From the drum chamber 4.4 the gas is pressed through the hook pipe 5 to the gas outlet. At the same time the measuring chamber 4.2 starts to emerge from the confining liquid 3 and to be filled with fluid. With each rotation the measuring chambers separate a given gas volume. Since the geometric content of the individual chambers is not exactly the same it is necessary to have at least one complete rotation of the drum to be able to perform accurate measurements. Measurements with a drum-type gasmeter also require to maintain necessary filling level height of the confining liquid and the horizontal alignment of the meter. For this purpose the meter is fitted out with necessary adjusters (water-level and stand pipe).

In the ASMW a number of drum-type gasmeters of different types was tested with the standard measuring device operated according to the indirect weighing method with air at atmospheric pressure (see 4.3.2.). The error distribution curve of a tested drum-type gasmeter is shown in fig. 12. The experimental standard deviations are equal to $8 \cdot 10^{-4}$. This curve which decreases with increasing flowrates is characteristic of drum-type gasmeters. The most important cause of this response is the pressure loss in the fluid which is due to the expenditure of energy on the rotation of the drum. This pressure loss is approximately equal to the difference of levels of the confining liquid in the measuring chambers which are just at the inlet and outlet of the meter. Increasing flowrates also lead to a higher pressure loss and thus a larger difference of level, the volume within the measuring drum increases and the error distribution curve decreases.

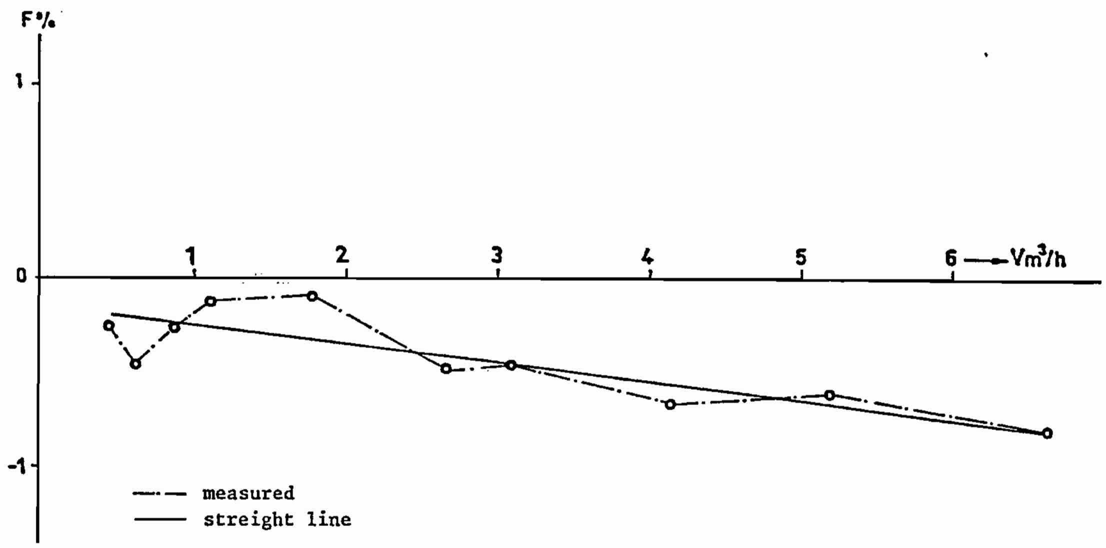


Fig. 12 — ERROR DISTRIBUTION CURVE OF THE STANDARD DRUM-TYPE GASMETER OF THE NB 6 TYPE

Drum-type gasmeters are also used as laboratory meters and for gas volume measurements in automatic calorimeters, primarily at flowrates of less than 20 m³/h.

4.8. **Turbine flowmeters**

Turbine flowmeters were at first designed for volume or mass measurements of flowing liquids [12] and after that also for flowing gases. There do not exist any fundamental differences in the design of these two types of meters. Unlike the volume measuring gasmeters such as rotary displacement meters and CVM PD meters, the turbine flowmeter has not any measuring chambers which are alternately filled and emptied, but it is fitted with a blade wheel. The fluid flows against this wheel and thus puts it into rotation. Its rotational speed is proportional to the average flowrate so that each rotation is equal to a given volume or mass fraction of the fluid. The number of rotations is either mechanically transferred to a counter or through an inductive transducer. Fig. 13 shows the diagram of a turbine flowmeter. The fluid enters the meter through 1 and flows through an annular stop 3 on to the turbine wheel 2. This annular stop is intended to improve the metrological characteristics of the meter. The rotations of the turbine wheel 2 are picked up by the sensing head 4 (induction coil) and displayed by a counter.

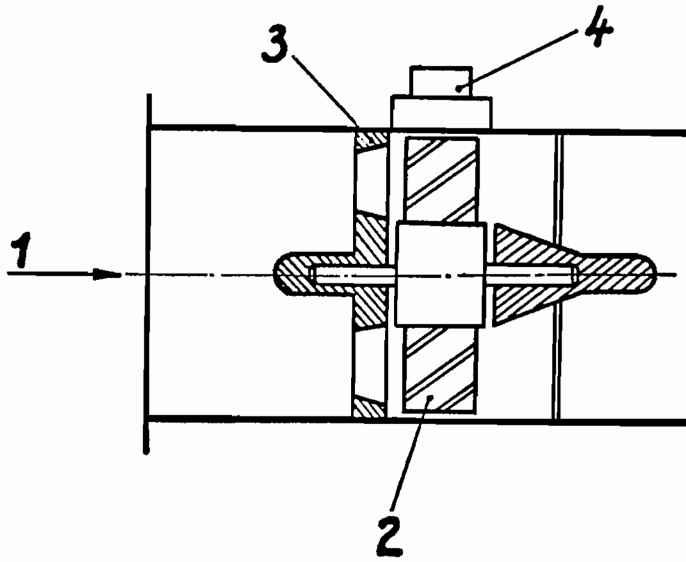


Fig. 13 — TURBINE FLOWMETER

1 gas inlet
2 turbine wheel
3 annular stop
4 sensing head

In the ASMW a turbine flowmeter for the range of flowrates from 50 to 1 000 m³/h was calibrated by means of the standard differential pressure measuring device of the ASMW (see 4.9.). According to the producer, a proper operation of the meter requires a minimum pressure of 0.3 MPa of the fluid. Contrary to that, the tests could be successfully performed only at atmospheric pressure.

During the first test which was carried out without an inlet pipe the meter was found to exhibit error values between + 1 and + 2 % and an experimental standard deviation of $5 \cdot 10^{-3}$ for the range of flowrates from 100 to 600 m³/h. During the second test an inlet pipe of 1.5 m in length was connected in series before the turbine flowmeter. Error values were determined to range from + 2 to + 3 % at an experimental standard deviation of $6 \cdot 10^{-4}$. Very large scatters of errors were found in the ranges of flowrates from 50 to 100 m³/h and from 600 to 1 000 m³/h so that it is not possible to give definite data.

The measured results show that turbine flowmeters for a limited range of flowrates and with an inlet pipe can be conditionally used as standards for calibrations in the low-pressure range. During tests performed at high pressures [13] turbine flowmeters have been found to exhibit limits of error of ± 1 % and to be suitable for use as standards too. As they are considerably lighter than rotary displacement meters, turbine flowmeters may be used as transportable standards.

The major application of the turbine flowmeters is the measurement of large flowing gas volumes under high pressures in gas pipe-lines.

4.9. **Differential pressure flowmeters**

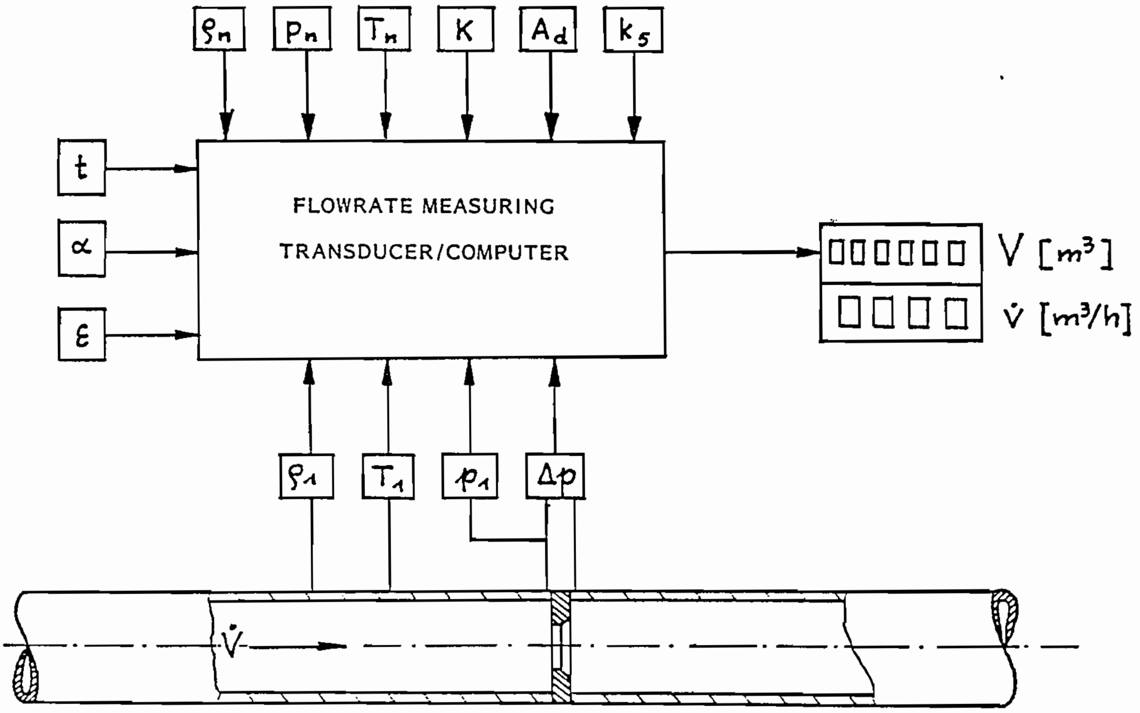
Fig. 14 shows the diagrammatic view of the set-up of a standard flowmeter with a differential pressure device. A throttling element (orifice plate or nozzle) has been placed in a specially processed pipe section (measuring section). If a gas flows through the pipe, a differential pressure is generated over the throttling element. The square root of the differential pressure is proportional to the flowrate. According to the BERNOULLI equation and the continuity equation, the relation given below can be used for calculating the volume which flows through the differential pressure flowmeter

$$V_N = \alpha \cdot \varepsilon \cdot A_d \cdot t \sqrt{\frac{2}{\rho_1}} \cdot \sqrt{\Delta p} \qquad (6)$$

$$= k_5 \cdot \alpha \cdot \varepsilon \cdot A_d \cdot t \sqrt{\frac{T_1 \cdot p_n \cdot k}{\rho_n \cdot T_n \cdot p_1}} \cdot \sqrt{\Delta p}$$

with

$$\rho_1 = \rho_n \frac{T_n \cdot p_1}{T_1 \cdot p_n \cdot K} \qquad (7)$$



Throttling element
(Orifice plate/Nozzle)

Fig. 14 — STANDARD DIFFERENTIAL PRESSURE FLOWMETER

The standard differential pressure flowmeter of ASMW has already been described in detail in [14]. This is why, we only want to mention a few advantages and disadvantages of this standard method :

Advantages :

— larger measuring range (1 : 50 and more, achievable through exchangeable throttling elements with different orifice diameters) ;

— no pulsation in the flow of the fluid ;

— a low interference susceptibility since the meter has no moving parts ;

— a practically unlimited volume of fluid ;

— the possibility of calibrating in the fundamental units if the determination of flow coefficients is performed with a standard gravimetric measuring device.

Disadvantages :

— a relatively large permanent pressure drop ;

— a large constructional length requiring a large floor space ;

— a time-consuming calibration ;

— the meter cannot be used as a transportable standard, particularly at large pipe diameters.

In the ASMW, stationary differential pressure standard flowmeters have since long been operated with air at atmospheric pressure and calibrations or verifications of standard measuring devices of the patterns mentioned in chapter 4 and other special patterns have been carried out up to a volume flowrate of 400 m^3/h (1 000 m^3/h). Moreover, in individual cases it has also been possible to use the measuring section of this standard flowmeter as a flowrate standard with a modified measured data acquisition system.

The uncertainty of the standard differential pressure flowmeter is equal to $4 \cdot 10^{-3}$ ($6 \cdot 10^{-3}$) ; the experimental standard deviation is equal to $\leqslant 5 \cdot 10^{-4}$.

4.10. **Vortex meters**

In a liquid or gas flow the edges of a bluff body make vortexes alternately shred (Kármán's vortex path ; see fig. 15). If the bluff body has been given a suitable form, the frequency of vortex shreddings is proportional to the flow velocity and thus to the flowrate. This phenomenon has been known for about 100 years. However, its technological utilization to perform volume or flowrate measurements has been possible only as a result of the application of advanced microelectronic equipment.

In the ASMW vortex meters have been subject to metrological tests. They showed that a minimum Reynolds number of $Re = 1 \cdot 10^5$ has to be kept, the output frequency at a constant flowrate is subject of short-term variations from pulse to pulse and the display is affected by pulsations of the flow [15]. The short-term frequency variations from pulse to pulse can be almost compensated by setting minimum pulse frequency rates or minimum test volumes, pulsations have to be reduced by taking appropriate measures before the flow enters the vortex meter.

When a vortex meter with a nominal diameter of 80 mm was subjected to a metrological test, it was found to exhibit an error band range of 0.6 % at an experimental standard deviation of $1 \cdot 10^{-3}$ in a limited range of flowrates from 100 to 400 m^3/h.

From the results it may be concluded that vortex meters can be used as standards in gas flow measurement technology in future too.

In industry, vortex meters have already been successfilly used in the measurement of aggressive gases.

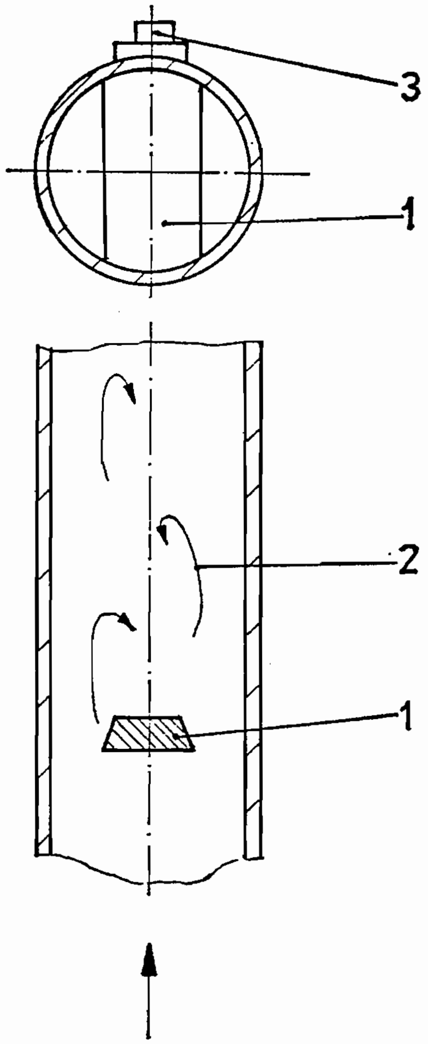


Fig. 15 — VORTEX METER

1 bluff body
2 vortex
3 sensor for vortex frequency

5. Conclusions

Standards used for the calibration of gas flowmeters are either special standard measuring devices or specially selected commercial measuring means. The special standard measuring devices are in general intended to calibrate standards of a lower order (standards of low accuracy).

A comparison of the described measuring devices or measuring means shows that uncertainties which are an essential performance criterion of standards do not vary a great deal. The present limit of uncertainty is equal to some 10^{-3}.

In the past few years gas transport in pipe-lines has been greatly increased, with a simultaneous rise in gas pressure. Uncertainties of only a few tenths of per cent may result in balance-errors of several million marks. The development of the metrological equipment in the ASMW is therefore aimed at :

— reducing uncertainty of the standards ;
— expanding the range of flowrates of standard measuring devices (for example, by parallel connection) ;
— making available standards for all pressures to be measured, which can be found in industry ;
— operating standard measuring devices with real gases (such as natural gas).

Symbols used in the equations

Symbol	Signification
A_d	cross-sectional area in the smallest nozzle diameter
D	diameter of measuring pipe
c_d	discharge factor
K	compressibility factor of the fluid
Kor	correction
$k_1, ..., k_5$	constants
L	length
p	absolute pressure of the fluid
R	special gas constant
T	absolute temperature of the fluid
t	time used for measurement
V_N	volume of the fluid at the standard
$\dot{V}_N$	volume flowrate at the standard
α	flow coefficient
ε	expansibility factor
Δm	indication of the weighing device
Σm_i	sum of corrections for the indication of the weighing device
Δp	differential pressure
$\varkappa$	relationship of specific heats of the fluid
φ	relative humidity of the fluid
ρ	mass density of the fluid
ρ_w	mass density of the indirect fluid
Indices	
1	condition in front of the nozzle
n	standard reference condition

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ROYAUME-UNI

BULK LIQUID METERING
A SURVEY of CURRENT PRACTICE
and a FORECAST of FUTURE TRENDS *

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SUMMARY. — This paper discusses the various types of meter known to be used for the custody transfer metering of liquids including differential pressure meters, displacement meters, inferential rotary meters, electromagnetic meters, ultrasonic meters, vortex-shedding meters, and mass flowmeters. II also describes equipment currently being used for the calibration of such meters, including reference meters, volumetric and gravimetric tanks of both the standing-start-and-finish and flying-start-and-finish types, and pipe provers of both conventional and compact types. An attempt is made to outline new developments in this area that may be expected over the next few years.

1. Introduction

This paper is concerned solely with what is known as the « custody transfer metering » of liquids. The term is used to refer to the metering with high accuracy of large or fairly large volumes for the purposes of large-scale (wholesale) trading, or in connection with the payment of taxes on dutiable liquids. It excludes metering to a rather lower standard of accuracy for process control or internal accounting purposes, or small-scale metering and retail trading. These definitions clearly exclude such devices as metering pumps at road vehicle filling stations, and domestic water meters. Truck-mounted meters used for dispensing domestic heating oil in batches of hundreds of litres are a borderline case which are probably best included within the scope of custody transfer metering.

The main types of meter used for custody transfer operations are discussed below, along with methods used to calibrate them.

2. Differential pressure meters

The main custody transfer use of differential pressure meters is in large water supply lines — for example, where a water supply company sells water to a very large industrial user or to a municipal distribution network. Because of the cost of pumping very large volumes of water, only those differential pressure meters with a low permanent pressure loss are acceptable. These include the classical venturi meter as shown in Figure 1, and a variety of proprietary devices, of which the Dall tube (Figure 2) is a widely used example. Because even the small pressure loss caused by these meters is undesirable, they are gradually losing ground to more modern meters with zero pressure loss, such as the electromagnetic and ultrasonic meters described below. There are, however, still many large differential pressure meters in current use in the water supply industry.

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* Presented at the OIML seminar on Calibration of Liquid Volume Measuring Installations, Arles, France, 11-15 May 1987.

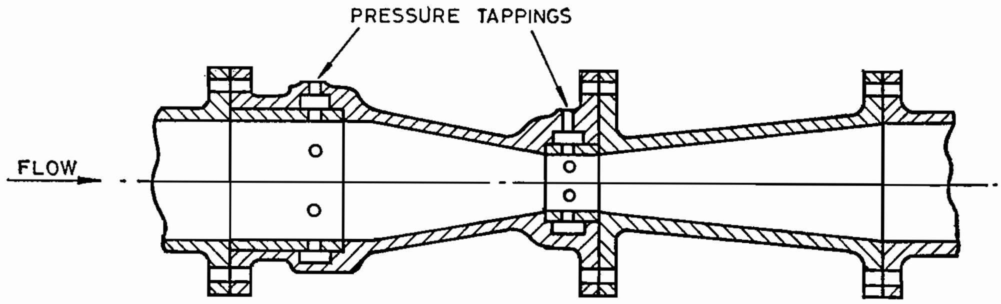


Fig. 1 — VENTURIMETER.

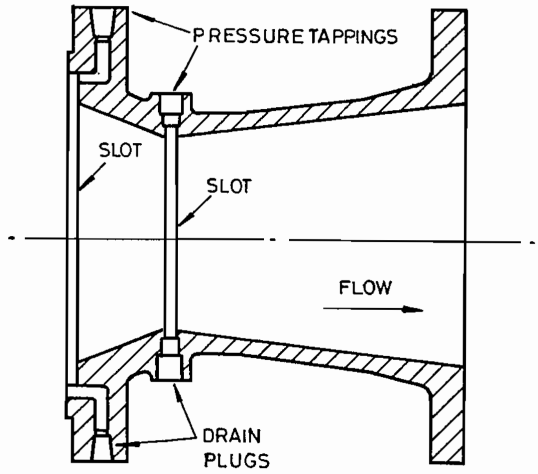


Fig. 2 — DALL TUBE.

Differential pressure meters may also be used for metering oils and other viscous liquids. In such cases these will generally be of the orifice type, not the normal sharp-edged orifice plate shown in Figure 3, but one of a number of devices developed especially for use at low Reynolds numbers. These include the quadrant-entry orifice plate (Figure 4) and its near relation the conical-entry orifice plate, as well as the « Taylor Wedge » flowmeter (Figure 5). These devices are widely used for process control, but only rarely as custody transfer meters.

3. **Displacement meters**

Displacement meters are rotating or reciprocating mechanical devices that divide the flowing liquid into a number of separate portions of practically constant volume, and then count the number of portions. They may be visualised as resembling pumps running in reverse, that is to say, with the flow of the liquid producing a rotation of the mechanism and not the other way round. They were formally termed « positive displacement » meters, a name which still lingers on in many countries. Their readout may be through a mechanical counter or an electrical pulse generator, or both of these together.

A wide variety of mechanical principles is used in the construction of displacement meters. Some of the best known types include helical gear, oval wheel, mutating disc, multiple piston, and sliding-vane meters. An example of the last of these is given in Figure 7, and an experimentally determined performance curve for such a meter is shown in Figure 6. This is remarkably close to the ideal of a horizontal straight line, and demonstrates the high performance that can be obtained from such meters under favourable conditions.

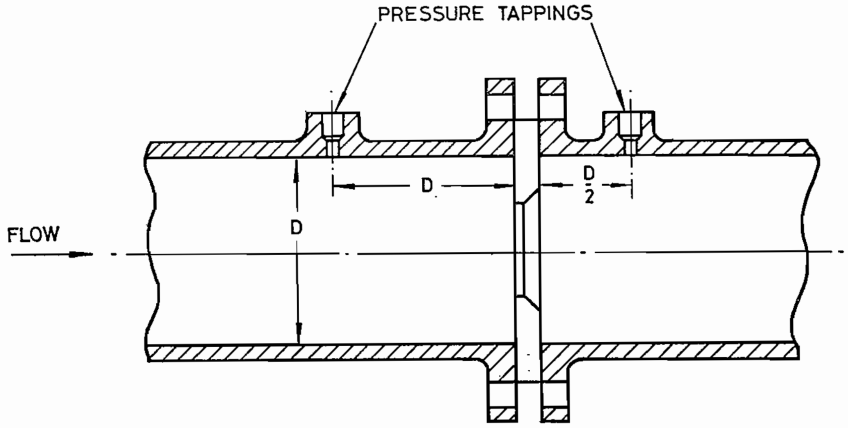


Fig. 3 — ORDINARY ORIFICE PLATE (CONCENTRIC, SHARP-EDGED, D AND D/2 TAPPINGS).

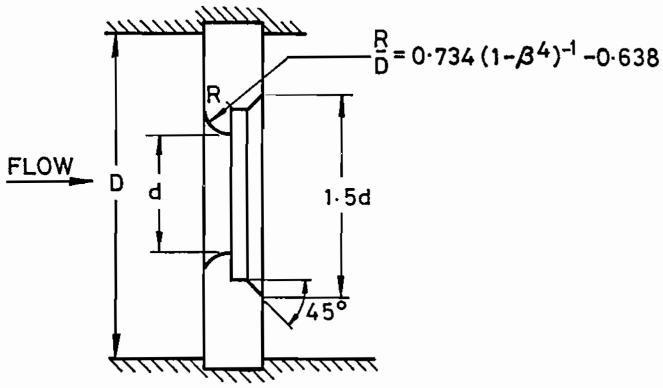


Fig. 4 — QUADRANT-ENTRY ORIFICE PLATE.

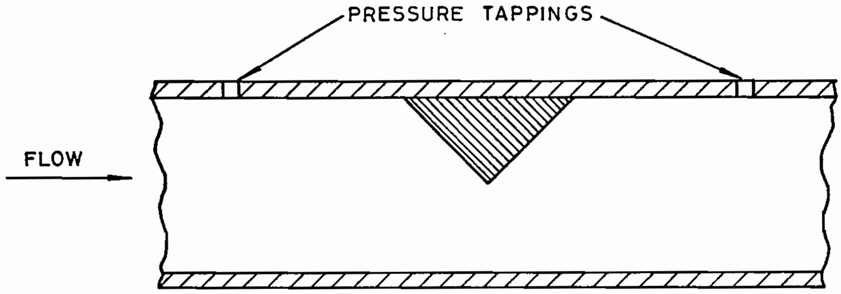


Fig. 5 — PRINCIPLE OF THE TAYLOR WEDGE FLOWMETER.

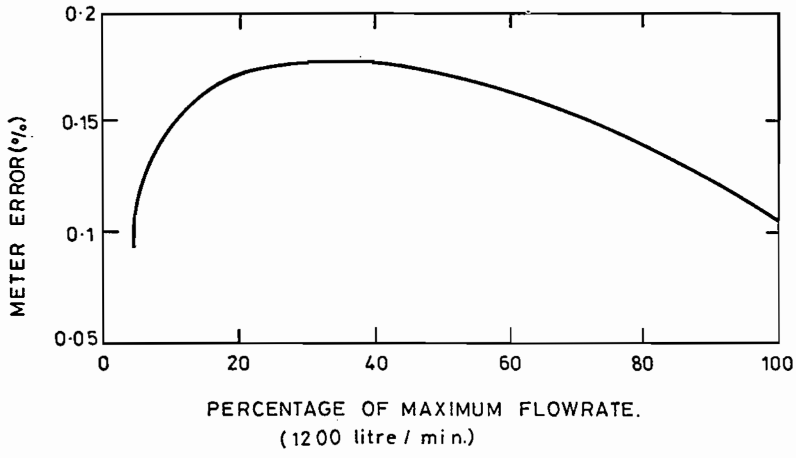


Fig. 6 — PERFORMANCE CURVE OF A SLIDING-VANE DISPLACEMENT METER.

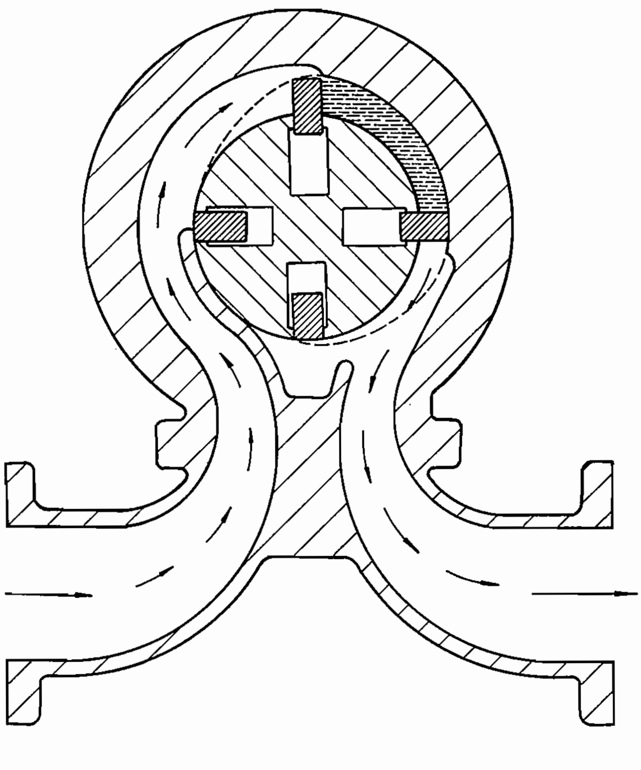


Fig. 7 — PRINCIPLE OF THE SLIDING-VANE DISPLACEMENT METER.

The sliding members of displacement meters do not contain elastomeric seals, since this would create an unacceptable amount of friction. Instead, they normally have metal-to-metal sliding contact, and a small amount of leakage has to be tolerated and allowed for in the calibration of the meters. This leads to their most significant disadvantage : the leakage flow (sometimes called « slip ») is greater with liquids of very low viscosity than with more viscous liquids. Consequently, if a meter has been calibrated so that it reads accurately with gasoline, then it cannot be used with, say, kerosene unless the calibration setting is changed or a numerical correction factor is introduced into subsequent calculations. For liquids with viscosities above about 4 mm^2/s (or cSt) the leakage flow becomes negligible, so that these meters perform best with the more viscous liquids.

Displacement meters will continue to give good results over a period of many months of continuous service between calibrations, and they rarely break down between overhauls. For these reasons they are by far the most commonly used meters at the lower end of the custody transfer range — say, in pipe sizes up to about 100 or 150 mm.

4. Inferential rotary meters

Several other types of rotating meter do not have such a direct relationship between the geometry of the meter and the volume passed during one revolution as does the displacement meter ; they are therefore termed « inferential » meters.

The most important of these is the turbine meter, which is illustrated in Figure 9. These have a free-running turbine rotor axially mounted within the pipe so as to occupy practically the whole cross-sectional area of the pipe. Over a fairly wide range of flowrates the turbine rotates at a speed which is approximately proportional to the flowrate, as is evident from the typical performance curve shown in Figure 8. This is noticably less linear than that of the sliding-vane meter shown in Figure 6. The passage of each blade creates an electrical impulse in the pick-up coil shown in Figure 9, and if the number of pulses counted during a delivery is divided by the calibration factor or « K-factor » for the meter the result is the volume of the delivery.

Provided that they are recalibrated fairly frequently, or that they are used in pairs so that their outputs can be compared to insure that the performance of one meter has not started to deteriorate, and provided that due allowance is made for the effect of significant changes in viscosity, turbine meters will give highly accurate results. In the larger pipe sizes they tend to be considerably less expensive than displacement meters, and are therefore widely used at the higher end of the custody transfer range with petroleum and its products, and in particular for the fiscal metering of crude oil. They perform best with oils of viscosities below about 50 mm^2/s (or cSt), and are not normally used for the metering of highly viscous oils.

The only inferential rotary meter commonly used with highly viscous oil is of the so-called « constrained vortex » meter. This has a rotating member shaped like the paddle wheel of a nineteenth-century steam ship, the axis of which is perpendicular to the axis of the pipe, and so positioned that only half of the blades project into the flowing fluid, with the outer portion of the rotor turning freely in an enclosed chamber protruding from the pipe.

Other inferential rotary meters are used for water metering in the smaller main supply pipes.

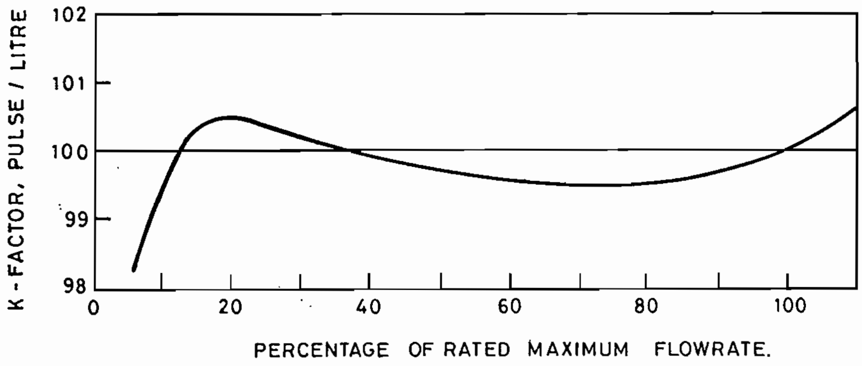


Fig. 8 — TYPICAL TURBINE METER CALIBRATION CURVE.

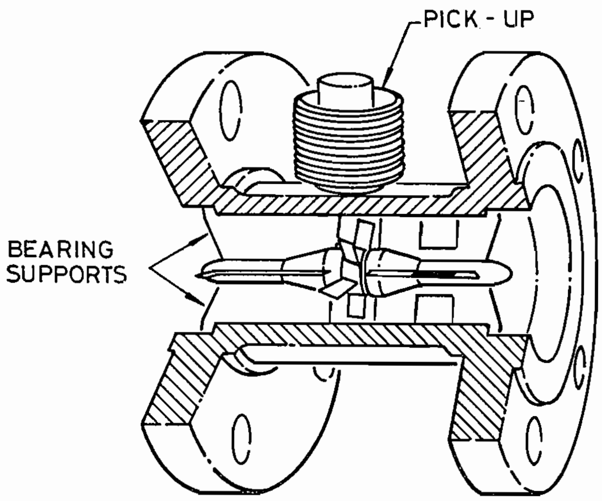


Fig. 9 — TYPICAL TURBINE METER.

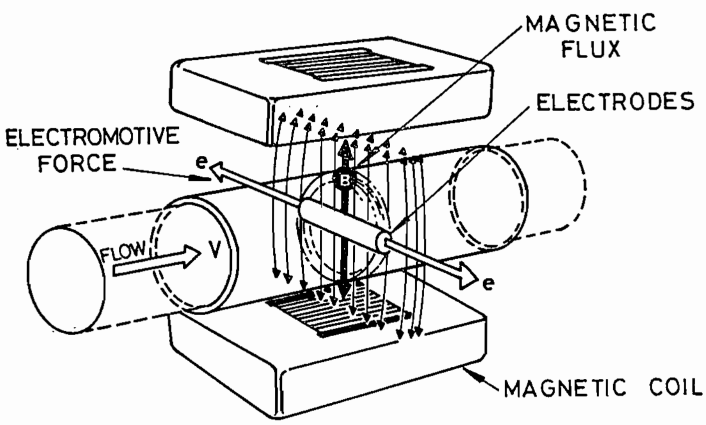


Fig. 10 — PRINCIPLE OF THE ELECTROMAGNETIC FLOWMETER.

5. Electromagnetic meters

The principle of the electromagnetic meter is illustrated in Figure 10. A magnetic field, which nowadays is usually generated by square-wave alternating current, generates an electromotive force in the flowing fluid which can be measured and which is directly proportional to the mean velocity of flow. By integrating the output and using a calibration constant the total flow can be derived. Such meters will work only with electrically conducting liquids, but they are widely used in the water industry in supply mains of all sizes. Their popularity for this purpose results from the combination of accuracy, reliability and zero pressure loss.

6. Ultrasonic meters

Several entirely different ways of using ultrasound have been employed in various types of ultrasonic flowmeter, but the only one of these that is generally regarded as sufficiently accurate for custody transfer use is the diagonal-beam meter, illustrated diagrammatically in Figure 11. The transit time of a sudden pulse of ultrasound between two diagonally opposed transducers is measured, alternately in the downstream and upstream directions. The difference in transit time is a measure of the mean flow velocity across the diagonal through the flowing fluid.

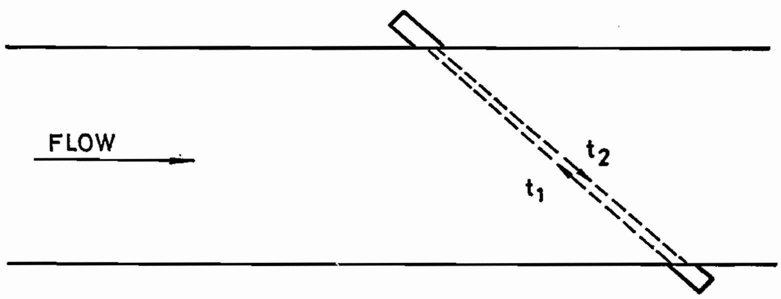


Fig. 11 — PRINCIPLE OF THE DIAGONAL-BEAM ULTRASONIC FLOWMETER.

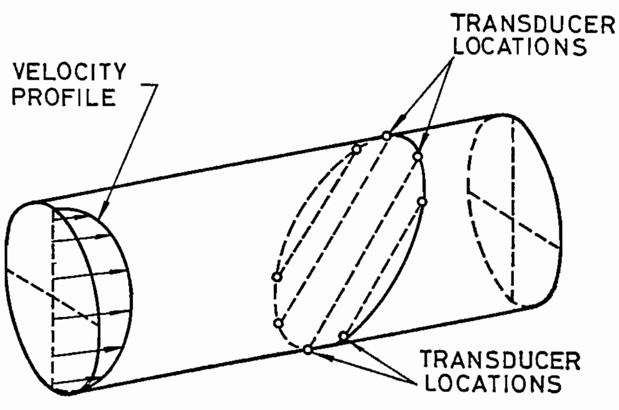


Fig. 12 — ARRANGEMENT OF TRANSDUCERS IN A FOUR-PATH DIAGONAL-BEAM ULTRASONIC METER.

Because of turbulence fluctuations it is necessary to take several hundred readings in succession over a period of several seconds, and to average the results, in order to obtain a reasonably repeatable measure of flow velocity, which can then be used to derive a value of flowrate ; this in turn can then be integrated to give the total volume passing during an accounting period.

If there is only one pair of transducers, and hence only one path through the flowing fluid, the result will only be an accurate measure of flowrate if the velocity profile of the flowing fluid is symmetrical and regular. Where this condition cannot be guaranteed it is necessary to use several parallel paths, as illustrated diagrammatically in Figure 12 ; this makes for greater accuracy but is considerably more expensive. The main custody transfer use of ultrasonic meters is in the water industry, where they provide an alternative to electromagnetic meters, but they have occasionally been used also in the oil industry, especially on liquefied gases.

7. Vortex-shedding meters

The principle of the vortex-shedding meter is shown in Figure 13. What is known as a « bluff body », which is really nothing more than a non-streamlined bar extending across a diameter of the pipe, sheds vortices alternately from opposite sides of the bar, and the frequency of these is proportional to flowrate. Some electronic device is used to generate electrical pulses every time a vortex is shed, and if these pulses are counted over a delivery period they can be multiplied by a calibration factor to derive the delivered volume.

Vortex meters do not have a particularly high repeatability and accuracy, and for many years they were used only for process control. Within recent years, however, high quality vortex meters specially designed for the purpose have been approved in several countries for the custody transfer metering of natural gas ; these have twin detection systems, as illustrated in Figure 14. It would appear to be only a matter of time before similar high quality vortex meters specifically designed for the custody transfer measurement of liquids appear on the market. In the meantime a system developed by the present author for metering natural gas liquids under difficult conditions, as illustrated in Figure 15, has already been accepted for custody transfer measurement in the British sector of the North Sea. This employs two conventional vortex meters separated by a Sprenkle flow conditioner, which serves to suppress the vortices shed by the upstream meter so that they cannot interfere with the performance of the downstream meter. The performances of the two meters are constantly compared in the system computer, so that an alarm can be sounded if one meter begins to deteriorate. Such a system is not so accurate as a newly calibrated turbine meter, but it is much more stable over long periods between calibrations than turbine meters running on liquids of poor lubricating qualities.

8. Mass flow measurement

It has generally been the custom for liquids to be sold by volume, and for small scale transactions this practice will doubtless continue for a long time because of its convenience. But in large transactions the higher accuracy required has always meant that with expensive liquids such as petroleum products allowance must be made for thermal expansion and compressibility, thus reducing the data to a volume

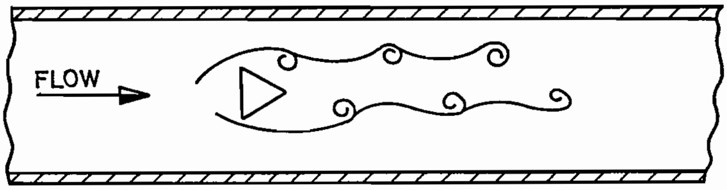


Fig. 13 — VORTEX SHEDDING BY A BLUFF BODY.

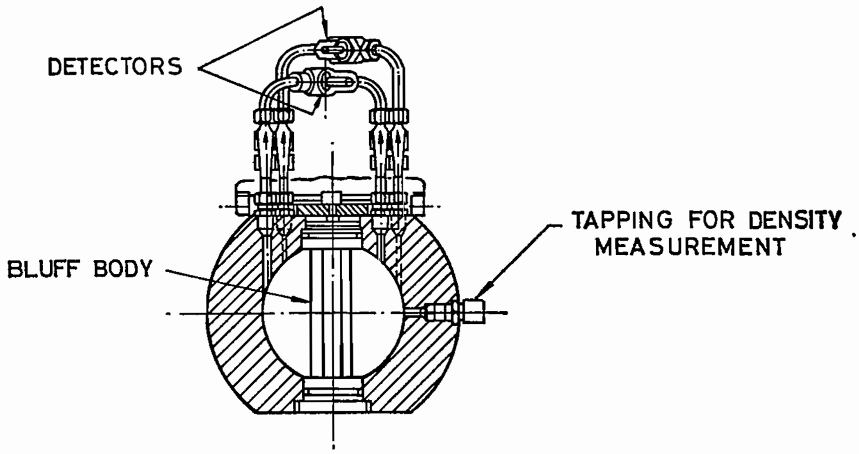


Fig. 14 — MODERN HIGH-ACCURACY VORTEX SHEDDING METER FOR CUSTODY TRANSFER MEASUREMENT OF NATURAL GAS.

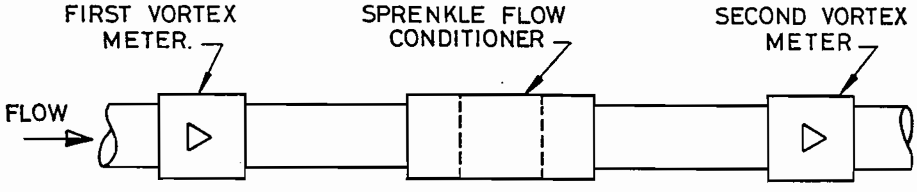


Fig. 15 — DIAGRAMMATIC REPRESENTATION OF REDWOOD VORTEX METER SYSTEM FOR CUSTODY TRANSFER METERING OF LIQUIDS.

at standard conditions of pressure and temperature. This requires knowledge of the PVT properties of the liquid being measured, and sometimes this information is not available, especially when the liquid is a liquefied gas. Consequently there has developed an interest in measuring the mass of certain liquids during a delivery, instead of the volume.

Mass flow may be measured either directly or indirectly. As shown in Figure 16, the indirect method involves measuring volume with a normal volumetric flowmeter and combining this with a value of density so that mass may be computed. The density value may be obtained either by computation from pressure and temperature measurements with the aid of an equation of state for the liquid, or from direct measurements with a density meter. At the higher end of the custody transfer range the indirect method is the only feasible one.

In pipe sizes up to about 100 mm a practical alternative is to use a direct mass flowmeter. A number of types of mass flowmeter are now available, but the type gaining acceptance in the oil industry is the vibrating-tube coriolis-force meter. Several manufacturers are offering versions of this, some with curved tubes like that shown in Figure 17 and some with straight tubes like that shown in Figure 18. Mass flow may be derived either from measurements of the extent to which the tubes distort under flow, or the extent to which there is a phase change in the vibration under flow.

These meters all occupy a considerable amount of space, and are expensive. But they do appear to have a good performance, and are rapidly gaining favour.

9. Methods of calibrating meters

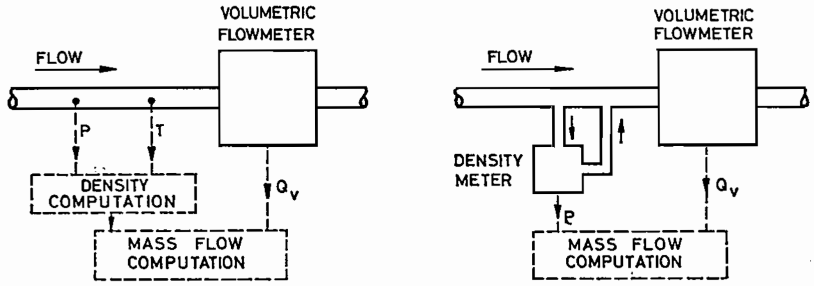
A wide variety of calibration equipment is used with liquid flowmeters, and the principal types are discussed below.

9.1. Reference Meters

A reference meter is a flowmeter of high quality and excellent performance which is put in series with the meter requiring calibration. Reference meters are nearly always of the displacement type, because of the acknowledged high stability and reliability of these meters. Even so, they need recalibration themselves against a primary standard at fairly frequent intervals — say, once every three months, or less, depending upon the level of accuracy required from the reference meter.

Reference meters are used both in laboratories as secondary standards and as portable secondary standards, sometimes known as « transfer standards », for on-site calibration of other meters ; in particular, they are the principal method of calibrating (proving) displacement meters used at distribution depots for petroleum products.

Reference meters are generally used on their own, and are accepted as having only the accuracy appropriate to a secondary standard. They are suitable for calibrating those meters where an accuracy of measurement of around ± 0.5 percent is acceptable. Where a higher accuracy is required, the reference meter may be permanently connected to a volumetric standard, against which it can be quickly recalibrated once per day. In this way the accuracy of the reference meter can be upgraded almost to that of the volumetric standard — say, ± 0.1 or ± 0.2 per cent, depending upon circumstances — whilst retaining much of the convenience and speed of use of the reference meter. An illustration of such a combination is given in Figure 19.



(a) MEASUREMENTS OF PRESSURE TEMPERATURE AND VOLUMETRIC FLOWRATE. (OR TOTAL VOLUME.)

(b) MEASUREMENTS OF DENSITY AND VOLUMETRIC FLOWRATE (OR TOTAL VOLUME.)

Fig. 16 — INDIRECT METHODS OF MEASURING MASS FLOW.

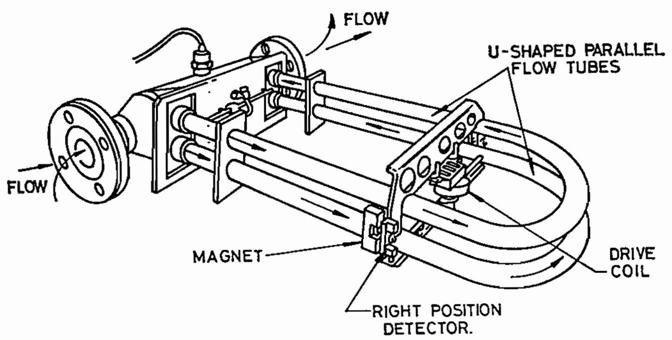


Fig. 17 — THE BROOKS VIBRATING TUBE TRUE MASS FLOWMETER.

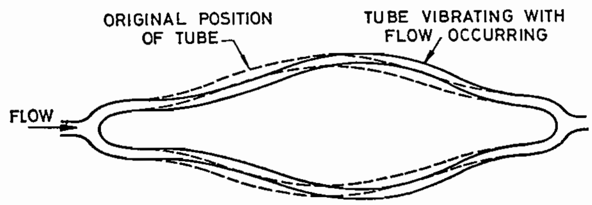


Fig. 18 — PRINCIPLE OF THE STRAIGHT-TUBE VIBRATING CORIOLIS MASS FLOWMETER.

Fig. 19 — EXAMPLE OF A « COMBINATION CALIBRATOR » —
A REFERENCE METER COUPLED TO A VOLUMETRIC TANK.
(Photo by courtesy of Moore, Barrett & Redwood Ltd.)

It is important to remember that only displacement meters of the very highest quality, sold specifically for the purpose of reference meter use, are suitable to be used in this way. Attempts to use ordinary displacement meters for reference meter purposes have frequently led to serious disappointment.

9.2. Standing-Start-and-Finish Calibrators

The principle of the standing-start-and-finish method of calibration is illustrated in Figure 20. It bears this name because at the instants of beginning and ending the test the flowrate through the meter is zero, with both stop-valves closed. It is highly suitable for use with displacement meters, because they allow only very little unregistered flow to pass at low flowrates, but is not suitable for other types of meter which allow quite large quantities of flow to pass at low flowrates without registering.

Referring to Figure 20, the sequence of operations in a calibration run is as follows. (1) Start the pump running. (2) Take the initial reading on the meter and check the lower level in the volumetric tank. (3) Quickly open the stop-valve so that liquid can pass from the meter into the volumetric tank at the required flowrate. (4) When the liquid reaches the upper neck of the tank, quickly stop the flow by shutting the valve. (5) Take the final reading of the meter and read the level in the upper neck

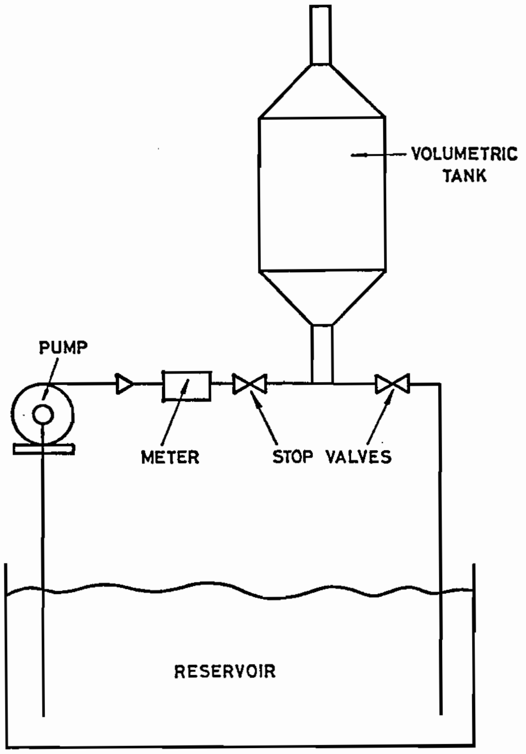


Fig. 20 — PRINCIPLE OF METER CALIBRATION USING A VOLUMETRIC TANK.

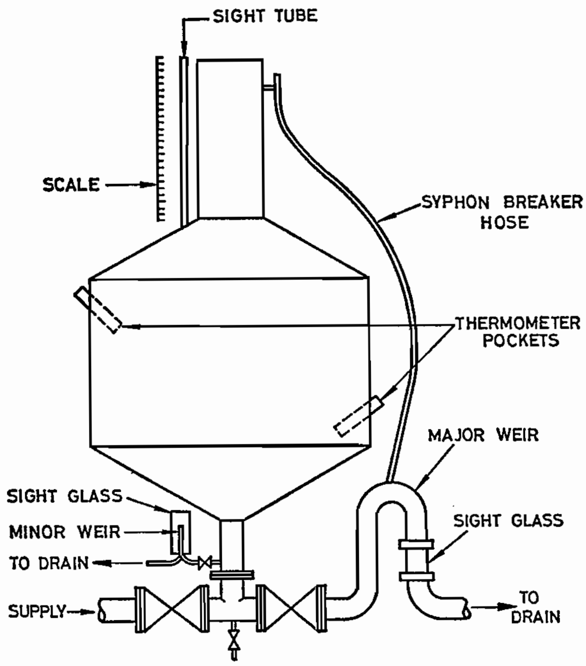


Fig. 21 — DETAILS OF ONE TYPE OF VOLUMETRIC TANK.

of the volumetric tank, so as to derive the volume that has passed into the tank. (6) After making any necessary allowance for thermal expansion, compare the volume indicated by the meter with the volume indicated by the tank. Finally, drain the tank by opening the valve on the right, in readiness for the next test.

Various designs of volumetric tank are in use, some filling from the top and some filling from the bottom. One design of bottom-filling tank is shown in Figure 21. This incorporates a double weir system to ensure that the starting level is always precisely defined, and a site glass against a calibrated scale in parallel to the upper neck of the tank.

If correctly used, and if recalibrated at appropriate intervals (say, yearly) a volumetric tank should have an accuracy of about ± 0.05 per cent. Significant errors may arise, especially in smaller tanks, by varying amounts of liquid clinging to the wall of the tank. To avoid such errors it is necessary for a precise drainage time to be used whenever the tank is emptied, and viscous liquids, say, above 5 mm^2/s (or cSt), to be avoided. With highly volatile liquids such as gasoline serious errors can also be caused by evaporation. For these reasons, the highest accuracies are likely to be obtained by the use of water and kerosene.

The standing-start-and-finish method can also be used with a gravimetric tank, as shown in Figure 22. This is generally less convenient in use than a volumetric system, but has the advantage that there are no clingage errors, so that viscous liquids may be used.

Gravimetric systems must of necessity always be top-filling. This requires the use of a swan-neck filling device with a double weir, as shown in Figure 23, or some comparable device that ensures a constant volume between the meter and the tank at the beginning and end of each calibration run.

Volumetric tanks are widely used in laboratories, but may also be mounted on trucks or trailers for portable and on-site use. Gravimetric tanks are less widely used in the laboratory, and are generally regarded as being insufficiently stable for use as portable devices.

9.3. Flying-Start-and-Finish Gravimetric Calibrators

Flying-start-and-finish gravimetric systems are used mainly for calibrating flowrate meters, such as differential pressure, ultrasonic, and electromagnetic meters, as well as quantity meters such as turbine meters which cannot accurately be calibrated against a standing-start-and-finish system. Two entirely different systems are in use, one employing static weighing and the other dynamic weighing.

The principle of the static weighing method is shown in Figure 24. A long, narrow jet of water is suddenly diverted into a weighing tank by the rapid movement of a diverter plate, which simultaneously starts a timer. When sufficient liquid has entered the weighing tank the diverter plate is rapidly returned to its original position, and the operation of the diverter automatically stops the timer. After applying a buoyancy correction the mass of liquid in the weighing tank divided by the time taken gives the mass flowrate.

Such a system is capable of giving high accuracy (say, ± 0.2 per cent on flowrate) provided that it is well designed and that special attention is paid to adjusting the diverter and timing mechanism to ensure that accurate synchronisation is obtained. Failure to attend to this matter is a common cause of significant error in systems of this type.

The most accurate type of dynamic weighing system is that which incorporates the method of weight substitution, as illustrated in Figure 25. Liquid enters the weighing tank continuously through a free-falling jet, and prior to the start of the test it simultaneously drains from the tank through a dump valve. When it is desired to run a test the dump valve is rapidly closed, and when the mass on the electronic

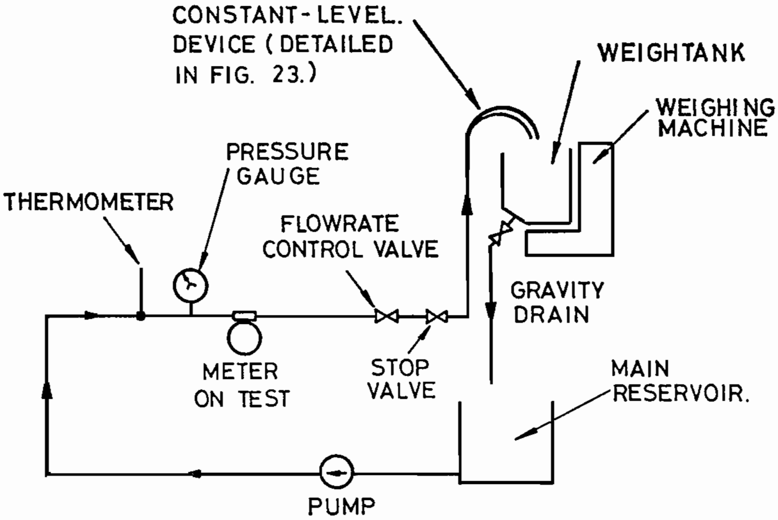


Fig. 22 — PRINCIPLE OF STANDING-START-AND-FINISH GRAVIMETRIC CALIBRATION OF FLOWMETERS.

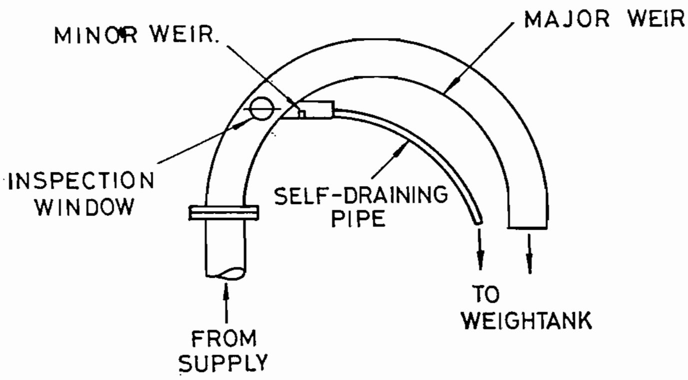


Fig. 23 — DETAIL OF CONSTANT-LEVEL DEVICE (AS SHOWN IN FIG. 22).

weighing machine reaches a preset value a timer is started. Then the weight, W, which initially sat beside the weighing tank on the weighing machine, is lifted clear, and when the total mass on the weighing machine reaches the same level as when the timer was started, then the timer is automatically stopped. Thus the weight of water entering the tank during the measured time is exactly equal to that of the substituted weight, W. In this way any possible errors through inadequate calibration of the weighing machine are eliminated. Mass flowrate is calculated as in the previous method.

Provided that a good quality electronic weighing machine, and not a mechanical machine, is used, and provided that special care is taken to ensure that the pipe delivering the jet to the tank always runs completely full, this method is capable of giving accuracy comparable with that of the static weighing method.

When gravimetric systems are being used to calibrate volumetric flowmeters, it is usual for water to be used as the calibration liquid, because of the ease with which its density can be evaluated from temperature and (if hard water is used) a knowledge of the relative density of the water. Other liquids may, however, be used with gravimetric calibrators, and if they are used only for calibrating mass flowmeters there is no density problem to complicate the method.

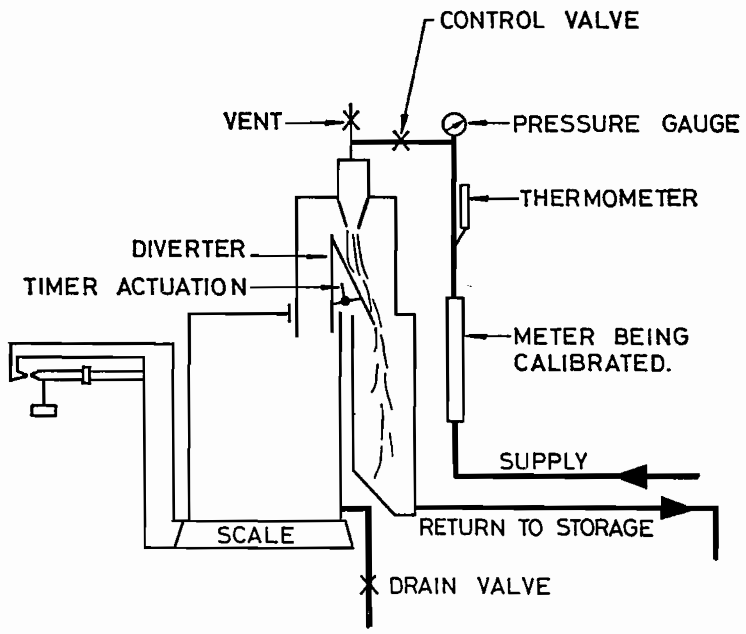


Fig. 24 — PRINCIPLE OF FLYING-START- & FINISH METHOD OF CALIBRATION, WITH STATIC WEIGHING.

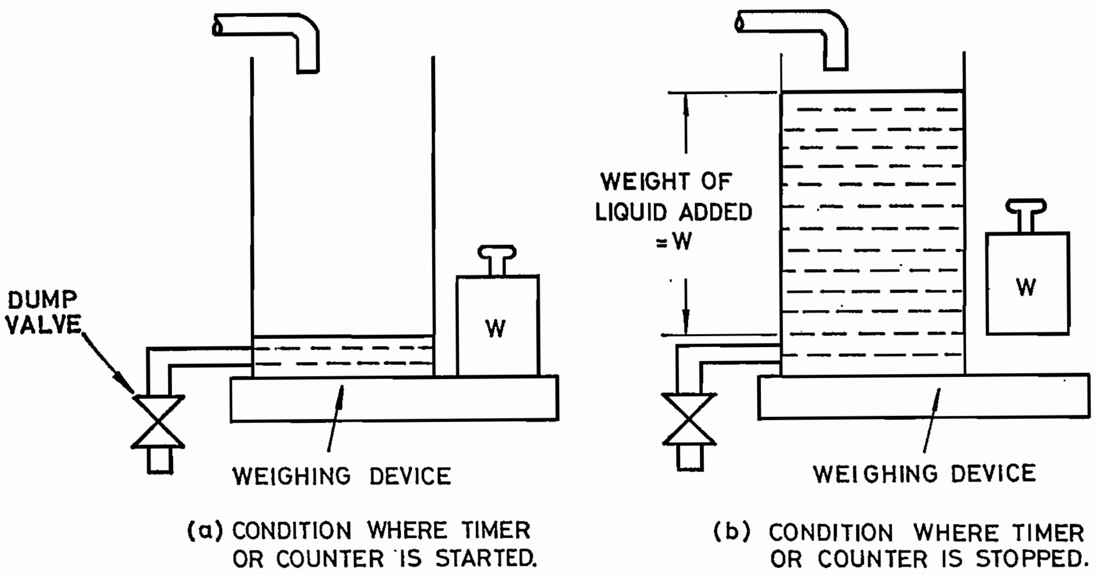


Fig. 25 — PRINCIPLE OF FLYING-START-AND-FINISH METHOD OF CALIBRATION, WITH DYNAMIC WEIGHING BY WEIGHT SUBSTITUTION.

9.4. **Pipe Provers**

Pipe provers are used extensively throughout the oil industry for the calibration of oil and fuel quantity meters in their installed positions and on their normal working liquids. They are also used to a limited extent in other areas, including the calibration of flowmeters in the premises of manufacturers.

The principle of operation is shown in Figure 26. A travelling body known as a displacer, which is either a well-sealed piston or an inflated (or, in small pipes a solid) elastic sphere acting as a piston, traverses a length of pipe between two detectors. As the displacer passes the first detector this opens an electronic gate so as to admit pulses from the flowmeter on test to a counter, and, similarly, as the displacer passes the second detector the pulse count is made to cease. Then the pulse count from the meter can be compared with the known volume of the pipe between detectors, thus giving a calibration factor for the meter.

Conventional pipe provers may be either of the unidirectional type as shown in Figure 27, where the displacer takes the form of a sphere and returns to its starting point by travelling unidirectionally through a sphere-handling valve, or of the bi-directional form shown in Figure 28, where the displacer is made to travel in alternate directions through the calibrated volume by means of a flow reversing (4-way) valve. Bidirectional provers are commonly in the form of a loop as shown in Figure 28, a geometry which necessitates the use of a sphere as a displacer, or they may be in the form of a straight length of calibrated pipe, in which case the displacer may be a piston.

In recent years compact pipe provers, with a volume of approximately one tenth of that of a comparable conventional prover, have come into use. Their compactness is the result of combining two important developments. First, the calibrated pipe is a short length of honed-bore tubing, with a precision piston, which carries a piston rod extending to the outside of the prover pipe. On the external part of the piston rod is fitted an optical detection system which can position the piston with very much greater precision than was possible in conventional provers.

The other development without which compact provers would not be practicable is pulse interpolation. This is the name given to a number of alternative electronic systems whereby the pulse count from a meter can be read to a fraction of a pulse, thus greatly reducing the rounding-off error of ± 1 pulse, which is inevitable when only a whole number of pulses is counted.

The piston rod in most compact provers also serves the purpose of mechanically returning the piston to its starting point ready for the next run, whilst a by-pass valve is open. In the form of compact prover shown in Figure 29 the by-pass valve is an integral part of the piston ; in the alternative form of Figure 30 the by-pass valve is on an external loop of pipe.

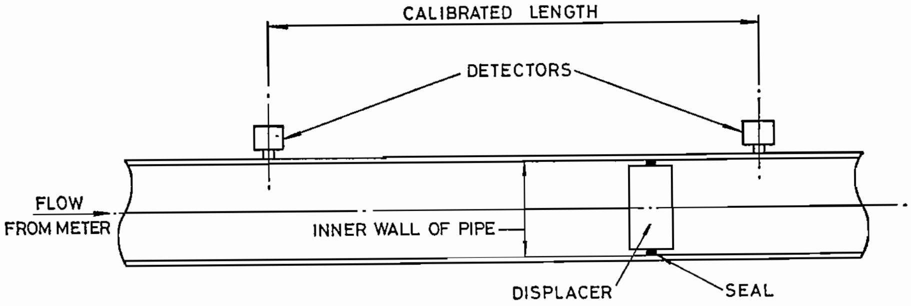


Fig. 26 — PRINCIPLE OF OPERATION OF PIPE PROVER.

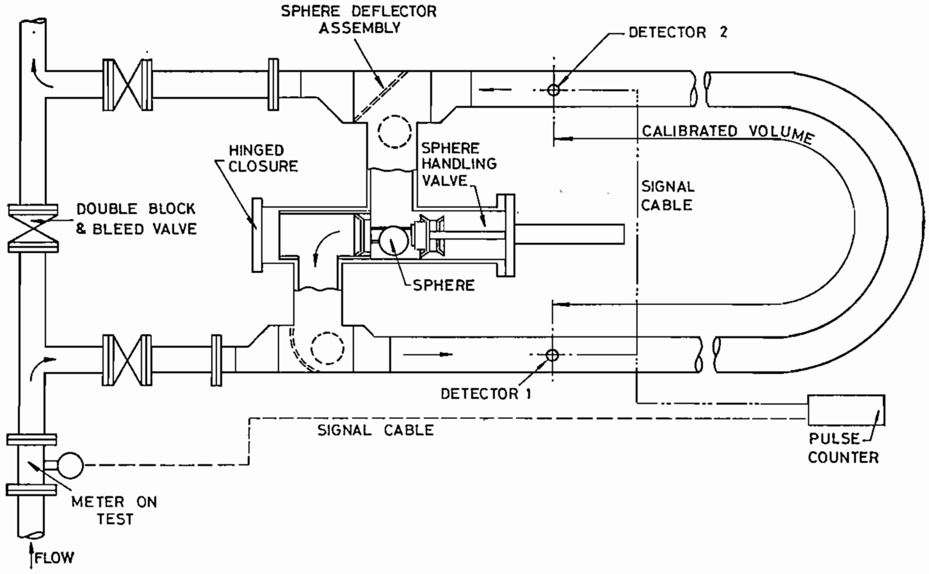


Fig. 27 — EXAMPLE OF SPHERE-TYPE UNIDIRECTIONAL PROVER.

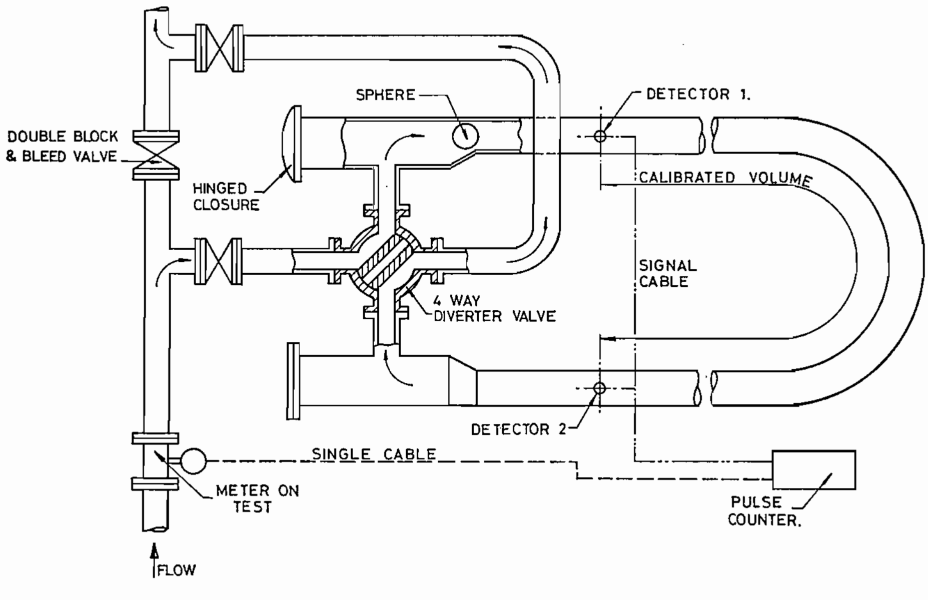


Fig. 28 — EXAMPLE OF SPHERE-TYPE BIDIRECTIONAL PROVER.

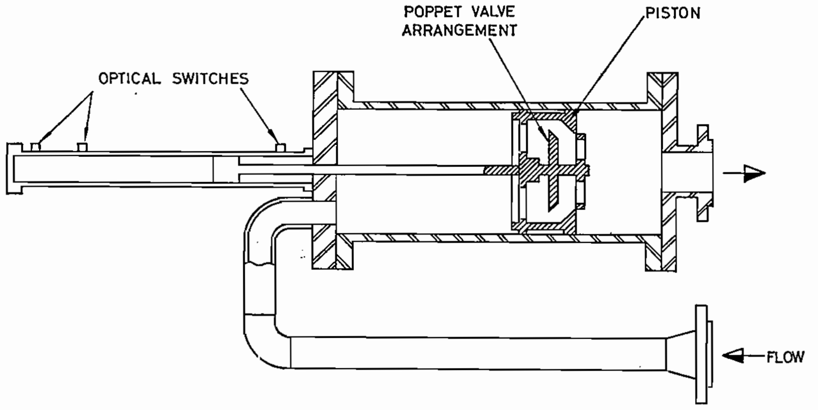


Fig. 29 — EXAMPLE OF UNIDIRECTIONAL COMPACT PROVER WITH INTERNAL VALVE.

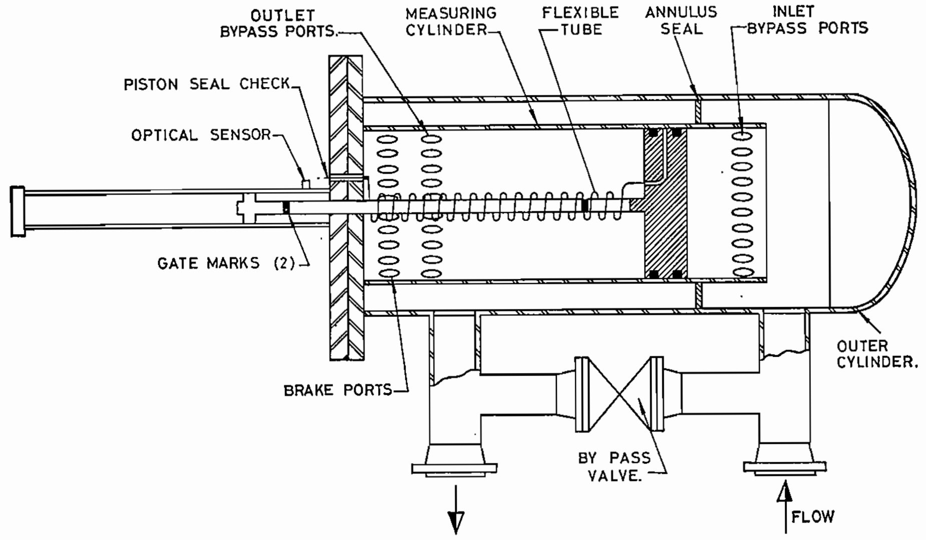


Fig. 30 — EXAMPLE OF UNIDIRECTIONAL COMPACT PROVER WITH EXTERNAL VALVE.

In order to obtain from a compact prover the same accuracy as is normally obtained from a conventional prover, it is necessary to take a larger number of proving runs with the compact prover and to average the result. In practice this takes no longer than to make a single run with a conventional prover, because the smaller size of the comptact prover enables proving runs to be accomplished in a small fraction of the time taken with the larger conventional provers. It is also important to avoid using compact provers with meters that emit electrical pulses at irregular intervals ; such meters include vortex-shedding meters and certain forms of displacement meter, all of which demand the counting of a large number of pulses if accurate proving is to be obtained.

10. Future prospects

In attempting to forecast developments that are likely to take place in this field over the next few years, it is important to make the distinction between those developments which are fairly easy to foresee, because they merely constitute an extrapolation of present trends, and those which are purely speculative. These two very different kinds of forecasts will therefore be presented separately, below.

10.1. Present Tendencies Extrapolated

At the present time only a very small proportion of meters are fitted with integral microcomputers. This proportion is almost certain to increase steadily, as the advantages of « smart » meters become more widely recognised. They are currently used for such purposes as linearising the output of meters that are not quite linear, providing pulse interpolation within the meter, and enabling pulsating flows to be measured more accurately by making large numbers of calculations and averaging the results. Other uses for microcomputers in flowmeters will doubtless develop as time goes by.

The market share of compact pipe provers will continue to increase at the expense of conventional provers, but whether they will ever supplant the larger type altogether remains to be seen. It is possible that conventional provers will stage something of a comeback by borrowing some of the advanced technology that has been developed for compact provers. The present fairly clear cut boundary line between conventional and compact provers may tend to become blurred, with the emergence of a more or less continuous spectrum of prover types, with the most compact of compact provers at one end and the most bulky of conventional provers at the other end.

As compact provers become more common, meter manufacturers may feel obliged to develop meters especially designed to be proved with compact provers. This applies particularly to displacement meters, which are difficult to prove accurately with compact provers unless they are fitted with a direct drive that by-passes the gearing and calibration mechanism on the meter head. Some displacement meters are already fitted with direct-drive pulse generators, and increasing numbers of these are likely to be sold in the future.

The present very hesitant move in the direction of mass measurement, by both direct and indirect means, is likely to gather momentum gradually. Whether it will ever totally replace volumetric measurement, and if so, how long it will take to do so, is impossible to predict.

The present limited use of modern types of non-rotating meter, especially electromagnetic, ultrasonic, and vortex-shedding meters, is bound to continue in those specialised fields where the use of such meters has particular advantages. Again, it is impossible to predict whether rotating meters will ever be phased out altogether.

10.2. Some Speculative Suggestions

Speculation about the future is a highly subjective matter, and doubtless a great many flow measurement specialists would disagree with the opinions of the present writer. For what they are worth however, the writer's views are that three major new developments are quite likely to come about within, say, the next ten years.

First, the meter with the greatest potential for making large inroads into the custody transfer metering of petroleum fluids is the vortex-shedder. Improved designs of vortex-shedding meter will have a greater regularity of pulse spacing (which will facilitate the proving of such meters), and a higher repeatability and reliability than those at present in use. The envisaged new generation of vortex-shedders is more likely to take away market share from turbine meters than from displacement meters, because, like turbine meters, vortex-shedders will always suffer from the disadvantage of slip at low flowrates.

Secondly, the rapidly increasing use of direct mass flowmeters will require the development of on-site portable proving devices for such meters. These will have to include gravimetric provers that can be used with liquefied gases, in view of the importance of this area in the field of direct mass metering.

The third and most highly speculative suggestion is that new systems will be developed to permit the custody transfer metering of two-phase flow. This development is badly needed, so that the flow direct from oil wells can be metered before separation. It would also be of some value if it were possible to meter directly the discharge from marine tankers, which, when the tanks are nearly empty, tends to have gas mixed with the oil. The problems of obtaining sufficient accuracy under such conditions are quite formidable, but an increasing amount of research directed to their solution is in progress, and there seems a fair prospect that in due course a solution will become available.

The one forecast that can be made with absolute confidence is that the future of custody transfer metering of valuable liquids will be full of interest, if not actually exciting.

RECENT METROLOGICAL DEVELOPMENTS in the KINGDOM of SAUDI ARABIA *

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SUMMARY — The paper outlines the activities, infrastructure and future plans of the Saudi Arabian Standards Organization (SASO). Special attention is focused on the new metrological resources required to support quality control testing, and to provide technical assistance to the emerging manufacturing industries in Saudi Arabia.

The initial industrial research, detailed technical planning, construction methods, equipment procurement and commissioning of a National Metrology Facility for SASO is presented as a useful model for other developing countries.

The Saudi Arabian Standards Organization

Recognizing the role of standardization in the economic development of the nation, the Kingdom of Saudi Arabia established a national standards organization by Royal Decree No. M/10 in April 16th 1972, as a public autonomous body with its own budget.

SASO is the only Saudi organization responsible for all of the activities related to standards and measurements, including :

- The formulation and adoption of national standards for all commodities and products as well as metrology, symbols, definitions of commodities and products, methods of sampling and testing and any other assignment approved by the Board of Directors.
- Publication of standards by the most suitable means.
- Distribution of standards information and the coordination of activities relating to standards and measurements in the Kingdom.
- Setting the rules for granting certificates of conformity, quality marks, laboratory accreditation, as well as regulating their issuance and use.

At present there are more than 450 obligatory Saudi Standards, and another 700 draft standards in various stages of development. Out of these approved standards more than 50 % deal with food and agricultural products, and the remaining 50 % cover domestic appliances and light industrial goods.

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* This paper was presented to the Arab Organization for Standardization and Metrology (ASMO) Symposium in Amman, Jordan 24-26 November 1986.

In the field of metrology, nine standards deal with units, quantities, tolerances and conversions that have to be observed by all concerned with measurements. Another 20 standards deal with measuring instruments and their calibration. These include clinical thermometers, pressure gauges, fuel dispensing pumps, cold water meters etc., with 7 standards specifically regulating the precision of weights and balances used by shops and jewellers trading to the public.

In its fourth five year plan (1985-1990) SASO have introduced new measures including a National Quality Mark, a Test Laboratory Accreditation Scheme and a Product Conformity Certification System to encourage local producers to attain acceptable quality standards.

All Ministries in the Kingdom, independent agencies and government bodies are requested to adopt the mandatory national standards as a basis for purchase specifications and other related activities. Furthermore, the Kingdom's Ministry of Industry and Electricity have stipulated standardization as a principle element for the granting of new industrial licences, and local manufacturers are now obliged to seek SASO's advise during various stages of product development and production.

All this is now a significant new area of activity, and requires a considerable expansion of SASO's laboratory facilities to ensure that the local producers have access to reliable quality testing and calibration facilities.

SASO's own laboratories are presently equipped to carry out chemical and mechanical testing, including compliance testing on samples of foods and drinks, textiles and domestic electrical products sampled from the local market, or to act as an arbiter when there is a dispute.

The enforcement of the approved standards is not the responsibility of SASO and the appropriate routine inspections of petrol pumps, weights, balances and length measurements used for trade are carried out by the established laboratories of the Quality Control Department within the Ministry of Commerce.

Several branches of the Quality Control Department are located close to the points of import into the Kingdom, and all have well equipped laboratories and trained staff to test the quality of imported food and certain other products in accordance with Saudi Standards.

Arab Gulf Cooperation Council

There are clearly broad similarities between the economies and cultures of the member states of the Arab Gulf Cooperation Council (GCC). Their needs for standardization and metrology are similar, and SASO is now acting as the secretariat for the Gulf Arab Standards and Metrology Organisation (GASMO), and to date 53 harmonized Gulf Standards have been approved.

Free trade between the Arab Gulf Cooperation Council countries is expected to increase rapidly, and is being encouraged by reduced or zero import tariffs on goods manufactured within the member states. Traceability of national measurements and test results is vital for a meaningful recognition of quality in a free trade environment and SASO, through GASMO, is active in establishing the required infrastructure.

SASO Laboratory Complex

The lack of comprehensive new product research, testing and calibration resources at SASO's headquarters were identified some years ago as a significant barrier to technological progress, import substitution and free trade between neighbouring GCC countries. It was also recognized that independent quality assurance and calibration resources were urgently required at SASO headquarters to provide the essential testing and support activities now being demanded by export orientated industries in the Kingdom.

SASO, mindful of this national need, have already finished the greater part of the technical design concepts for a residential « Headquarters and Laboratory Complex » which will provide comprehensive testing and industrial research facilities in the Kingdom of Saudi Arabia.

The large new site will also include a purpose built 12 000 m^2 « National Metrology and Calibration Centre » housing the national reference standards of Saudi Arabia with top echelon equipment traceable to the established international units of measurement (SI).

It is expected that this Metrology Centre will eventually become the higest level of reference for precision measurements and calibration science both in the Kingdom and Arab Gulf States.

Metrology design considerations

The site is close to the King Saud University in Riyadh on a prestigious visual position at the junction of two 60m wide roadways. Early on in the design phase it was decided that the most critical metrology laboratories should be underground, and through the UNIDO Expert at SASO, a study was made of recently constructed underground metrology laboratories to see which best suited the intense summer heat of Saudi Arabia.

In Riyadh, seasonal ambient temperatures vary from 9 to 49 °C but studies indicated that at about 9 metres underground these seasonal changes merge to produce a fairly steady « all year round » soil temperature close to 26 °C on the SASO site.

All primary interferometric and dimensional laboratories, including mass, density and pressure will be maintained at 20 °C in a long underground gallery, totally surrounded by dust free air conditioned « buffer corridors » and additional utility spaces also maintained at approximately 20 °C. Special anti-vibration precautions as appropriate for the precision measurement of length, height, pressure and force will be incorporated into the supporting foundations.

The primary electrical standards laboratories and primary temperature laboratories etc., will be located above the underground laboratories, and these will be maintained at 23 degrees and shielded as appropriate against magnetic and radio interference.

To bridge the long construction gap and to provide the most urgent calibration services needed to support the introduction of a National Quality Mark and a Laboratory Accreditation System, the SASO metrology programme was recently split up into Phase I & Phase II.

Measurement and calibration survey

In order to document the actual scope and immediate priorities for the « Phase I start-up facility » and to collect useful information for the detailed planning of the National Metrology & Calibration Centre (Phase II), SASO carried out a national measurement and calibration survey.

The format of the circulated questionnaire consisted of eight questions chosen to identify the various measurement processes being carried out in a representative sample of the Kingdom's industries and Government Agencies.

The first question collected information on the company product and was subdivided into one of nine categories viz :

construction
engineering
electrical
chemical
food/water
paper textiles
education
services
others

The second question identified the major production process being used and any associated measurement parameters such as force, pressure, mass, flow, thermal etc., which are essential for the process.

The third question, and possibly the most important question for the planning of the new SASO Metrology Laboratories, concerned the actual measurement or test parameters in daily use, their range and associated measurement accuracy.

To simplify and analyse the complex feedback generated by this question, the replies were compressed into a simple matrix containing « three levels of measurement accuracy », and « three levels of parameter range ».

Level 1 = highest (reference) level	i.e. 0.001 %	0.01 C
Level 2 = calibration level	i.e. 0.05 %	0.1 C
Level 3 = industrial level	i.e. 1.0 %	1 C

Sub-dividing or grouping of the parameter range was not as easy, but for analysis purposes it was necessary to define a typical middle range, for example 1 mV to 1 kV, 1 mg to 2 kg or — 20 to + 300 °C and to group other values above or below this middle range as « high » or « low » as appropriate.

The SASO calibration survey clearly indicated that the original proposed Phase I facility was not sufficient to cater for the full range of the identified tests/measurements being carried out in the Kingdom's petrochemical and construction industries.

With this advance knowledge SASO was able to extended the proposed Phase I calibration capabilities to include higher temperatures to 1 100 °C, higher gas and oil pressures to 100 MPa, higher force to 1 MN and precision volume to 50 L respectively.

The remaining questions identified those industries actually carrying out quality control testing or product research, and their needs for external metrology support services, the type of reference standards maintained (if any), and where traceability (if any) was obtained from ?

The replies to these latter questions were a source of constant encouragment for SASO, as they endorsed and identified the actual difficulties some companies were experiencing in obtaining a valid traceability for their measurements, and that at least 35 % of these companies were obliged to go outside the Kingdom to obtain their traceability requirements.

The questionnaire also identified at least five good commercial calibration laboratories carrying out highest precision electrical and radio frequency calibration work for various Government clients, and the precision of their own maintained reference standards.

As already discussed, this kind of technical information was vital to obtain early in the planning stages, as SASO had to be fully aware of the precision and likely cost of the metrology resources needed to :

(a) audit and accredit these commercial secondary calibration laboratories
(b) support local industries
(c) verify the accuracy of mass, length and volume legal metrology resources maintained by the Quality Control Department (Ministry of Commerce)

The results of the survey are shown in a schematic form in Fig. 1.

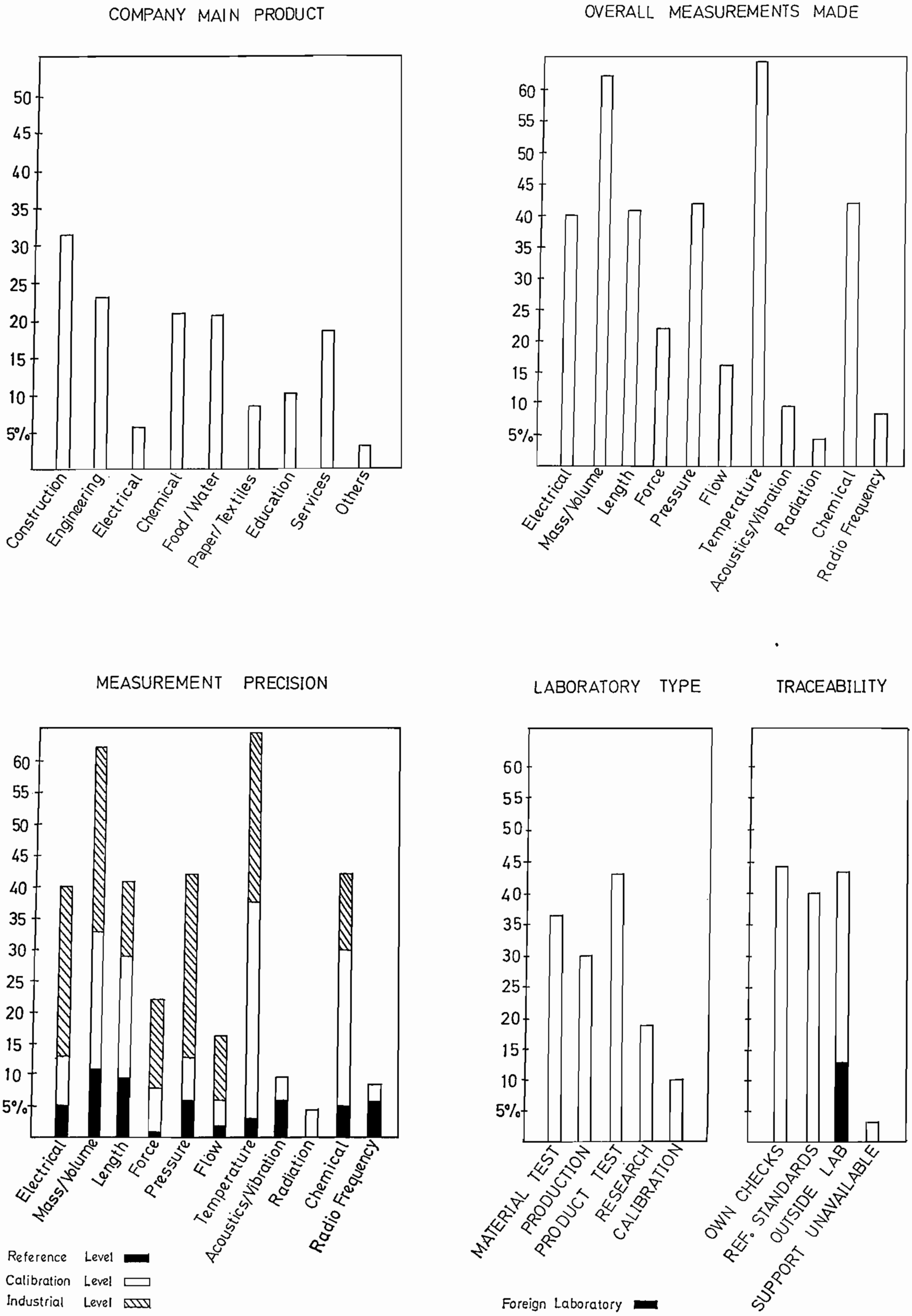

Fig. 1 — Summarized results of the national measurement and calibration survey.

Phase I calibration facilities

The Phase I start-up calibration facility is now constructed on the old site, and consists of the following laboratories :

(1) Length and Dimensional Metrology
(2) Mass
(3) Volume and Density
(4) Force and Pressure
(5) Electrical Standards
(6) Electrical and Radio Frequency
(7) Temperature
(8) Electrical Power and Energy
(9) Radio and Television Testing

The metrology laboratories occupy the central 900 m^2 of a new laboratory extension block adjacent to SASO's existing test/research laboratories. The new extension block was constructed with substantial thermal insulation both in the walls roof and floor i.e. double walls with a 200 mm cavity space incorporating 100 mm expanded foam insulation. All windows and doors are double glazed and all external windows are protected with solar shading to prevent sunlight radiating directly into the building.

In addition, the actual metrology laboratories were built with the only external laboratory walls facing to the north and these are without external windows. An internal double glazed corridor is also provided to buffer the climatized calibration rooms from that of the adjacent offices.

Air conditioning for the most critical 20 °C laboratories (i.e. 1, 2, 3 & 4). is provided in two stages, with the final stage consisting of constant volume proportional control, and recent tests have confirmed a long term stability better than 0.2 degrees. The remaining laboratories are maintained at 23 °C and all compressors are roof mounted on remote and isolated structural parts of the building to reduce the effects of transmitted vibrations.

To further minimize the transmission of ground vibrations from a nearby workshop on the site, a sand filled vibration absorbing trench surrounds the whole building and the individual laboratory floors are themselves further isolated from internal sources of vibration (doors slamming and footsteps etc.) by 200 mm of compacted dry sand under the floor.

Metrology equipment selection and local training of staff

As United Nations have a special arrangement with the Government of Saudi Arabia for this project, the metrology equipment market research and subsequent selection and procurment was carried out on behalf of SASO by the United Nations Industrial Development Organization (through UNDP).

The metrology equipment selection was based on exact compliance with written technical performance and specifications designed to provide SASO with the highest calibration capabilities, consistent with a minimum dependence on regular foreign recertification.

Special attention was paid to :

(a) metrology equipment of the self-calibrating or ratiometric type
(b) robust and compact travelling devices
(for international traceability linkage)
(c) the provision of super stable in-house reference standards for the SASO Project
(d) computer aided calibration and systems management

The SASO start-up calibration facility is expected to be fully operational in 12 months time to all clients requiring certification support and traceable measurements for the basic parameters of mass, length, volume, density, pressure, force, temperature and electrical quantities.

At the same time SASO will start implementing a pilot programme of official accreditation for existing commercial test and calibration laboratories, currently operating in the Kingdom, by evaluating their capabilities with portable precision audit devices from the SASO Phase I laboratories.

It is expected that the Phase I laboratories at SASO will immediately provide the nucleus of a practical inhouse metrology and calibration training programme for SASO Cadres during the long construction period of Phase II, and yet allow the Saudi Arabian Standards Organization to discharge its responsibilities to local industries, Government Agencies, the Gulf Arab Standards and Metrology Organization (GASMO) and neighbouring Arab countries importing or exporting goods to the Kingdom of Saudi Arabia.

LITTERATURE

République Populaire de Chine

Des résumés du contenu des articles publiés en Chine sont maintenant disponibles en langue anglaise, y compris ceux publiés dans Acta Metrologica Sinica et dans 40 autres publications.

Le journal analytique Chinese Science Abstracts Part A contenant ces informations est une revue bi-mensuelle (environ 450 articles dans chaque numéro) éditée par Science Press, Beijing et distribuée hors de Chine par VNU Science Press, P.O. Box 2093, 3500 GB, Utrecht, Pays-Bas.

République de Corée

Le BIML a reçu de Korea Standards Research Institute (KSRI) une copie d'un livre en langue coréenne ayant pour titre (en traduction) « La première décennie de Korea Standards Research Institute 1975-1985 ».

Depuis sa création, en décembre 1975, cet Institut a largement contribué à l'amélioration de la capacité en métrologie de précision de l'industrie nationale par l'établissement, la maintenance et la dissémination des étalons nationaux. Il a aussi joué un rôle primordial dans la création d'un système national d'étalonnage en effectuant les travaux de recherche et de développement nécessaires dans ce but.

Une partie dominante des activités de KSRI est consacrée à la métrologie. L'Institut publie également sous le titre Journal of Research of KSRI des volumes contenant des articles scientifiques et techniques écrits par ses ingénieurs. Plusieurs de ces articles sont en langue anglaise ou comportent des résumés en anglais. Le Volume 3, 1986 contient 39 articles sur des sujets tels que interférométrie et lasers, comparateurs de masse, cellules de charge, mesure de masse volumique, étalons de courant alternatif, thermocouples, cellules à point triple, systèmes d'étalonnage en débitmétrie, mesures micro-ondes, etc.

Etats-Unis d'Amérique

Le National Bureau of Standards a publié un cours sur les interférences et la compatibilité électromagnétique (hautes fréquences). Ce livre doit en particulier intéresser ceux des métrologistes qui s'occupent d'approbations de modèle d'instruments électroniques : NBS Technical Note 1099 « Electromagnetic Compatibility and Interference Metrology », 178 pages, juillet 1986, auteurs : M.T. Ma et M. Kanda.

L'association « International Society of Weighing and Measurement », ISWM (précédemment National Scale Men's Association) réunit comme membres des fabricants et réparateurs d'instruments de pesage ainsi que des particuliers s'occupant des poids et mesures. Le nouveau nom de l'association a pour but d'élargir le nombre de ses membres hors des Etats-Unis.

L'association publie une revue bi-mensuelle « Weighing & Measurement ». Une liste d'autres publications est reproduite dans la version anglaise « Literature » de ce Bulletin.

Italie

M. E. MENNA que nous connaissons pour sa participation aux activités de l'OIML et ses articles dans notre Bulletin, a écrit une brochure d'information destinée aux commerçants et employés municipaux de son pays :

E. MENNA — Pesi e misure (Origine, sviluppi e importanza della misura. Disposizioni di legge, aggiornamenti, pratica e critica), Casanova Editore, Parma, 1986.

Commission Electrotechnique Internationale

Il est intéressant de noter que le premier projet sur des compteurs statiques (électroniques) d'énergie électrique (classes 1 et 2) vient d'être mis en circulation par le comité technique CE 13.

Centenaire de la PTR-PTB

La fondation de la Physikalisch-Technische Reichanstalt (PTR) date du 28 mars 1887. Pour célébrer cet événement, la Physikalisch-Technische Bundesanstalt (PTB), qui constitue le successeur en République Fédérale d'Allemagne de cette institution prodigieuse, organise cette année une exposition intitulée « Mass und Messen » dont nous avons reçu le catalogue. Cette publication de 168 pages donne, en suivant l'ordre des objets exposés, des indications historiques sur les plus éminents collaborateurs et les travaux scientifiques effectués à l'institut.

LITERATURE

People's Republic of China

Abstracts in English of Chinese scientific literature are now available including those of papers published in Acta Metrologica Sinica and in more than 40 other publications.

Chinese Science Abstracts Part A is published bi-monthly (about 450 abstracts) by Science Press, Beijing and distributed outside China by VNU Science Press, P.O. Box 2093, 3500 GB, Utrecht, The Netherlands.

Republic of Korea

The BIML has received from Korea Standards Research Institute a copy of a book with the translated title « First Decade of Korea Standards Research Institute 1975-1985 ».

Since its foundation in December, 1975, the Korea Standards Research Institute (KSRI) has contributed a great deal to improving the precision measurement capability of nation's industries, through establishment, maintenance, and dissemination of the national standards. It has been playing a fundamental role in construction of the national calibration system and carrying out relevant research and development activities necessary to do so.

A great part of the activities of KSRI is devoted to metrology. The Institute also edits, under the title Journal of Research of KSRI, volumes of collected research papers written by staff members. Several of these papers are in English or have English summaries. Volume 3, 1986 contains 39 papers on subjects such as interferometry and lasers, mass comparators, load cells, density measurements, AC voltage standards, thermocouples, triple point cells, flowmeter calibration systems, microwave measurements and a number of other items related to metrology.

United States of America

The National Bureau of Standards has published NBS Technical Note 1099 « Electromagnetic Compatibility and Interference Metrology », 178 pages, July 1986, authors M.T. Ma and M. Kanda. This book is a full course on EMC/EMI measurements mainly high frequency. It is of particular interest to laboratories concerned with pattern approval of electronic instruments.

The International Society of Weighing and Measurement, ISWM (formerly National Scale Men's Association) has among its members producers of weighing instrumentation, repair companies as well as individuals connected with weights & measures activities. The new name of the association is intended to enlarge membership to outside the USA.

The association publishes the bi-monthly magazine « Weighing & Measurement ». Furthermore the publications below relative to weighing can be purchased (reduced rate for members) :

- Complete Scaleman's Handbook of Metrology
- Design Principles of Weighing Machines : Electronic Scales : Instrumentation & Indication
- Installation & Maintenance of Scale Equipment : Electronic Scales ; Preventive Maintenance
- Installation & Maintenance of Scale Equipment : Adjustment Procedures, Calibration & Trouble Shooting ; Workmanship Standards
- ANSI Publication B157.1-1981
- Mantro Conversion Tables
- Load Cell Terminology & Definitions and Recommended Load Cell Test Procedures
- Electronic Counting Scales—How They Compare to Conventional Ratio Counting Scales
- Digital Indicators for Electronic Scales... Some Important Considerations

The Reliability of Electronic Weighing Systems
Steelyard Rod Using Load Cells

For information on purchase of publications or membership contact :

International Society of Weighing
and Measurement
2506 Gross Point Road
Evanston, IL 60201
USA

Italy

Mr. E. MENNA who in the past took part in OIML activities and published papers in our Bulletin has written an information brochure on weights and measures for the attention of merchants and municipality staff :

E. MENNA — Pesi e misure (Origine, sviluppi e importanza della misura. Disposizioni di legge, aggiornamenti, pratica e critica), Casanova Editore, Parma, 1986.

International Electrotechnical Commission

The first draft on alternating static (electronic) watthour meters (class 1 and 2) has been issued by TC 13/WG 11.

Centenary of PTR-PTB

The Physikalisch-Technische Reichanstalt (PTR) was founded on 28 March 1887. In order to celebrate this event the Physikalisch-Technische Bundesanstalt (PTB) which constitutes the successor in the Federal Republic of Germany of this famous institution, organises this year an exhibition with the title « Mass und Messen » of which we have received the catalogue. This publication of 168 pages gives, by following the order of the items exhibited, historical notes on the most eminent collaborators and the scientific work undertaken at the institute.

INFORMATIONS

MEMBRES DU CIML

REPUBLIQUE POPULAIRE DEMOCRATIQUE DE COREE — Monsieur DJEUNG KI TCHEUL remplace Monsieur TCHEU HWA TCHOUN comme membre du CIML.

INDE

L'organisation indienne de normalisation Indian Standards Institution (ISI) vient de changer son nom en BUREAU OF INDIAN STANDARDS, en application de la loi Indian Standards Act, 1986. Les dispositions de cette loi, qui prévoit également la possibilité pour le Gouvernement de déclarer obligatoire la conformité aux normes, sont entrées en vigueur au 1er avril 1987.

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INFORMATION

CIML MEMBERS

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA — Mr DJEUNG KI TCHEUL replaces Mr TCHEU HWA TCHOUN as CIML Member.

INDIA

The Indian Standards Institution has been renamed as BUREAU OF INDIAN STANDARDS as a result of Bureau of Indian Standards Act, 1986, passed by the Government of India. The Bureau has come into existence from 1 April 1987.

The Act empowers the Government of India to notify any article or process of any scheduled industry to conform to the relevant Indian Standards and direct the use of the Indian Standard under a certification marks licence as compulsory on such article or process.

REUNIONS OIML

	Groupes de travail	Dates	Lieux
SP 7 - Sr 4	Instruments de pesage à fonctionnement non automatique	1-5 juin 1987	BRAUNSCHWEIG R.F. D'ALLEMAGNE
SP 6	Mesure des gaz	15-19 juin 1987	BIML PARIS
SP 6 - Sr 1	Compteurs de gaz à parois déformables		
SP 6 - Sr 2	Compteurs de gaz à pistons rotatifs Compteurs de gaz non volumétriques		
SP 20	Produits préemballés	22-26 juin 1987	GÖTEBORG SUEDE
SP 20 - Sr 1	Problèmes généraux pour les préemballages		
SP 20 - Sr 2	Vérification des quantités dans les emballages		
SP 2 - Sr 5	Contrôle par échantillonnage		
SP 30	Mesures physico-chimiques	14-19 sept. 1987	TBILISSI U.R.S.S.
SP 30 - Sr 1	pH-métrie et ionométrie		
SP 30 - Sr 2	Conductométrie		
SP 30 - Sr 4	Hygrométrie des matériaux solides		
SP 30 - Sr 9	Viscosimétrie		
SP 30 - Sr 10	Analyseurs de gaz		
SP 17	Mesure des pollutions	21-25 sept. 1987	BIML PARIS
SP 17 - Sr 2	Mesure des pollutions de l'eau		
SP 17 - Sr 4	Mesure des pollutions par pesticides et substances toxiques		
SP 17 - Sr 5	Mesure des pollutions par déchets dangereux		
SP 5D - Sr 3	Compteurs d'eau	16-18 nov. 1987 *(provisoire)*	BIML PARIS
SP 31	Enseignement de la métrologie	11-15 avril 1988	LA HAVANE CUBA
SP 31 - Sr 1	Formation des ingénieurs en métrologie		

22ème Réunion du Comité International de Métrologie Légale	2-4 septembre 1987	PARIS FRANCE
Réunion du Conseil de Développement	11-15 avril 1988	LA HAVANE CUBA

Note : Cette liste a été établie le 5 juin et peut ne plus être à jour.
This list was established 5th June and may no longer be up to date.

PUBLICATIONS

— Vocabulaire de métrologie légale
Vocabulary of legal metrology

— Vocabulaire international des termes fondamentaux et généraux de métrologie
International vocabulary of basic and general terms in metrology

RECOMMANDATIONS INTERNATIONALES

INTERNATIONAL RECOMMENDATIONS

RI N°

1 — Poids cylindriques de 1 g à 10 kg (de la classe de précision moyenne)
Cylindrical weights from 1 g to 10 kg (medium accuracy class)

2 — Poids parallélépipédiques de 5 à 50 kg (de la classe de précision moyenne)
Rectangular bar weights from 5 to 50 kg (medium accuracy class)

3 — Réglementation métrologique des instruments de pesage à fonctionnement non automatique
Metrological regulations for non automatic weighing instruments

4 — Fioles jaugées (à un trait) en verre
Volumetric flasks (one mark) in glass

5 — Compteurs de liquides autres que l'eau à chambres mesureuses
Meters for liquids other than water with measuring chambers

6 — Prescriptions générales pour les compteurs de volume de gaz
General specifications for volumetric gas meters

7 — Thermomètres médicaux (à mercure, en verre, avec dispositif à maximum)
Clinical thermometers (mercury-in-glass, with maximum device)

9 — Vérification et étalonnage des blocs de référence de dureté Brinell
Verification and calibration of Brinell hardness standardized blocks

10 — Vérification et étalonnage des blocs de référence de dureté Vickers
Verification and calibration of Vickers hardness standardized blocks

11 — Vérification et étalonnage des blocs de référence de dureté Rockwell B
Verification and calibration of Rockwell B hardness standardized blocks

12 — Vérification et étalonnage des blocs de référence de dureté Rockwell C
Verification and calibration of Rockwell C hardness standardized blocks

14 — Saccharimètres polarimétriques
Polarimetric saccharimeters

15 — Instruments de mesure de la masse à l'hectolitre des céréales
Instruments for measuring the hectolitre mass of cereals

16 — Manomètres des instruments de mesure de la tension artérielle (sphygmomanomètres)
Manometers for instruments for measuring blood pressure (sphygmomanometers)

17 — Manomètres, vacuomètres, manovacuomètres indicateurs
Indicating pressure gauges, vacuum gauges and pressure-vacuum gauges

18 — Pyromètres optiques à filament disparaissant
Optical pyrometers of the disappearing filament type

19 — Manomètres, vacuomètres, manovacuomètres enregistreurs
Recording pressure gauges, vacuum gauges, and pressure-vacuum gauges

20 — Poids des classes de précision E_1 E_2 F_1 F_2 M_1 de 50 kg à 1 mg
Weights of accuracy classes E_1 E_2 F_1 F_2 M_1 from 50 kg to 1 mg

21 — Taximètres
Taximeters

22 — Tables alcoométriques internationales
International alcoholometric tables

23 — Manomètres pour pneumatiques de véhicules automobiles
Tyre pressure gauges for motor vehicles

24 — Mètre étalon rigide pour agents de vérification
Standard one metre bar for verification officers

25 — Poids étalons pour agents de vérification
Standard weights for verification officers

26 — Seringues médicales
Medical syringes

27 — Compteurs de volume de liquides (autres que l'eau). Dispositifs complémentaires
Volume meters for liquids (other than water). Ancillary equipment

28 — Réglementation technique des instruments de pesage à fonctionnement non-automatique
Technical regulations for non-automatic weighing machines

29 — Mesures de capacité de service
Capacity serving measures

30 — Mesures de longueur à bouts plans (calibres à bouts plans ou cales-étalons)
End standards of length (gauge blocks)

31 — Compteurs de volume de gaz à parois déformables
Diaphragm gas meters

32 — Compteurs de volume de gaz à pistons rotatifs et compteurs de volume de gaz à turbine
Rotary piston gas meters and turbine gas meters

33 — Valeur conventionnelle du résultat des pesées dans l'air
Conventional value of the result of weighing in air

34 — Classes de précision des instruments de mesurage
Accuracy classes of measuring instruments

35 — Mesures matérialisées de longueur pour usages généraux
Material measures of length for general use

36 — Vérification des pénétrateurs des machines d'essai de dureté
Verification of indenters for hardness testing machines

37 — Vérification des machines d'essai de dureté (système Brinell)
Verification of hardness testing machines (Brinell system)

38 — Vérification des machines d'essai de dureté (système Vickers)
Verification of hardness testing machines (Vickers system)

39 — Vérification des machines d'essai de dureté (systèmes Rockwell B, F, T - C, A, N)
Verification of hardness testing machines (Rockwell systems B, F, T - C, A, N)

40 — Pipettes graduées étalons pour agents de vérification
Standard graduated pipettes for verification officers

41 — Burettes étalons pour agents de vérification
Standard burettes for verification officers

42 — Poinçons de métal pour agents de vérification
Metal stamps for verification officers

43 — Fioles étalons graduées en verre pour agents de vérification
Standard graduated glass flasks for verification officers

44 — Alcoomètres et aréomètres pour alcool et thermomètres utilisés en alcoométrie
Alcoholometers and alcohol hydrometers and thermometers for use in alcoholometry

45 — Tonneaux et futailles
Casks and barrels

46 — Compteurs d'énergie électrique active à branchement direct (de la classe 2)
Active electrical energy meters for direct connection (class 2)

47 — Poids étalons pour le contrôle des instruments de pesage de portée élevée
Standard weights for testing of high capacity weighing machines

48 — Lampes à ruban de tungstène pour l'étalonnage des pyromètres optiques
Tungsten ribbon lamps for calibration of optical pyrometers

49 — Compteurs d'eau (destinés au mesurage de l'eau froide)
Water meters (intended for the metering of cold water)

50 — Instruments de pesage totalisateurs continus à fonctionnement automatique
Continuous totalising automatic weighing machines

51 — Trieuses pondérales de contrôle et trieuses pondérales de classement
Checkweighing and weight grading machines

52 — Poids hexagonaux. Classe de précision ordinaire de 100 g à 50 kg
Hexagonal weights. Ordinary accuracy class, from 100 g to 50 kg

53 — Caractéristiques métrologiques des éléments récepteurs élastiques utilisés pour le mesurage de la pression. Méthodes de leur détermination
Metrological characteristics of elastic sensing elements used for measurement of pressure. Determination methods

54 — Echelle de pH des solutions aqueuses
pH scale for aqueous solutions

55 — Compteurs de vitesse, compteurs mécaniques de distances et chronotachygraphes des véhicules automobiles - Réglementation métrologique
Speedometers, mechanical odometers and chronotachographs for motor vehicles. Metrological regulations

56 — Solutions-étalons reproduisant la conductivité des électrolytes
Standard solutions reproducing the conductivity of electrolytes

57 — Ensembles de mesurage de liquides autres que l'eau équipés de compteurs de volumes. Dispositions générales
Measuring assemblies for liquids other than water fitted with volume meters. General provisions.

58 — Sonomètres
Sound level meters

59 — Humidimètres pour grains de céréales et graines oléagineuses
Moisture meters for cereal grains and oilseeds

60 — Réglementation métrologique des cellules de pesée
Metrological regulations for load cells

61 — Doseuses pondérales à fonctionnement automatique
Automatic gravimetric filling machines

62 — Caractéristiques de performance des extensomètres métalliques à résistance
Performance characteristics of metallic resistance strain gages

63 — Tables de mesure du pétrole
Petroleum measurement tables

64 — Exigences générales pour les machines d'essai des matériaux
General requirements for materials testing machines

65 — Exigences pour les machines d'essai des matériaux en traction et en compression
Requirements for machines for tension and compression testing of materials

66 — Instruments mesureurs de longueurs
Length measuring instruments

67 — Ensembles de mesurage de liquides autres que l'eau équipés de compteurs de volumes. Contrôles métrologiques
Measuring assemblies for liquids other than water fitted with volume meters. Metrological controls

68 — Méthode d'étalonnage des cellules de conductivité
Calibration method for conductivity cells

69 — Viscosimètres à capillaire, en verre, pour la mesure de la viscosité cinématique
Glass capillary viscometers for the measurement of kinematic viscosity.

70 — Détermination des erreurs de base et d'hystérésis des analyseurs de gaz
Determination of intrinsic and hysteresis errors of gas analysers

71 — Réservoirs de stockage fixes. Prescriptions générales
Fixed storage tanks. General requirements

72 — Compteurs d'eau destinés au mesurage de l'eau chaude
Hot water meters

73 — Prescriptions pour les gaz purs CO, CO_2, CH_4, H_2, O_2, N_2 et Ar destinés à la préparation des mélanges de gaz de référence
Requirements concerning pure gases CO, CO_2, CH_4, H_2, O_2, N_2 and Ar intended for the preparation of reference gas mixtures

74 — Instruments de pesage électroniques (*)
Electronic weighing instruments (*)

75 — Compteurs d'énergie thermique (*)
Heat meters (*)

DOCUMENTS INTERNATIONAUX

INTERNATIONAL DOCUMENTS

DI N°

1 — Loi de métrologie
Law on metrology

2 — Unités de mesure légales
Legal units of measurement

3 — Qualification légale des instruments de mesurage
Legal qualification of measuring instruments

4 — Conditions d'installation et de stockage des compteurs d'eau froide
Installation and storage conditions for cold water meters

5 — Principes pour l'établissement des schémas de hiérarchie des instruments de mesure
Principles for the establishment of hierarchy schemes for measuring instruments

6 — Documentation pour les étalons et les dispositifs d'étalonnage
Documentation for measurement standards and calibration devices

7 — Evaluation des étalons de débitmétrie et des dispositifs utilisés pour l'essai des compteurs d'eau
The evaluation of flow standards and facilities used for testing water meters

8 — Principes concernant le choix, la reconnaissance officielle, l'utilisation et la conservation des étalons
Principles concerning choice, official recognition, use and conservation of measurement standards

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(*) Projet à sanctionner par la Huitième Conférence Internationale de Métrologie Légale - octobre 1988
Draft to be sanctioned by the Eighth International Conference of Legal Metrology - October 1988.

9 — Principes de la surveillance métrologique
Principles of metrological supervision

10 — Conseils pour la détermination des intervalles de réétalonnage des équipements de mesure utilisés dans les laboratoires d'essais
Guidelines for the determination of recalibration intervals of measuring equipment used in testing laboratories

11 — Exigences générales pour les instruments de mesure électroniques
General requirements for electronic measuring instruments

12 — Domaines d'utilisation des instruments de mesure assujettis à la vérification
Fields of use of measuring instruments subject to verification

13 — Conseils pour les arrangements bi- ou multilatéraux de reconnaissance des : résultats d'essais - approbations de modèles - vérifications
Guidelines for bi- or multilateral arrangements on the recognition of : test results - pattern approvals - verifications

14 — Qualification du personnel en métrologie légale
Qualification of legal metrology personnel

15 — Principes du choix des caractéristiques pour l'examen des instruments de mesure usuels
Principles of selection of characteristics for the examination of measuring instruments

16 — Principes d'assurance du contrôle métrologique
Principles of assurance of metrological control

Note — Ces publications peuvent être acquises au / *These publications may be purchased from* Bureau International de Métrologie Légale, 11, rue Turgot, 75009 PARIS.

ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

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