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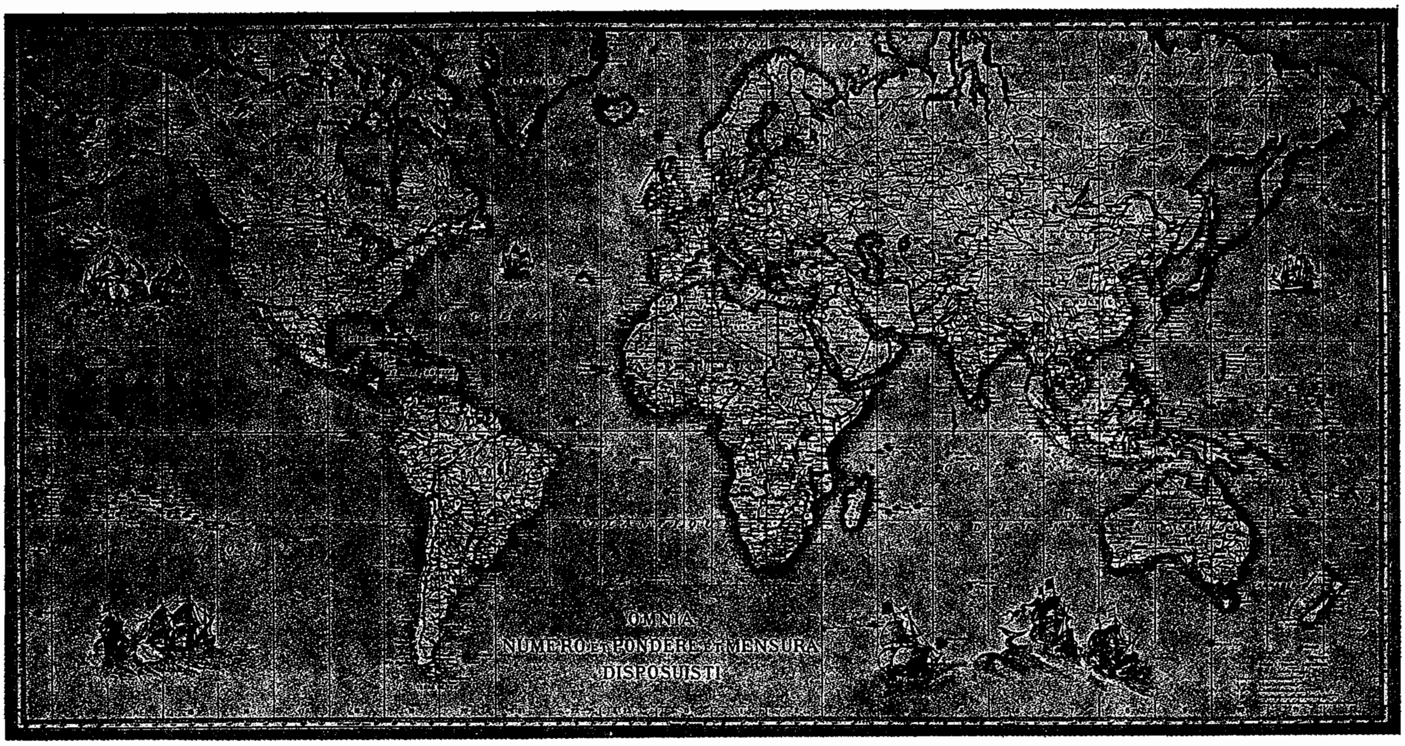
L'ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

Meilleurs voeux

Organe de Liaison entre les Etats membres



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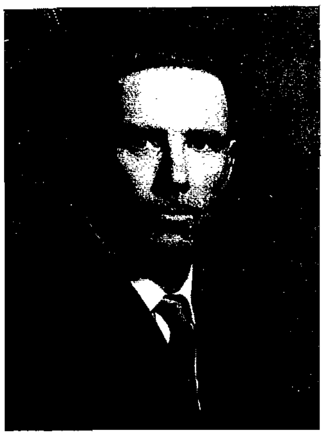
IN MEMORIAM



Ernest William ALLWRIGHT

1914-1987

Monsieur Ernest William ALLWRIGHT, ancien Adjoint au Directeur du BIML, est décédé le jeudi 10 décembre 1987.

Né le 3 avril 1914 à Londres, il entrait dans l'Administration des Poids et Mesures en 1932, tout en poursuivant ses études en vue de l'obtention d'un Certificat de Qualification d'Inspecteur des Poids et Mesures, ainsi qu'en suivant des cours à l'Ecole Technique Supérieure de Wandsworth (Londres SW).

A la déclaration de guerre il interrompit ses études et participa aux combats comme engagé volontaire. Atteignant le grade d'adjudant chef, il se consacra principalement à l'administration et à la formation des soldats sanitaires et au service des blessés.

Après trois années comme prisonnier de guerre il était libéré, puis participait au débarquement de Normandie comme agent de liaison et interprète.

Après la guerre il retrouvait le Service des Poids et Mesures et occupait à partir de 1947 le poste d'Inspecteur Divisionnaire à Gloucestershire où il était responsable de l'administration des poids et mesures (vérification et inspection des instruments), du contrôle des produits alimentaires et pharmaceutiques (contrôle de qualité, répression des fraudes) et de la poursuite des infractions devant les tribunaux ; il avait à cette époque plusieurs Inspecteurs sous ses ordres.

En 1964 il posait sa candidature d'Adjoint au Directeur du Bureau International de Métrologie Légale et, après un an de stage, était nommé dans cette fonction à partir d'octobre 1965.

Ses activités au BIML furent extrêmement importantes : participation à l'élaboration de nombreuses Recommandations Internationales, préparation du Bulletin de l'OIML, travaux administratifs divers, introduction de la langue anglaise comme langue de travail de l'OIML.

Il prenait sa retraite en juin 1978 et, avec son épouse née en France, retrouvait son pays d'origine et ses quatre enfants, tous installés en Grande-Bretagne.

REP. FED. d'ALLEMAGNE

PATTERN APPROVAL TESTING of LIQUID METERING ASSEMBLIES *

by **Dr.-Ing. Detlev MENCKE**
PTB, Braunschweig

0. Introduction

Only a small part of the great number of measuring instruments used in trade and industry are usually subject to controls by institutions of the state. In the Federal Republic of Germany, the Verification Act regulates the scope of the controls and the competences of the authorities. According to this Act, the Physikalisch-Technische Bundesanstalt in Braunschweig is responsible for the pattern approval (prototype approval) of measuring instruments, and the authorities of the eleven federal states are responsible for the verification of the individual measuring instruments. When types of measuring instruments have already been known for a long time, an approval by the PTB is not required. In this case, the local authorities take the responsibility for the quality of the measuring instruments if an instrument of a new series is tested.

When a flowing liquid quantity is measured, not only the measuring instrument used is of importance, but also its installation in the measuring assembly and its correct use. That is why the following International Recommendations are applicable to the field of work of OIML Pilot Secretariat 5 D « Dynamic measurement of volume of liquids » :

No. 5 Meters for liquids other than water with measuring chambers.

No. 27 Volume meters for liquids (other than water) - Ancillary equipment.

No. 57 Measuring assemblies for liquids other than water fitted with volume meters.

In the last-mentioned OIML Recommendation, the measuring assembly is defined as follows : « Ensemble which comprises, in addition to the meter itself and any ancillary equipment which may be associated with it, all the devices required to ensure correct measurement or intended to facilitate the measuring operations, as well as any other equipment which could in any way affect the measurement ».

The diagram of Fig. 1 shows the devices of the measuring assembly mentioned in the definition. Basically, the diagram is applicable to all types of measuring assemblies ; in some types, certain devices may be missing or their order may have been changed. The devices of the measuring assembly can be arranged in the following groups of devices :

1. Auxiliary devices ;
2. Devices to ensure uniform liquid flow (filter, gas elimination device, flow straightening device) ;
3. Devices of the volume meter (measuring device, indicating device) ;

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

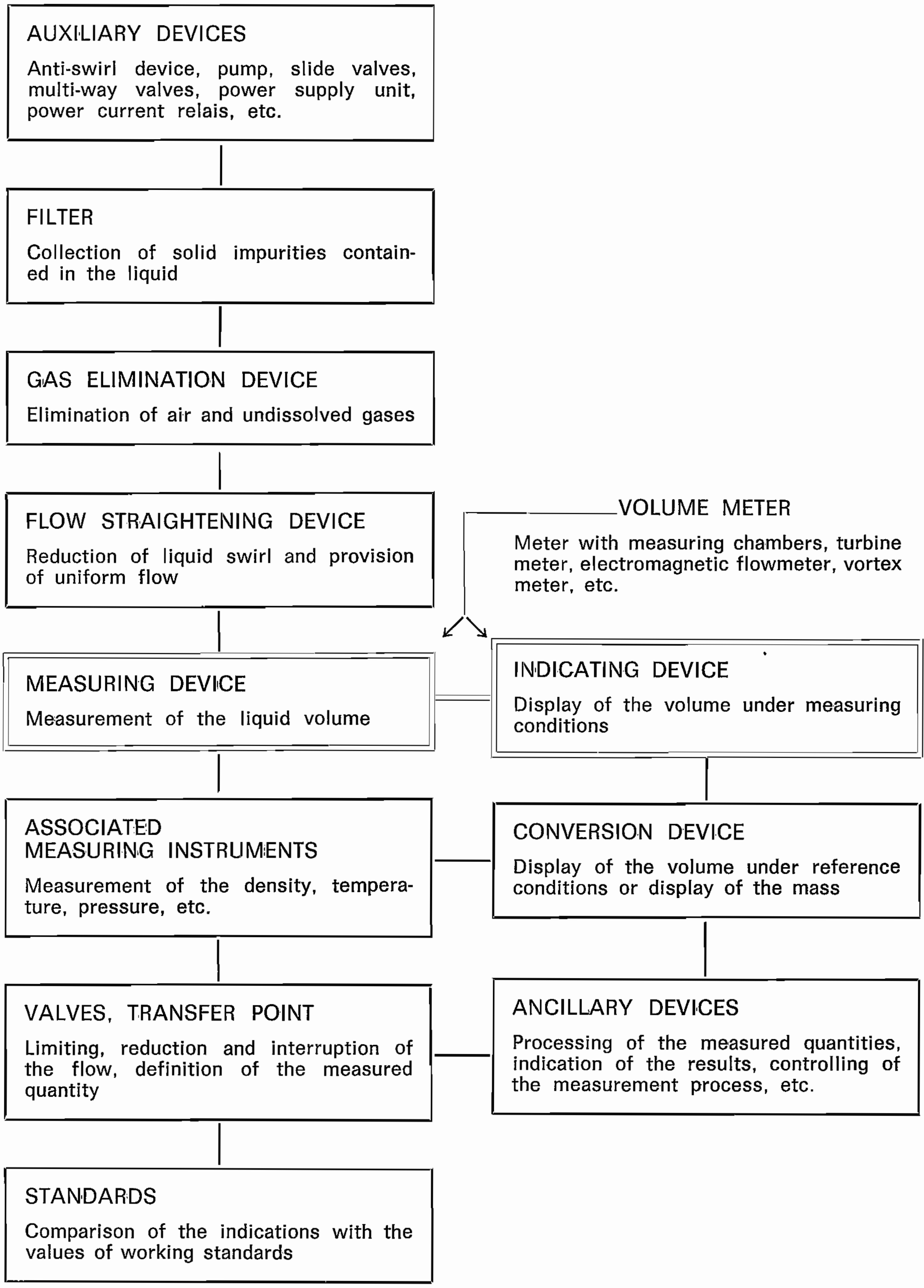


Fig. 1

MEASURING ASSEMBLY FOR LIQUIDS OTHER THAN WATER

4. Ancillary devices (conversion devices with associated measuring instruments, other ancillary devices) ;
5. Devices for limiting the liquid quantity ;
6. Standards.

This diagram serves as a basis for the following remarks on how the tests of the individual devices of the measuring assembly are carried out at the Physikalisch-Technische Bundesanstalt or by the competent authorities of the German federal states.

1. Auxiliary devices

The auxiliary devices stated in the diagram, i.e. anti-swirl device, pump, slide valves, multi-way valves, power supply unit and power current relays are only in rare cases submitted to a special test when the pattern of the measuring assembly is approved. If the instrument comprises electronic components, only the power supply unit is tested within the scope of the test of these components.

2. Devices to ensure uniform liquid flow

In order to make a perfect measurement of the liquid quantity possible, a uniform single-phase flow before the meter must be guaranteed. For this purpose, the following devices are required :

2.1 Filter

The filter serves to collect solid impurities contained in the liquid. Although its installation, if required, has been explicitly prescribed by the OIML Recommendation No. 57, as far as we know, its function has never been especially examined within the scope of the pattern evaluation.

2.2 Gas elimination device

The gas elimination device is used to eliminate air and undissolved gases from the liquid. In the OIML Recommendations for « Measuring assemblies for liquids other than water - General provisions » (No. 57) and « Provisions specific to particular assemblies » (draft), the following devices are specified as gas elimination devices : gas separator, gas extractor, special gas extractor and condenser tray.

The complex subject of gas elimination can be touched upon here only briefly. That is why only a few selected results of the extensive investigations so far carried out in the Federal Republic of Germany with regard to the efficiency of these devices will be referred to here. Fig. 2 shows a modern road-tanker filling station (truck terminal) with 2 measuring systems as it is commonly used in Germany. In the system in front, the big gas separator can clearly be seen ; it is so dimensioned that it towers above all other devices of the measuring assembly. The filter can be seen on the right-hand side of the gas separator and the measuring device of the volume meter on its left-hand side. The size of the gas separator follows from the requirement that its effective volume must correspond to at least 8 % of the volume delivered in one minute at maximum permissible flowrate of the measuring assembly. This numerical value of 8 %, in conjunction with the constructional solution that the distance between inlet and outlet tube shall amount to approximately twice the diameter and that the height of the gas volume above the inlet tube shall be almost equal to the diameter, has been determined in tests carried out in cooperation with industry in the years between 1964 and 1970.

For more than 50 years, special gas extractors have been used as gas elimination devices for road-tanker filling stations. In 1963, a special test rig for the testing

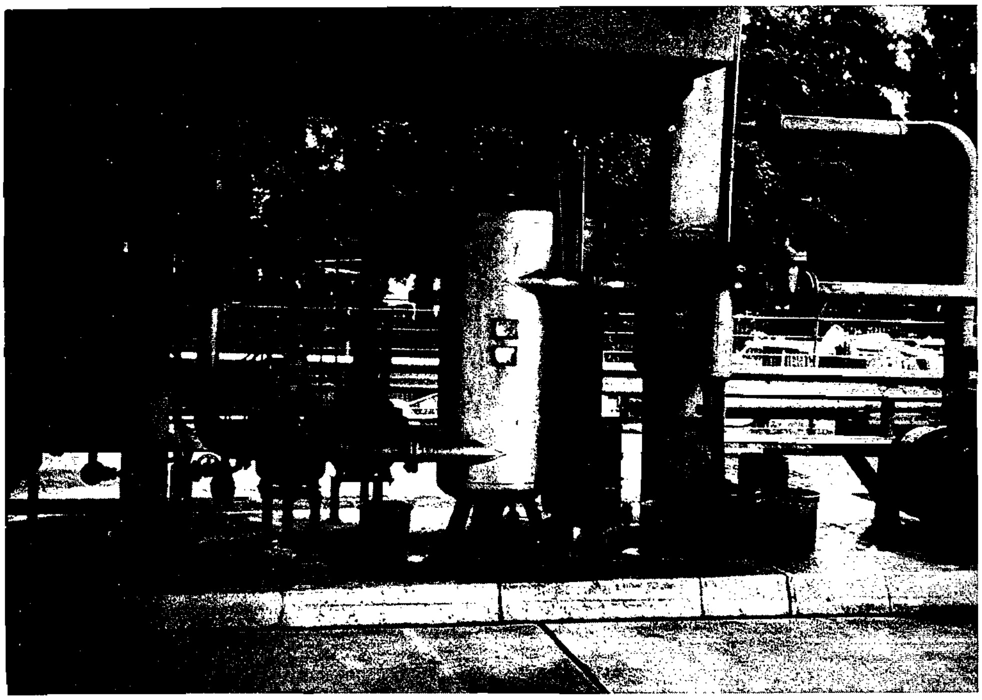


Fig. 2 — Road tanker filling station

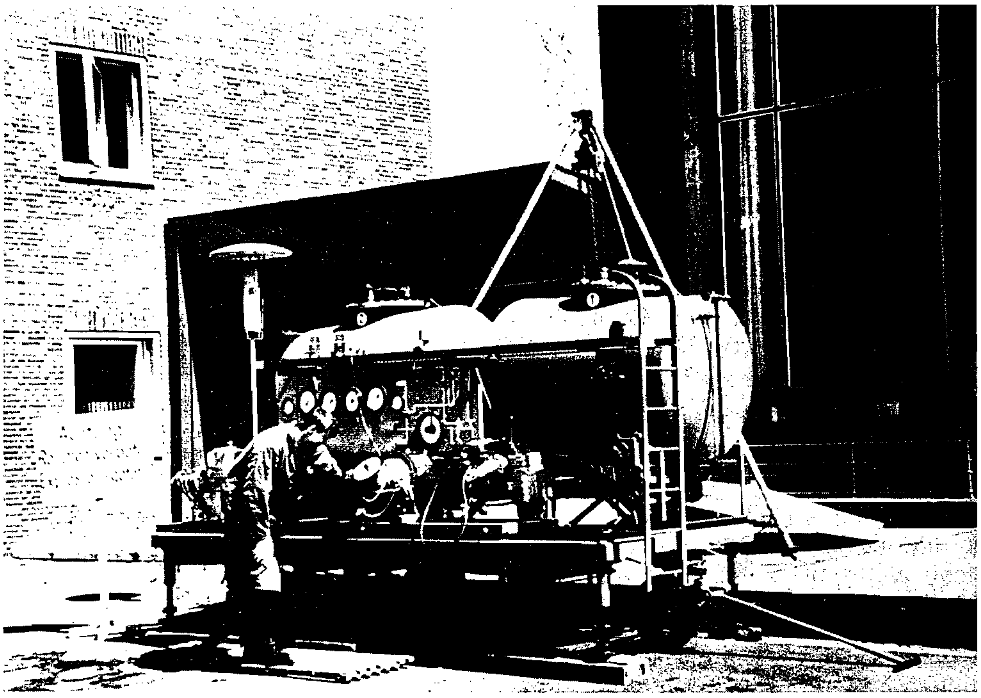


Fig. 3 — Test rig for gas extractors

of these devices was developed and constructed in the Physikalisch-Technische Bundesanstalt ; it is shown in Fig. 3. The design of the test rig is in accordance with scheme 5 of the OIML Recommendation No. 57. At the top of the figure, two storage tanks can be seen, below them are the measuring instruments for gas pressure and gas volume ; on the left you see the special gas extractor to be tested and on the right the volume meter whose error curve is known. In the cellar below the test rig, which cannot be seen in the figure, a 1 000 L volumetric standard is located. A predetermined quantity of air or nitrogen is mixed into the liquid in the pipeline upstream of the device to be tested. The difference of the errors of the volume meter without and with gas addition is determined and plotted in a diagram against the amount of added gas. Fig. 4 shows such a diagram for special gas extractors with a maximum permissible flowrate of 1 000 L/min. The figures above the curves indicate the year of pattern approval. It can clearly be seen how the separation capacity has been improved in the course of the years by suitable constructional measures.

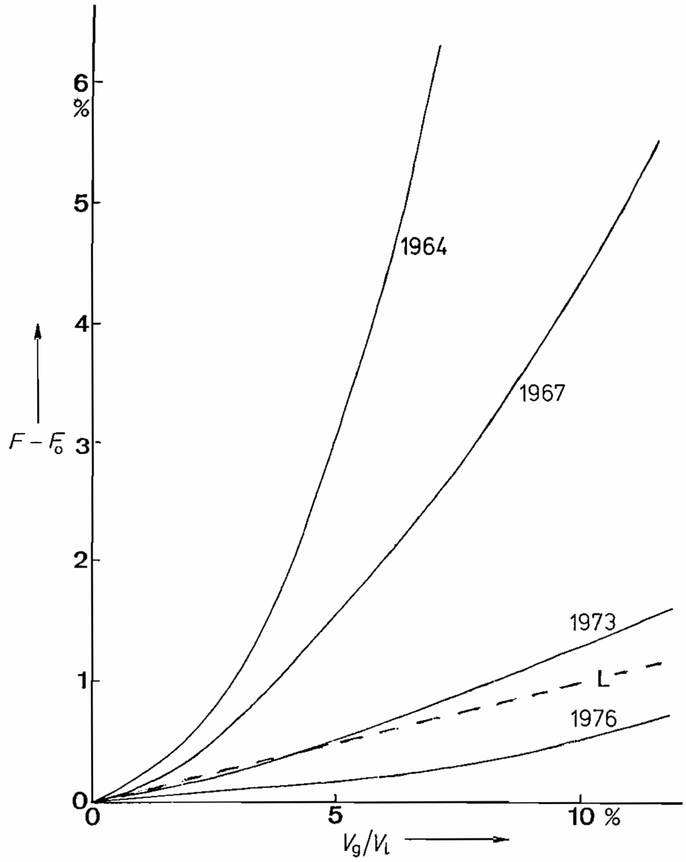


Fig. 4 — Tests of special gas extractors

$F-F_o$ = difference of errors with and without gas addition
V_g/V_l = gas to liquid volume ratio
L = error limit (OIML RI 57)

The error limit curve in compliance with the requirements of OIML Recommendation No. 57, is also indicated with L in the diagram.

2.3 **Flow straightening device**

The flow straightening device serves to reduce liquid swirl and to provide uniform flow ; it is required for all liquid meters with the exception of meters fitted with measuring chambers. As in the case of the gas elimination devices, extensive individual investigations have been carried out with respect to the effects which disturbances of the flow profile have on the error curve of a volume meter. The investigations are, however, in most cases limited to specific disturbances and special meter types. In order to collect, coordinate and theoretically evaluate the experience gained, the Community Bureau of Reference within the Commission of the European Communities arranged a meeting of experts from European institutes. It is the objective of the proposed cooperation to produce defined disturbances of the flow profile, which are recognized by all participants, to determine the profile with the aid of laser Doppler anemometers and to agree upon a common concept for a theoretical model of the profile. The effects of these defined disturbances of the flow profile on the behaviour of several meter types will then be investigated theoretically and in practice for the field of legal metrology.

3. **Devices of the volume meter**

The OIML Recommendation No. 5 « Meters for liquids other than water with measuring chambers » includes the important sentence :

The expression « meter » means an instrument composed only of a « measuring device » and of an « indicating device ».

At the meeting of the OIML working groups of SP 5D-Sr 1, Sr 8 and Sr 9 in Paris at the end of November 1986, it was decided that this definition should also be applicable to other liquid meter types. Consequently, the volume meter for liquids comprises the volume measuring device, the correction device and the indicating device for the volume under measuring conditions.

3.1 **Volume measuring device**

In the volume measuring device of the volume meter, the partial volumes ΔV are either converted into angles of rotation α or electrical or pneumatic pulses i, or the flowrate $\dot{V}$ is converted into a differential pressure Δp an electric voltage U or a current I.

From among the great number of possibilities of influencing the measuring process, only 3 examples will be cited.

On the occasion of the pattern approval of a modern piston meter, the same device could be tested with several petroleum products and with liquefied petroleum gas (LPG). Fig. 5 shows the error curves which resulted from these tests. For crystal oil, the test medium with the highest viscosity which almost corresponds to that of diesel oil, a straight error curve was determined in the flowrate range between 1 and 40 L/min. In the case of petrol (gasoline), a straight error curve was found in the flowrate range between 3 and 75 L/min. ; it lay by about 0.02 % below the error curve of crystal oil. The shape of the error curve of LPG which contained propane as greatest volume fraction, is remarkable. Here the highest point of the curve is by about 0.02 % lower than the error curve of petrol ; however, the curve strongly descends and is again horizontal in the range between 16 and 35 L/min. ; it lies, however, by about 0.74 % below the error curve of petrol.

The shape of the LPG curve can be explained by the behaviour of the main flow in the cylinder and the by-pass flow in the control valve. In the error curves for crystal oil and petrol as well as at the highest point of the LPG curve, both flows are laminar. In the lower part of the LPG curve, both flows are turbulent, in the part of the LPG curve descending to the right, the main flow is laminar and the by-pass flow is turbulent.

Within the framework of the pattern approval of a piston meter with mechanical register and price computer, the influence of the torque on the error curve of the meter was investigated at higher unit prices. The error curves are shown in Fig. 6.

In the case of the upper curve E, the mechanical register was replaced by a pulse generator (practically no torque) and an electric register. For the second curve 0, the unit price of the mechanical price computer was set to 0.000 DM/L and for curves 1, 2 and 3 to 1.999 DM/L, 2.999 DM/L and 3.999 DM/L respectively.

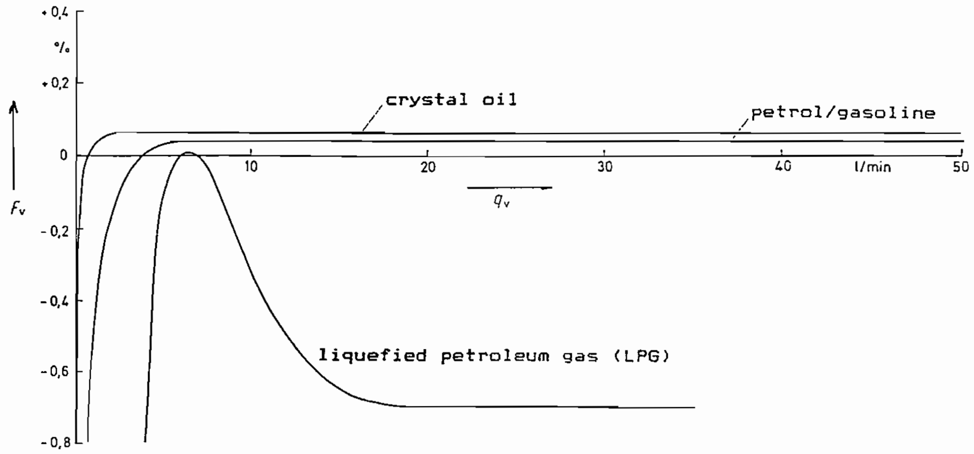
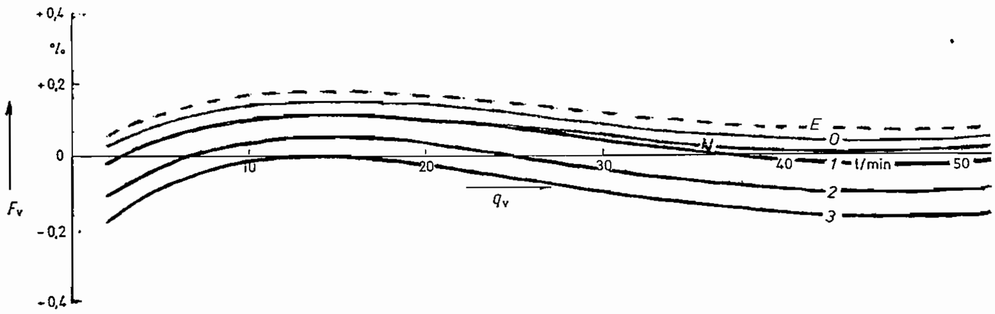


Fig. 5 — Error curves for a modern piston meter



E = Electronic computer
O = 0,000 DM/litre
N = 1,990 DM/litre
1 = 1,999 DM/litre
2 = 2,999 DM/litre
3 = 3,999 DM/litre

Fig. 6 — Influence of the torque of the register and price computer on the error curve of a meter

Upon closer examination of these error curves - the deviation between curve E and curve 3 amounts to approximately 0.25 % - the question arises of why the error curves are displaced parallel to one another and why they do not have the shape of a bell mouth as in the case of the dependence upon the medium. The behaviour can be explained by the fact that the torque exerted by the mechanical price computer depends upon the speed of the volume measuring device. Here the most important strain is exerted by the jerky stepping of the second drum (seen from the right) and the other drums of the price indicator. Curve N is also worth mentioning : here, the last decade of the unit price was set to zero instead of nine, i.e. the unit price was 1.990 DM/L. The difference between curves N and 1 results from the fact that the gear axles for the fractions of the monetary unit must rotate 10 times, 100 times and 1 000 times faster than the shaft of the volume measuring device.

The mechanical construction of the pulse generator used is a problem which must be taken into account when an electric indicating device is connected to the volume measuring device of a meter fitted with measuring chambers. Fig. 7 shows the diagram of pulse sequences determined some time ago on the PTB's test rig. The pulse generator used at that time was not equipped with an anti-backlash clutch. By swinging of the built-in magnetic clutch between wet and dry room, a swinging of the pulser disk of the pulse generator could also be brougth about during the tests. Consequently, the disk rotated backwards for a short time at the time of pulses 6 and 7 so that an additional pulse was generated in the upper channel compared with the lower channel. Further investigations led to the requirements specified by the Physikalisch-Technische Bundesanstalt, which prescribe the installation of anti-backlash clutches in liquid meters in order to prevent swinging, and the provision of the two-channel generation and transmission of the pulses.

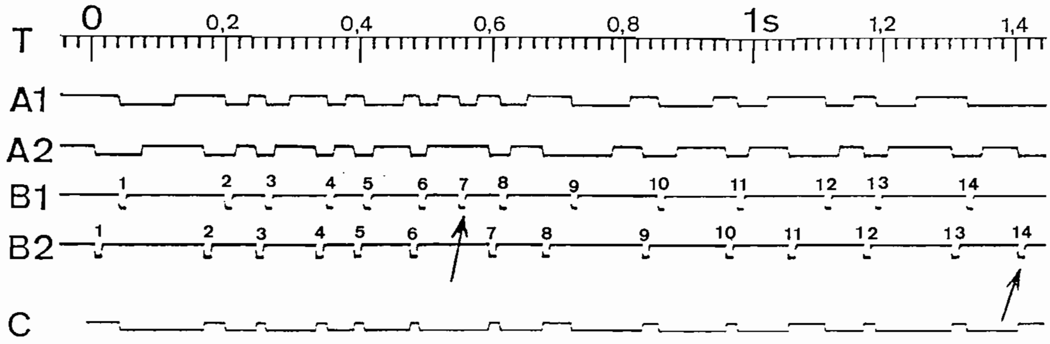


Fig. 7 — Recording of pulses from the two channels (B1 and B2) of a mechanical pulse generator not equipped with anti-backlash clutch.

3.2 **Indicating device**

The signals emitted by the volume measuring device are converted in the indicating device of the volume meter, and the volume under measuring conditions is indicated as measurement result. The indicating device often comprises the correction device for the displacement and - if required - fitting of the error curves.

Nothing must be said here with regard to the mechanical indicating devices ; their construction features have been known for years and they are only seldom subject to changes.

In 1970, the Physikalisch-Technische Bundesanstalt granted the first pattern approval for a turbine meter equipped with an electric indicator instead of a mechanical indicator ; the first pattern approval for a piston meter with electric register and price computer in a fuel dispenser was granted in 1972. For these approvals, the principle of operational fault security was applied to the electronic devices, which since 1963 had been successfully used for electronic remote indicators. In addition to the already mentioned two-channel pulse transmission, the principle provided, and still provides today, the use of checking facilities and redundant codes.

With the approval of the first microprocessor-controlled indicator in 1977, the principle of operational fault security has also been applied to the programming of microprocessors.

In addition to the determination of the error curve, the following tests are carried out for the pattern approval of a meter with electronic register : First, the documents submitted by the applicant for the hardware and software of the electronic devices are checked with regard to the requirements for the pattern which result from the principle of operational fault security for the type of device in question. Many requirements which are known by the applicant or correspond to the state of the art have normally already been met before the application is filed. Secondly, extensive performance tests are carried out with the pattern made available by the applicant. Thirdly, for about two years, part of the electrical tests and, if required, climatic and

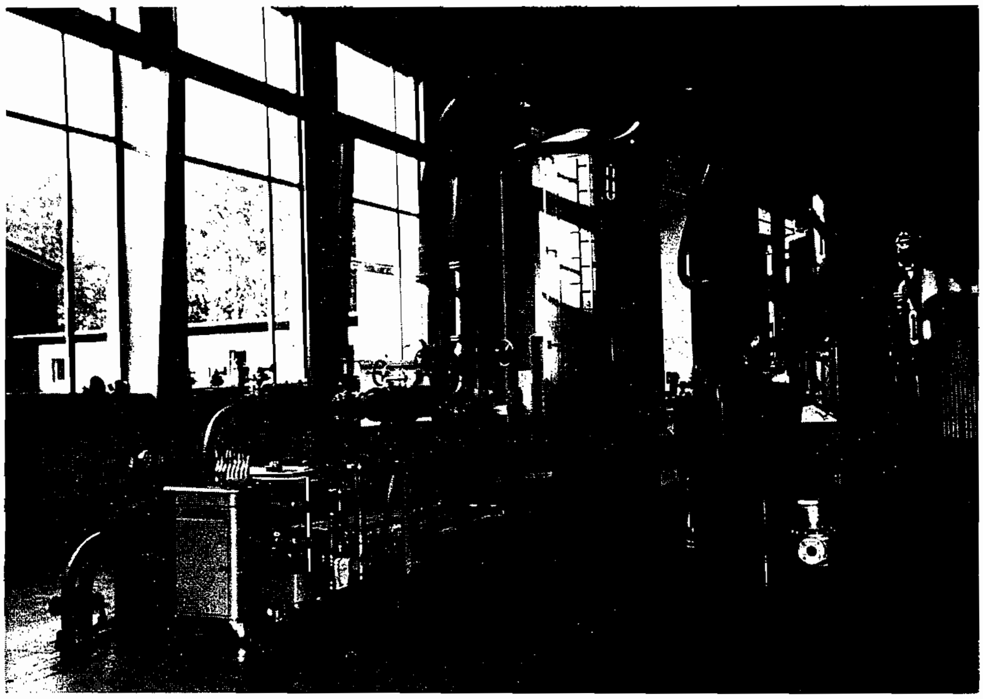


Fig. 8 — Hydrocarbon meter test rig

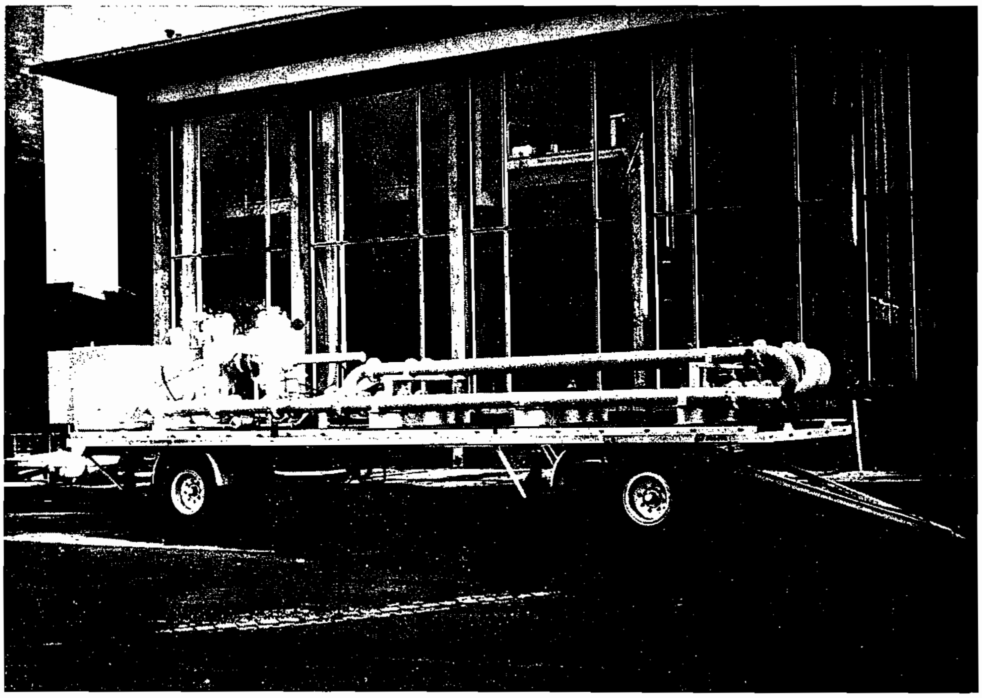


Fig. 9 — Mobile bi-directional prover

mechanical tests as specified in the Annex of OIML Document No. 11 « General requirements for electronic measuring instruments », are carried out with the pattern. In some cases, further tests are carried out with devices in practical operation under the supervision of employees of the PTB.

4. Ancillary devices

The ancillary devices of liquid meters can be divided into three groups :

a) Ancillary devices for forming other measured or calculated values (examples : volume corrector, price computer) ;

b) Ancillary devices for the additional indication of the measured and calculated values (examples : remote indicator, printer) ;

c) Ancillary devices for facilitating or controlling the measuring process (examples : zeroising mechanism, volume preset).

4.1 Conversion device with associated measuring instruments

From the metrological point of view, conversion devices are the most important ancillary devices of a liquid meter. The volume under reference conditions or the mass of the liquid is calculated and indicated by the electronic converter with the aid of the measuring instruments for density, temperature and pressure associated with it. The electronic converter and the electronic register are frequently combined to form a unit, the so-called flow computer. When the pattern of a conversion device is to be approved, the documents submitted by the applicant are checked with respect to the connection between the measurement values, the fail-safe design of the electronic device and the intended installation of the measuring instruments. Moreover, the same practical tests as for an electronic indicating device are carried out.

In addition to these tests executed at the Physikalisch-Technische Bundesanstalt, further tests of the complete system are required with devices in practical use. Difficulties are sometimes encountered in practical tests. It thus happens that it is only possible to take the samples of the liquid required for the temperature and density measurement by quickly pulling out the fill pipe and then collecting the residual quantity.

4.2 Other ancillary devices

The German Verification Act mentioned at the beginning is completed by a number of regulations. Important are the « Exceptions from Verification Liability Regulations ». Pursuant to these regulations, ancillary devices intended for the additional indication of measurement values and, if applicable, of prices to pay are exempted from mandatory verification if the receipt stating these data is printed with a verified printing device. In the case of direct selling of the public, this receipt must be meant for the buyer.

This ordinance has proved its worth in practical application. On the basis of its provisions, complicated data processing equipment can be exempted from mandatory verification ; the measurement values must only be printed with a verified printer before the data are transmitted. The patterns of the printers must have been approved by the Physikalisch-Technische Bundesanstalt. In retail business, the receipt printer incorporated in the cash register often takes over this function. That is why ten patterns of cash registers have been tested and approved since 1978. In addition to the tests of the electronic devices which have already been referred to above, details concerning the type face of the printed values were also defined. A characteristic feature is the use on the printed receipts of the special character* (asterisk) in order to mark the tested data. On the back of the receipt, the customer finds the following note concerning the meaning of the special character : « For special marking, data from verified components of the facility are enclosed in asterisks ».

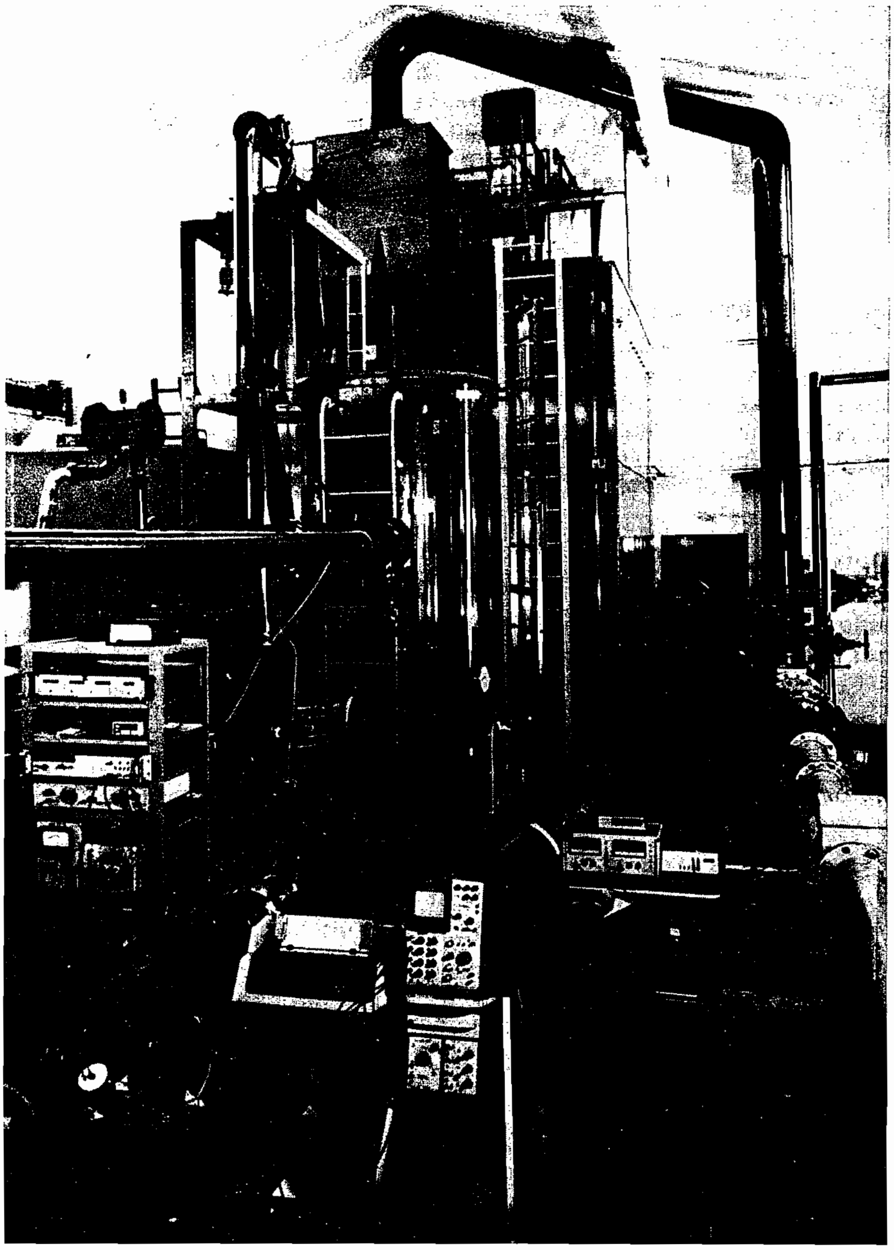


Fig. 10 — Water meter test rig

It should also be mentioned here that two types of interfaces have been developed by the Physikalisch-Technische Bundesanstalt in cooperation with several manufacturers from home and abroad. These interfaces are meanwhile being used by many manufacturers in the field of liquid measurement. The first type is a special design of type RS-232 C (V.24) ; it serves to connect cash registers with remote indicators. The second type corresponds to specification RS-422 (V.11), it is used for master-slave connections.

There are a great number of ancillary devices which serve to facilitate or control the measuring process. I will, however, mention only the accepting devices for bank notes and credit cards incorporated in fuel dispensers. In the last few years, several patterns of devices of this kind have been approved. During pattern evaluation, the incorporated acceptors for bank notes and coins on the one hand and for credit cards and keys on the other hand, were not tested with regard to their security, reliability and correct function. Only the correct joint functioning of all components was tested.

5. Devices for limiting the liquid quantity

When the pattern of a measuring assembly is approved, the valves and the transfer point are seldom submitted to a special test. Only if a two-step valve or a flow reduction valve is installed is it checked if the flow in the reduction state is greater than the minimum permissible flowrate of the volume meter.

6. Standards

In conclusion, the standards of the Physikalisch-Technische Bundesanstalt which are used for pattern evaluation will be shown. Fig. 8 shows the oil meter test rig. On this test rig, meters with nominal diameters of up to 80 mm can be tested with white spirit, kerosene or crystal oil ; meters with nominal diameters of up to 150 mm can be tested with white spirit. The standards have volumes of 100 L, 150/200 L, 500/1 000 L and 2 000/5 000 L and are affected by an uncertainty of measurement of $5 \cdot 10^{-4}$. A balance with a capacity of up to 1 500 kg and affected by a measurement uncertainty of 0.02 kg ($2 \cdot 10^{-5}$ for 1 000 kg) is available for mass meters.

Fig. 9 shows the mobile bidirectional prover loop. It is designed for a maximum pressure of 25 bar and a flowrate range of 20 to 3 600 L/min. Its nominal volume amounts to 2 001,4 L with an uncertainty of measurement of $1 \cdot 10^{-4}$.

Fig. 10 shows the test rig for water meters. With this facility, meters with nominal diameters of up to 400 mm and a flow rate of 30 m^3/min can be tested with cold water. The standards have volumes of 50 L, 100 L, 200 L, 500 L, 1 000/2 000 L, and 5/15/30 m^3 with an uncertainty of measurement of $1 \cdot 10^{-3}$.

ETATS-UNIS d'AMERIQUE

DIRECT MASS FLOW MEASUREMENT
A METROLOGICAL PERSPECTIVE *

by **Brian HOOVER,** Product Market Manager
Micro Motion, Inc., Boulder, Colorado U.S.A.

Introduction

Fluid flow meters have been used extensively for operational and custody transfer measurements. This paper focuses on Coriolis effect direct mass flow measurement devices used in custody transfer applications.

High levels of accuracy and reliability are necessary in custody transfer applications since monetary value is directly associated with the fluid's measured quantity. Historically, positive displacement and turbine meters have been used for custody transfer measurements. These meters measure the volume of fluids very accurately. A major disadvantage of volumetric measurement is the fact that actual volume varies with changes in fluid temperature and pressure.

Variations in fluid volume are directly related to changing fluid densities. Fluid density is dependent on its temperature and pressure. The density of liquids decreases with increasing temperature. Density also increases with increasing pressure but the effects are less severe than those that occur with changing temperature. The effects of changes in fluid properties is a function of the specific fluid (see Figure 1).

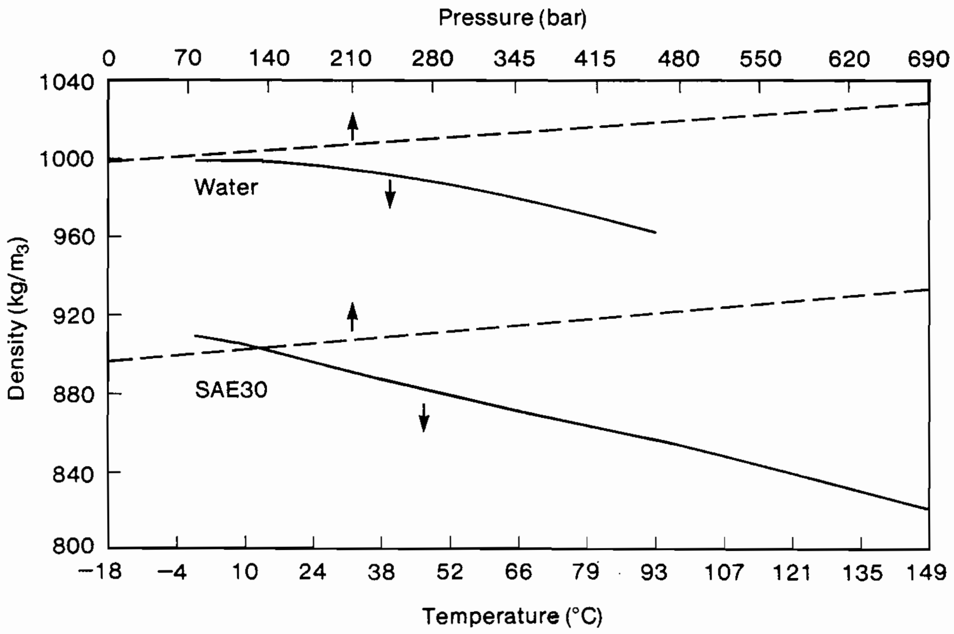


Fig. 1 — Effect of temperature and pressure on the density of fluids

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

Figure 2 depicts the effects that changing temperatures can have on the volume of gasoline.

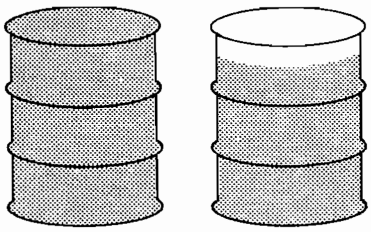

Figure 2

Environmental Effects on Volume

Within a flow system, mass flow remains constant while volumetric flow and fluid density can vary throughout the system. The effects of changing fluid properties are minimized by computing the net volume. This is accomplished by measuring gross volume and applying temperature and pressure compensation factors. Temperature and pressure compensation factors are typically complex functions that require look-up tables or flow computers. If the measured fluid is not widely studied and characterized, the buyers and sellers of fluid products must agree on the correction factors utilized. While this works reasonably well for internal accounting, it is not a good practice in legal custody transfer.

Mass Measurement Technologies

In an effort to minimize the economic imbalance that can occur when fluid transactions are made in units of volume, a trend is emerging where these transfers are more frequently made in units of mass. Mass measurement technologies used include inferred mass systems and direct mass flow measurement technologies.

Inferred Mass Systems

Inferred mass systems use volumetric flow meters, typically positive displacement or turbine type meters, high accuracy vibrating densitometers, and flow computers. Alternatively, fluid density is corrected to standard conditions using temperature and pressure correction factors published by API, ASTM, and other organizations. Standard density and volume information is used to calculate mass units using a flow computer.

The overall accuracy of the system degrades as the number of system components increases. The system error can be calculated using the « square root of the sum of the squares » method. For example, a high accuracy positive displacement meter may have an accuracy of ± 0.2 % of the represented quantity, a precision densitometer may have an accuracy of ± 0.15 %, and a flow computer may have an accuracy of ± 0.1 %. The system error is calculated using the square root of the sum of the squares to be ± 0.27 %.

Each component of the system is typically proven independently. A volumetric prover is used on the flow meter, the densitometer is proven with a pycnometer, and the temperature probe is proven with a temperature standard. Proving these individual components is often costly and time consuming.

Direct Mass Measurement

A number of meters have been developed that measure mass directly. These include thermal, impeller-type angular momentum, and Coriolis effect mass flow meters. To date, the Coriolis effect mass flow meter is the only type of direct mass flow meter technology to be used extensively in custody transfer applications. High accuracy and low maintenance are the primary reasons that the Coriolis effect direct mass flow meter technology has been applied successfully.

Evolution of the Coriolis Effect Mass Flow Meter

In 1835, at the Ecole Polytechnique in Paris, Gaspard Gustave de Coriolis quantified the natural phenomenon that caused objects moving freely over the surface of the earth to appear to curve. This effect was later termed the « Coriolis » effect. The Coriolis effect, coupled with Newton's second law (Force = Mass × Acceleration), would ultimately lay the foundation for developing a true direct mass flow meter.

Early Patents

In the early 1950's, U.S. patents began to be published for gyroscopic mass flow meters. Figure 3 shows a « Flowmeter » patented in 1953 by John Pearson for Sun Oil Company.

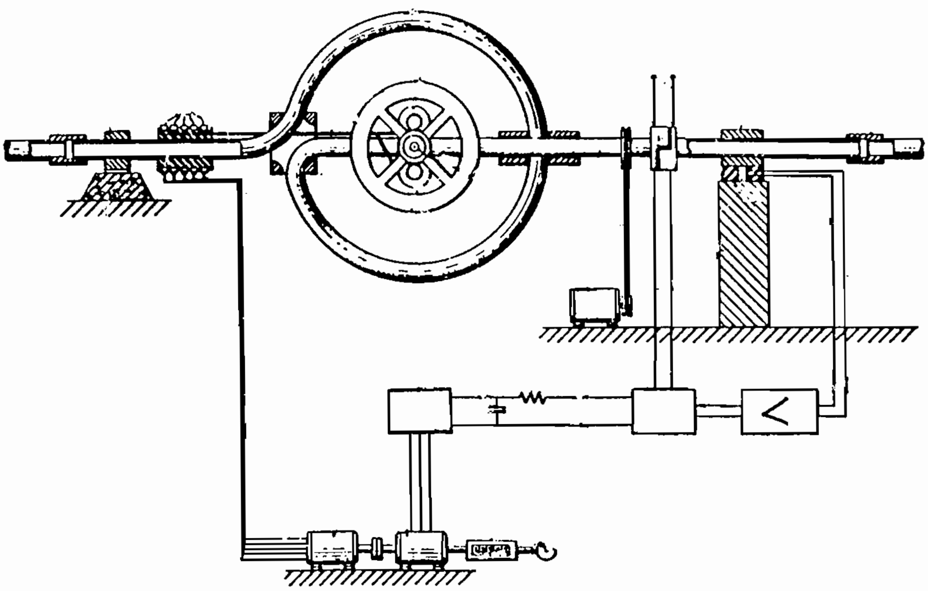

Figure 3

William Jones and George Chernlak patented their « Gyroscopic Flowmeter » in 1958. This flow meter is illustrated in Figure 4.

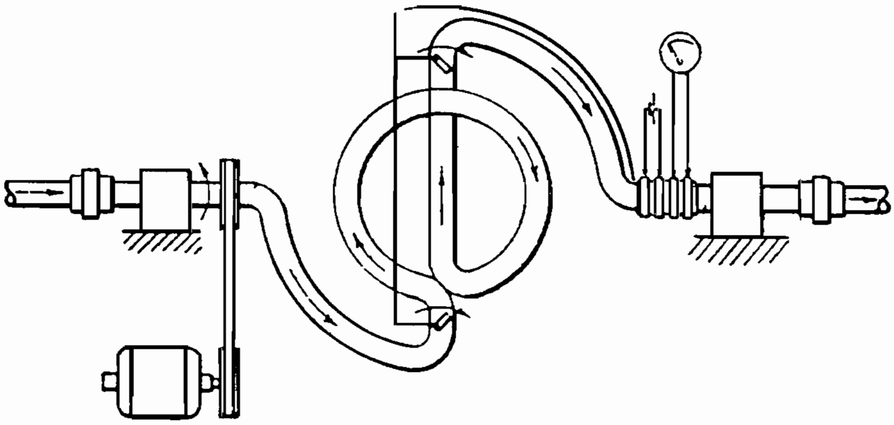

Figure 4

In 1958 and 1964, Wilfred Roth also patented the « Gyroscopic Mass Flowmeters » shown in Figure 5. The flow meters invented by Pearson and Jones used a continuously rotating curved member. The design patented by Roth used an oscillating curved member. All used flexible couplings or bellows.

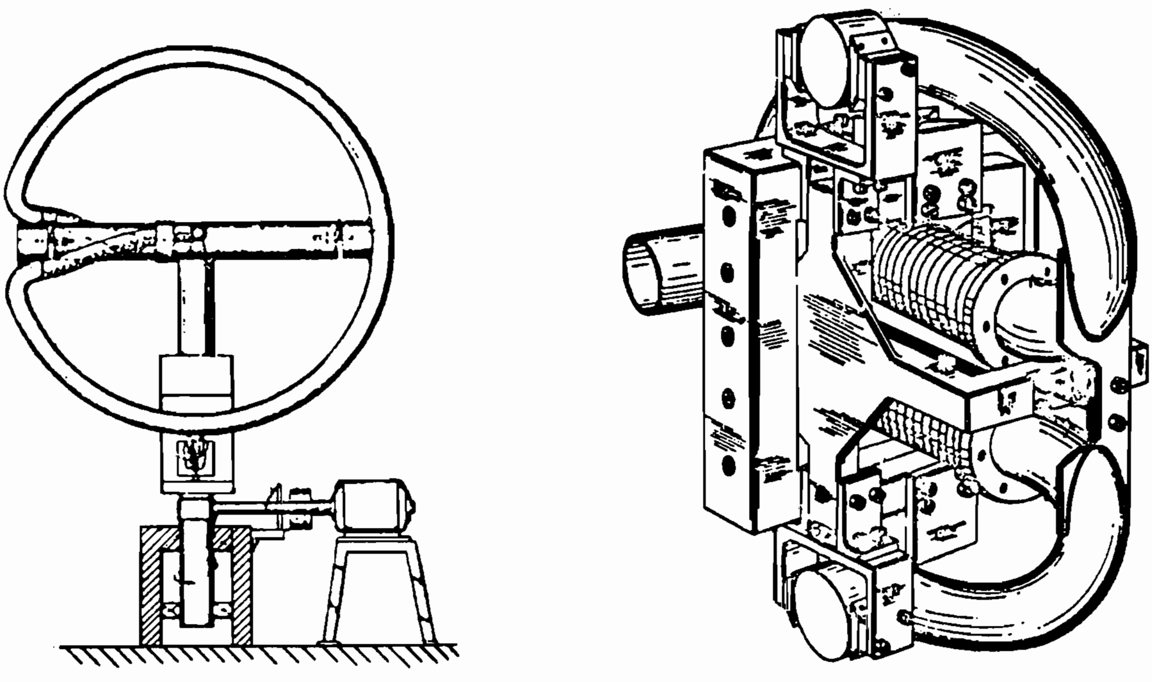

Figure 5

Research continued in the area of using the Coriolis effect to measure mass flow. The most notable reaseach was conducted by inventors Wilfred Roth, Anatole Sipin, and James Smith. All three inventors used the oscillating drive technique.

However, a practical and accurate design remained elusive until July 20, 1978. On this date, James Smith filed a patent application entitled « Method and Structure for Flow Measurement ». This flow meter overcame most of the problems encountered by the other patented designs. Most notably, the Smith flow meter used a cantilevered beam-like mounting of a « U » shaped conduit. His configuration minimized the distortion resulting from the influence of the two non-measured forces of velocity drag and acceleration of mass. Mounting the conduit in a beam like fashion also eliminated the need for bellows or highly flexible conduit.

James Smith continued his research and filed additional patents resulting in the introduction of the first mass flow meter for use within process control environments. These meters were manufactured by Micro Motion, Inc., Boulder, Colorado, U.S.A. and were the first direct mass flow meters that could be manufactured successfully.

Applications in Process Control

The direct mass flow meter instantly became successful in the process control industry since its mass measurement capability was ideal for ensuring successful chemical reactions. The non-intrusive design enabled the Coriolis type meter to be placed in service on applications which could historically not be metered (i.e. molasses, peanut butter, liquid slurries). The needs of the process control user resulted in an evolution of Coriolis effect technology.

Design Evolution

The initial Coriolis meter manufactured was the Micro Motion Model B Mass Flow Meter. This design used optical sensor technology, a single flow tube, and a center tine with a natural frequency close to the « U » shaped flow tube. The optical sensors limited the applications of the B meter to non-hazardous environments. The center tine had a weight that could be adjusted to accommodate various density ranges.

As the Coriolis mass flow meter continued to evolve, James Smith integrated numerous improvements into the Micro Motion Model C Mass Flow Meter. The C meter design used a single flow tube with an additional counterbalance tube and weights. Magnetic velocity sensors replaced the optical sensors allowing the C meter to be placed in hazardous environments. The patented magnetic velocity sensors consisted of a magnet affixed to each side of the enclosure and coils attached to the flow tube. External vibration of the case could induce error into the mass measurement signal. The counterbalance tube and weights also required adjustment for specific fluid density ranges.

James Smith continued to refine the Coriolis meter technology and introduced the Micro Motion Model D Mass Flow Meter in 1983. This design had many advantages over the previous designs. Most noticeably, the Model D sensor utilized dual flow tubes. The second tube in essence functioned as the counterbalance. Since each tube had the same resonant frequency regardless of the fluid density, it could be placed in service where wide fluid density changes might occur. The magnets were attached to one tube assembly and the coils were attached to the other. This modification increased the sensitivity of the measurement and made the measurement accuracy far less susceptible to external vibrations. The D Meter design also provided the capability to mount the sensor directly into the process line.

The dual tube design quickly gained acceptance within the process control industry. As Coriolis effect direct mass flow measurement has gained acceptance, a number of companies have introduced products that use the Coriolis effect to measure mass flow directly. Virtually all other manufacturers of Coriolis effect direct mass flow meters have also adopted the dual flow path although tube geometries differ. To date, the following companies have announced that they have or are developing Coriolis effect mass flow meters.

1) Endress + Hauser	5) EXAC
2) Krohne	6) Moorco/Smith Meter
3) Bopp and Reuther	7) Danfoss
4) K-Flow	8) Bailey Controls
5) Neptune	

Realizing the advantages available with Coriolis effect mass flow meters, Micro Motion, Inc., set out to develop a system that can be used in custody transfer applications where legal metrology enforcement is a factor. The requirements of the final product are dependent upon not only the end user, but ultimately by international weights and measures requirements. Since the products primary purpose is for making commercial measurements, high levels of accuracy and reliability have to be maintained.

The agencies that have been most instrumental in developing standards and requirements for Coriolis effect direct mass flow metering devices are the Physikalisch-Technische Bundesanstalt (PTB) in the Federal Republic of Germany and the National Bureau of Standards/Office of Weights and Measures (NBS) in the United States of America.

International Standards for Direct Mass Measurement

The PTB was the first agency to develop preliminary standards for direct mass flow measurement devices. The PTB emphasize maintaining functional integrity as well as maintaining an accurate measurement. The equipment is evaluated to determine fault detection and alarm capability, electro-magnetic compatibility, as well as its accuracy characteristics.

The tests are conducted at their facilities in Braunschweig, FRG. The primary reference is a mechanical weighing instrument that determines the mass of the product measured by the Coriolis flow meter. The indicated mass is corrected for air buoyancy so that a true mass comparison can be derived. The maximum permissible error must be maintained over a minimum of a 10:1 rate of flow ratio.

The National Conference of Weights and Measures (NCWM) in the United States first recognized direct mass measurement for liquid measuring devices used for metering agricultural chemicals and cryogenics at their annual conference in July, 1986. A proposal will be presented at the July, 1987 conference to recognize direct mass measurement devices for use in wholesale metering applications. A meter manufacturer can receive approvals from each of the 50 states or, at the manufacturer's discretion, apply to the NCWM for « National Type Evaluation ». The NCWM « Type Evaluation » certifies that a direct mass metering device satisfies the requirements of NBS Handbook 44, « Specifications, Tolerances and Other Technical Requirements for Weighing and Measuring Devices ».

Applied Maximum Permissible Errors

Initial maximum permissible errors applied by PTB for direct mass flow meters are equivalent to the maximum permissible errors applied to volumetric measurement devices. The maximum permissible errors are dependent upon fluid characteristics such as rate of flow and fluid temperature, but a typical loading rack installation requires a maximum permissible error of ± 0.5 % The PTB will be developing specific maximum permissible errors for direct mass flow meters once sufficient data and operational experience is obtained.

The first maximum permissible errors to be applied within the U.S. for direct mass flow meters were specified by the State of Florida, Bureau of Weights and Measures. Florida concluded that the direct mass flow meter measured dynamic mass much like the continuous totalizing weighing instruments (belt conveyor scales). However, the initial tests of the Coriolis effect meter indicated that the meter could measure more accurately than belt conveyor scales. Therefore, Florida specified a maximum permissible error equivalent to 1/2 that of the belt conveyor scale. The meter errors applied on the initial installation of the direct mass flow meter for truck loading was ± 0.25 % as an initial maximum permissible error and ± 0.5 % as an in-service maximum permissible error. Experience has shown the installation to be well within these parameters.

The NBS Handbook 44 currently specifies a maximum permissible error of ± 0.11 % on initial verification and an in-service maximum permissible error of ± 0.23 % using test drafts of 1 000 gallons. All maximum permissible errors are currently stated in terms of volume, but relative errors for mass equivalents can be easily calculated. The maximum permissible errors are applicable over a 5:1 flow rate. Since the relative maximum permissible error can vary considerably with the size of the test draft, the NCWM has made a new proposal. The new proposal would be stated in relative terms. The proposed maximum permissible errors are ± 0.2 % on initial verification and ± 0.3 % in-service over a 5:1 flow rate ratio.

As Coriolis effect mass flow meters become available for use in custody transfer applications, international specifications and maximum permissible errors will need to be developed for approving these devices. Manufacturers of these devices need uniform standards which can be applied worldwide. Establishing the specifications and maximum permissible errors will provide guidance to the manufacturers as they invest in the development of products designed to meet custody transfer requirements. A recent OIML survey has been distributed which asks for input from the OIML member countries concerning their positions relative to addressing the requirements of direct mass measurement devices. The information received from the member countries will assist OIML in determining its objectives regarding the recognition of these devices.

Proving Procedures

Laboratory proving is typically performed using a certified weighing instrument and a volumetric container for holding the measured liquid. Water and benzine have been used most frequently but most fluids are acceptable. The Coriolis effect mass flow meter can measure either true mass or apparent mass. The metered mass is compared to the quantity of mass indicated by the weighing instrument. The weighing instrument's indicated value can be compensated for air buoyancy if a true mass measurement is desireable.

A number of proving runs are made at the same flow rate. Different flow rates are used to determine if the meter is within the maximum permissible error over a minimum of a 5:1 flow range.

Proving the meter in the field has been accomplished by using a weighing instrument located within close proximity to the meter under test. In many cases, a weigh bridge (truck scale) is used to verify the performance of the Coriolis effect meter. A number of environmental factors must be taken into consideration prior to testing a direct mass meter with a truck scale.

Development of a Mass Prover

As Coriolis effect mass flow meters are placed in service for custody transfer, acceptable mass provers will need to be developed. Traceability to a primary reference (known weight) is only one of the criteria to be used in determining an acceptable design. The mass prover needs to be portable and must be able to be thoroughly cleaned to avoid product contamination.

Volumetric ballistic provers which use high accuracy densitometers have been used successfully by some end-users of Coriolis effect mass flow meters. As alternative proving systems are proposed, the international weights and measures community will need to work with the prover system fabricator to insure that an acceptable design is developed.

Conclusion

Coriolis effect direct mass flow meters will be used more extensively for custody transfer as the technology continues to emerge. Specifications for design and performance and proving procedures for this technology need to be developed and accepted internationally. International cooperation on the development of standards and procedures will expedite the acceptance of Coriolis effect mass flow meters and other new technologies used for custody transfer. The weights and measures community, by participating in the acceptance of new technologies with the manufacturer, will insure that products are developed which meet weights and measures operational requirements and maintain equity in the marketplace.

The accuracy of Coriolis effect direct mass flow meters can be proven to actual working standards using certified weights and a weighing instrument as a transfer standard. Alternative proving technology (i.e. ballistic provers) may also be used in certain applications. As mass meters are placed in service for the commercial transfer of liquid commodities, mass provers will be developed that are capable of providing the necessary reference for accuracy verification of the installed meters. Weights and measures regulatory agencies should actively participate with the prover fabricators to make certain that the prover complies with the weights and measures requirements.

REP. FED. d'ALLEMAGNE

DIRECT MASS FLOW METERING, in PARTICULAR by MEANS of CORIOLIS METHODS *

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SUMMARY — The principles of direct mass flow metering and their historical development are described in particular the Coriolis method with its most significant development from rotating to oscillating systems between 1952 and 1962. The various arrangements of Coriolis measuring instruments in common use today are listed and their characteristics discussed.

The paper also deals with the calibration of Coriolis systems and the influence of variations in temperature and pressure. Typical interference in practical operation such as the effect of shocks and vibrations and their suppression as well as the limits of application for several phase mixtures are discussed.

1. Introduction

The wish to measure the mass flow rate as accurately as possible has its basis, for example, in the mass relationship of the majority of chemical reactions, which may thus be controlled in relation to mass and whose components should also be recorded and accounted in relation to mass. Tried and tested indirect methods exist in numerous measuring combinations. Direct methods of measurement should be very accurate and as independent as possible of other parameters of the material to be measured, the flow profile and the process parameters. Measuring methods based on the Coriolis principle have gained in significance in recent years.

2. The Principles of Direct Mass Flow Measurement and its Historical Development

Various physical principles have been used for mass flow measurement. Typical examples are shown in the following survey, which lays no claim to being comprehensive.

2.1. The Thermal Methods

The thermal mass flow methods date back to the 1930s [1]. The principle, such as is put into practice in the « Thomas » meter, is based on maintaining a constant difference in temperature between two set points by means of adding heat and measuring the amount of energy required to compensate for the amount of heat removed by the flow to be measured. In a modern form [2], a second temperature

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

sensor which also generates heat is positioned downstream of the temperature sensor recording the temperature of the medium. The electrical power is according to King's equation :

$$P \sim \sqrt{A + B \cdot \dot{m}^{1/2}}$$

$\dot{m}$ is the mass flow ; A describes the loss of heat independent of the flow by convection, radiation and loss via mountings ; B contains, alongside the geometric dimensions, the arrangement of the material data : heat conductivity, viscosity and specific heat. The mass flow can thus be calculated from the input electrical power. These thermal methods are used in numerous variations and enable the measurement of even small flow rates e.g. of gases. They react quickly to any changes in flow and the loss of flow pressure generated by the measuring instrument is negligible. They are thus extremely widely used in the measurement of gases.

The limitations result from material data being part of the method, meaning that the system must be calibrated for the particular measuring agent used. In addition as the readings are taken at a specific point, the flow profile has a considerable influence ; the pressure of the procedure is also included in the measurement. The measured value itself is primarily non-linear, making a relatively complex conversion necessary. Essentially, this is a quasi-direct method of mass flow measurement, suited above all for measuring gas flow.

2.2. **Conservation of Momentum**

Direct mass flow measuring methods make use of the direct mass properties of a flowing measured medium, i.e. its inertia, its resistance to any alteration in its state of movement. Various approaches have been developed from this in the history of mass flow measurement. A number of examples are given in the following.

The mechanical system pipe - flowing liquid mass has a mechanical momentum. This is conserved when the flow is diverted and forces are thus generated against the diversion, here in an illustration from 1955 [3] in Figure 1, the diversion in a pipe bend mechanically separated from the remaining piping by means of flexible connections. The forces are measured as displacement of the movable upper part of the pipe bend.

In actual fact, the only thing which is direct is the change in the momentum of the system, which is directly proportional to the product of the mass and velocity of the flow, i.e. the mass flow rate. A great drawback is that all sorts of outside forces have an effect on a pipe bend of this kind (heat expansion, alterations to the pressure of the system and mechanical pipe tension) which, as there is no entirely flexible connector, cannot be entirely eliminated. Applications of this system can today be seen for example in impact plate measuring systems for bulk material.

2.3. **Conservation of the Moment of Momentum**

One method which was already widespread by the 1950s was based on the conservation of the moment of momentum in the flowing liquid. The schematic diagram in Figure 2 is taken from [3]. A turbine running at a fixed speed supplies the flow with a fixed velocity component in the circumferential direction (moment of momentum). The torque exercised by the agitated liquid column equipped with the moment of momentum is measured by means of an identically constructed fixed rotor fitted downstream. This moment of momentum is directly proportional to the mass flow.

This principle is relatively widespread, though it is restricted to very pure liquids due to the complex precise mechanical moving parts in the liquid stream. The relatively high loss of pressure also proves to be a drawback. Further disadvantages are mentioned as being the influence of the medium's viscosity and the large influence of flow instability on the measuring effect.

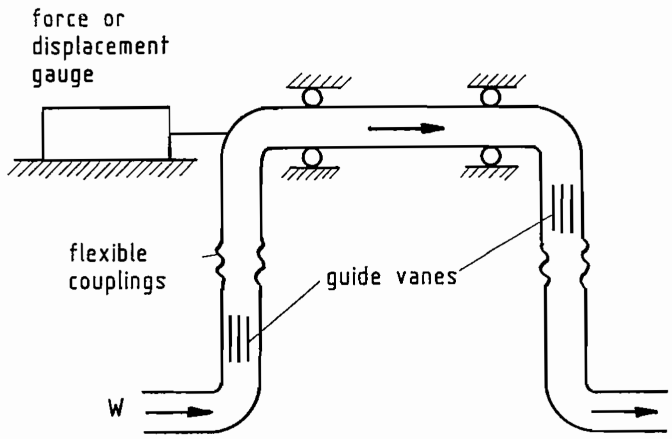

Fig. 1 — Mass flow measurement according to the rate of momentum [3]

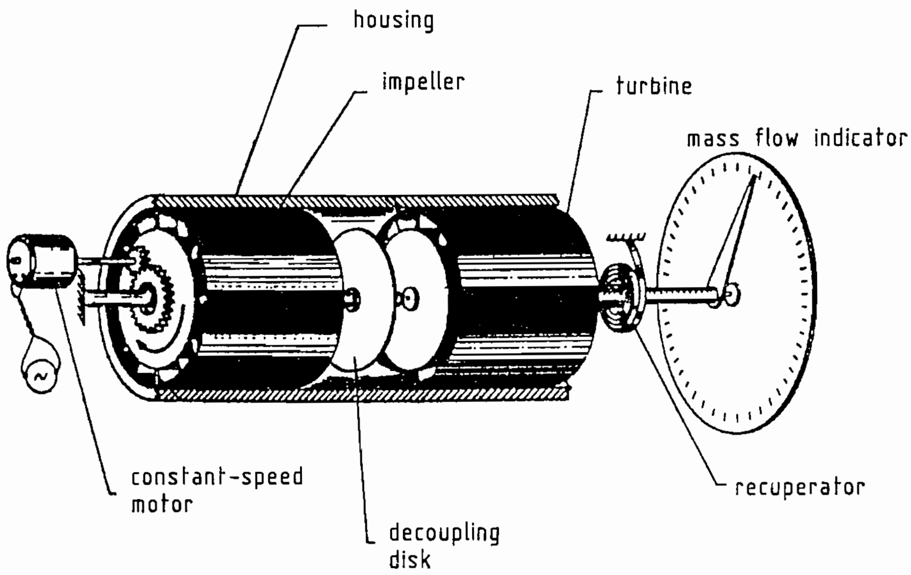

Fig. 2 — Mass flow measurement using the torque [3]

2.4. **Coriolis Methods**

The Coriolis methods first appeared in the early 1950s. As early as 1952, Li and Lee [4] pointed out that any piece of pipe containing mass flow which is rotated around an axis vertical to its longitudinal axis will receive a Coriolis acceleration vertical to the axis of the pipe, which will be strictly proportional to the mass flow rate. This is also true not only for pipes, but for any other shape of mass container which is rotated so that the inflow and outflow directions of the medium to be measured are radial, i.e. in a line vertical to and passing through the axis of rotation. Figure 3 again illustrates the action mechanism in a simple, straight piece of pipe.

If this piece of pipe is rotated around axis A at the angular velocity ω (which need not necessarily be constant), the particles of the liquid will move at zero flow rate on orbits equivalent to their temporary distance r from the axis of rotation and thus at different velocities $r \cdot \omega$. The circular movement leads to the creation of centrifugal forces which effect those particles of the mass m with the size $m \cdot r \cdot \omega^2$, driving them in the direction of the pipe axis. These are of no importance for flow measurement. If the liquid flows in the direction away from the axis A at the flow velocity v, each mass particle must be accelerated equivalent to its movement along the axis from a low to a higher orbital velocity. This increase in velocity is in opposition to the mass inertia resistance which is felt as a force opposing the pipe's direction of rotation. Conversely, particles in the liquid flow which are moving towards the axis are forced to slow down from a high velocity to a lower one, in other words decelerated, and exercise inertia forces in the direction of rotation. These forces are named Coriolis forces after the French scientist who first described them.

These Coriolis forces are directly proportional to the product of the masses in motion, their speed and the angular velocity of the rotation : $K_c = - 2 \cdot m \cdot v \cdot \omega$. This Coriolis force can be measured if the piece of pipe is driven at a constant torque. With a flow rate as in Figure 3, a braking torque is exercised, the extent of which at a constant angular velocity directly describes the mass flow rate. Coriolis forces are detected in practically all arrangements in their effect on the elastically yielding pipe arrangement.

Numerous various forms of pipe arrangements and their movement have become known in the course of the development of Coriolis methods of mass flow measurement. Li and Lee described in 1953 [4] a mass flow meter as shown in Figure 4, in which 2 T-shaped pieces of pipe are fitted to the end of an axis and rotated at a constant rotational velocity. The liquid mass flowing outwards from the centre has a retarding effect on the rotational movement as described above, which is measured by the rotation of the T-piece in comparison to the housing which is also rotating. The rotational seals necessary had an unfavourable effect. In 1954, Wildhack [5] described a Coriolis measuring system based on an oscillating loop (Fig. 5). With this method, a pipe loop bent into a circle through which liquid is flowing and which is fixed at the lower end is caused to torsionally oscillate along a vertical axis. The Coriolis forces thus cause the pipe loop to oscillate at the same frequency along its axis of fixation.

From 1955 [6] dates a description of a mass flow meter based on the Coriolis principle with a rotating pipe loop which is rotated along an axis by the mountings at its beginning and end. The Coriolis forces here cause the loop to bend along the Z-axis. From 1957 [7] (Fig. 6), dates the illustration of a mass flow meter based on the Coriolis principle with an oscillating pipe loop as in Fig. 5, in which a resonance frequency is made use of to keep down the vibrational energy. The movements of the loop are recorded inductively. Numerous variations of oscillating arrangements follow in the literature, examples in [7], [8].

3. **Different Models of Coriolis Measuring Systems**

The survey of the historical development essentially shows all of the fundamental characteristics of Coriolis measuring instruments in various arrangements, in basically

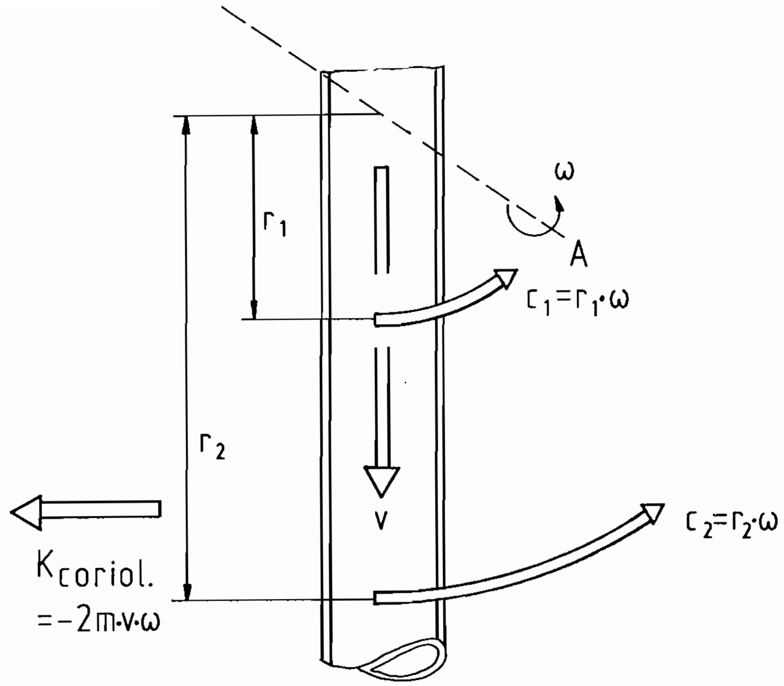

Fig. 3 — Coriolis forces in a rotating section of pipe

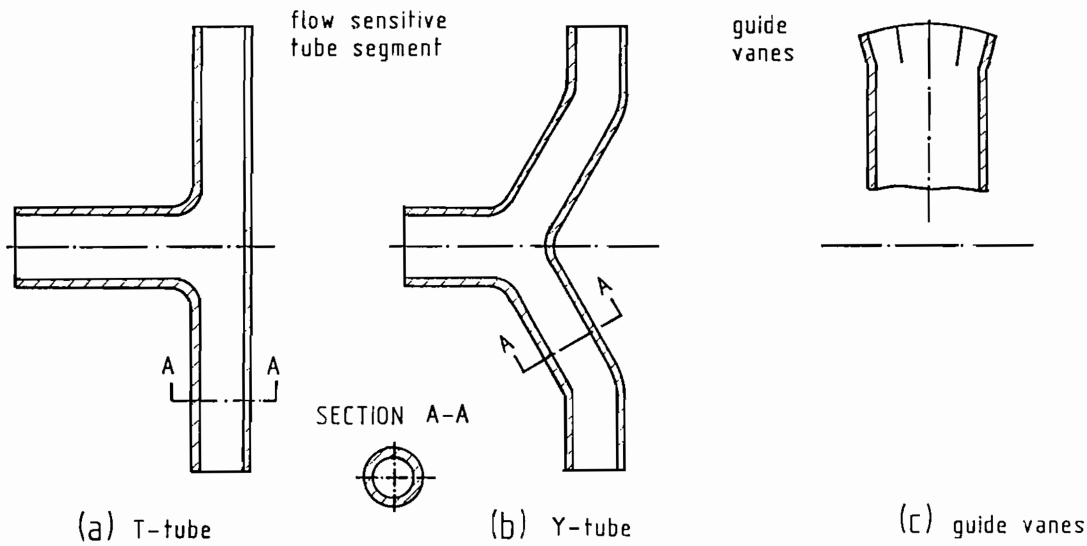

Fig. 4 — Coriolis mass flow meter after Li and Lee [3] (rotating T-pipe, Y-pipe)

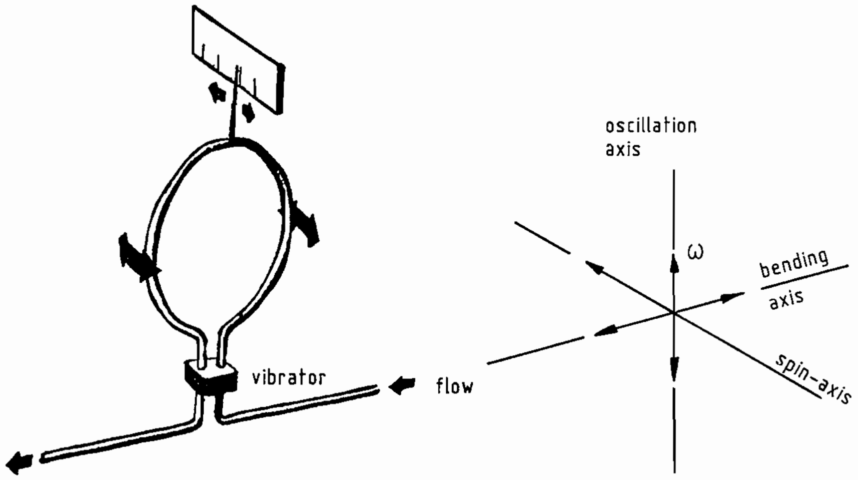

Fig. 5 — Coriolis mass flow meter after Wildhack [5] (oscillating pipe loop)

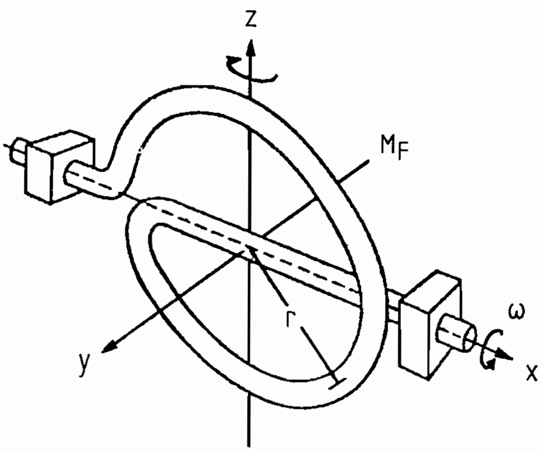

Fig. 6 — Mass flow meter after [6] with resonant vibration

all of which rotatable pieces of pipe are combined in all forms and all possible rotations. Due to the problem with rotational seals, an oscillating rotational movement established itself at an early date (oscillation instead of rotation). The choice of mechanical points of resonance has the advantage of saving energy on generating oscillation, but also the additional complication of having to take into account the form of the oscillation of resonating mechanical systems, as well as the influence of the physical parameters of the medium being measured, e.g. the density, and the external parameters such as pressure and temperature, on the resonance behaviour.

3.1. **Fundamental arrangements of Coriolis Mass Measuring Instruments.**

Fig. 7 shows a number of basic arrangements of Coriolis measuring systems in use today :

a) A straight pipe fixed on one side oscillates on an axis vertical to the pipe axis, the excitation is performed inductively, as is the measurement of movement. This « basic form » of a Coriolis measuring instrument enables it within large limits to be adapted to the particular measuring task by variations in the parameters

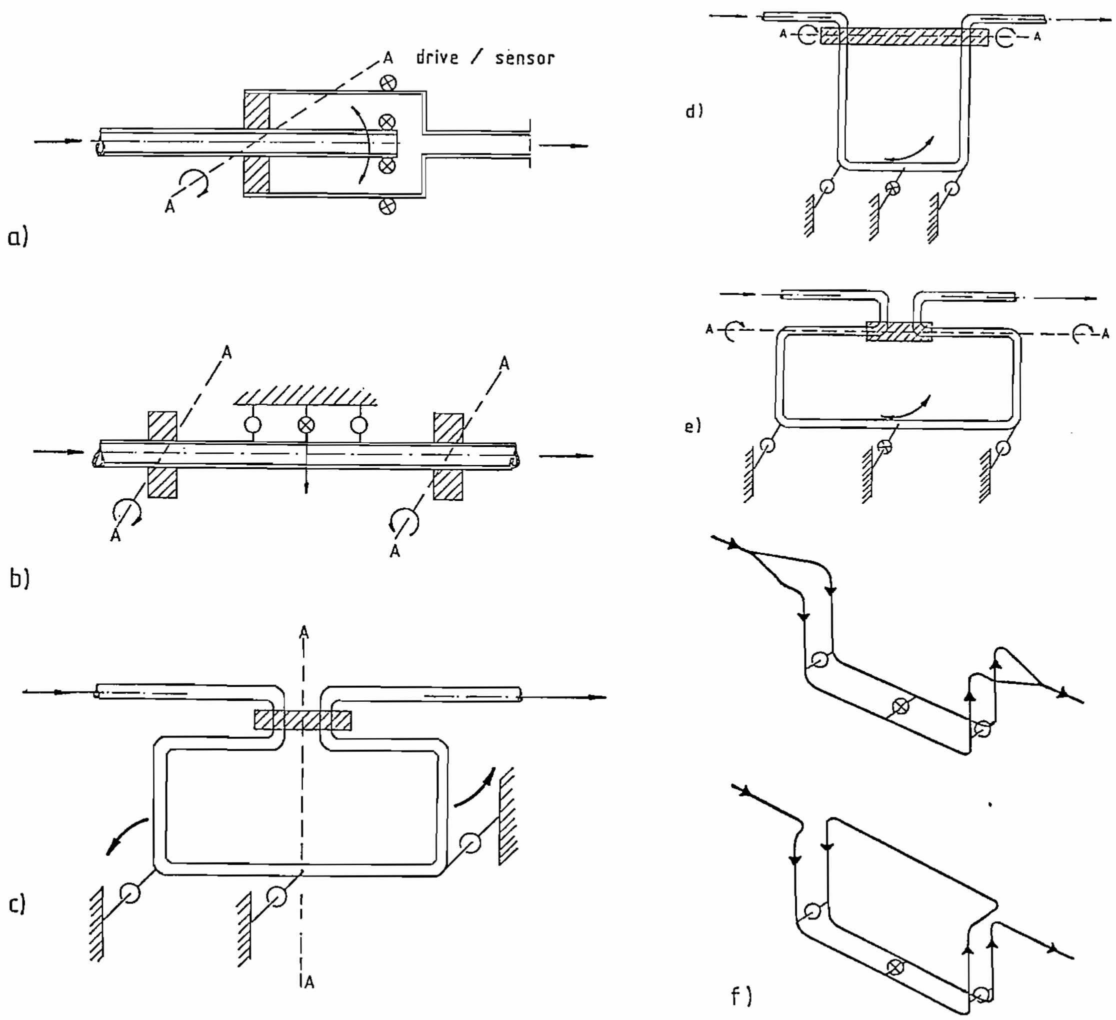

Fig. 7 — Fundamental arrangements for measuring mass flow :
a) straight pipe fixed on one side
b) straight pipe fixed on both sides
c) pipe loop with torsional vibration
d) pipe loop with bending vibration
e) pipe loop with torsional/bending vibration
f) double loop arrangements, above parallel flow below serial flow

of the oscillating pipe. One drawback, however, is the fact that the pipe is damped by the oscillations in the measuring medium. Turbulence at the end of the pipe may disturb the Coriolis effect.

b) A straight pipe fixed on both sides. The pipe oscillates with a maximum of movement in the centre of the pipe (« string vibration »). This is equivalent to both halves of the pipe being rotated on axes vertical to the pipe axis by the mountings. A positive aspect is the simple arrangement. Drawbacks are the high frequency of the fundamental resonance at technically acceptable pipe parameters as well as the influence of temperature stress on the resonance behaviour.

c) Pipe loop with torsional vibration. In this arrangement (as in Fig. 5), the mechanical tension of the oscillating movement is well distributed over the length of the pipe, i.e. relatively high oscillation amplitudes can be operated without overloading the pipe. A drawback is that this point of resonance is not generally equivalent to the fundamental resonance of a pipe loop of this kind. General vibrational disturbance from the pipe network may amplify the lower fundamental resonance and thus falsify the tilting motion caused by the Coriolis movement.

d) Pipe loop with bending vibration. This arrangement has found widespread use in a great many measuring instruments. The straight sections of pipe, necessary for the generation of Coriolis forces, are exceptionally long. A drawback is the short lever arm for the Coriolis forces to take effect and thus also for the measuring effect, as well as the high bending stress at the points of fixture.

e) Pipe loop with torsional/bending vibration. The pipe loop is extended and fixed so that in the fundamental mode the stress at the points of fixture is considerably reduced as opposed to d) by being split up into rotation and bending. An initial drawback is the longer construction length. On the other hand, however, the effect of the Coriolis forces on the vertical sections of pipe has a greater lever arm, i.e. a greater resilience available.

f) Double Pipe Arrangements. Oscillating systems exercise oscillating torque on the points of fixture which must be absorbed. In many cases, large counterweights (foundations) are sufficient to adequately compensate. The demands on a large, heavy foundation are not wished for with measuring instruments, and this led to double arrangements with symmetrical pipe loops oscillating in opposition to each other being used in vibrational systems for the measurement of density [9] as early as the start of the 1960s. The torque resulting from the oscillation in the points of fixture was largely able to be compensated. At the first convergence, moments from external sources are symmetrically distributed to the two halves of the pipe. As these oscillate in opposition by definition, thus providing contrary measuring effects, an effective « common mode rejection » occurs. This technique was soon to be used in Coriolis mass flow metering in two-pipe arrangements. The flow of the material being measured can be split up by means of a flow divider for the parallel loop arrangement. The flow can alternatively be passed through two loops with the same oscillating part arranged in sequence. Both arrangements have advantages and drawbacks.

In the parallel arrangement, the sum of the cross sections of both pipes is available, relatively small cross sections of the individual pipes can be selected with acceptable loss of pressure, thus increasing their sensitivity to the Coriolis effect. A drawback is the increasing contribution of the pressure loss caused by the flow divider at higher flow rates.

In the serial arrangement, the total length of pipe is considerably greater, additionally increased by the return to the second loop. The pipe must then have a sufficiently large cross section for the entire length and is thus more rigid i.e. initially less sensitive to Coriolis influences. Of advantage, however, is the fact that the pipe has more favourable loss of pressure properties at high flow rates from start to finish and is easier to clean.

3.2. Forms of Signals in Oscillating Systems in Resonant Motion and their Evaluation

In all Coriolis arrangements, the mass flow has a braking effect on the movement of the pipe section with the current flowing away from the axis of rotation, and accelerates the movement of the section of the pipe with the current flowing towards the axis of rotation. In the arrangements in Figs. 7d to f, the loop bends are retarded or accelerated on mass flow as compared to the situation with zero flow rate, the arrangement being twisted. In the linear systems, this twisting is proportional to the effect of the Coriolis force and thus also to the mass flow. With oscillating loop movements, the Coriolis forces, and thus the twists, also oscillate.

Fig. 9 above shows the time sequence of the sensor voltage which reproduces the movement of, for instance, the left bend of the loop Fig. 8 with zero flow rate, e.g. recorded using an inductive sensor. As the oscillation concerned is resonance vibration, the sequence Sosc has a sinusoidal shape. The Coriolis forces with a positive flow rate are not only proportional to the mass flow rate but also to the actual angular velocity. The angular velocity of the oscillating loop has the value 0

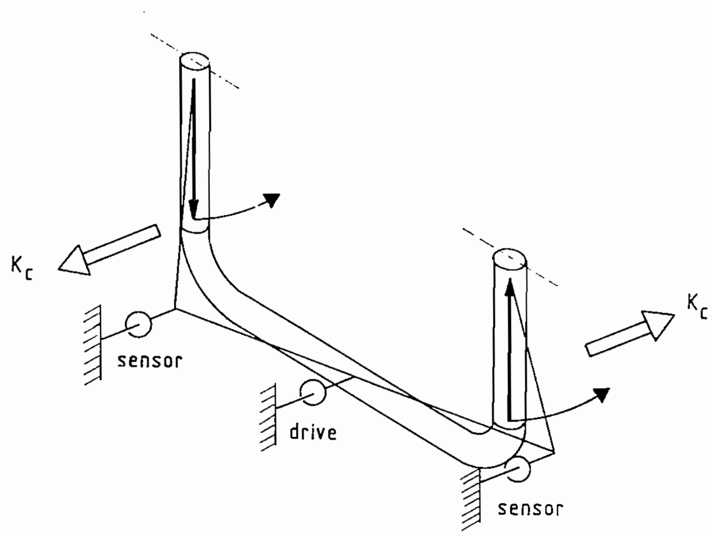

Fig. 8 — Effects of Coriolis forces on a pipe loop

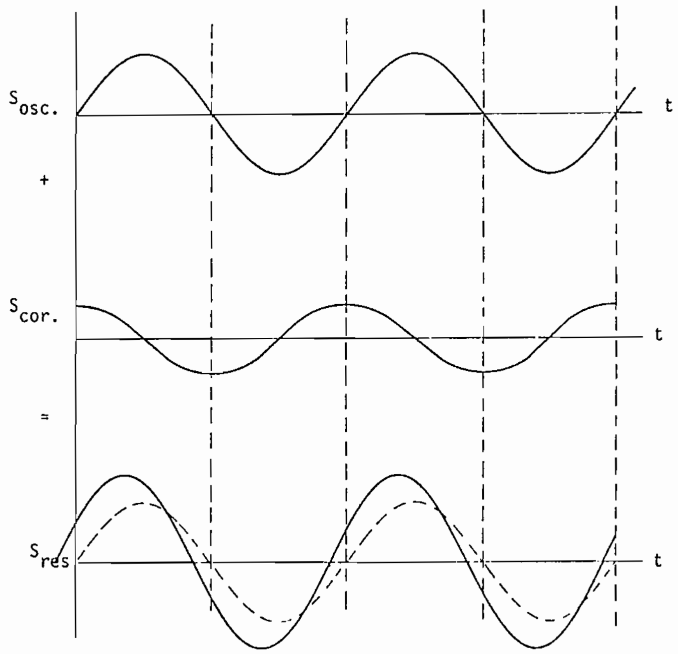

Fig. 9 — Sensor voltages : fundamental movement, additional Coriolis movement and resulting movement

at the points where the loop's movement is reversed ; these are the points of maximum divergence ; the angular velocity reaches a maximum where the loop passes through the middle position. The time sequence of the Coriolis forces themselves is accordingly also sinusoid, the same applying to the additional movement of the loop as a result of the Coriolis forces (Fig. 9 centre Scor), the time sequence now, however being shifted from that of the fundamental movement by exactly 90 degrees. The sequence Scor effected by the Coriolis forces is added to the time sequence of the fundamental movement Sosc. The resulting sequence of the entire movement Sres is shown in the lowest part of Fig. 9. The sensor registers a sequence which is different to the fundamental movement in amplitude and temporal position. A sensor at the right bend of the loop (Fig. 8) registers the superposition of the fundamental movement with the movement resulting from the Coriolis forces with the reverse signs. A signal processing evaluates the difference between the two sensor signals. These differences in sensor signals are very small with respect to the dimensions involved. Typical oscillation amplitudes of a loop at, for example, a frequency of around 80 Hz are restricted to approx. 1 mm at the end of the loop in order to keep the mechanical tension on the pipe at the point of fixture within limits. The distorsion caused by Coriolis forces at a medium flow rate is then around 100 times smaller, i.e. of a magnitude of 10 μm ; with a desired resolution in the area of 0.1 %, this leads to a necessary measurement resolution of a magnitude of several nanometers. These are very small mechanical dimensions which require exceptional precision in the mechanical construction and in the electronic evaluation.

In common arrangements, the output signals from sensors at the opposite bends of the loop are processed. The evaluation is clearly illustrated on the basis of the vector presentation of the alternating voltages in the complex place (Fig. 10). The central vector is equivalent to the movement at zero flow rate which supplies the same vector from both sensors. At a positive flow rate, the 90 % out of phase Coriolis movements add with the reverse signs to this fundamental vector. The two resulting measured voltages are characteristically different from the situation at zero flow rate.

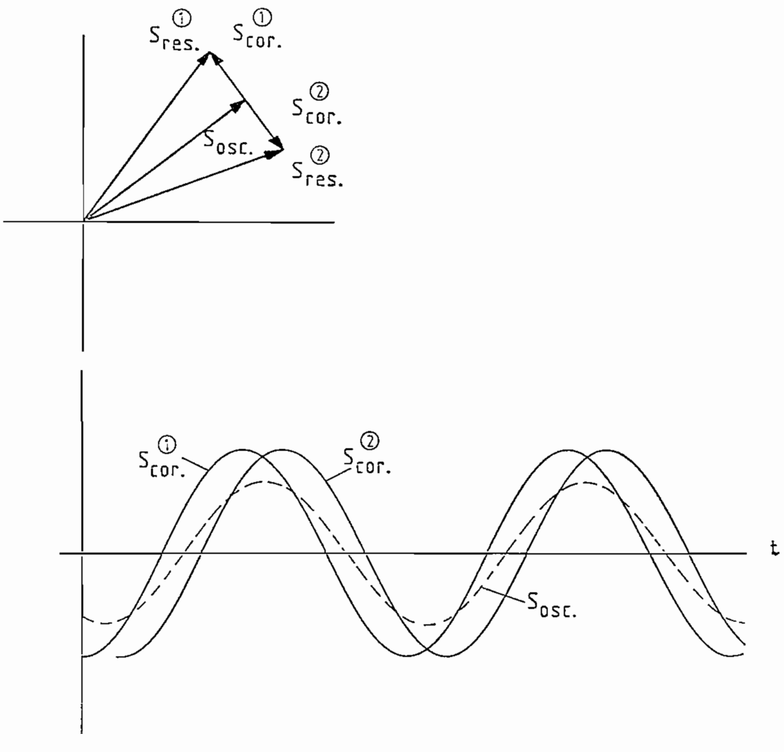

Fig. 10 — Sensor voltages on the complex level (above) and on the time chart (below)

A great many systems measure the time difference at the zero crossing of the sinus signals in Fig. 10 below as the standard for the Coriolis force. The simplicity of this method is contrasted by the disadvantage that only two points of measurement are available per period at zero crossing, which can be easily disturbed by overlapping noise.

With modern methods of digital measuring it is possible to convert the signal into a sequence of digital values at a number of points during a single period and to calculate the overlapping Coriolis movement from the magnitude of the signals at the various sensor points. The drawbacks of this more complicated processing of signals are contrasted by the advantages of digital processing at a large number of measuring points per period, whereby the measuring accuracy is considerably increased by means of the high number of readings per period.

4. Measuring Characteristics of Coriolis Systems

In their basic procedure, Coriolis measuring instruments are strictly linear and their readings independent of the viscosity, the electrical conductivity, the thermal properties and the flow profile of the material being measured. They are fundamentally suited for both gaseous and liquid media. The practical arrangements, however, only display demonstrable readings with gases for mass flow rates such as are also typical for liquid media. These are generally only attained by gases of a high density. The following statements are therefore essentially based on liquid measuring materials.

Coriolis instruments should fundamentally be independent of the density of the medium. The resonance frequency of a pipe arrangement filled with the medium to be measured becomes lower the higher the density of the medium. This is exactly the measuring effect used in vibrational density meters, and the evaluation of the oscillation frequency of a Coriolis mass meter also supplies the density of the medium being measured. The angular velocity which determines the Coriolis force also directly changes, however, with the oscillation frequency, meaning that the reading has to be corrected. This is, however, simple to perform as the frequency of the oscillation system can be easily measured externally. The temperature of the pipe system through which the stream passes also changes with the temperature of the medium being measured, and thus also the modulus of elasticity of the pipe system.

With the modulus of elasticity, the oscillation frequency also changes, but also the flexibility of the loop system to the effective forces and thus the measuring effect. The temperature must therefore be measured as an independent measured quantity e.g. by means of a sensor on the pipe, and this value be used for a compensator.

The pressure in the pipe system may play a certain role due to increasing the geometric rigidity of a pipe system to bending (« inflation effect »). This influence can be kept to a minimum by modelling and sufficient wall thickness of the pipe system.

In practice, a mass flow meter is fitted into a pipe system which, by way of the flange fixture, passes mechanical tension into the measuring instrument resulting from changes in temperature and operating pressures. In addition, shocks and vibrations in the pipe system cannot be entirely avoided. As the measuring principle only supplies very small quantities of motion and the resolution, as mentionned above, is of an order of magnitude of nanometers, the mechanical construction of the entire measuring system must prevent these external influences from affecting the points of fixture of the oscillating pipe. In addition, pressure losses, insert dimensions etc. must be kept within reasonable limits if the instrument is to be technically useful. The mathematical finite element method (FEM) today enables the simulation of complex oscillating pipe arrangements on fast-operating computers, as well as the calculation of their static and dynamic behaviour ; mechanical Coriolis oscillation systems can thus be simulated and optimized on the computer. Fig. 11 shows the run of a measuring tube of a Coriolis meter optimized in this fashion (serial flow, double pipe system) as well as the very robust mounting structure which connects the areas of the flange-bearing pipes very rigidly by means of a lattice, thus preventing as far as possible the momentum coming from the pipeline from affecting the points of fixture of the oscillating pipe above.

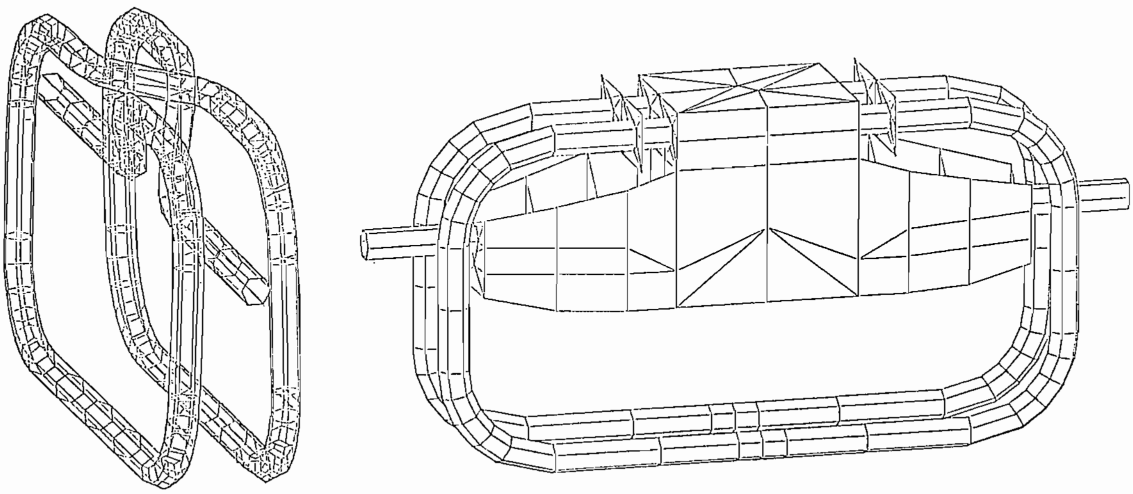

Fig. 11 — Finite element presentation of a measuring tube arrangement and its mounting

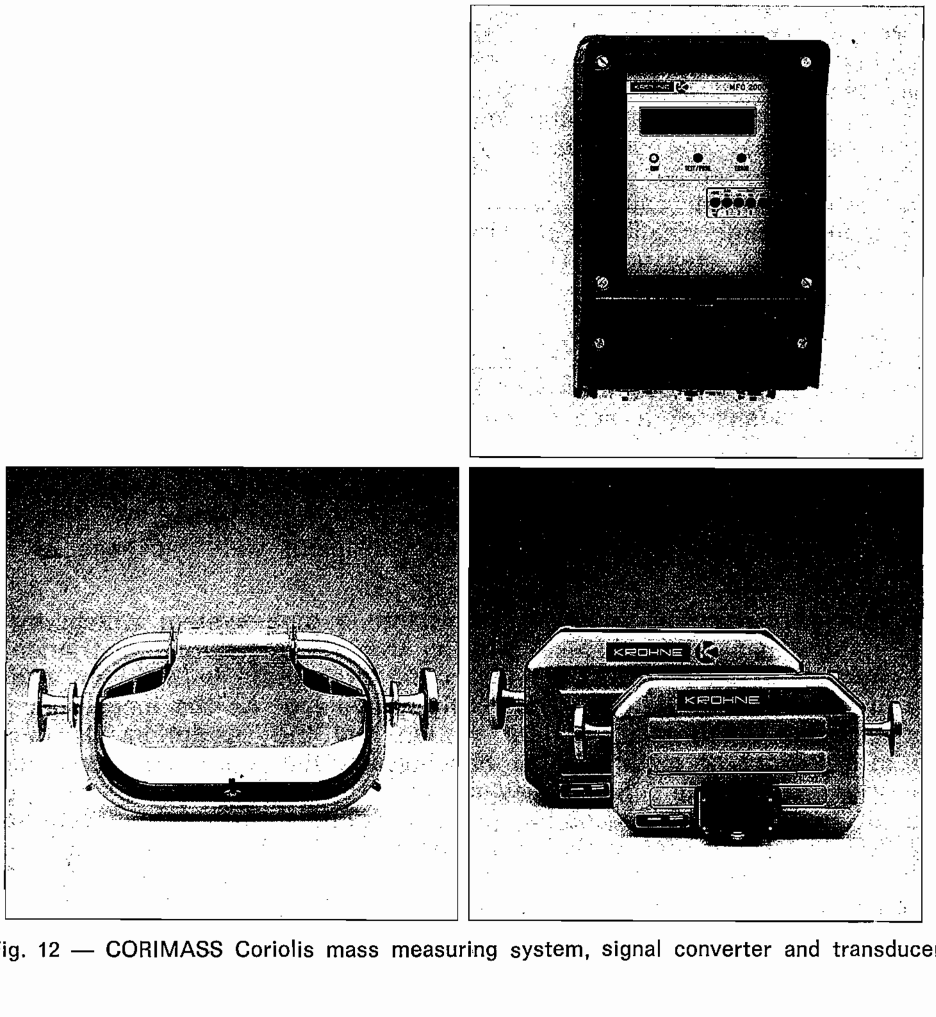

Fig. 12 — CORIMASS Coriolis mass measuring system, signal converter and transducer

Pipe arrangements of this kind can be bent on modern pipe bending machines to enable a connection to be made with only 2 weld seams, placed at the bottom of the pipe loop at points of low mechanical tension. Weld seams in the vicinity of the points of fixture, the points with the greatest mechanical load as a result of oscillation, are thus avoided, reducing the risk of overload from fatigue. All remaining points of juncture and fixture in the system can, for example, be soldered, as they do not come into contact with the medium.

The oscillation of the material in contact with the medium and subject to attack by corrosion means an increased risk of corrosion fatigue. The modern metallurgical industry provides rust resistant materials with different properties for the various kinds of application, ranging from the classic special steel 1.4571, via special steel 1.4529 to steels with high nickel content, such as Hastelloy C 4.

Figure 12 shows one type of Coriolis transducers with a flow rate range of 120 g/min to 600 g/min and an accuracy of 0.3 % of the actual measured value over a measuring range of 1:10. The entire measuring range may be 1:100. The transducers operate at medium temperatures of — 50 to + 200 °C and at operating pressures of up to 63 bar. The evaluation electronics (signal converter) in the field housing is highly digitalized with two rapid microprocessor systems and is thus flexible and safe from interference.

5. Calibrating Coriolis Systems

A balance presents itself as a tried and tested calibrating unit for the calibration of mass flow measuring systems. Fig. 13 is a schematic illustration of a calibrating device with a circuit fed from a 5 m^3 tank. It is driven by a centrifugal pump, the flow rate and pressure conditions in the measuring tube feed system being able to be finely adjusted by means of the pump speed and a control valve. Calibration is performed by comparing the mass sum formed in the measuring system with the mass which has passed through the system and been collected in a vessel on the balance. In the specified load range, the balance easily achieves a resolution of between 0.02 and 0.03 %. The drawback is that after opening and closing the control valve at the start and finish of the measuring procedure, the flow rate passes through all values from 0 to the set required value, meaning that the measuring

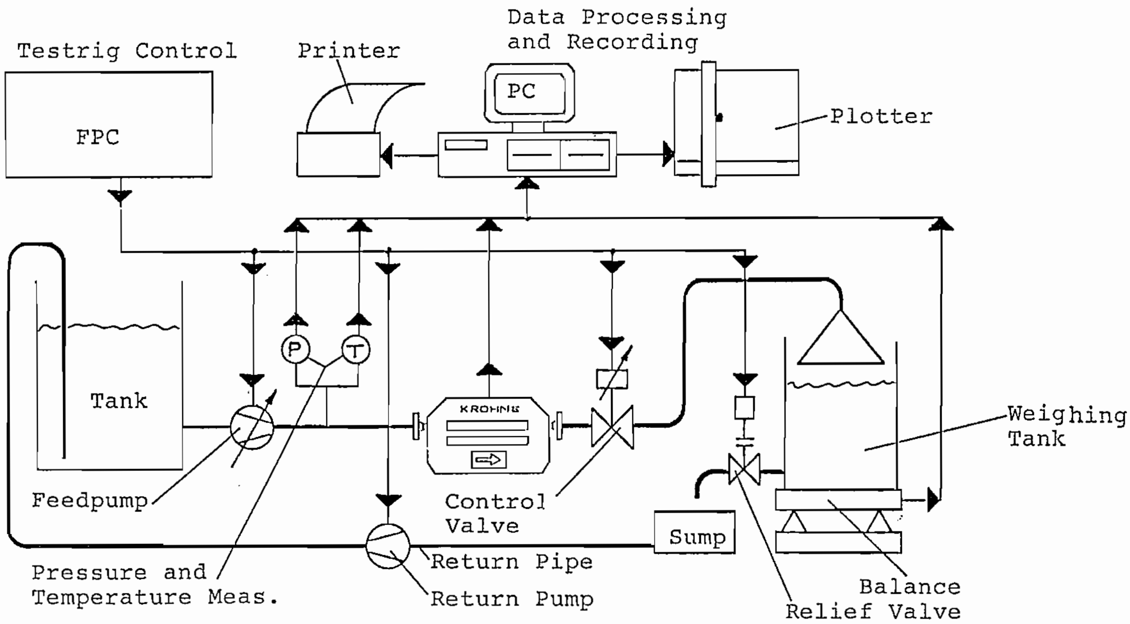

Fig. 13 — Calibration rig (schematic)

error is relatively high even around zero. The total error calculated thus represents the upper limit for the error calculated on calibration. An alternative would be to switch an already controlled circuit to the balance and back again with the aid of a diverter with other error influences. Finally, continuous reading of the balance is conceivable with constant flow with possibilities of error due to agitation of the balance (liquid flowing into the vessel on the balance).

The first-named method has proved its value, whereby the systematic calibration errors can be acceptably reduced by means of controlling the opening and closing of the circuit in terms of time and of a sufficiently long measuring period with the valve opened.

Figure 14 shows the deviation of the measured total mass from the weighing result in percentage of the measured value for a Coriolis measuring instrument with flow rates of between 1 and 80 kg/min (water) at temperature variations of between 23 and 73 °C. The error limits (over a flow rate range of 1:5 and hyperbolically increasing in the lower range) have been included. Figure 15 shows the relevant devitations on varying the system pressure from 0 to 8 bar with the same specified error limits. It can be seen that Coriolis systems of this kind prove to be very linear and technically exact under practice-related conditions. The accuracy achieved is a good prerequisite for the use of systems of this kind in custody transfer applications.

6. Interference

6.1. Mechanical Interference

A Coriolis system measures mass flow by analysing mechanical movements of the measuring tube system, fitted into industrial pipelines. Shocks resulting from flow turbulence vibrations induced by pumps and water hammer effects in the liquid column due to valve operations are unavoidable here.

Figure 16 shows the spectral dispersion (logarithmic scale) of the sensor voltage in the Coriolis measuring system for the frequency range of 0 to 200 Hz. The necessary resolution at the sensor for the above specified measurement resolution has been marked in. The Coriolis instrument oscillates at 86.5 Hz, hence the thin peak at this point. Interference from various sources can be seen over a wide frequency range : primarily building vibrations in the lower frequency range, in the centre a number of peaks (mains line hum and its multiples) and a relatively white distribution of spurious signals partially caused by the turbulence in the flow stream. The required measuring resolution is to a great extent covered by signal noise.

The oscillation frequency of the system might change with the temperature and density of the medium, but it is always measurable and thus known. It would seem sensible to fit filters of a narrow bandwidth lockable to the system frequency. This is an exceptionally problematic matter with analogous electronic means, as filters of this kind, particularly of a narrow bandwidth, might themselves cause distortion of the signal. It has proven to be effective to digitalize the sensor signals at a very early stage and to use the mathematical algorithm of a digital filter. The characteristic curve of a digital filter of this kind is shown in Fig. 16 centre. For this presentation, a bandwidth widened by a factor of 20 was selected in order to make the characteristic curve visible graphically. The effect of the filter on the disturbed signal is shown in Fig. 16 below. The influence of the interference from the pipeline system is practically suppressed.

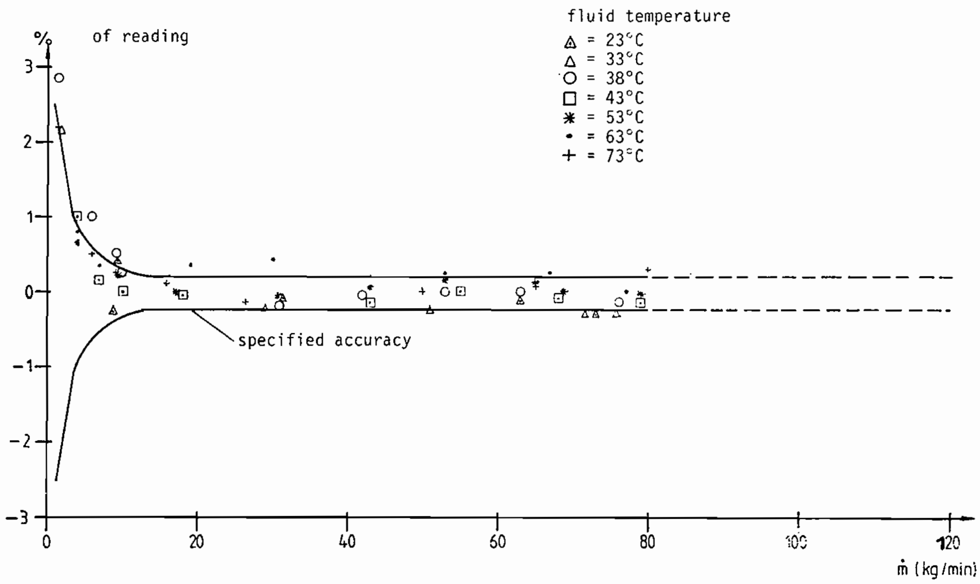

Fig. 14 — Measuring error in % of measured value with temperature variation (water)

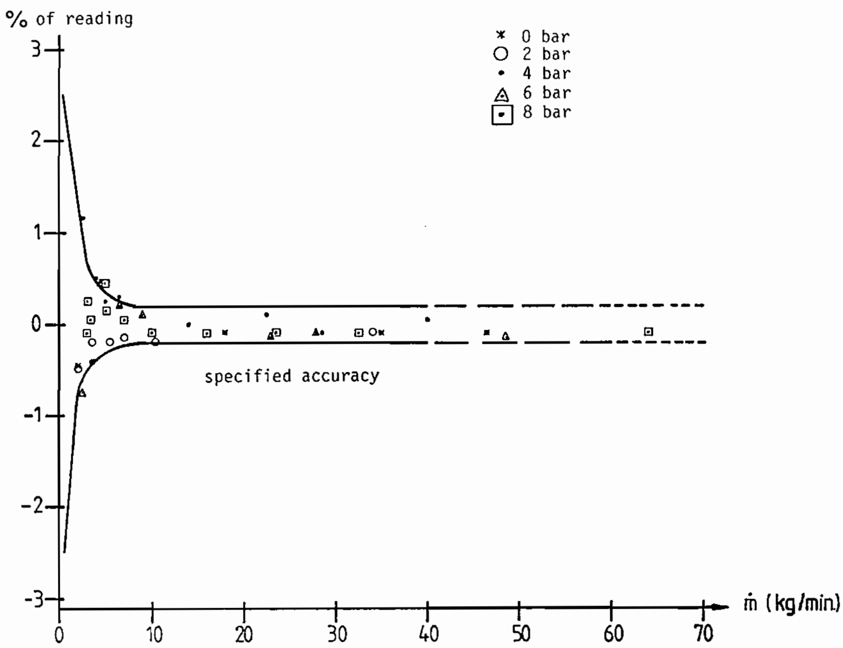

Fig. 15 — Measuring error in % of measured value with pressure variation (water)

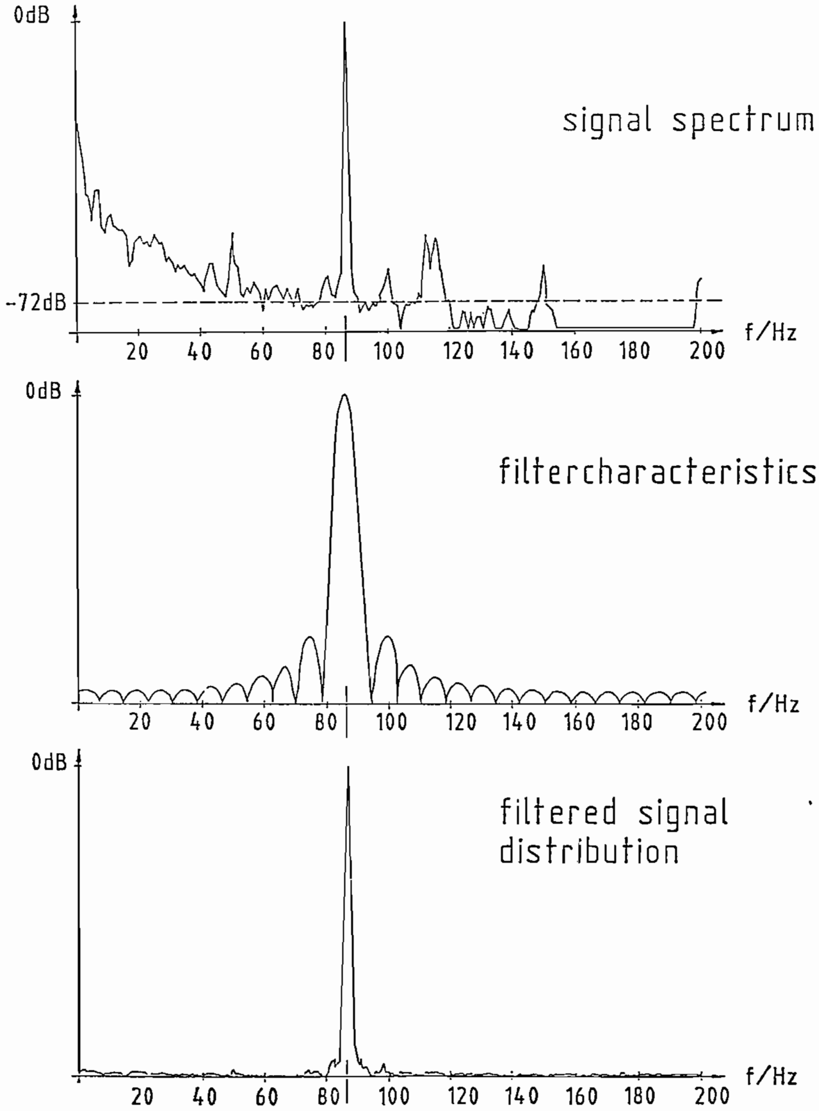

Fig. 16 — Interference due to shocks in the piping and suppression by means of digital filtering

By means of digitalization at an early stage, it is also possible with the aid of mathematical algorithms to work out the Coriolis contribution to the measured signal (Fig. 10) as a raw measuring value for the mass flow rate. In the computer available, the influence of temperature, frequency and, calculated from these, density can easily be calculated and the true mass flow rate value determined. In addition, the formation of the measuring value outputs common in industry (current output, frequency output), further signal evaluation such as sum formation, formation of limit values, density determination, etc. can be performed very variedly in the computer and the control of further functions from the communication bus, convenient display of measured values in the instrument and a convenient user operation in several languages for setting the instrument can be installed.

A Coriolis measuring system is not only a receiver of mechanical interference, it also generates vibrations itself at the oscillation frequency of the pipes. By means of carefully mechanically balancing the pipes oscillating in opposition to one another, the emission of oscillation energy can effectively be excluded. The vibration does however, via the centrifugal forces, generate a non-compensated pulsation of the liquid column with double the operating frequency, which primarily has no influence on the Coriolis effect ; interference by means of reflection in the pipe system with non-narrow band filtered systems cannot be excluded.

6.2. **Multiple Phase Flow Streams**

The state of aggregation of the medium to be measured basically has no influence on the Coriolis effect. In an oscillating arrangement, however, the medium to be measured must be accelerated by the movement of the pipe wall. With an increase in the frequency of these movements, sound propagation phenomena begin to gain in significance in the medium.

Almost homogenous mixtures with several phases - e.g. admixtures of finely injected gas to liquids or fine grain solid admixtures - react almost like a single phase liquid. The admixtures merely alter the density. A Coriolis mass measurement is thus still effective.

Two problem areas occur with respect to oscillation systems at higher levels of inhomogeneity. First, for a resonance arrangement, an inhomogenous mixture means an irregularly fluctuating density and thus a constantly fluctuating resonance frequency which can put the system out of phase. On top of this, increasing amounts of oscillation energy are lost in friction processes in the fluid and have to be replaced by the exciter. Performance limits of oscillation excitement e.g. in order to prevent the danger of explosion, may make the application of such instruments more difficult. Secondly, the velocity of sound declines considerably in gas-liquid mixtures with a high proportion of gas. The Coriolis method with oscillating pipes assumes that all particles of the medium are accelerated on orbits in accordance with the movement of the pipes. This is the case with homogenous liquids and relatively slow pipe movements as the time of flight of the sound waves, which are emitted from the wall of the pipe and which accelerate the particles within the pipe, is very short as compared to the oscillation period of the pipe itself. With a high proportion of gas and greatly decreasing velocity of sound, the time of flight of the waves in the pipe can approach the order of magnitude of the oscillation periods ; particles in the middle of the pipe will then no longer complete the movement of the pipe and, conversely, the Coriolis forces of the mass particles in the centre of the pipe will no longer have a complete effect on the walls of the pipe. The measuring value will be systematically reduced. Experience shows that a share of gas volume of between 4 and 6 % (air-water system) can still be tolerated with good agitation. The behaviour of liquid-gas mixtures depends on the distribution of bubbles and the resulting velocity of sound very largely on the kind of materials involved, meaning that the above figures cannot simply be transfered to other mixtures. With liquids having a lower surface tension than water, for example, a considerably higher proportion of gas will be tolerated.

The conditions for sound propagation are a great deal more favourable for proportions of solids in water. Experience shows that suspensions of fine grain solids can be measured without any difficulty. It is purely a technical problem, such as erosion and abrasion, which play a role here.

7. **Final Comments**

The Coriolis principle has proved to be a measuring system of high practical accuracy and linearity able to be used for a wide range of applications. Numerous measuring problems which were either not able to be solved by other measuring methods, or only with difficulty, are now accessible for exact measurement. The measuring limit at small flow rates with sufficient accuracy is essentially influenced by the thermal noise of the movements of a system of this kind, whereby the mechanical load capacity of the oscillating pipe sets a limit to increasing the measuring effect by increasing the movement. Pressure loses in the measuring tube, cavitation and, should they exist, mechanical abrasions form the upper limit of the flow rate, the measuring accuracy being excellent. In areas with measuring ranges of 1:100, instruments according to the Coriolis method have found a rapidly growing range of uses and no doubt have a great future.

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ROYAUME-UNI

A PROPOSED VERIFICATION SCHEME in GREAT BRITAIN for TRADE MEASURING EQUIPMENT

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Introduction

The principles of quality assurance are being applied in ever more areas of industry and commerce, and the field of weights and measures is no exception. Quality assurance techniques are of relevance to all stages of metrological control - pattern examination, initial verification and in-service inspection - and may be applied with good effect by both instrument manufacturers and metrological authorities. This paper, however, concentrates on the process of initial verification, for it is here that we are likely to see the most important changes in practice. Specifically, the paper reviews the results of a recent study in the UK and describes proposals for a new scheme which will allow accredited firms, with independently certified quality assurance systems, to carry out initial verification of their own products - so called self-verification.

Background

It is necessary first to describe briefly the legal position in Britain for trade equipment — largely controlled by the 1985 Weights and Measures Act and its subordinate regulations. Most commonly used trade equipment (counter scales, weighbridges, petrol pumps, etc.) are subject to the three familiar stages of metrological control. Pattern examination is the sole responsibility of central government (The National Weights and Measures Laboratory, NWML) ; initial verification (stamping) and in-service inspection are the responsibility of local government, exercised by qualified Trading Standards Officers (otherwise known as inspectors of weights and measures). There are no requirements for statutory re-verification but equipment found to be performing outside « inspection » tolerances or in any other way unfit for trade use will have its stamp removed and must be reverified. For most classes of equipment, 100 % verification is still required, though statistical sampling is permitted in the particular cases of some drinking measures (SI 1983/1655) and, under a European Community Directive 85/146/EEC, for material measures of length (SI 1985/1871).

Let us remind ourselves of what exactly an inspector of weights and measures does when he initially verifies a piece of equipment - let's say a counter scale. First, he must satisfy himself that the equipment is made to an approved pattern ; secondly, he must perform tests to ensure that it is within the required metrological tolerances ; finally, he needs to make sure that any other requirements in regulations are met, for example regarding the environment or manner of use. All being well, the inspector will then stamp the equipment to show it is « fit for use for trade ».

This procedure has been followed in one form or another for many years, so why the need for change ? There are two not entirely separate developments in industry which have called for a re-think on initial verification. First, the advent of new technology, especially the use of microprocessors in weighing and measuring equipment. It is a very remarkable inspector indeed who can « inspect » a ROM or logic array and satisfy himself that it complies with an approved pattern ! Secondly, there is the new emphasis on quality assurance in industry and, at least as important, the growth of certification schemes which can provide independent confirmation of a firm's quality procedures. This means that the measurement tests an inspector performs may simply be duplicating those already carried out by a manufacturer or repairer. Clearly, then, it was time to review this and other aspects of metrological control to reflect modern practices.

In 1984, the UK Government set up a Committee to carry out this review. It was chaired by Dr E.N. Eden and its members were drawn from industry, the trading standards service, consumer organisations and central government. After a year of intensive study and vigorous debate, the Committee published its recommendations (Cmnd 9545) and, having consulted widely on these, the Government published its response accepting nearly all the Committee's recommendations (Cmnd 9850). Perhaps most important of all, the Government agreed that there should be a change in the law to allow accredited commercial firms to carry out « initial verification » and « stamping » for themselves - in other words, there should be a self-verification scheme.

Since the publication of the Government's response, there has been much consultancy and debate on the details of the scheme. The general arrangements have now been finalised, and a new Weights and Measures Bill is being prepared to make the necessary amendments to the existing Act. In the remainder of this paper the main features of the proposeed self-verification scheme - probably to be known as ASSET (Accreditation Scheme for Self-verification of Equipment in use for Trade) - will be described.

The Self-Verification Scheme

It is important to be clear about the objectives of the scheme. First, the Government regards it essential that the high levels of confidence currently placed in the fairness of trading be preserved. In other words, a stamp placed by an ASSET-accredited manufacturer must give the same assurance as the inspector's traditional stamp. Secondly, self-verification should be optional, not mandatory, at least for some years. Thirdly, the scheme should encourage the adoption of quality assurance procedures. Fourthly, repairers and installers, as well as manufacturers, should be eligible to self-verify provided, of course, the same criteria of accreditation are achieved. Finally, the scheme should be operated with a minimum of bureaucracy (and cost) and be subject to regular review.

What, then, are to be the criteria a firm must satisfy in order to be accredited by the Government (NWML) to self-verify ? By far the most important and essential criterion is a quality management system, certified to a recognised standard by an independent (third-party) certification body. We are fortunate in the UK in having a well established quality standard - BS 5750, closely equivalent to ISO 9000 - and a growing number of certification bodies able to carry out the necessary assessments. These assessments are carried out using written procedures tailored by the certification body to the firm's activities. Ideally, these procedures will pay particular attention to the calibration of the firm's measuring equipment and standards - traceability to national standards is essential - and also to the firm's arrangements for ensuring that production is consistently made to an approved pattern. If for any reason the formal assessment by the certification body does not adequately cover to these two important criteria - traceability and pattern compliance - then NWML will need to be satisfied before accreditation to self-verify is granted. It is relevant to mention here that the proposed Weights and Measures Bill will make it a legal requirement for all manufacturers, whether self-verifying or not, to be responsible for the conformity of their products to an approved pattern.

The fourth and final criterion for accreditation has proved to be rather controversial - at least with the industry; this is the requirement that a sample of the « output » of a self-verifying organization must be subject to statutory auditing by an inspector (Trading Standards Officer). It has been suggested that such auditing is unnecessary and undermines the credibility of a quality management certificate. Like most controversies, it is based on an element of misunderstanding, however. It is important to distinguish between certification of a *quality management system* (such as BS 5750), which the scheme will insist on, and certification of a *product approval system*. The latter should, of course, encompass the former, but sampling and testing of products is an essential part of any product approval certification. A quality management system alone is not designed to give product assurance. Such sampling and testing is necessary for any product approval scheme - whether we are talking of garden spades or children's shoes - but metrologists will appreciate the particular importance in the case of weighing and measuring equipment which must be adjusted to within tolerances.

There are at least three good reasons, incidentally, why weights and measures inspectors should perform these audits. First, it has been mentioned that the self-verification scheme will be optional, not mandatory, and the proposed arrangements will ensure consistency of the two regimes. Secondly, the Government places emphasis on the need to maintain public confidence in fair trade and the inspector's role in auditing will help ensure this. Finally, perhaps most importantly, it is likely to be the cheapest and simplest arrangement, bearing in mind that inspectors will usually be visiting firms anyway as part of the quality management system surveillance, so will often be able to audit a sample of the output at the same time.

In developing the arrangements for the ASSET accreditation scheme, the UK authorities have been aware of the need to follow international guidelines. It would be most unfortunate if national authorities all developed their own self-verification schemes independently, particularly as we should anticipate the prospect of mutual recognition agreements in the future. Fortunately, the International Organization for Standardization (ISO) has published a series of guidelines for various types of certification system, the most comprehensive of which is that described in ISO/IEC Guide 28. This system (originally known as System No 5 in the ISO/ITC publication « Certification - Principles and Practice ») is described as follows (bracketed comments inserted by author) : -

> A third party certification system of determining conformity with product standards through initial testing (i.e. pattern approval) and assessment of a factory quality management system and its acceptance followed by surveillance that takes into account the factory quality management system and the testing of samples from the factory (i.e. audit) and the open market.

The British accreditation scheme has been designed to follow these international guidelines. Similarly, the sampling arrangements for the statutory audit of self-verified products will be based on internationally agreed standards. These arrangements will take fully into account the high confidence that can be placed in an organization with a certified quality management system, and may, for example, be based on the « skip-lot » sampling plan described in BS 6001 Part 3, soon to be published as the technically identical ISO 2859/3. Experience will show the most appropriate sampling plan for various circumstances, and the work of the OIML reporting secretariat SP2-Sr5 « Control by Sampling » in developing an International Document will be of value.

Costs and Benefits

Having discussed the criteria for ASSET accreditation, it is now timely to consider the privileges and benefits which will result. Obviously, the immediate benefit will be in the right to stamp equipment - this will save both money and time, since at present the release of equipment must await the arrival of an inspector who will charge a fee for testing and stamping. But there should also be something of a cachet attached to self-verification, indicating that the high standards of accreditation have been met. There is also, of course, a great deal of evidence that firms of every size, whether involved in manufacturing or servicing, benefit financially by introducing a quality management system through reduced scrap or reworking, lower warranty costs, etc.

All these benefits do not come entirely free of charge, of course. The certification body concerned will charge for its services according to normal commercial practice, and both NWML and local authority inspectors must recover their costs in operating the scheme. Needless to say, the accredited firm will have a number of legal obligations to observe since it will, in effect, be performing the duties of an inspector. Our industry has, perhaps understandably, been concerned about this talk of legal obligations and sanctions, but they are no more severe than have been applied to inspectors for many decades.

Concluding Remarks

It should be emphasised that the arrangements described apply to UK national regulations - the Crown stamp - and would not, at least at present, apply to European Community or OIML verification. However, we live in a rapidly changing world and doubtless the European Commission, BIML and other bodies will be watching developments with great interest and will be proposing how these quality-assurance techniques may best be applied at an international level. There are, of course, comparable arrangements to these described for Britain being developed and tested in several other countries. Provided all the authorities ensure that ISO guidelines are followed throughout, there should be great value in comparing experiences and, in due course, developing internationally agreed guidelines for self-verification.

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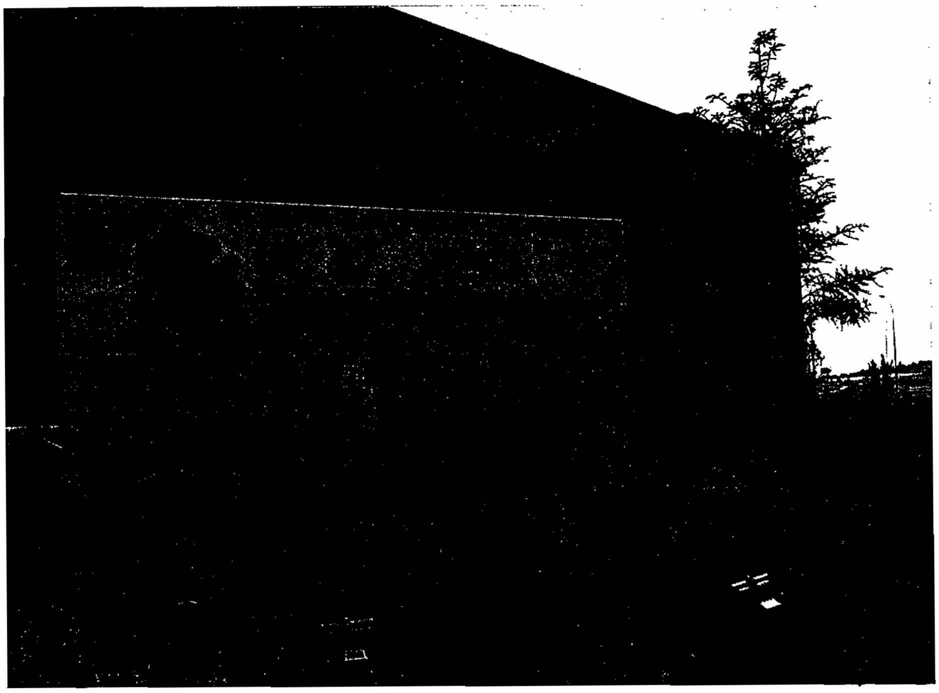


Les nouveaux laboratoires du CENTRE ESPAGNOL de METROLOGIE

La métrologie espagnole a connu, au cours de ces dernières années, des modifications importantes. Sur le plan juridique, une nouvelle loi (mars 1985) a restructuré les différents organismes concernés et leur a donné les armes réglementaires leur permettant de faire face, plus efficacement, à des tâches toujours croissantes. L'Espagne s'est également préparée à son entrée dans le Marché Commun, effective depuis le début de 1986, et aux obligations nouvelles que cette adhésion entraîne. Par ailleurs, on a pu remarquer une participation croissante des autorités métrologiques espagnoles tant aux activités régionales (WEMC) qu'internationales (OIML).

Ces progrès et ces changements ont été accompagnés d'une action décisive pour l'avenir de la métrologie espagnole, la création des nouveaux laboratoires du Centre Espagnol de Métrologie (CEM).

Les missions des laboratoires du Centre Espagnol de Métrologie consistent à :

— maintenir les étalons primaires, assurer leur raccordement au BIPM, effectuer des comparaisons avec les étalons d'autres pays,

— offrir aux autres laboratoires espagnols et aux industriels des services d'étalonnage, maintenir des liens avec les systèmes d'étalonnage d'autres pays,

— appliquer la loi et les règlements, en particulier en ce qui concerne la métrologie légale et assurer la participation aux travaux de l'OIML et du Marché Commun. (En ce qui concerne la métrologie légale, il est à noter que la vérification est assurée par des organismes à caractère régional).

Le projet a démarré en mars 1984 et, sous l'impulsion énergique de son auteur, le Dr. Cadarso, Directeur du CEM et représentant de l'Espagne au Comité International de Métrologie Légale, il est actuellement dans sa phase ultime d'achèvement, la construction proprement dite s'étant étalée d'avril 1985 à juin 1987.

Les réunions EUROMET et WEMC, tenues à Madrid en septembre 1987 (voir information dans ce même Bulletin), ont donné l'occasion aux responsables des laboratoires de métrologie des pays européens de l'ouest et aux représentants du BIPM et du BIML de visiter ces nouveaux laboratoires, dont l'équipement et la mise en fonctionnement commencent à se faire progressivement. Tous les visiteurs ont été très impressionnés par cette réalisation dont le côté moderne et fonctionnel apparaît au premier regard.

Le site choisi est celui de « Tres Cantos », à 20 kilomètres au nord de Madrid. Sur une surface urbanisée de 62 700 m^2 ont été construits 18 700 m^2 de bâtiments, dont 10 600 m^2 pour les laboratoires.

L'ensemble comprend (Fig. 1) :

— un bâtiment d'entrée, comprenant en particulier une salle de conférence pour près de 300 personnes et un musée,

— un bâtiment de services généraux et administratifs : salle du conseil, bureaux du directeur et des chefs de sections, salles de réunions, bibliothèque, cantine,

— en sous-sol, la centrale de régulation thermique et d'épuration de l'air. Le contrôle du conditionnement est centralisé dans une salle de commande et géré par ordinateur ; la centrale étend ses ramifications sous chacun des six laboratoires, qui font donc l'objet d'un conditionnement individuel,

— six bâtiments de laboratoires,

— un bâtiment d'habitation pour le personnel (6 appartements), des garages et des équipements sportifs, ainsi qu'une piste pour hélicoptères.

INSTALLATIONS DES LABORATOIRES

Les laboratoires sont répartis sur six bâtiments dont trois occupent au sol 45 × 15 m et trois autres 60 × 15 m et embrassent les activités métrologiques suivantes : métrologie dimensionnelle, masses, électricité et températures, gaz, hydrocarbures et autres fluides, forces.

Certains de ces bâtiments comportent deux niveaux dont la partie inférieure située en sous-sol est utilisée pour des mesures de haute précision (voir Fig. 2). L'enveloppe des laboratoires est au rez-de-chaussée constituée de 40 cm de briques et 6 m d'isolant et les ouvertures sont d'une façon générale orientées vers le nord avec doubles huisseries et doubles vitrages.

Tous les laboratoires disposent d'un accès extérieur pour l'entrée des machines d'essai ou d'objets qui doivent être vérifiés au essayés. Les accès latéraux sont équipés de plates-formes de déchargement de 0,6 m de hauteur pour fourgonnettes et de 1 m pour les camions.

Les portes de tous les laboratoires ont une largeur de 2 m et un montant supérieur démontable de façon à permettre une hauteur de passage libre de 3,5 m.

L'accès des équipements au niveau du sous-sol s'effectue au moyen de plates-formes élévatrices.

L'équipement général de tous les laboratoires est le suivant :

— Tous les sols, murs et plafonds sont recouverts de produits résistants ne produisant pas de poussière et conçus de façon à éviter une accumulation de celle-ci.

— Dans les laboratoires où il est nécessaire d'éviter des interférences de champs magnétiques ou électriques, il a été prévu un éclairage utilisant des ballasts électroniques en conformité avec la norme CISPR (DE 0871 classe B) et annulant en même temps des effets stroboscopiques.

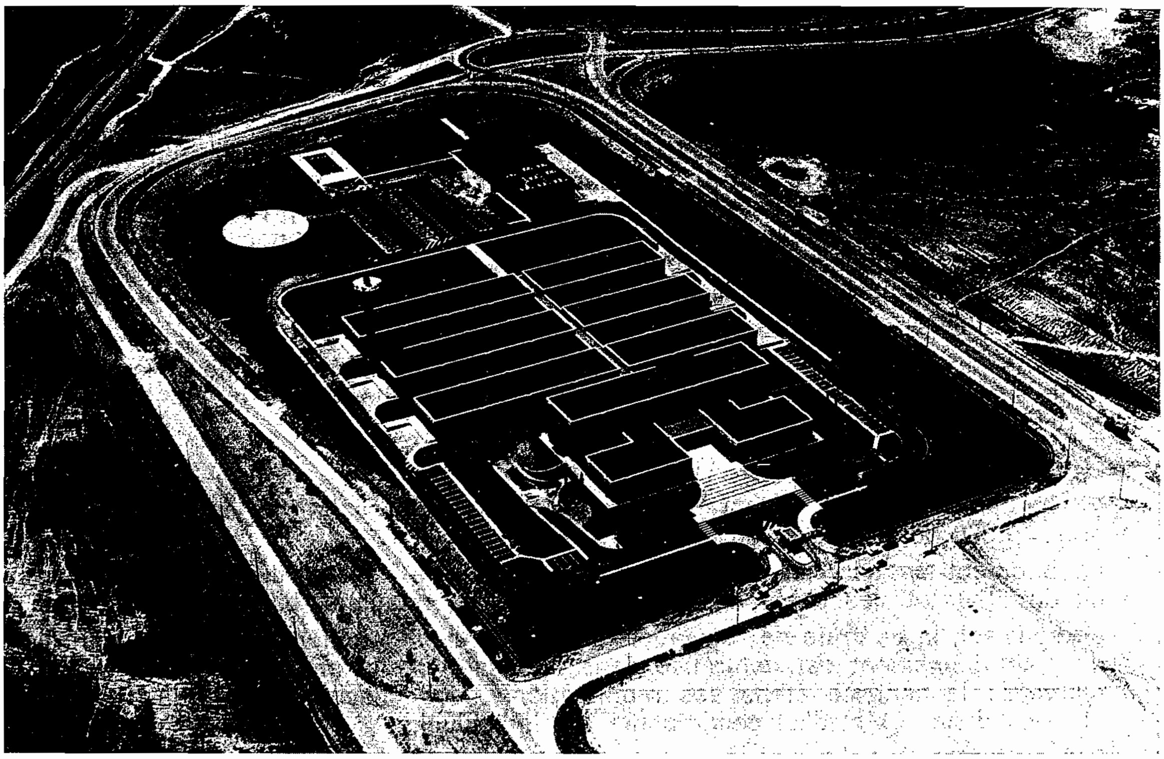


Fig. 1

— Tous les laboratoires sont équipés d'une canalisation électrique préfabriquée qui permet de passer des câbles monophasés et triphasés pour des puissances jusqu'à 10 kW dans le cas normal et jusqu'à 50 kW dans quelques cas spéciaux. Ces puissances sont très supérieures aux besoins actuels mais permettent l'installation future d'autres équipements d'essai.

— Tous les branchements électriques d'appareils sont protégés individuellement par un contacteur magnétothermique et différentiel.

— Un groupe électrogène permet d'assurer l'alimentation électrique en éclairage et force (y compris l'air conditionné) en cas de défaillance du secteur.

— Tous les laboratoires sont équipés d'un câble monophasé relié à une alimentation centrale de continuité électrique permettant de garantir une alimentation électrique sans micro-coupures.

— Tous les laboratoires disposent d'une alimentation en air comprimé à 7 bar.

— A l'exception des laboratoires électriques et masses étalons, tous les laboratoires sont équipés d'une alimentation en eau froide et chaude et écoulement des eaux usées.

— Pour l'installation des machines d'essai propres aux laboratoires et en vue de futures modifications ainsi que pour transporter de lourds objets d'essai, on dispose de : un pont grue de 3 t dans le laboratoire de métrologie dimensionnelle, un de 1 t et un autre de 2 t dans le laboratoire de gaz, un de 4 t et un de 1 t dans le laboratoire de forces et pour finir un portique monorail de 1 t dans le laboratoire de pesage.

— Un système de détection d'incendie en tous lieux.

— Surveillance centralisée par enregistrement des maxima et minima de température et d'humidité dans tous les laboratoires.

— Accès d'ouverture des portes par carte magnétique.

— Entrées par un sas avec portes à ouverture électrique évitant la communication directe de l'ambiance climatisée des laboratoires avec les couloirs.

— Les laboratoires électriques sont équipés de trois cages de Faraday pour l'atténuation des champs électromagnétiques et une cage de Faraday revêtue de matériaux absorbant les micro-ondes à type anechoique.

CLIMATISATION

Exigences générales

La climatisation était d'une importance fondamentale dans la conception des laboratoires. Le but recherché était d'obtenir dans tous les laboratoires exigeant une haute précision les conditions suivantes :

Température	:	20 ± 0,1 °C
Humidité relative	:	50 ± 5 %
Filtrage de l'air	:	99,97 % d'efficacité pour des particules de 0,3 μm

Ces conditions étaient en principe faciles à réaliser avec des équipements disponibles sur le marché à l'exception de la variation maximale de ± 0,1 °C en température.

Afin de tenter de réaliser ce critère, la planification des laboratoires a tenu compte des points suivants :

— réduction de l'influence thermique extérieure en plaçant les laboratoires de haute précision au sous-sol avec une importante isolation thermique et les autres laboratoires au rez-de-chaussée (exigence 20 ± 0,5 °C) avec des doubles fenêtres au nord et huisseries en bois,

— obtention d'une grande inertie contre les variations thermiques extérieures en utilisant des dalles en béton et des murs en briques massifs de 40 cm d'épaisseur,

— réalisation d'une homogénéité de température dans le laboratoire de façon à obtenir en tous points la même température que celle de la sonde de régulation,

— utilisation d'un système de climatisation de haute stabilité et réglable par échelons utilisant des sondes et contrôleurs analogiques réagissant aux variations de l'ordre du centième de degré,

— centralisation en un point facile d'accès de tous les équipements nécessaires pour l'entretien.

Avant d'établir les plans d'architecture définitifs, des essais ont été réalisés à pleine échelle sur un modèle du laboratoire de mesures dimensionnelles dont les dimensions sont 60 × 10 × 4,65 m, voir section en Fig. 2. Les résultats de ces essais ont montré une uniformité satisfaisante dans la zone de travail (entre 0,5 et 1,5 m du sol) tout le long du laboratoire indépendamment de l'emplacement de la sonde de température.

REALISATION

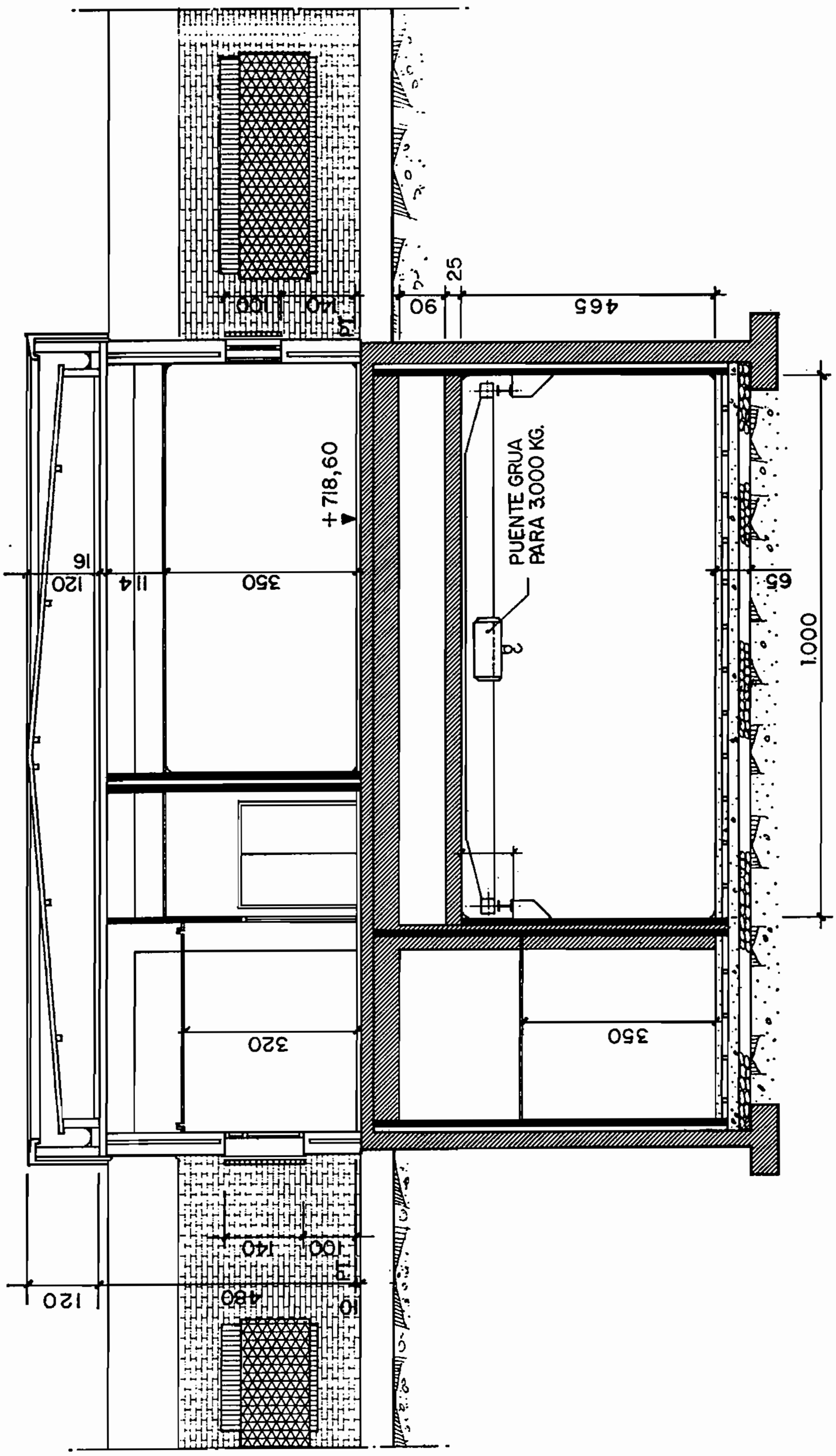
Production et distribution de l'eau du circuit thermique

La production d'eau froide et chaude pour les échangeurs thermiques est effectuée dans une salle de machine unique pour tous les bâtiments au moyen d'un système de sept pompes à chaleur à haut rendement.

Les conduites d'eau passent dans une galerie située en sous-sol reliant la centrale aux chambres d'échangeurs thermiques et traitement d'air qui sont situées à côté de chaque laboratoire mais isolées de ceux-ci de façon à rendre le travail de maintenance indépendant de la centrale thermique.

Système de climatisation de l'air des laboratoires

Nous choisissons pour cette description comme référence le laboratoire de métrologie dimensionnelle dont la réalisation est la plus complexe.



SECCION TRANSVERSAL
1:100
DIMENSIONALES
(SUPERFICIE DEL LABORATORIO 10m. x 59,8m. = 598 m²)

Fig. 2

Celui-ci est situé au sous-sol et isolé du reste du bâtiment par un double plafond constitué par une dalle en béton de 30 cm et un mortier céramique de 25 cm, d'un sol formé d'une dalle de 20 cm reposant sur des bandes de néoprène et un isolement rigide de 8 cm qui repose à son tour sur une dalle de 20 cm. Les cloisons verticales sont constituées par des murs en brique de 25 cm d'épaisseur, une isolation rigide de 8 cm et un mur en béton de 40 cm.

Sur le mur et sur le sol devant l'isolant est disposé un réseau de tuyauteries en forme de panneaux dans lesquelles circule de l'eau à 20 °C.

La climatisation intérieure du laboratoire s'effectue en régulant individuellement la température de l'air dans 4 zones de 15 m dans le sens de la longueur.

Le climatiseur utilisé est du type multizone avec un préfiltrage de l'air d'entrée à haute efficacité (90-95 % selon la méthode Dust-Spot) et avec un micro-filtrage à la sortie d'une efficacité de 99,75 % pour des particules de 0,3 µm selon la méthode DOP. Une vanne pressostatique maintient la pression constante pour éviter l'influence d'encrassement du filtre. Chaque section de ce climatiseur multizone a son propre ensemble d'échangeurs thermiques à contrôle séquentiel. Le maximum des sauts de température entre l'air ambiant et l'air pulsé est de 4 °C en froid et 2 °C en chaleur.

La distribution de l'air s'effectue à l'aide de diffuseurs linéaires répartis sur deux rangées dans l'axe longitudinal du laboratoire.

La régulation est effectuée pour chaque zone à l'aide des valves à trois voies et à haute résolution (1:400) placées dans les batteries correspondantes de froid et de chaleur de l'échangeur thermique.

Chacune des quatre zones du laboratoire est équipée d'une sonde à résistance Pt-100 spécialement choisie permettant d'obtenir une discrimination et une stabilité de l'ordre du centième de degré. Chaque sonde est reliée à un convertisseur de signal de la classe 0,1.

Toute la régulation est contrôlée par un central de mesure et de contrôle permettant un choix de 40 programmes différents ainsi que l'enregistrement de la température et de l'humidité de tous les laboratoires avec alarme lorsque les limites programmées sont dépassées.

Pour les laboratoires exigeant une stabilité de température moindre, la climatisation est en principe la même, il n'y a cependant pas de panneaux de circulation d'eau et l'exigence d'exactitude des sondes et organes de contrôle est aussi moindre.

Résultats obtenus en pratique

Durant les quelques mois pendant lesquels les laboratoires ont été en fonctionnement on a pu tirer les conclusions provisoires suivantes :

— L'exigence de stabilité de température de ± 0,1 °C pour les laboratoires de haute précision a pu être réalisée en présence d'apports thermiques variables.

Dans le cas de laboratoires exigeant ± 0,5 °C la température a en réalité pu être maintenue à ± 0,3 °C.

— Dans des conditions d'apport thermique fixe, le système de climatisation est capable de maintenir la température à ± 0,01 °C.

— Les laboratoires ont une grande inertie thermique. On a constaté une variation de température de seulement 0,3 °C en 24 h avec le système de conditionnement arrêté et sans apport thermique important de l'intérieur.

ASMW PTB

CENTENAIRE

de la

PHYSIKALISCH-TECHNISCHE REICHANSTALT

1887-1987

La fin de l'année a été marquée par deux célébrations du centenaire de la création de la Physikalisch-Technische Reichanstalt (PTR), organisées par les deux instituts nationaux, la Physikalisch-Technische Bundesanstalt (PTB) en République Fédérale d'Allemagne et de l'Amt für Standardisierung, Messwesen und Warenprüfung (ASMW) en République Démocratique Allemande, qui sont en fait les « héritiers » de la PTR.

Le Dr H. Lilie, Président de l'ASMW, accompagné du Vice-Président K. Möbius et du Dr K. Hasche (Membre du CIML) était le 7 octobre 1987 à Braunschweig (République Fédérale d'Allemagne) et inversement, le Dr D. Kind, Président de la PTB, accompagné du Vice-Président S. German et du Dr M. Kochsiek (Membre du CIML), se rendait le 10 décembre 1987 à Berlin (République Démocratique Allemande) pour ces commémorations auxquelles assistait également une nombreuse représentation internationale.

Les deux organismes intergouvernementaux de métrologie y étaient représentés par MM. K. Birkeland, Président du CIML (le Président du CIPM étant le Dr Kind), P. Giacomo, Directeur du BIPM et B. Athané, Directeur du BIML.

Chacune des cérémonies, organisées avec le faste qui convient à une telle célébration, comprenait des messages de félicitation de nombreuses personnalités allemandes et étrangères, des conférences à caractère scientifique et d'autres à caractère historique*, évoquant les conditions de la création de la PTR et le rôle qu'elle a joué dans la coopération métrologique internationale.

Rappelons, en ce qui concerne l'OIML, que le Dr W. Kösters, alors Directeur de la division des Poids et Mesures de la PTR, participait à la première Conférence Internationale de Métrologie Pratique, tenue à Paris en 1937 ; qu'il était nommé Membre du Comité provisoire de métrologie légale et qu'il avait convié le Comité provisoire à se réunir en 1939 à Berlin, où devait se tenir la Conférence constitutive de l'OIML. Après la guerre, en 1947, M. Costamagna, futur Directeur du BIML, rendait visite au Dr Kösters, pour relancer la coopération internationale.

En 1956, lors de la première Conférence Internationale de Métrologie Légale, la délégation allemande unique comprenait, entre autres membres, MM. W. Mühe et H.W. Liers, futurs membres du CIML pour la R.F. d'Allemagne et la R.D. Allemande, respectivement.

L'absence de liens diplomatiques entre la R.D.A. et la France empêchait l'ASMW de participer aux travaux de l'OIML jusqu'en 1974, mais depuis cette participation est complète et les deux pays assument au total la responsabilité de trente Secrétariats Pilotes et Rapporteurs, soit plus qu'aucun autre Etat Membre de l'OIML.

Le Bureau est heureux d'adresser à ces deux organismes, tous deux extrêmement actifs au sein de l'OIML, ses meilleurs vœux de développement et de succès.

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* A l'occasion de ce centenaire, la PTB et l'ASMW ont publié :

— Mass und Messen, voir références dans la section Littérature de ce Bulletin

— 100 Jahre staatliche Metrologie, ASMW Metrologische Abhandlungen Band 7, 1987, Heft 2/3.

ASMW PTB

CENTENARY

of

PHYSIKALISCH-TECHNISCHE REICHANSTALT

1887-1987

Two remarkable events by the end of 1987 were the celebrations of the centenary of the creation of Physikalisch-Technische Reichanstalt (PTR) organized by the two national institutes the Physikalisch-Technische Bundesanstalt (PTB) in the Federal Republic of Germany and the Amt für Standardisierung, Messwesen und Warenprüfung (ASMW) in the German Democratic Republic, institutes which are the successors of the PTR.

The President of ASMW, Dr H. Lilie, accompanied by the Vice-President Dr K. Möbius and Dr K. Hasche (CIML Member) were on 7 october 1987 at Braunschweig (Fed. Rep. of Germany) and inversely the President of PTB, Dr D. Kind accompanied by the Vice-President Dr S. German and Dr M. Kochsiek (CIML Member) went on 10 December 1987 to Berlin (German Democratic Republic) for these two celebrations at which there was an important international participation.

The two international metrology organisation were represented by Mr K. Birkeland, President of CIML (the President of CIPM is Dr D. Kind) and by Mr P. Giacomo, Director of BIPM and Mr B. Athané, Director of BIML.

Each of these two events organised with the ceremony that accompanies such occasions comprised congratulation messages by a number of German and foreign personalities, scientific presentations and others of historical nature* evoking the conditions of the creation of the PTR and its role in international metrology co-operation.

It should be reminded that as concerns the OIML, the Director of the Weights and Measures Division of the PTR Dr W. Kösters took part in the first International Conference of Practical Metrology in 1937 in Paris and was then nominated Member of the Provisory Committee of Legal Metrology. He had invited the Provisory Committee to meet in Berlin in 1939 where it was planned to hold the constituting Conference of OIML. After the war, in 1947 Mr Costamagna future Director of BIML met Dr Kösters to restart the international co-operation.

In 1956 at the first International Conference of Legal Metrology there was one German delegation composed of among others Dr W. Mühe and Dr H.W. Liers future CIML Members of the Federal Republic of Germany and the German Democratic Republic respectively.

The lack of diplomatic relations between the German Democratic Republic and France prevented ASMW from participating in the work of OIML until 1974 but since that year the participation is complete and the two States are on the whole responsable for a total of 30 Pilot and Reporting Secretariats which is more than any other OIML Member State.

The BIML is happy to convey to both Institutes, so extremely active within OIML, all the best wishes for further development and success.

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* The following special publications have been published by PTB and ASMW :

— Mass und Messen, see references in section Literature in this Bulletin

— 100 Jahre staatliche Metrologie, ASMW Metrologische Abhandlungen Band 7, 1987, Heft 2/3

COOPERATIONS METROLOGIQUES EN EUROPE

METROLOGICAL COOPERATION IN EUROPE

Le Bulletin OIML N° 106 - Mars 1987, avait présenté un résumé des divers aspects de coopération métrologique entre pays européens. Cette coopération va toujours se développant, et un événement important, pour les pays européens de l'ouest, s'est récemment produit : la signature à Madrid, le 23 septembre 1987, par les représentants des instituts nationaux de métrologie de 16 pays européens * (membres de la Communauté Economique Européenne ou de l'Association Européenne de Libre Echange) ainsi qu'un représentant de la Commission des Communautés Européennes, de l'accord créant EUROMET, c'est-à-dire un système de collaboration européenne en matière d'étalons.

On trouvera ci-après des extraits de l'accord, dans sa langue originale, l'anglais (les articles non reproduits sont relatifs au fonctionnement interne d'EUROMET). Il est à noter que si la métrologie légale a été exclue de la collaboration EUROMET, cela n'empêchera pas les membres de s'informer mutuellement des développements de cette activité dans leurs pays respectifs.

Par ailleurs, le « Western European Metrology Conference (ou Club) » poursuivra ses activités au moins pendant les prochaines années, son maintien ou sa disparition dépendent des développements que connaîtra EUROMET.

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*The OIML Bulletin No. 106 - March 1987 included a summary of various aspects of cooperation in metrology between European countries. This cooperation is still progressing and an important event for the West-European countries took recently place : the signature in Madrid on 23 September 1987 by the representatives of 16 European countries * belonging to the European Economic Community or to the European Free Trade Association and by a representative for the Commission of the European Economic Community of an agreement creating EUROMET covering a system of European cooperation in the field of measurement standards.*

Extracts of this agreement are given below (articles concerning the internal functionning of EUROMET have been left out). Though legal metrology has been excluded within the framework of EUROMET this will not prevent its members from mutual information on developments within this field.

It may be added that the « Western European Metrology Conference (or Club) » will continue its activities at least during the next years and its future remaining in existence will depend on the developments of EUROMET.

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* R.F. d'Allemagne, Autriche, Belgique, Danemark, Finlande, France, Grèce, Irlande, Italie, Luxembourg, Norvège, Pays-Bas, Portugal, Suède, Suisse, Royaume-Uni.

EUROMET

MEMORANDUM OF UNDERSTANDING

(Extracts)

SECTION 1

1 *The Signatories to the Memorandum of Understanding declare their common intention to take part in EUROMET, a European collaboration in measurement standards.*

2 *EUROMET is open to national metrology institutes of all States of the European Communities, of all States of the European Free Trade Association and to the Commission of the European Communities.*

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SECTION 2

1 *The Objective of EUROMET.*

The participating metrology institutes intend to collaborate in EUROMET, with the objective of promoting the co-ordination of metrological activities and services with the purpose of achieving higher efficiency.

2 *The Aims of EUROMET are :*

I) *To develop a closer collaboration between Members in the work on measurement standards within the present decentralised metrological structure.*

II) *To optimise the utilisation of resources and services of Members and emphasise the deployment of these towards perceived metrological needs.*

III) *To improve measurement services and make them accessible to all Members.*

IV) *To ensure that national facilities developed in the context of EUROMET collaboration are accessible to all Members.*

3 *EUROMET has the following specific tasks :*

I) *Co-ordination of projects on measurement standards.*

II) *Co-ordination of major investments for metrological facilities.*

III) *Transfer of expertise in the field of primary or national standards between Members.*

IV) *Provision of a framework for collaboration among interested Members on specific projects.*

V) *Provision of information on resources and services.*

4 *The EUROMET COMMITTEE meets to review and discuss the aims and specific tasks of EUROMET. The COMMITTEE decides itself upon its rules of procedure. The COMMITTEE elects its chairman from its Delegates for a period of two years. The chairman normally provides the necessary secretarial assistance for the administration of the EUROMET COMMITTEE.*

5 *Members retain their national autonomy.*

6 *The EUROMET COMMITTEE will have no funds of its own.*

SECTION 3

In order to achieve the aims and objectives of EUROMET, Members will have especially the following rights :

1 *All Members will have access to national standards of the other Members, on an equal footing basis.*

2 *All Members will have the right to propose to the EUROMET COMMITTEE that specific measurement standards and associated measurements services be set up, and that interested Members will carry out such projects on terms to be decided among them.*

3 *All Members may seek assistance, through consultancies, secondments, or other mechanisms, on specific measurement problems, on terms to be decided between the parties concerned.*

SECTION 4

Members commit themselves to the pursuance of the objectives, aims and tasks of EUROMET. In particular they will carry out the following responsibilities.

1 *When an area of metrological activity is under consideration in the EUROMET COMMITTEE, all Members will normally make available to the EUROMET COMMITTEE information on current and planned work in that area with the exception of any work carried out in confidence.*

2 *Members will do their best to provide an adequate service to all customers on an equal footing with their own national requests.*

3 *The attainment of the aims and objectives of EUROMET requires participation by Members to the extent commensurate with resources and expertise at their disposal.*

4 *The Member will make every effort to ensure that necessary resources are made available under their internal procedures.*

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SECTION 6

This Memorandum of Understanding is of an exclusively recommendatory nature. It will not create any binding legal effect in public international law.

Annex

CLARIFICATION OF MEMBERSHIPS AND APPROPRIATE ACTIVITIES

1 CLARIFICATION OF MEMBERSHIP

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2 ACTIVITIES APPROPRIATE FOR COLLABORATION

The lists below detail the areas that would be included in collaborative work under EUROMET and areas that would be specifically excluded, even though certain of the excluded areas may be within the responsibilities of some Members.

A) *Activities Included in EUROMET Collaboration*

i) *Research and development on national measurement standards.*
ii) *Research associated with the development of primary standards, eg. fundamental constants, materials, measurement techniques.*
iii) *Development of calibration services at the highest metrological level, appropriate to each Member.*
iv) *Highest level measurement techniques.*
v) *Development of travelling standards.*

B) *Activities excluded from EUROMET Collaboration*

i) *Accreditation schemes.*
ii) *Specification standards (norms).*
iii) *Legal metrology.*

However, this would not excluded work on measurement standards or techniques in support of these activities.

LITTERATURE

Métrologie historique

Le Comité International pour la Métrologie Historique (CIMH), lors de son 4e Congrès à Linz, Autriche en 1986, a décidé de créer un Bulletin d'information dont le premier numéro a paru en 1987, en français et allemand. Le congrès ordinaire de cette association doit en principe se tenir en Hongrie en 1988. Pour plus de renseignements, s'adresser au secrétaire général M. Jean-Claude Hocquet, 34, allée de la Comédie, 59650 Villeneuve d'Ascq, France.

Le Bulletin du CIMH nous signale également que l'Union Internationale d'Histoire et de Philosophie des Sciences tiendra son 18e Congrès International à Munich du 1er au 9 août 1989 sur le thème : L'Etat et les poids et mesures.

Centenaire de la PTB (suite)

Le centenaire de PTR/PTB (voir Bulletin de l'OIML N° 107, p. 49) a donné lieu à l'édition d'un livre (375 pages) intitulé « Forschen - Messen - Prüfen » (en français : recherches-mesures-essais) rédigé par J. Bortfeldt, W. Hauser et H. Rechenberg et édité par Physik-Verlag GmbH, D-6940 Weinheim, R.F.A.

La première partie de cet ouvrage retrace par périodes le développement historique de cette prodigieuse Institution depuis sa création en 1887. La deuxième partie contient des articles descriptifs sur les différentes activités techniques de PTB.

Industrie pétrolière

La série de publications « Petroleum Measurement Manual » de l'Institute of Petroleum, qui est diffusée par l'éditeur John Wiley & Sons, vient d'être complétée par un fascicule sur les procédures de mesures de pétrole en vrac par des inspecteurs de cargaisons : Part XVI - Procedures for Oil Cargo Measurements by Cargo Surveyors, 48 p., March 1987.

Radar de contrôle de vitesse

Des modèles de spécifications sur les radars de contrôle de vitesse ont été édités aux Etats-Unis d'Amérique en 1982 par l'administration nationale des autoroutes. Ce rapport de 85 pages contient également des schémas de simulation pour l'essai de ces équipements : Model Performance Specifications for Police Traffic Radar Devices, National Highway Traffic Safety Administration Report DOT HS-806-191. Ce rapport peut être acheté en s'adressant à National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

Assurance Qualité en Chimie Clinique

Un livre sur les méthodes à adopter en vue d'obtenir des résultats fiables et comparables dans les analyses de laboratoire vient d'être publié en anglais par l'Association scandinave de chimie clinique. Nous signalons ce livre, qui contient par ailleurs une bibliographie très étendue, vu son intérêt de caractère métrologique assez général et dont les principes énoncés s'appliquent également à d'autres domaines d'essais de matériaux utilisant des matériaux de référence : « Quality Assurance in Clinical Chemistry » by Adam Uldall, Scandinavian Journal of Clinical Laboratory Investigation - Vol 47 - Supplement 187, 1987, Blackwell Scientific Publications, UK, USA and Australia.

Brochures du BIML en espagnol

Quelques brochures élaborées dans le cadre de l'assistance aux pays en développement ont été traduites en espagnol par le département d'information de l'Instituto de Investigaciones en Metrologia, Comite Estatal de Normalizacion, C. de la Habana, Cuba. Ces brochures sont :

— Equipos de verificacion para los servicios nacionales de metrologia

— Planificacion de los laboratorios de metrologia y ensayo.

Métrologie industrielle en Espagne

Le 3e Congrès international de métrologie industrielle s'est tenu à Saragosse, Espagne du 23 au 25 novembre 1987. Cette importante manifestation, en langue espagnole, comportant une cinquantaine d'exposés, était comme précédemment organisée dans le cadre d'une exposition sur l'instrumentation et l'automatisation. Elle a été suivie de deux journées techniques sur l'application de la robotique.

LITERATURE

Historical metrology

The International Committee for historical metrology (CIMH) has at its 4th Congress in Linz, Austria, 1986 decided to create an information Bulletin of which the first issue was published in 1987 in French and German. The ordinary congress of this association is planned to be held in Hungary in 1988. For more information contact the secretary general Mr Jean-Claude Hocquet, 34, allée de la Comédie, 59650 Villeneuve d'Ascq, France.

The CIMH Bulletin also informs us that the International Union of History and Philosophy of Sciences will hold its 18th International Congress in Munich, 1-9 August 1989 on the subject : The State and Weights and Measures.

Centenary of PTB (continued)

At the occasion of the centenary of PTR/PTB (see OIML Bulletin No. 107 p. 49) a book has been published with the title Forschen-Messen-Prüfen (in English : research-measurements-testing). The editors are J. Bortfeldt, W. Hauser and H. Rechenberg and the publisher : Physik-Verlag GmbH, D-6940 Weinheim, F.R.G.

The first part of this book relates by periods the historical development of this famous Institute since its creation in 1887. The second part contains descriptive papers on the various technical activities of PTB.

Petroleum industry

The publication series « Petroleum Measurement Manual » of the Institute of Petroleum, which is published by John Wiley & Sons, has been completed by Part XVI - Procedures for Oil Cargo Measurements by Cargo Surveyors, 48 p. March 1987.

Radar speed controllers

Model specifications for radar speed control devices were issued in the USA in 1982 by the National Highway Traffic Administration. This report of 85 pages also contains schemes for simulated tests of such equipment : Model Performance Specifications for Police Traffic Radar Devices, NHTSA report DOT HS-806-191. This publication can be procured from National Technical Information Service, 5285 Port Royal, Springfield, Virginia 22161.

Quality assurance in clinical chemistry

A book has recently been published in English by the Scandinavian Society for Clinical Chemistry on methods to adopt in view of obtaining reliable and comparable results in laboratory analysis. This publication which contains an extensive bibliography is of general interest to metrologists as the principles described also apply to other fields of materials testing using reference materials : « Quality Assurance in Clinical Chemistry » by Adam Uldall, Scandinavian Journal of Clinical Laboratory Investigation - Vol. 47 - Supplement 187, 1987, Blackwell Scientific Publications, UK, USA and Australia.

Spanish translations of BIML brochures

Some of the brochures developed by OIML within the framework of assistance to developing countries have been translated into Spanish by the department of information of Instituto de Investigaciones en Metrologia, Comite Estatal de Normalizacion, C. de la Habana, Cuba. These brochures are :

— Equipos de verificacion para los servicios nacionales de metrologia

— Planificacion de los laboratorios de metrologia y ensayo.

Industrial Metrology in Spain

The third International Congress on industrial metrology was held in Zaragoza, Spain from 23 to 25 November 1987. This important event in Spanish language comprising about 50 presentations was as previously organized jointly with an exhibition on instrumentation and automation. It was followed by a two days technical workshop on the application of robotics.

INFORMATIONS

MEMBRES DU COMITE - COMMITTEE MEMBERS

EGYPTE — Monsieur le Prof. Dr. M. HILAL, nouveau Président de Egyptian Organization for Standardization and Quality Control, remplace Monsieur SALEM comme Membre du Comité.

EGYPT — Prof. Dr. M. HILAL, new President of the Egyptian Organization for Standardization and Quality Control, replaces Mr SALEM as Committee Member.

QUELQUES EVENEMENTS A VENIR - SOME COMING EVENTS

13-17 juin 1988	Quality - Progress - Economy, 32d EOQC Annual Conference, Moscow Information : Gosstandart, 9 Leninsky Prospekt, Moscow 117049, USSR
11-13 juillet 1988	International Symposium on trends in control and measurement education, Swansea, U.K. Information : Conference Division, The Institute of Measurement and Control, 83 Glower Street, London WC1E 6AA, U.K.
22-24 août 1988	Symposium IMEKO TC 8 on metrological assurance for environmental control, Helsinki Information : The Finnish Society for Automatic Control, P.O. Box 165, SF-00101 Helsinki, Finland
13-16 septembre 1988	INSYMET 88, 9th International Symposium on metrology, Bratislava Information : Czechoslovak Scientific and Technical Society, Ing. J. Kalinayová, Skultetyho 1, 83227 Bratislava Czechoslovakia
16-21 octobre 1988	11th IMEKO World Congress, Houston, Texas Information : Instrument Society of America, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709, USA

REUNIONS OIML

	Groupes de travail	Dates	Lieux
SP 31	Enseignement de la métrologie	11-15 avril 1988	LA HAVANE CUBA
SP 31 - Sr 1	Formation des ingénieurs en métrologie		
SP 31 - Sr 2	Formation des techniciens en métrologie et des agents de vérification		
Réunion du Conseil de Développement			
Séminaire sur la métrologie			
SP 7 - Sr 8	Cellules de pesée	11-15 avril 1988 *(provisoire)*	TEDDINGTON ROYAUME-UNI
SP 7 - Sr 5	Instruments de pesage à fonctionnement automatique	18-22 avril 1988	TEDDINGTON ROYAUME-UNI
SP 5D - Sr 3	Compteurs d'eau	5-6 mai 1988	BIML PARIS
SP 2 - Sr 6	Instruments électroniques	16-20 mai 1988	COPENHAGUE DANEMARK
SP 7 - Sr 2	Mesure des masses. Dispositifs électroniques		
SP 17 - Sr 1	Mesure des pollutions de l'air	9-11 mai 1988	BERLIN-OUEST
SP 19 - Sr 4	Base internationale de référence de dureté	9-10 juin 1988	PRAGUE TCHECOSLOVAQUIE

Conseil de la Présidence	20-22 janvier 1988	BIML PARIS
Huitième Conférence Internationale de Métrologie Légale et 23e Réunion du CIML	24-28 octobre 1988	SYDNEY AUSTRALIE

Note : Cette liste a été établie le 16 novembre et peut ne plus être à jour.
This list was established 16th November 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.

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