Bulletin OIML n° 97
Décembre 1984

ISSN 0473-2812

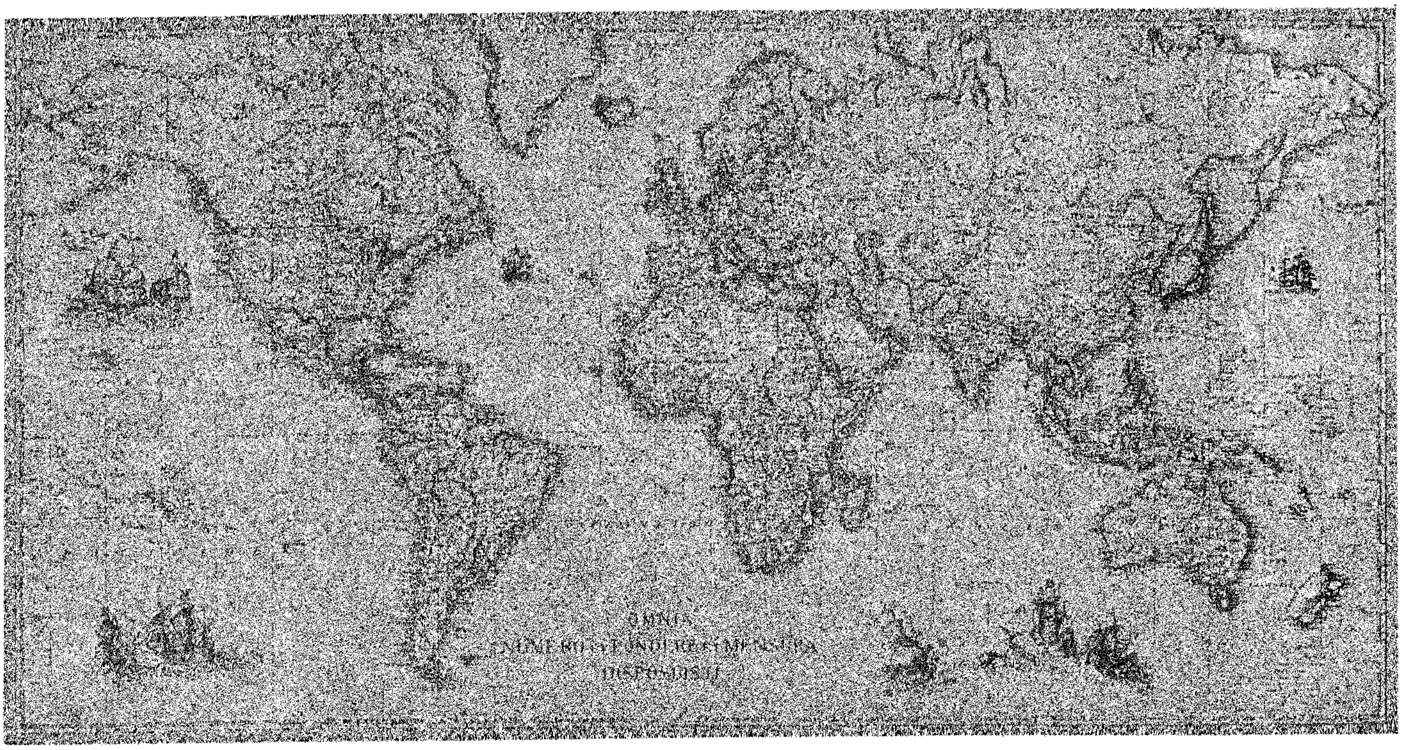
BULLETIN

DE

L'ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

Meilleurs voeux

Organe de Liaison entre les Etats-membres



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11, Rue Turgot — 75009 PARIS — France

Bulletin OIML n° 97
25e Année — Décembre 1984
Trimestriel
ISSN 0473-2812

BULLETIN
de
l'ORGANISATION INTERNATIONALE de MÉTROLOGIE LÉGALE

SOMMAIRE

Abonnement pour 1985 : Europe : 100 F-français
Autres pays : 120 F-français
Chèques postaux : Paris 8 046-24 X
Banque de France : B.P. 140-01 - 75049 Paris Cedex 01
Comptes Courants, Banques Etrangères : n° 5051-7

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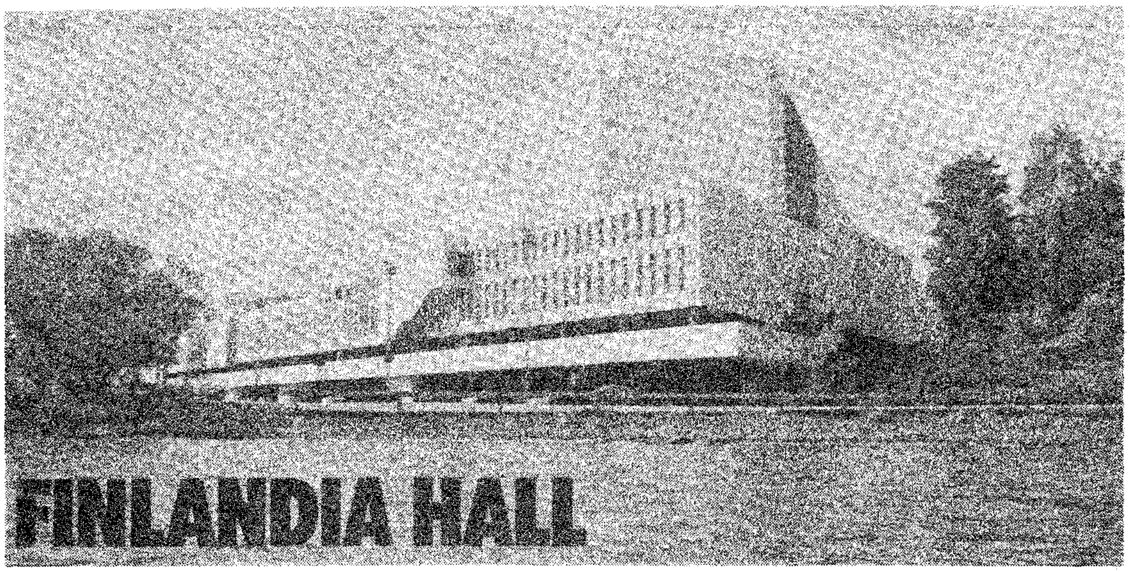
BRÈVES INFORMATIONS sur la SEPTIÈME CONFÉRENCE INTERNATIONALE de MÉTROLOGIE LÉGALE et la VINGTIÈME RÉUNION du COMITÉ INTERNATIONAL de MÉTROLOGIE LÉGALE



La Septième Conférence Internationale de Métrologie Légale s'est réunie à Helsinki, du 1er au 5 octobre 1984, sur l'invitation du Gouvernement de la Finlande. Plus de cent trente participants y ont représenté 37 Etats Membres de l'OIML, 3 Membres Correspondants et 11 Institutions Internationales, ainsi que la République Populaire de Chine qui n'est pas encore Membre de l'OIML.

La Conférence a été ouverte, dans la salle de réunion du Palais Finlandia, par Mr. LINDBLOM, Ministre du Commerce et de l'Industrie, et Mr. NAVALAINEN, Directeur en chef du Centre d'Inspection Technique. Elle a ensuite élu son Président et ses deux Vice-Présidents, respectivement le Prof. KAKKURI, Président du Conseil National de Métrologie de Finlande, Mr. ZLATAREV, Membre du CIML, Bulgarie et Mr. NDOUGOU, Membre du CIML, Cameroun.

La Conférence a tenu cinq sessions plénières et deux séances de commissions. Les questions les plus importantes sont résumées ci-après.

SITUATION PRESENTE ET FUTURE DE L'OIML

Dans son rapport d'activité, Mr BIRKELAND, Président du Comité International, a fait état des progrès réalisés par l'OIML durant les quatre dernières années, et aussi des difficultés rencontrées, en ce qui concerne en particulier la recherche de ressources nouvelles pour assumer les travaux toujours plus nombreux qui sont du ressort de l'Organisation. Il a également évoqué les changements souvent radicaux que connaissent beaucoup de Services nationaux de métrologie, en raison de l'extension de leurs activités et de la nécessité de moderniser toujours davantage les méthodes de travail. Il a insisté sur le rôle important, coordonnateur et moteur, que doit jouer l'OIML dans l'évolution de la métrologie légale.

TRAVAUX DES SECRETARIATS

Seize projets de Recommandations Internationales nouvelles et quatre projets de révision de Recommandations existantes ont été sanctionnés par la Conférence, qui a par ailleurs été informée de toutes les questions touchant aux travaux des Secrétariats : état d'avancement, mise en application dans les réglementations nationales, etc.

PAYS EN DEVELOPPEMENT

Le programme de travail pour 1985-1986, présenté par Mr. GOMEZ ROSELL, Membre du CIML pour Cuba et Président du Conseil de Développement de l'OIML, a été discuté et approuvé par la Conférence. Les représentants d'Institutions Internationales concernées par ces problèmes, comme le Commonwealth Science Council, ont confirmé leur souci de collaborer étroitement avec l'OIML.

COLLABORATION AVEC D'AUTRES INSTITUTIONS INTERNATIONALES

Les représentants des 11 Institutions Internationales présentes ont tour à tour pris la parole pour présenter leur point de vue en ce qui concerne leur collaboration avec l'OIML. Parmi elles, on citera en particulier l'ISO et la CEI, dont certains travaux normatifs sont étroitement liés aux activités de l'OIML. La Conférence s'est félicitée du bon état général de cette collaboration.

FINANCES

La Conférence a pris connaissance de la situation financière de l'Organisation et a voté le budget proposé pour la période 1985-1988.

CLÔTURE

A l'issue de ses débats, la Conférence a tenu à exprimer sa satisfaction à tous ceux qui avaient contribué au succès de la réunion, en particulier à Madame LÄHTEENMÄKI, Directeur du Département de Métrologie et Membre du CIML pour la Finlande, et à ses Collaborateurs.

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Le Comité International de Métrologie Légale a tenu sa vingtième réunion le lundi 1er en matinée et le vendredi 5 après-midi.

Un certain nombre de questions, administratives et techniques, ont été débattues ; en particulier un système de planification des travaux des Secrétariats de l'OIML a été adopté avant sa présentation à la Conférence. Par ailleurs le Comité a nommé Membre d'Honneur Mr. PERLSTAIN, qui quitte ses fonctions de Membre du Comité pour la Suisse le 1er janvier 1985.

Le Comité a enfin fixé sa vingt et unième réunion au printemps 1986.

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Cette semaine finlandaise a été marquée, pour le plus grand plaisir des participants, par trois réceptions offertes par le Ministre du Commerce et de l'Industrie de Finlande, le Maire d'Helsinki et le Président du Comité International de Métrologie Légale.

Certains constructeurs finlandais d'instruments de mesure avaient organisé, dans le Palais Finlandia, une exposition de leurs productions. Deux visites techniques et touristiques ont par ailleurs été proposées aux participants.

Allocution d'ouverture par Mr S. LINDBLOM, Ministre du Commerce et de l'Industrie de Finlande

Opening address by Mr S. LINDBLOM, Minister of Trade and Industry of Finland

BRIEF NOTE
on the SEVENTH INTERNATIONAL CONFERENCE of LEGAL METROLOGY and the TWENTIETH MEETING of the INTERNATIONAL COMMITTEE of LEGAL METROLOGY

The Seventh International Conference of Legal Metrology met in Helsinki at the invitation of the Government of Finland, from the 1st to the 5th October 1984. Over 130 delegates represented 37 OIML Member States, 3 Corresponding Members and 11 International Institutions as well as the People's Republic of China which is not yet Member of OIML.

The Conference was opened in the meeting hall of the Finlandia Hall by Mr. LINDBLOM, Minister of Trade and Industry and Mr. NAVALAINEN, Director General of the Technical Inspection Centre. The Conference elected its President and Vice-Presidents in the persons of Prof. KAKKURI, President of the National Metrology Council of Finland, Mr. ZLATAREV, CIML Member for Bulgaria and Mr. NDOUGOU, CIML Member for Cameroon.

The Conference held five plenary sessions and two commission meetings. A summary of the most important problems is given below.

PRESENT AND FUTURE SITUATION OF OIML

In his report on the activities of OIML, Mr. BIRKELAND, President of the International Committee, gave an account of the progress accomplished by OIML during the last four years, and of the difficulties which were encountered, especially concerning search for additional resources in order to tackle the ever increasing number of tasks which are within the competence of the Organization. He has also called to mind the often radical changes experienced by many of the National Metrology Services, caused by the widening of their activities and the necessity to continually modernize their methods of working. He pointed out that OIML, as the coordinating and driving force, has an important role to play in the evolution of legal metrology.

WORK OF SECRETARIATS

Sixteen new Draft International Recommendations and four Draft Revisions of existing Recommendations were sanctioned by the Conference ; in addition, the Conference was informed about all the problems concerning the work of the Secretariats, the state of progress of the work, the implementation in national regulations, etc.

DEVELOPING COUNTRIES

The work program for 1985-1986, presented by Mr. GOMEZ ROSELL, CIML Member for Cuba and President of the OIML Development Council, was discussed and approved by the Conference. The representatives of the International Institutions concerned with these problems, like the Commonwealth Science Council, have confirmed their wish to collaborate closely with OIML.

COLLABORATION WITH OTHER INTERNATIONAL INSTITUTIONS

The representatives of 11 International Institutions present one by one took the floor to present their points of view on the collaboration with OIML. Amongst them, one should quote in particular ISO and IEC since their standardization work is closely linked with OIML activities. The Conference was pleased about this very successful collaboration.

FINANCES

The Conference took note of the financial situation of the Organization and adopted the budget proposed for the 1985-1988 period.

CLOSURE

At the end of the discussions the Conference expressed its thanks to all who have contributed to the success of the meeting especially to Mrs. LÄHTEENMÄKI, Director of the Department of Metrology and CIML Member for Finland, and to all her Collaborators.

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The International Committee of Legal Metrology has held its 20th meeting, Monday morning 1st and Friday afternoon 5th of October.

A number of administrative and technical problems were discussed ; in particular, a system of planning the work of OIML Secretariats was adopted before being presented to the Conference. In addition, the Committee elected as Honorary Member Mr. PERLSTAIN, who is vacating his position as Committee Member for Switzerland on 1st January 1985.

To conclude, the Committee fixed its 21st meeting for spring 1986.

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The week of meetings in Finland included three receptions which were offered for the entertainment of the participants by the Ministry of Trade and Industry of Finland, the Mayor of Helsinki and the President of the International Committee of Legal Metrology.

Some of the Finnish manufacturers of measuring instruments had arranged an exhibition of their products in the Finlandia Hall and two technical and turistic visits were organized for the participants.

REP. FED. D'ALLEMAGNE

PATTERN APPROVAL PRINCIPLES for ELECTRONIC MEASURING INSTRUMENTS

by **E. SEILER**

Physikalisch- Technische Bundesanstalt, Braunschweig

SUMMARY — The author explains the divergences of views which exist between some countries concerning criteria for pattern approval of electronic instruments. Referring to a recent IEC TC 66 draft document he personally suggests the use of the square law of combination of partial errors when estimating the over-all metrological performance of instruments subject to external influences. He also discusses the difficulties of legally ensuring this performance over long periods of time.

RESUME — L'auteur explique les différences de points de vue qui existent entre certains pays en ce qui concerne les critères d'approbation de modèle des instruments électroniques. En se référant à un projet du Comité d'Etude N° 66 de la CEI, il suggère l'utilisation de la loi quadratique de combinaison des erreurs lorsqu'il s'agit d'estimer les performances métrologiques globales d'instruments soumis aux influences extérieures. Il traite également les difficultés pour assurer sur le plan légal le maintien de ces performances pendant de longues périodes de temps.

1. Introduction

The efforts to reach agreement on requirements for measuring instruments subject to mandatory verification either regionally within the European Community (EC) or world-wide through the International Organization of Legal Metrology (OIML) have been successful in the field of mechanical measuring instruments.

The negotiations are however not yet finalized as concerns general requirements for electronic measuring instruments, although the latter have already superseded the mechanical measuring instruments in many fields.

The discussions held at an international level have shown how different the national requirements for the pattern approval of measuring instruments are. Some ideas concerning this problem will be discussed here.

For testing of the correctness of measurement, a method is proposed which differs from requirements set up for example in the OIML-Recommendation on Sound Level Meters [14] which is based on the Publication 651 of the International Electrotechnical Commission [15]. According to this publication the measuring instrument is tested under different influence quantities and permissible deviations from the correct values are specified for each influence quantity. The method proposed here is based on the maximum permissible error concept used in legal metrology. The same approach has been described in the draft of the International Electrotechnical Commission (IEC) entitled « Expression of the performance of electrical and electronic measuring equipment, 66 (Secretariat) 48 » [1].

For the testing of the stability of a measuring instrument which has not been dealt with in the above-mentioned IEC draft, differentiated methods will be proposed which conform to the specific conditions.

As an introduction into the special problems involved, some basic principles of Legal Metrology will be elucidated and the specific properties of electronic components indicated.

2. Basic principles of Legal Metrology

In the sense of legal metrology, the indication of a measuring instrument is correct if the maximum permissible errors are complied with.

In some countries, however, measuring instruments will be verified only if they comply with sufficient probability with these maximum permissible errors over a sufficiently long period - at least for one period of validity of verification. The organs of state guarantee the stability of the measuring instruments by a system of pattern evaluation and verification at regular intervals. Measuring instruments whose stability is debatable are not approved (preventive system). In other countries, these precautionary measures are not as far-reaching. The certification covers only the correctness at the moment of initial verification. A routine subsequent verification is not generally carried out. The user of the measuring instrument must himself ensure that it is correct. He will be responsible for applying for a subsequent verification if he has any doubts. The verification officers make spot checks to find out whether this obligation is met (repressive system).

This explains why different criteria are applied when measuring instrument patterns are approved, according to whether the verification system is of a preventive or a repressive nature.

In the first case, the long-term behaviour - the stability - is a decisive criterion for approval, whereas in the latter case, this property is not of such great importance.

In addition to the specific problems of electronic measuring instruments, these differences between the national systems are a hindrance to international approximation efforts.

3. Special features of electronic measuring instruments

A special feature of electronic measuring instruments is their sensitivity to electric, magnetic, electromagnetic and electrostatic influences. There are numerous examples from all fields of application in electronics for the effect of these influences : aircraft and rocket crashes, accidents of motor cars with electronic antiskid braking systems as well as errors in indication of measuring instruments which are of particular interest here [2] [3].

Electromagnetic disturbances can occur in any place where a measuring instrument is used. It must therefore be required that within definite limits, measuring instruments should be insensitive to such disturbances if they are intended to be used in Legal Metrology. This must be checked within the scope of pattern approval. As compared with mechanical measuring instruments which are essentially influenced by the quantities temperature, air moisture and, possibly, atmospheric pressure, this implies a considerable extension of the environmental tests.

In this connection the question arises which variations of the indication of measuring instruments are permissible under the effect of an influence quantity and how to empirically assess the effect of all influence quantities.

Another special feature of electronic components is that their failure does not announce itself ; it occurs sporadically. There are usually no symptoms of fatigue or wear as with mechanical components. A precautionary replacement of components after a definite time of use aimed at preventing failures is not possible. It is often not practicable to assess the reliability on the basis of computation models, as safe values, for example, for the mean-time between-failure of components are not available at the time of approval. Owing to the rapid development of new electronic components, this situation occurs repeatedly.

It is understandable that under these circumstances the requirements depend strongly upon whether or not the stability is an essential prerequisite for the approval.

4. Checking of the correctness of measurement

Within the scope of pattern approval [4], it is to be investigated whether correct measurement results can be expected of the pattern within the normal operating ranges (*).

The following method to check the correctness of measurement is proposed :

(1) determination of the intrinsic errors of the measuring instrument under reference operating conditions,

(2) determination of the deviations in indication under the effect of influence quantities within the normal operating ranges of the measuring instrument,

(3) estimate of the maximum error under normal operating conditions.

Determination of the intrinsic errors under reference operating conditions

Reference operating conditions are defined in order to allow the intrinsic error of measuring instruments to be determined and compared with that of other measuring instruments.

For the influence quantities temperature, relative air moisture and atmospheric pressure, reference values are laid down at an international level [5] :

e.g. $T = 20\,°C \pm 1\,°C$

rel. air moisture : 63 % to 67 %

atm. pressure : 860 mbar to 1 060 mbar.

Reference values or reference ranges for the other influence quantities must be so selected that their influence upon the measurement result is negligible.

The specimen must have been adjusted by the manufacturer. The reference operating conditions must be provided.

The intrinsic errors of the measuring instrument are to be determined in a sufficient number of points within the mesuring range.

If a reference range (e.g. $15\,°C \leqslant T \leqslant 25\,°C$) is specified instead of a reference value (e.g. $T = 20\,°C$), the intrinsic errors must be determined at the limits of the range.

The intrinsic errors are determined as the deviation of the indicated value from the conventional true value in a sufficient number of points within the measuring range. The conventional true value is obtained using a measurement standard whose errors must be negligible or known with sufficient accuracy and corrigible. To decide whether a sufficient accuracy of measurement can be expected of a pattern, the testing of one specimen of the pattern will normally not suffice. At least three specimens are therefore to be tested to assess the pattern-specific dispersions of the intrinsic errors. If it turns out that the intrinsic errors for the same measuring point show distinct differences (i.e. dispersion exceeding half the maximum permissible errors on initial verification), additional specimens must be included into the pattern evaluation.

(*) The terms used here are those defined in the IEC draft document 66 (Secretariat) 48.

If errors are discovered which exceed or are equal to the maximum permissible error on initial verification, it must be investigated whether they are due to incorrect adjustment or calibration. This can be inferred if all the intrinsic errors can be reduced by addition/subtraction of a constant value (zero drift) and/or multiplication by a constant factor (change in sensitivity).

If the measuring instrument can be adjusted more accurately, it will not be necessary to stop pattern approval. The manufacturer must be informed of the incorrect adjustment/calibration and its causes eliminated (e.g. by readjustment of the manufacturer's standards).

If the errors are pattern-specific or the manufacturer does not ensure correct adjustment/calibration, the pattern evaluation must be stopped. Should the dispersion be equal to or exceed half the maximum permissible error on initial verification in one or more measurement points, the intrinsic errors must be determined for (three) additional specimens. If a substantial amount of the dispersion is due to systematic errors of adjustment/calibration, the manufacturer must be informed that he will encounter difficulties in the initial verification of the instruments if he does not carry out the adjustment/calibration more thoroughly.

Of interest are the extreme values of the intrinsic errors of all specimens tested. In the example given in fig. 1 the maximum values are represented by specimen 2 marked by a cross with the exception of point B, where the maximum value is given by specimen 1 marked by a triangle. The minimum values are represented by specimen 3 and marked by a dot. For the further considerations it is assumed that the intrinsic errors of other measuring instruments of this pattern are within the range of these extreme values.

Determination of the deviations in indication under the effect of influence quantities under normal operating conditions

Measuring instruments are used only seldom under reference operating conditions. When used under normal conditions, they are subjected to environmental influences which can have effects upon their metrological properties.

To ensure proper use, the permissible ranges of the various influence quantities (normal operating ranges) must therefore be stated. These ranges must be specified by the manufacturer or defined during pattern approval. The IEC document 359 defines ranges for three different degrees of severity which may serve for orientation [6].

Under normal operating conditions the measuring instruments must not exceed the maximum permissible errors in service. The experimental check must cover all quantities which tend to influence the metrological properties of the measuring instrument.

If, for example, vibrations are to be anticipated when a measuring instrument is used because it is of the portable type or such vibrations can occur at the place of installation (personal dosimeters, taximeters), their influence must be investigated. If, however, measuring instruments are concerned which are verified at their place of use and not subjected, or allowed to be subjected, to considerable vibrations (e.g. Class I weighing instruments), this investigation will be dispensed with. Normal operating ranges need not be defined if the influence quantities involved do not or cannot have an appreciable effect. If there are any doubts, this should be checked by experiments. Within the scope of pattern approval, in particular the efficiency of special protective devices against definite influence quantities should be checked. The manufacturer's statement « hermetically enclosed » does not suffice to dispense with moisture tests.

Carrying-out of the tests

As the experimental determination of the most unfavourable combination of all influence quantities is practically scarcely possible and would entail considerable

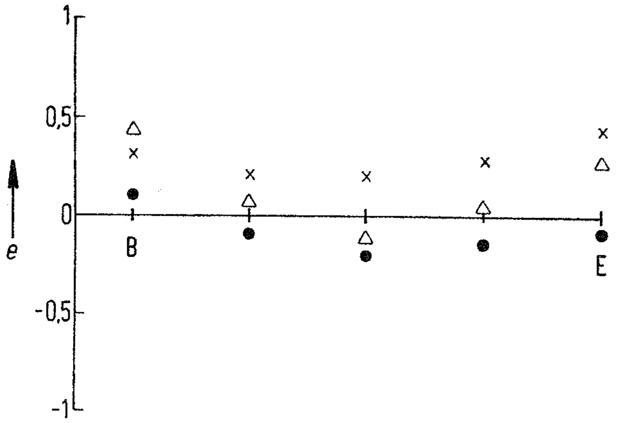

Fig. 1

Intrinsic errors of 3 measuring instruments of the same pattern under reference conditions

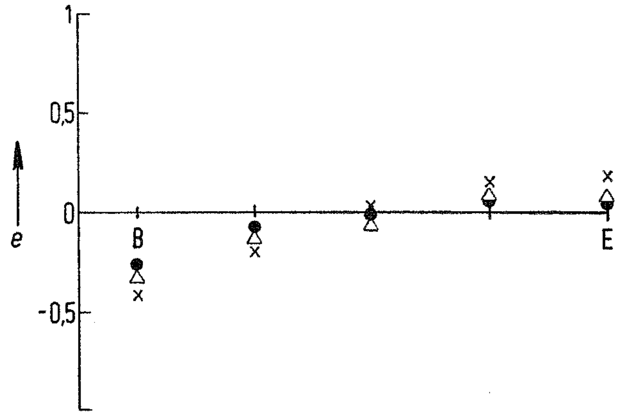

Fig. 2

Deviations under the effect of the influence quantity Q_1 within the nominal operating range (partial error) for 3 measuring instruments of the same pattern.

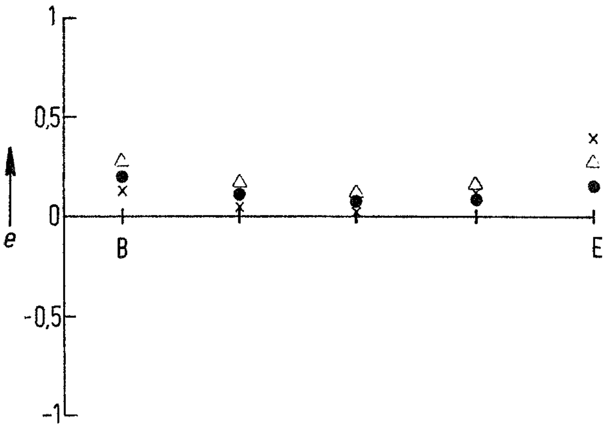

Fig. 3

Deviations under the effect of the influence quantity Q_2 within the nominal operating range (partial error) for 3 measuring instruments of the same pattern.

Δ Specimen 1
× Specimen 2
● Specimen 3

e maximum permissible error on initial verification
B lower limit of the specified measuring range (minimum capacity)
E upper limit of the specified measuring range (maximum capacity)

expense, the effect of only one influence quantity is determined at a time. For all the other influence quantities reference operating conditions are provided which are not altered during the testing process which is carried out as follows :

(1) Provision of the reference operating conditions (as for the determination of the intrinsic errors).

(2) Stepwise change of the first influence quantity Q_1 up to the upper limit of the operating range $Q_{1\,(max)}$ and subsequently down to the lower limit $Q_{1\,(min)}$.

Determination of the deviation of the indication of the measuring instruments with respect to the indication under reference conditions for all steps and measurement points used for determining the intrinsic errors.

The influence quantity must be changed by such steps that the maximum effect of the influence can be covered or extrapolated with sufficient accuracy.

(3) These deviations must be plotted over the measuring range for all values of the influence quantity Q_1 between $Q_{1\,(max)}$ and $Q_{1\,(min)}$ including these limiting values, in units of the maximum permissible error on verification e (Fig. 2).

(4) Repetition of point (1).

(5) Repetition of point (2) for the second influence quantity Q_2.

(6) Repetition of point (3) for the influence quantity Q_2 (Fig. 3).

The sequence described in points (1) to (3) is repeated for all other influence quantities Q_3, Q_4, ... Q_n.

Note : If instead of a reference value (e.g. $T = 20\,°C$) a reference range (e.g. $15\,°C \leqslant T \leqslant 25\,°C$) is specified for an influence quantity and the deviations differ clearly within the reference range, different reference conditions must be provided, as when the reference characteristic curve is determined (upper limit of the reference range, lower limit of the reference range). The effect of the influence quantities must be determined for these different reference conditions.

As a result of the tests, the effect of the influence quantities has been determined for a definite number of measurement points within the measuring range. The extreme deviations ascertained on the specimens tested within the measuring range are regarded as specific to the pattern. These deviations will hereinafter be referred to as partial errors F_n of the n influence quantities. In the example given in fig. 2 the pattern specific partial positive errors for the influence quantity Q_1 are zero for the first three measuring points and represented by specimen 2 and marked by a cross for the last two measuring points. The pattern specific partial negative errors are represented by specimen 2 for the first two measuring points, by specimen 1 for the third measuring point and are zero for the last two measuring points.

Estimate of the maximum errors under normal operating conditions

Method 1 : Linear addition of the partial errors (worst case errors)

Here and in the following, the intrinsic error is treated as a partial error. For each measurement point the pattern-specific partial errors of all influence quantities including the intrinsic error are combined as follows to form the pattern-specific operating errors : The sum of all positive partial errors yields the upper values and the sum of all negative partial errors the lower values of the operating errors which are considered representative of the pattern. In no point within the measuring range must these extreme values of the operating errors exceed the specified maximum permissible errors in service if the pattern is to be approved. Otherwise, the pattern must be rejected because the correctness of measurement is not ensured.

Before such a step is taken, it might be investigated whether the requirements on the correctness of measurement can be met if one or several normal operating ranges are reduced and whether the pattern can be approved under restricted normal operating conditions.

The method of linear addition of the partial errors yields extreme values of the operating errors which can be reached in the most unfavourable case with a corresponding combination of the influence quantities. As this is very seldom the case, these error values are too pessimistic.

Therefore this method is recommended if only one or very few influence quantities produce an effect on the measurement result ; it should be applied if exceeding the maximum permissible errors in service would have extremely serious consequences.

Method 2 : Geometrical addition of the partial errors

A more realistic estimate of the extreme values for the operating errors F, which is recommended for application, is obtained by extracting the root of the sum of the squares of the partial errors for all measuring points m.

$$F_m = \pm \sqrt{\sum_{i=o}^{n} F_{i,m}^2}$$

F_i pattern-specific partial error due to the i[th] influence quantity Q_i.

The intrinsic error is considered to be the partial error F_o under reference operating conditions.

m number of measuring point.

F_m operating error in measuring point m.

In the Annex to [1], this estimate is founded on considerations from the probability theory and statistics. The root is there preceded by the factor 1.15 which, on the assumptions made, pertains to a probability of 95 % that the maximum permissible errors thus calculated are not exceeded. As these assumptions are not always justified the factor 1.15 is dispensed with here, which results in a slightly different probability. The same formula is also used by others [18].

5. Checking of the stability

Not only the correctness of measurement but also the stability must be assessed. In the Federal Republic of Germany those patterns of measuring instruments are considered to be stable which, at the end of the period of validity of verification, still comply with the maximum permissible errors (with a probability of about 95 %). This statement applies to measuring instruments intended for use in commercial transactions.

For reasons which have already been stated above, the assessment of the stability of electronic measuring instruments is not as easy as that of mechanical measuring instruments for which it is possible to ascertain by endurance tests when symptoms of fatigue occur and what components must be replaced after what time of service. Besides the failures which are independent of time, electronic components are also subjected to drift and aging.

Furthermore, there is no electronic measuring instrument without printed boards, plug-type connectors, connecting cables or electromechanical components such as contactors, relays and circuit breakers. These non-electronic components show age-related failure mechanisms [7], [8].

What requirements must be made on the stability and how can the stability be proved ?

There is no simple answer to this question. The answer depends in essence upon the consequences which can result from the failure of a measuring instrument or an incorrect measurement. Danger to life and health justifies effort and outlay which cannot be answered for when measuring instruments are concerned which are used on the market. This results in the necessity of carrying out most varied tests within the scope of pattern approval. If checking the correctness of measurement on a sufficient large number of measuring instruments takes many months, which is not unusual with complex measuring facilities, the stability can be assessed at the end of the tests, and additional tests need not be carried out.

For simple patterns long testing times cannot be accepted.

For pattern approval which dispenses with endurance tests some metrology services require special measures to control the correct operation of electronic measuring instruments.

The principle of operational fault perceptibility is widely applied in particular to weighing machines and liquid measuring facilities. The concept is described in detail in [9], [10] ; applications for weighing machines and liquid measuring facilities are given in [11] and [12]. In the following, only the underlying idea will be highlighted :

The measuring signal is checked by suitable circuit patterns. Any error is signalled to the user of the measuring instrument. The kind and extent of the measures to be taken for perceiving operational faults depend upon the application of the measuring instrument and the type of the measuring signal (analog, incremental, coded). With measuring instrument types which are operated by specialized staff (e.g. class I weighing instrument), checking by hand is permissible, whereas, for example, for weighing machines used in direct selling to the public, automatic controls are required.

Checking facilities increase neither the stability nor the reliability. When conceived and executed properly, they signal incorrect measurements to the user and possibly prevent further measurements. This technique allows correct and false measurements to be distinguished. A more advanced technique allows for the construction of self-calibrating measuring instruments. Although this is not a requirement, the option of self-calibration would be a great step forward to reach the objectives of legal metrology.

If operational fault perceptibility is not possible or not provided, the stability must be checked. The Verification Act of the Federal Republic of Germany [13] allows practical trial by approvals which imply certain restrictions. Either only a limited number of measuring instruments is approved for verification or the validity of the approval is limited as to time. It is also possible to take both measures at a time. The lifting of the restrictions is made contingent on the metrological properties of the instruments under conditions of practical use. Checks carried out at regular intervals on a number of instruments furnish the required information. The approval procedure is concluded only after the practical trial. If the measuring instruments have not given satisfactory results, further specimens will not be approved. Changes to the instruments already in use can be required or their further use can be prohibited.

As compared with this procedure, an assessment of the stability without practical trial is more difficult and more expensive. In general it requires an analysis of the measuring instrument with respect to

— the design (measuring principle, mechanical design, design of the electric circuits, protection from external disturbances, permissible normal operating ranges)
— the components used (drift and aging behaviour, rates of failure, grades)
— the loading of the components (stress ratio)
— the manufacturing methods (e.g. for wire connections : soldered by hand, soldered mechanically, wire-wrap, welded, plug-type connection)
— the quality assurance measures (inspections on delivery, production control and aging of components and subassemblies, extent and thoroughness of the operational checks, qualification programmes for critical components).

After this analysis, model calculations must be carried out with a view of obtaining data on the failure rates to be expected of the measuring instrument. These calculations presuppose that the manufacturing and the components used will not be changed. On account of the great number of simplified assumptions underlying the calculation, its correctness must be supported empirically. To shorten testing times, methods are preferred which accelerate failure processes. The best-known methods are time compression processes for components by storage and static and dynamic operation at high ambient temperatures (up to 100 °C or more). They can, however, be applied to measuring instruments only with reservations. The ambient temperature must not result in an inadmissibly high load and, thus, in a failure due to stress of temperature-sensitive components.

The indication of a time compression factor which is representative of the measuring instrument implies problems, as quite different factors can be valid for individual components. Both experimental and theoretical checking of the reliability requires a lot of experience and a great deal of special knowledge.

Each pattern involves new problems. Simple, universally valid solutions cannot be applied. In addition to the expenses involved, this may be decisive for the fact that in Legal Metrology, the other solutions are preferred.

6. Conclusions

One of the important reasons for the delays which have occured in approximating the different national requirements on electronic measuring instruments is that the different strategies according to which the national verification services act (repressive or preventive) are not allowed for.

Advocates of the preventive system must make requirements on the stability and require its proof, whereas this may appear to be connected with too great an effort and outlay to the representatives of the repressive system. An agreement would be possible only if one of the systems was abandoned. This would, however, result in so far-reaching consequences that it is easier to dispense with requirements approximated at an international level.

A potential alternative would be to restrict the approximation efforts to the correctness of measurement. Requirements on the stability would have either to be reserved to national regulations or approximated between the states which make such requirements. With this proposal, the aim of coming to a general solution would be abandoned to the advantage of partial solutions.

It should be easier to reach an agreement on requirements on the correctness of measurement. There are no fundamental doubts about the necessity of the proposed operational tests under the effect of influence quantities. It will be possible to agree on the limiting values of the influence quantities to be checked. In this connection, practical experience and standard values are available which are accepted on an international level.

For the judgment of the correctness of measurement, the method described in point 4 offers the following advantages : The total errors of the measuring instrument for the intended range of use are estimated and compared with the maximum permissible errors assigned by the competent legal authorities. This is a very direct method, which avoids the establishment of maximum permissible variations of the effect of individual influence quantities. These maximum permissible variations have to be fixed arbitrarily with the following consequences. If a value equal to or negligibly smaller than the maximum permissible error is permitted, the simultaneous effect of only two or three influence quantities can result in the maximum permissible error being exceeded.

If only a fraction of the maximum permissible error is permitted, it will not be possible to approve patterns in which only one influence quantity yields to a variation greater than the permissible one even if the influence of the other quantities is negligible. While the first case involves the risk that measuring instruments do not comply with the maximum permissible errors under normal conditions of use, in the second case, very good patterns will not be approved because they are sensitive to one influence quantity whose effect does not result in the maximum permissible error being exceeded.

All these difficulties can be avoided if the effects of all influence quantities are ascertained and the correctness of measurement is assessed as described.

As Legal Metrology has already penetrated such fields as environmental protection, medical metrology, radiation protection, road traffic surveillance, it must also deal with findings from these fields which have been embodied in international performance requirements. A good occasion for this is the attempt to prepare requirements on electronic measuring instruments harmonized on an international level.

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REP. DEM. ALLEMANDE

A STANDARD CALIBRATOR for AIR HYGROMETERS

by Dr. **G. SCHOLZ**

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SUMMARY — This article describes the standard air humidity generator used by ASMW for calibration of air hygrometers. The article analyses in detail the various sources of error, the global influence of which results in a total relative uncertainty of 0.3 % in the mixing ratio of dry and water vapour saturated air.

The article has previously been published in German in ASMW Abhandlungen Heft 3, 1981.

RESUME — Cet article décrit un générateur étalon d'air humide utilisé par l'ASMW pour étalonner des hygromètres. L'article fait une analyse détaillée des différentes sources d'erreurs dont l'influence globale contribue à une incertitude relative de 0,3 % dans le rapport de mélange d'air sec et d'air saturé de vapeur.

Cet article a déjà été publié en allemand dans ASMW Abhandlungen, Heft 3, 1981.

1. Introduction

The present top requirements on accuracy of humidity measurement in industry and research may be characterised by an uncertainty of about 1 %. To give such measurements with very high level of accuracy a sufficient metrological basis, it is necessary to have standards with uncertainties of measurement of a few tenths of a per cent. In some countries exist already hygrometric standard devices which allow humidity measurements with a relative uncertainty of about 0.2 — 0.3 %, see [1], [2], [8]. Following these international trends, the Office for Standardization, Metrology and Quality Control (ASMW) has also set up a hygrometric standard device for a medium range of humidity. This device which in the meantime has been approved as a national standard is described in detail in this paper.

2. General Data of the Device

2.1. Basic Concept

The standard device represents the mixing ratio of moist air, defined as ratio of the mass of vapour to the mass of dry air in a given volume. This mixing ratio is the most suitable basic characteristic to be used for the elaboration of a hygrometric hierarchy scheme since it is independent of pressure and temperature changes of moist air, provided condensation, evaporation and sorptive moisture exchange are excluded.

The standard device fulfils the following basic functions :

— generation of a continuous flow of moist air with a constant mixing ratio (humidity generator) ;

— gravimetric fundamental determination of the mixing ratio (gravimetric hygrometer).

Its working range is characterised by the following data :

mixing ratio : 1.10^{-3} to 30.10^{-3} kg/kg

dew point temperature : — 16 to + 32 °C

absolute humidity : 1 to 34 g/m^3

relative humidity : 5 to 100 % for + 32 °C air temperature
30 to 100 % for — 5 °C air temperature

air temperature : — 5 to + 32 °C

air pressure in the test chamber : normal atmospheric pressure.

2.2. Gravimetric hygrometer

The principle of measurement of the gravimetric hygrometer is the separation of vapour and dry air and the separated absolute determination of their masses, see Fig. 1. For this purpose moist air from the outlet of the humidity generator is sucked into evacuated vessels. Three U-tubes containing highly effective dehydrating agents which absorb vapour are fixed in the suction stream. Phosphoric oxide P_2O_5 and magnesium perchlorate $Mg(ClO_4)_2$, mixed with a hygroscopically inactive material, are used as dehydrating agents. A needle valve is employed to adjust the flow rate of air.

The mass of absorbed vapour is determined by weighing of U-tubes before beginning and after finishing of a filling cycle.

The mass of dry air is indirectly determined by the density of air and the volume of collecting vessels. The exact volume of the vessels has been determined before assembling the device. For the determination of density it is necessary to measure pressure and temperature of collected dry air. Since with decreasing mixing ratio more air has to be sucked in, two vessels of 30 litres are employed, which can alternately be filled and evacuated and are built-in completely in a thermostatic bath. A barometer is used for leakage testing of the drying system. An auxiliary drying unit is necessary to dehydrate the system by means of dry air and to perform blank tests (see also 5.1.1.4.).

2.3. Humidity generator

The functional principle of the humidity generator is shown in Fig. 2. Compressed air from a compressor unit is adjusted by means of pressure reducing and control valves to a constant pressure in the interval from 0.11 to 0.3 MPa, it then bubbles through distilled water in a humidifier and is thus caused to reach a high relative humidity. After that it flows to a saturator which virtually is a heat exchanger. In the saturator the air flows through copper spirals in a thermostatic bath and, while doing so, conforms to the temperature of the bath which has been adjusted to a temperature which is by a few Kelvin lower than that of the humidifier. That means, flowing-in air is oversaturated with respect to the saturator's temperature, and cooling of air leads to precipitation until a full equalization of temperature of air and bath has been reached. The condensate may be removed through a separate outlet from time to time. After having passed the saturator, compressed air is adjusted to normal atmospheric pressure by means of a pressure reducing valve.

A pressure drop develops on a capillary tube the length of which can be varied, in order to guarantee constant flow rates, independent of the pressure. By passing another heat exchanger the air gets to the test chamber. The pressure reducing valve and the test chamber are in a joint thermostatic bath. The temperatures t_s and t_k of the bath of the saturator or test chamber are independently adjustable. To avoid condensation at the saturator outlet, the condition $t_s < t_k$ must be fulfilled. From the test chamber which has a volume of about 6 litres and is equipped with connections for sensors as well as for thermometers and pressure gauges, air is let into the room.

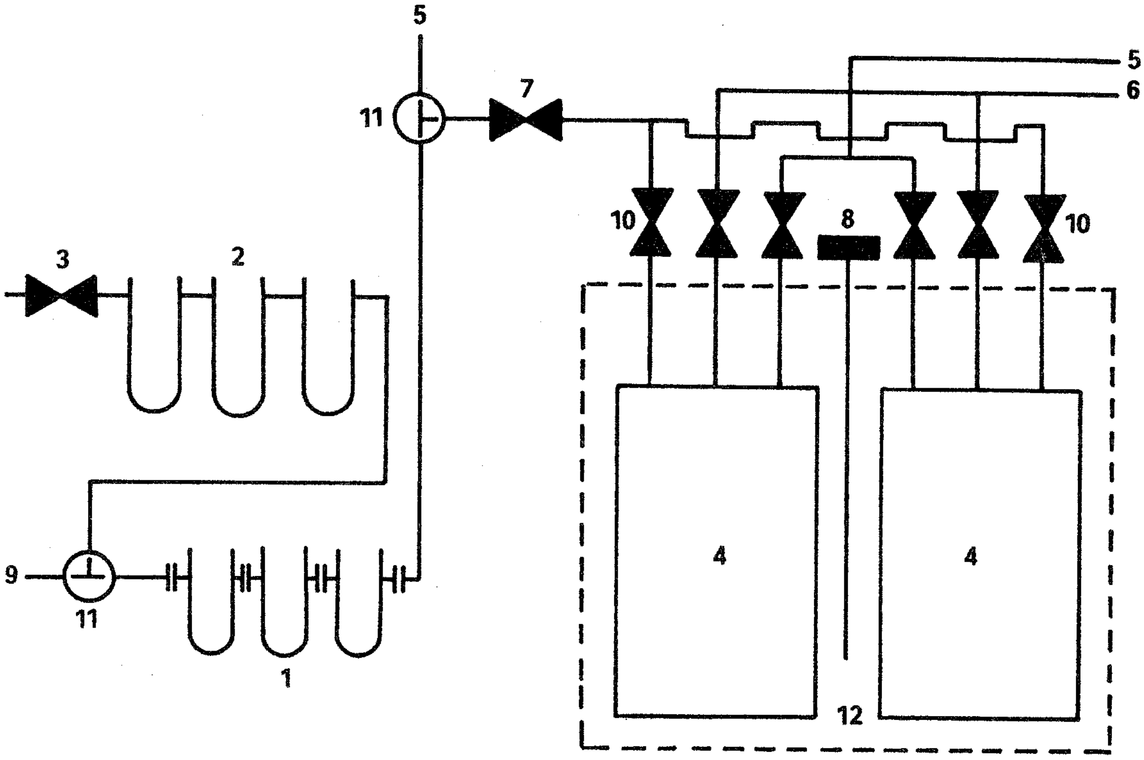

Fig. 1

Schematic diagram of the gravimetric hygrometer

1 - dehydratation system (U-tubes), 2 - auxiliary drying unit, 3 - inlet valve, 4 - collecting vessels, 5 - connection to barometer, 6 - connection to vacuum, 7 - needle valve, 8 - resistance thermometer, 9 - inlet of moist air, 10 - vacuum valves, 11 - three-way cock, 12 - thermostated bath ;

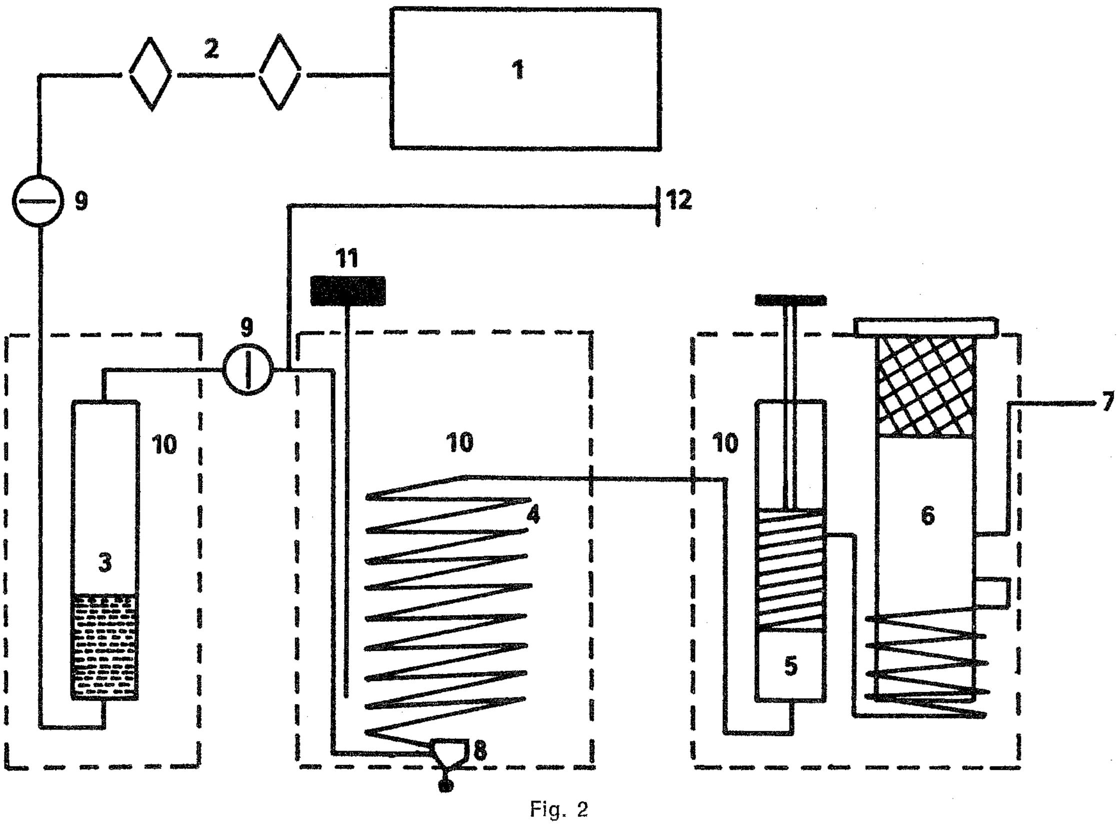

Fig. 2

Schematic diagram of the humidity generator

1 - compressor, 2 - pressure regulator, 3 - humidifier, 4 - saturator, 5 - pressure reducing valve, 6 - test chamber, 7 - outlet, 8 - condensate outlet, 9 - cock, 10 - thermostated bath, 11 - resistance thermometer, 12 - connection to piston-type pressure gauge

3. Operating Mode of the Humidity Generator

3.1. Calculation of mixing ratio

For saturated moist air the relationship between the mixing ratio, pressure p and temperature t of moist air is as follows :

$$r = 0.622 \frac{e_w(t)\ f_w(t,\ p)}{p - e_w(t) \cdot f_w(t,\ p)} \qquad (1)$$

Where :

0.622 is the ratio of relative molecular masses of vapour and dry air.

$e_w(t)$ is the saturation vapour pressure of water in the pure phase (to be substituted by the saturation vapour pressure of ice e_i (t) at temperature below 0 °C) to be taken from literature (3, 4). $f_w(t, p)$ is a factor for the nonideal gas correction of the saturation vapour pressure. It defines a so-called saturation vapour pressure of moist air :

$$e'_w = f_w(t,\ p)\ e_w(t) \qquad (2)$$

$f_w(t, p)$ varies from 1.004 to 1.012 in the temperature and pressure range of the humidity generator.

Substituting the temperature t_s and the pressure p_s of the air in the saturator in equation (1), one gets the mixing ratio r on the outlet of the saturator and with it also for the air in the test chamber. Knowing the temperature t_k and pressure p_k in the test chamber from the mixing ratio other humidity characteristics may be calculated such as the relative humidity, absolute humidity and dew-point temperature.

3.2. Metrological relationship between humidity generator and gravimetric hygrometer

The application of equation (1) to calculate the mixing ratio presumes that the exact saturation state is reached in the saturator, i. e. that no delay in condensation occurs, no droplets of water are carried along by the flow etc. The calibration of the humidity generator by means of the gravimetric hygrometer serves to check the validity of these premises. This is to be done as follows : $e_w(t_s)$ and p_s are substituted in equation (1) and also the value of r obtained by gravimetric determination. This leads to an expression for determination of $f_w(t_s, p_s)$. If f_w proves to be a reproducible function of t_s and p_s in the whole range of operation of the humidity generator and is in full agreement with the theroretical and experimental values given in (3) and (5), the premise as mentioned above may be considered to be fulfilled. After successful calibration of the humidity generator the gravimetric procedure is only used for periodic checks of correct operation.

A difficulty involved in the described procedure of calibration results from the fact that the gravimetric hygrometer gives only an integral value of r determined for a full cycle of measurement, i.e. for periods of about 30 min up to several hours, without regard for short-time variations of that quantity resulting from fluctuation of temperature and pressure in the saturator. For that reason a calibration on the basis of the above procedure is only possible, if for the period of a full gravimetric cycle the deviations of p_s and t_s from their mean values with respect to time $\overline{p_s}$ and $\overline{t_s}$ are small enough so as to be able to finish a power series expansion of equation (1) with the linear term.

4. Results of Calibration of the Humidity Generator

4.1. Stability of pressure and temperature

A high stability of pressure in the saturator is realized by several pressure regulators between the compressor and entrance of generator. Pressure fluctuations observed during various cycles of gravimetric measurements are smaller than 0.2 % of the mean value of pressure. The control of the saturator temperature is accomplished by direct connection of the thermostatic bath to a cryostat. Maximum deviations of temperature from its mean value are about 0.02 K.

The same stability of temperature has been found in the bath of the test chamber. The latter is without influence on the adjustment of mixing ratio, but it is decisive for the stability of relative humidity in the test chamber.

4.2. Calibration

The following table gives for some selected working points, characterized by t_s and p_s, a comparison of the values f_{exp} found by calibration and the theoretical values f_{th} from literature [5]. The confidence level is 0.99. The number of gravimetric determinations for the single working points is n.

f_{exp}	f_{th}	p_s	t_s	n
		MPa	°C	
1.0082 ± 0.0008	1.0069 ± 0.0006	0.2	20	37
1.0090 ± 0.0030	1.0074 ± 0.0006	0.2	0.4	10
1.0059 ± 0.0018	1.0055 ± 0.0004	0.15	5	8
1.0065 ± 0.0014	1.0069 ± 0.0004	0.2	20	8
1.0053 ± 0.0024	1.0055 ± 0.0002	0.15	25	10
1.0061 ± 0.0008	1.0051 ± 0.0002	0.13	28	9

There is no significant systematic deviation between f_{th} and f_{exp}. This may be understood as a validation of the premise mentioned above, that in the saturator is set up the exact state of saturation and the mixing ratio may be determined on the basis of equation (1).

5. Error Analysis

The accuracy of measurement of the hygrometric standard device is analysed as specified in [6]. Constant probability density functions (equidistribution) are assumed for all systematic components of error. Error propagation is performed by a procedure which equalizes the linear (too pessimistic) and quadratic (too optimistic) propagation. For random components of the error the well-known formulas of quadratic error propagation are used.

5.1. Gravimetric hygrometer

The mixing ratio r is determined by the gravimetric hygrometer in accordance with the defining equation :

$$r = \frac{m_w}{m_l} \qquad (3)$$

m_w is the mass of vapour,

m_l is the mass of dry air.

5.1.1. Determination of the mass of vapour

The essential sources of error for determination of m_w are : incompleteness of absorption of vapour, weighing errors, leakage effects and an empirical determined complex error, here to be called « manipulation error ».

5.1.1.1. Weighing errors

Weighing is performed by a substitution method. Buoyancy corrections have been kept as small as possible by chosing a suitable volume of the U-tubes and the weighing method. The residual error has been estimated to have a maximum value of 0.2 mg. A systematic error of 0.82 mg per one gramme of absorbed water resulting from the swelling of the dehydrating agents [1] has been corrected.

5.1.1.2. Incompleteness of absorption

The third U-tube of the dehydration system, which is also filled with P_2O_5, is used to control the completeness of absorption. If no systematic variation in its mass is observed, the assumption is justified that all vapour but a residual humidity of $2.0 \cdot 10^{-5}$ g/m^3 (the equilibrium absolute humidity over P_2O_5) has been absorbed in the first two U-tubes.

The effectiveness of absorption was experimentally checked. An additional U-tube containing a few drops of distilled water was arranged at the entrance of the dehydration system. Then the whole set up was swept with air which had been dried with P_2O_5. The water which had been picked up by the air stream from the first U-tube was regained in the dehydration system, of course with a random error which is in agreement with the results of blank runnings (see 5.1.1.4.).

5.1.1.3. Leakage effects

During measurements an underpressure of about 10 kPa against atmospheric pressure occurs in the dehydration system. This means that in possible leakages moist air from the room would be sucked in and would cause errors of measurement. Moist air which is enclosed in valves and pipe joints when the dehydration system is put together has similar effects. Leakage tests demonstrated that these factors cause an error, the maximum of which may be estimated to be 0.02 mg.

5.1.1.4. Manipulation error

For every cycle of measurements the U-tubes of the dehydration system have to be fixed and removed, their valves have to be frequently opened. Temperature and pressure in the U-tubes vary during the passage of air and the absorption of vapour, there are absorption processes on the walls of U-tubes, pipe joints etc. All these processes may result in an error of the determination of mass, the already mentioned « manipulation error ». This error cannot be theoretically estimated. Therefore it was tried to obtain experimental estimates. At first U-tubes were repeatedly subjected to the same manipulations which are necessary to perform the measurement, but without having air passed through them. During these tests the U-tubes showed random variations of their mass of a few tenths of a milligram. On a next test blank runnings were performed. The U-tubes, filled with desiccants, were flushed with air which had been dried with P_2O_5. Again the U-tubes displayed no systematic variation of mass during different periods of flushing, but random variations in the total mass of all three U-tubes with maximum values of $\pm$ 1 mg. Since it has to be assumed that these variations in mass also appear during gravimetric determinations, a « manipulation error » of 1 mg is taken into consideration in the error estimation.

5.1.2. Determination of the mass of dry air

The mass of collected dry air is determined by the equation

$$m_l = \rho V \tag{4}$$

V is the volume of the collecting vessel, ρ is the density of air. If the vessels are repeatedly filled, an according summation is neccessary. The volumes of the two vessels were determined by the water weighing method with an uncertainty of 4 cm^3.

The density of air is calculated by the ideal gas equation

$$\rho = \rho_o \cdot \frac{T_o}{T} \cdot \frac{p}{p_o} \qquad (5)$$

ρ_o is the density of dry air under the reference conditions $T_o = 273.16$ K (0 °C) and $p_o = 0.1013$ MPa. p and T are the pressure and absolute temperature of dry air in the vessel after filling has been finished.

For ρ_o a value of $1.29304 \cdot 10^{-3}$ g/cm^3 has been taken from [1]. It relates to a standard composition of dry air with a ratio of volume of CO_2 of 0.03 %. However, local deviations in the CO_2 concentration from the long-time average of about 0.02 % are possible and may cause an error contribution.

Filling and evacuation of the vessels involve temperature variations. To determine the true mean value of temperature in the vessel, the temperature must be allowed to equalize during 4 to 5 min after finishing of the filling. After that a sufficient temperature equilibrium is reached and it is justified, to perform the temperature measurement only in the bath. A value of 0.1 K is assumed as maximum random error of true mean temperature. The measurement is performed by a 10 ohm platinum resistance thermometer with a maximum error of 0.02 K. The pressure in the vessel is measured with a mercury barometer, the maximum error of which is 40 Pa. Against that, the errors from other sources as leakages, the residual pressure from evacuation (< 1 Pa) and the uncertainties of temperature and gravity correction are negligible. A systematic error in the measurement of pressure occurs when pressure in the barometric system differs from that in the collecting vessel. To eliminate this error, the difference between the final pressure in the vessel and pressure in the barometric system is limited to a value of 400 Pa.

5.1.3. Uncertainty of gravimetric determination

The above estimation of all contributions to overall uncertainty u_r of the fundamental determination of the mixing ratio r shows that the manipulation error is clearly dominating. In case of a quadratic error propagation all other components could be neglected and this would result in an uncertainty of 0.2 % for $p = 99$ %. If, however, errors are combined after [6], smaller components of errors have a something larger effect and we get

$$u_r = 0.35 \text{ \% for } p = 99 \text{ \%}.$$

This value is referred to a mass of collected water m_w of 400 mg. In case of small values of mixing ratio m_w may be smaller than 400 mg and the relative uncertainty of the mixing ratio then increases accordingly.

5.2. **Humidity generator**

5.2.1. Measurement of temperature

Errors due to changes of temperature are introduced into the evaluation by the dependence of e_w from t. The random error of temperature measurement is due to variations of bath temperature. Observed maximum deviations from mean value are at 0.02 K. As systematic error of the temperature measurement is assumed to be the maximum error of thermometer of 0.02 K.

5.2.2. Measurement of pressure

The absolute pressure p_s is measured in two parts : the pressure difference to atmospheric pressure is measured by means of a piston-type pressure gauge, the atmospheric pressure by a mercury barometer. The systematic error of pressure measurement is composed of maximum error of the piston-type pressure gauge of 0.05 % and the error of the barometer which is about 40 Pa. The random component of the error is estimated from the maximum deviation of pressure from the average, which comes to 0.2 %.

5.2.3. f factor

If the values given in the references available without additional measurements are used for routine operation of humidity generator, their uncertainty has after [5] to be assumed to be 0.06 %.

5.2.4. Saturation vapour pressure

Values of saturation vapour pressure of water and the value 0.622 of the ratio of relative molecule masses are assumed to be free from error.

5.2.5. Uncertainty of mixing ratio

By adding up the components of errors one gets for the relative uncertainty of mixing ratio

$$u_r = 0.3 \% \quad (p = 99 \%).$$

5.2.6. Uncertainties of other humidity characteristics

For the conversion of mixing ratio to other humidity characteristics the values of temperature t_k and pressure p_k in the test chamber are used. Taking their errors also into consideration the error estimation then leads to uncertainties as given below :

vapour pressure : 0.3 % of the measured value,
dew-point temperature : 0.04 to 0.06 K,
relative humidity : 0.35 % of the measured value.

It has to be noted that uncertainty of relative humidity is given in per cent of measured value, not in per cent of relative humidity itself.

6. Comparison with a Pneumatic Bridge Hygrometer

In spring 1980 the described standard device of ASMW has been compared with a pneumatic bridge hygrometer, constructed in the Czechoslovakian Institute of Metrology (CSMU) in Bratislava. On account of its high sensitivity and stability of indication this hygrometer is particularly suitable to be used as a transportable comparative instrument for fixed standard devices.

The theory of the pneumatic bridge has been described in detail in [7]. The principle of measurement is based on the adjustment of defined pressure conditions by means of critical nozzles. Analogous to an electric bridge circuit, the flow of moist air is branched into two separate flows. In one branch is a desiccator unit which absorbs vapour. A pressure difference, dependent on the mixing ratio of the moist air, occurs in the bridge diagonal. The ratio of this pressure difference and the absolute pressure in the diagonal, is called the bridge ratio J. According to theory, the dependence $J\ (r)$ is a root function which, however, for small values of r may be developed as polynominal of second order. During comparison the bridge ratio J was measured for 22 values of r in the range from 1 to 20 g/kg. A polynominal was taken as basis for a regression curve to evaluate the measurements.

The evaluation yielded :

$$J(r) = -0.00007 + 1.31\ r - 3.06\ r^2 \qquad (6)$$

Fig. 3 shows the graphic representation of equation (6) and the calibration curve of an American bridge hygrometer which has been derived from data in [7]. There exists a good agreement in the whole range of representation, differences are smaller than 0.5 %. Only near the origin of co-ordinates deviations are larger. This latter is due to the chosen different forms of mathematical evaluation. The compared curves are not related to identical bridge hygrometers. This means that also possible differences in the instrument constants have been included into the comparison (e. g. due to differences in the forms and dimensions of the nozzles). The deviations found are within the interval of uncertainty of comparison which

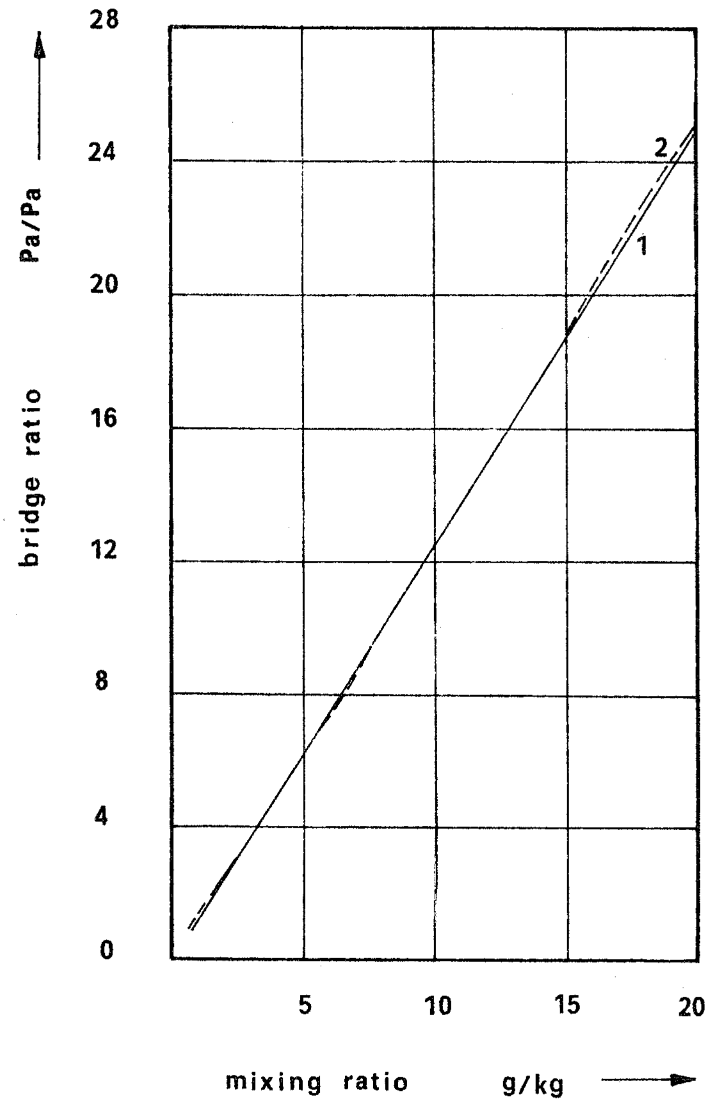

Fig. 3

Calibration curves of the pneumatic bridge hygrometers of the CSMU (1) and the NBS (2)

is found to be about 0.6 %. From that one may derive that neither the pneumatic bridge of the CSMU nor the hygrometric standard device of the ASMW exhibits any systematic deviations from the corresponding devices of the National Bureau of Standards of the USA.

7. Conclusions

With the described device the ASMW has got a humidity standard device which may be used to adjust the mixing ratio of moist air with a relative uncertainty of 0.3 %. By means of it calibrations and tests of most types of hygrometric sensors for industry and research centres are possible.

Through indirect comparisons it is also possible to test humidity generators, salt hygrostats and other reference standard devices.

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AUSTRALIE

CALIBRATION of WEIGHBRIDGES USED for WEIGHING TRAINS in MOTION

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National Standards Commission, Australia

SUMMARY — This paper describes the methods used in Australia in the field to calibrate weighbridges which are specifically designed for weighing trains in motion. Experience has shown that the methods are practicable and that weighbridges can be calibrated to an accuracy within the required maximum permissible errors.

RESUME — Cet article décrit les méthodes utilisées en Australie pour vérifier les installations spécialement conçues pour le pesage des trains en mouvement. L'expérience a montré que ces méthodes sont bien adaptées et que les installations peuvent être vérifiées avec une exactitude meilleure que l'exigence sur les erreurs maximales tolérées.

Introduction

A considerable part of Australia's overseas trade involves the export of raw materials such as coal, iron ore and wheat. Unit trains, consisting of 20 to 150 wagons of similar capacity and type, carry these products by rail from the source of supply to the shipping terminals. In order that these trains may be weighed without time consuming stoppages, the State Rail Authorities have installed weighing-in-motion weighbridges en route so that trains may be weighed at speeds of up to 10 km/h. The weighbridges are used to obtain total train mass for the determination of freight charges and to obtain individual wagon masses for the monitoring of overloading.

The National Standards Commission of Australia is responsible for the pattern approval of these weighing instruments and, in conjunction with the State Rail Authories and State Weights and Measures Authorities, has developed a test procedure to verify each weighbridge.

The design rules and procedures for testing the instruments are contained in the National Standards Commission's Manual No 8. Design Manual for Weighing-in-Motion Systems for Trade Use *. The following gives an outline of the procedures and design rules, together with examples of actual tests performed.

Test procedures

The examination of weighbridges consists of three stages :

(i) laboratory test of component parts,

(ii) static calibration,

(iii) dynamic calibration.

* published as NSC Document 117 (Dec. 1983)

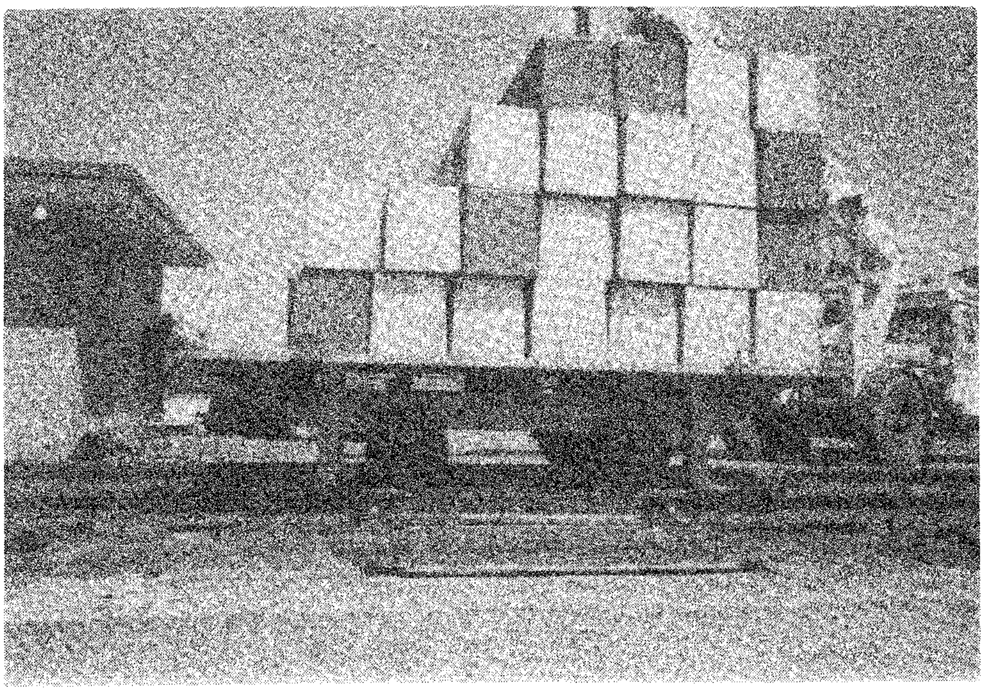


Figure 1
Static calibration of a weighbridge

Laboratory Test of Component Parts

The load cells used in the weighbridge are tested in a dead weight test machine fitted with temperature enclosures so that the performance of the cells can be obtained over the full temperature range. The load cells are tested in accordance with the National Standards Commission's Manual No 7, Design Manual for Load Cells for Trade Weighing Instruments ** which closely follows the OIML Metrological Regulations for Load Cells. The load cells are tested for the number of scale intervals required for the weighbridge as a static weigher.

The electronic processing unit and indicator are also checked in the laboratory for influence factors such as temperature, voltage variation and electrical interference. The indicator is tested for the number of scale intervals required for the weighbridge as a static weigher. The logic of the track switches is checked, but is not tested in the laboratory.

Static Calibration

Once laboratory tests are satisfactorily completed, the examination is continued on a site installation. A static calibration is first carried out to establish the following :

(i) calibration at maximum capacity,

(ii) linearity and hysteresis,

(iii) repeatability,

(iv) calibration at each end of the weighbridge.

The maximum permissible errors used are those contained in the National Standards Commission's Design Manual No 1, Design Manual for Non-automatic Weighing Instruments for Trade Use ***. This Manual closely follows OIML International Recommendation No 3.

** published as NSC Document 116 (1981)

*** published as NSC Document 100 (March 1981)

To facilitate this test, a « standard » four wheel trolley is used. The trolley is of a known mass and is used as the first test mass. If the weighbridge is a « bogie weigher » the trolley axle spacing is close to the bogie axle spacings of the wagons. If it is an « axle weigher », the axle spacing is as small as possible to maintain adequate stability (see Figure 1). The standard test masses are loaded onto the trolley to the maximum capacity of the weighbridge.

The trolley is placed in the centre of the weighbridge and loaded incrementaly to maximum capacity. The linearity and maximum capacity calibration is checked. If the calibration is outside the maximum permissible errors, adjustments are made at maximum capacity and zero by rolling the trolley on and off the weighbridge. Once calibration has been achieved, the trolley is moved on and off the weighbridge several times and placed at each end and in the centre of the weighbridge to check for repeatability and « end calibration ». If all is satisfactory, the trolley is replaced in the centre of the weighbridge and the test masses unloaded, and an unloading curve is produced which is checked for compliance with the maximum permissible errors. The use of the trolley considerably shortens the test time and allows accurate calibration of each pair of load cells and the maximum capacity calibration. If the weighbridge is too short for the trolley to be moved from end to end, the end tests are carried out by moving the test masses up to each end of the trolley as shown in Figure 1.

Dynamic Calibration

As the dynamic calibration of the weighbridge is heavily influenced by the site conditions and the size and type of unit train, the calibration is carried out using a typical unit train (see Figure 2). As it is usually impractical to ascertain the true

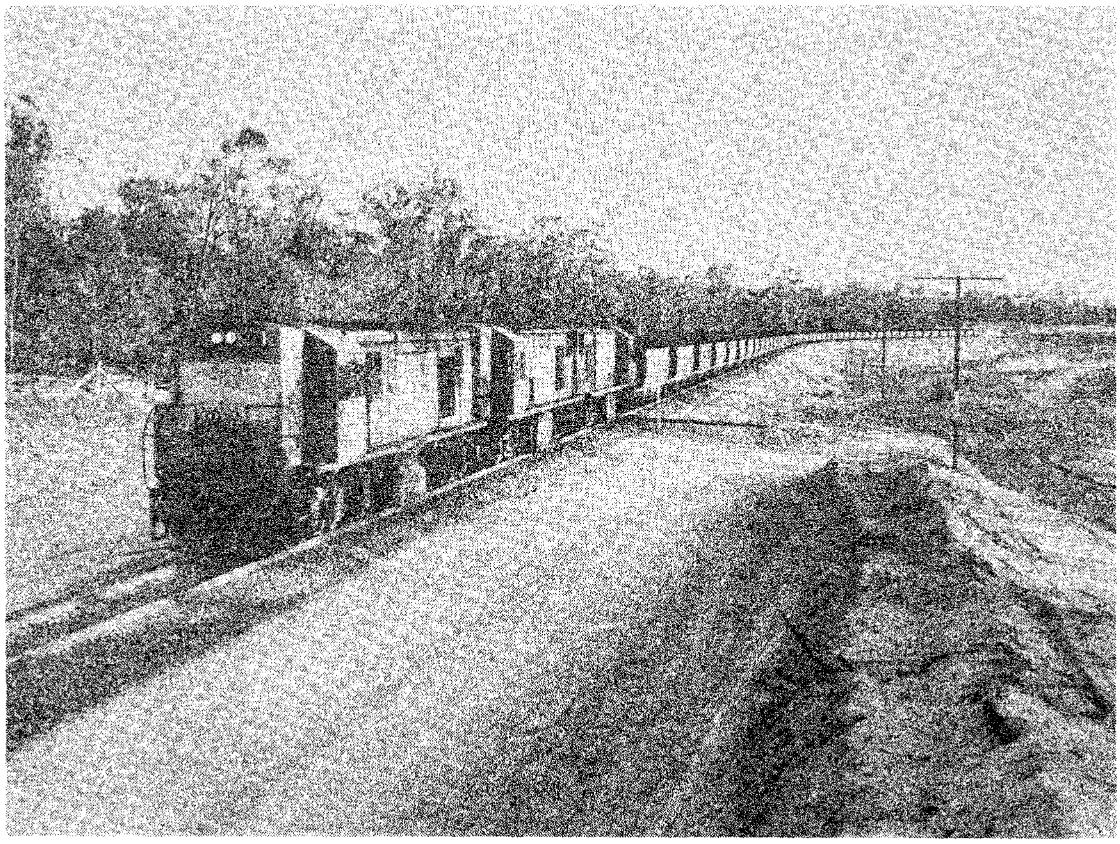


Figure 2

Typical unit train

mass of each wagon, a sample number of known mass test wagons are inserted at various positions in the train. The test wagons should have the same number of axles, the same bogie and axle centres and the same couplers as the wagons to be weighed. The test wagons are loaded with stable material such as steel rail so that the gross mass of each test wagon equals the gross mass of the wagons to be weighed (see Figure 3). Each test wagon is weighed statically, uncoupled and in a single weighing on a verified weighbridge to obtain its gross mass.

Five test wagons are used, with one inserted at each of the following positions in the unit train :

(i) after the first two wagons,

(ii) after 25 % of the wagons,

(iii) after 50 % of the wagons,

(iv) after 75 % of the wagons,

(v) at the end of the train.

The test wagons are not positioned directly after the locomotive as the errors are usually greater on the first wagon due to the influence of the locomotive. This error is not significant in the total train mass but it could be significant in the total mass of the five test wagons.

The five test wagons are used to sample the magnitude of the dynamic error throughout the train. This varies due to variations in drawbar load caused by the wagon's position in the train and by curves, points, positive and negative gradients etc. in the track work before and after the weighbridge. The dynamic errors of the five test wagons measured in a number of tests at varying speeds, are used to adjust the dynamic calibration offset of the instrument. It is assumed that the dynamic errors of the unknown wagons between the test wagons are proportional to the errors of the five test wagons. The unknown wagons are loaded as they would be in a typical train being weighed.

The track switches are also checked using the following tests :

(i) Overspeed test - the train is run approximately 10 % over the maximum speed to check that the overspeed signals operate and prohibit printouts or indications being recorded.

(ii) Roll-back safeguard - to check that no wagon is weighed more than once, 25 % of the train is reversed during a test and the weighing is then completed.

(iii) Unweighed vehicles - during the load tests checks are made to ensure that locomotives are not weighed.

Maximum permissible dynamic errors

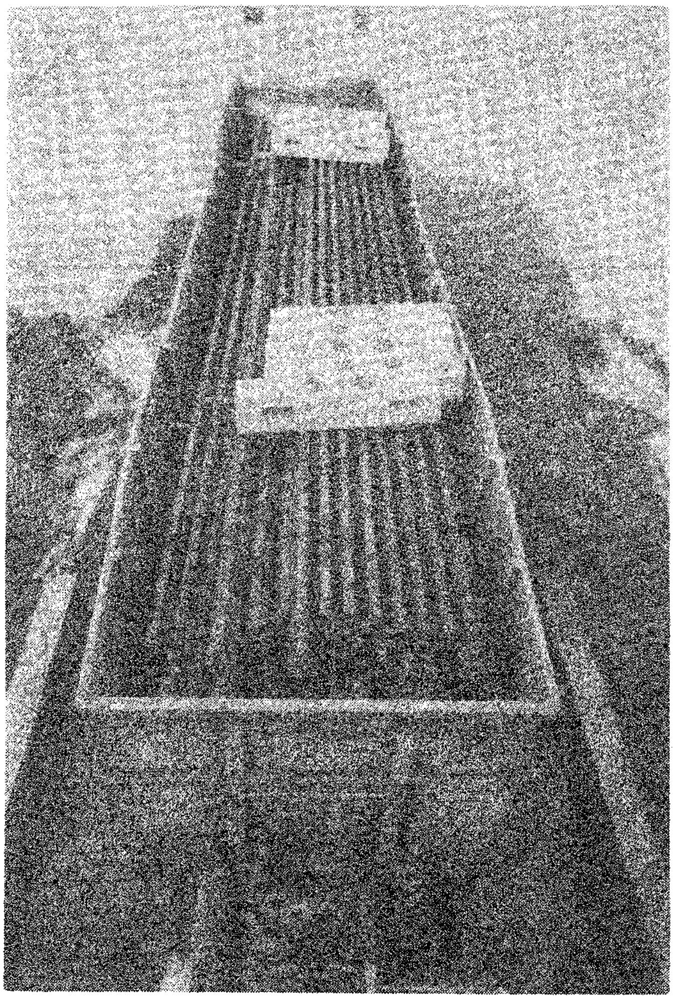
The maximum permissible dynamic errors specified by the National Standards Commission for trains weighed-in-motion are as follows :

(i) After the instrument has been adjusted to zero at no load, the maximum permissible dynamic errors, at any speed within the specified range, shall not be greater than the following :

total train mass ± 5 t or ± 0.2 % of total train mass, whichever is the larger ;

wagon mass ± 1 t or ± 1.0 % of the wagon mass, whichever is the larger.

(ii) The difference between any two indications obtained with respect to the same load measured under the same conditions shall not be greater than the absolute value of the maximum permissible dynamic errors.



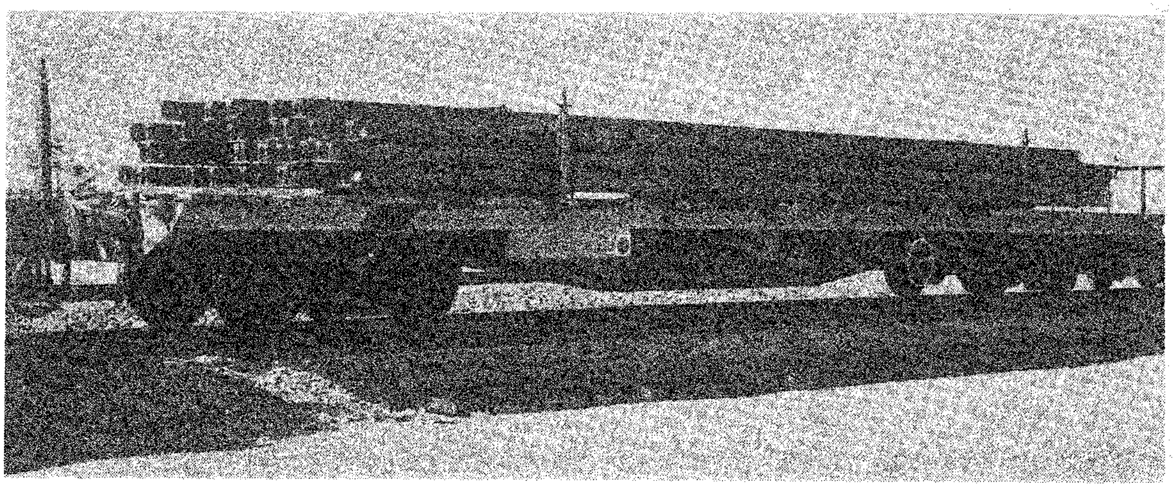


Figure 3

Test wagons

Application of maximum permissible errors

Wagon Mass

As described under dynamic calibration, only a sample number of test wagons are used to determine the dynamic calibration for the whole train. Figure 4 gives a typical graphical representation of the magnitude of the errors of each test wagon with respect to its position in the train. Five test runs are carried out and the mean wagon errors of the five runs are plotted, as well as the extreme errors for each wagon. The graph also shows the error limits for the mass of individual wagons, and if the errors for the test wagons are within these limits it is assumed that the errors of the unknown wagons between the test wagons are also correct.

Total Train Mass

Considering the error of the total train mass, if the mass of all wagons is known, then the dynamic error of the total mass for each test run can be found. However, as mentioned previously, it is not possible to find the true mass of all wagons because of the length of the trains weighed. The repeatability error of the total train mass can be found without knowing the true mass of all wagons, as it is defined by the difference between the two extreme totals found from the series of five test runs. If the mean of the dynamic errors of the total train mass for the five test runs is known, then together with the known repeatability error, it is possible to determine if all total train dynamic errors are within the maximum permissible dynamic errors specified above.

The method used by the National Standards Commission to find the mean dynamic error of the total train mass is based on the sampling theory, i.e. the standard deviation of the mean of the samples (σx) about the mean, X, of the parent

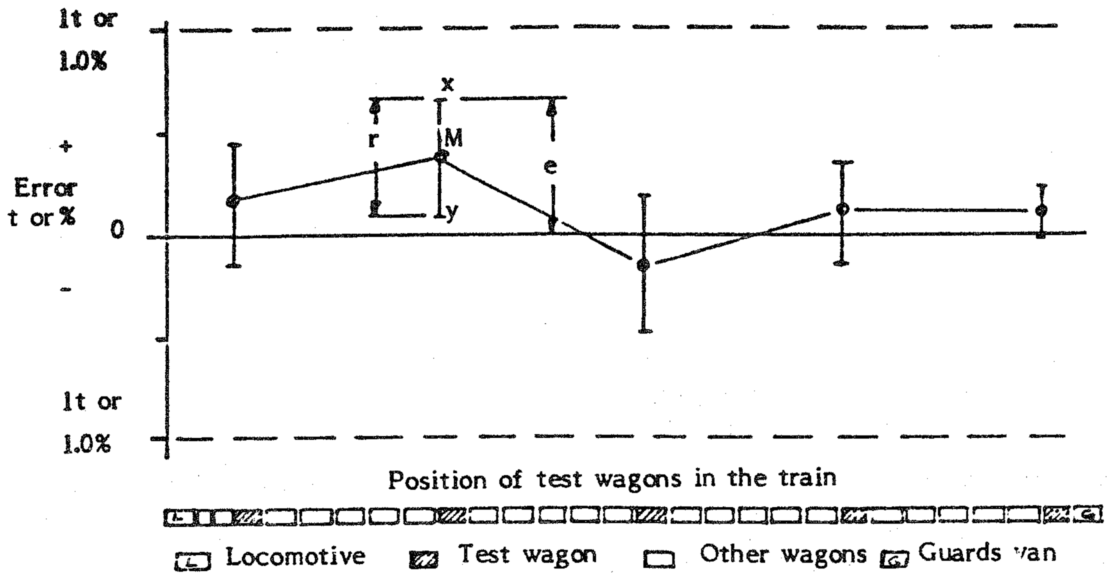


Figure 4

Wagon mass dynamic errors

M - Mean measured dynamic mass of each wagon at one speed

x & y - Maximum and minimum measured dynamic masses of each wagon at one speed

e - Maximum dynamic error of each wagon at one speed
Maximum permissible error ± 1t or ± 1.0 %

r - Maximum dynamic repeatability error of each wagon at one speed
Maximum permissible error 1t or 1.0 %

population is equal to the standard deviation of the parent population (σ) divided by $\sqrt{n}$ where n is the number in the sample. For the five test wagons used in the sample, and equating the standard deviations to the maximum permissible errors, the maximum permissible error of the mean dynamic error of the total mass of the five sample test wagons found from the tests when related to the maximum permissible dynamic error for the total train mass is as follows :

$$\text{MPE sample mean} = \pm \text{MPE of total train mass} / \sqrt{5}.$$

As different total masses are involved in the sample and the train, only the percentage error is considered. Therefore :

$$\text{MPE sample mean} = \pm 0.2 \% / \sqrt{5} = \pm 0.089 \%.$$

For convenience this value has been rounded to ± 0.1 %. Therefore the test method specified by the National Standard Commission requires the instrument to be dynamically calibrated so that the mean dynamic error of the total mass of the five sample test wagons is within ± 0.1 %.

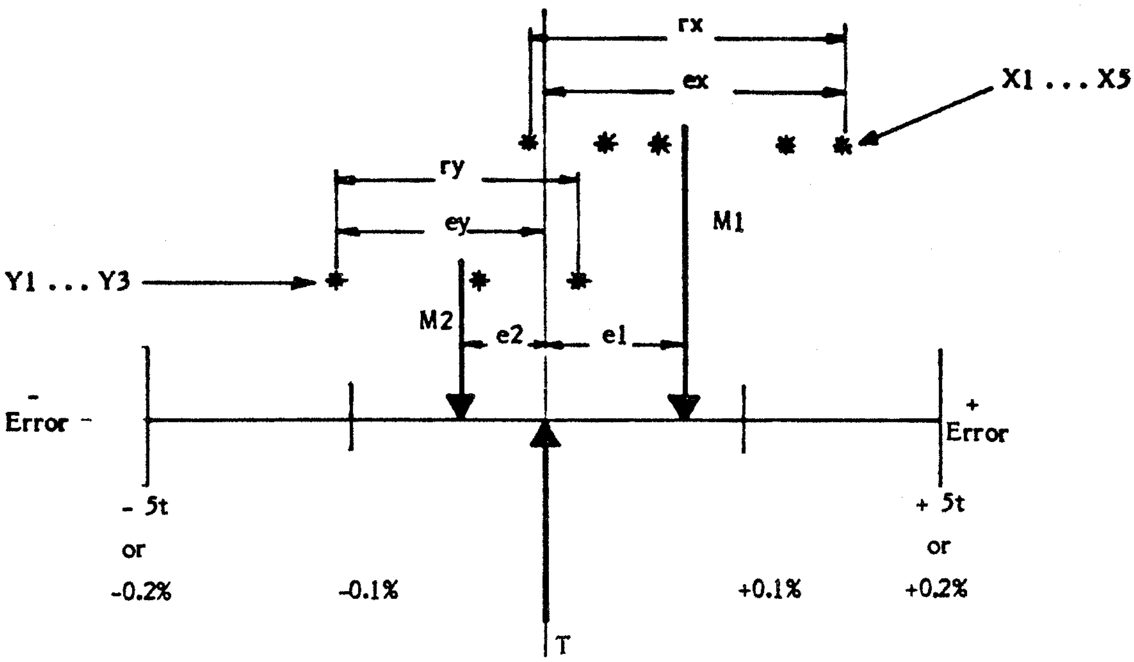


Figure 5

Total train mass dynamic errors

T - Total mass measured statically
(a) of sample test wagons (known)
(b) of train (unknown)

M1 & M2 - Mean total masses measured dynamically at the two extreme speeds of speed range
(a) of sample test wagons (known)
(b) of train (assumed)

e1 & e2 - Dynamic errors of the mean total masses at the two speeds
(a) of sample test wagons (known)
(b) of train (assumed)
Maximum permissible errors for e1 & e2 ± 0.1 %

X1 ... X5 & Y1 ... Y3 - Total train masses measured dynamically for individual test runs at the two speeds (known)

rx & ry - Dynamic repeatability errors of total train masses at each speed
Maximum permissible errors for rx & ry 5t or 0.2 %

ex & ey - Assumed dynamic total train mass errors. If e1, e2, rx and ry comply with above maximum permissible errors, it is assumed that ex and ey are within the maximum permissible errors of ± 5t or ± 0.2 %

If this is so, and the dynamic repeatability error of the total train mass is within the specified error of 5 t or 0.2 %, then the total train mass dynamic errors should be within the required maximum permissible dynamic errors of ± 5 t or ± 0.2 %. This is graphically illustrated in Figure 5.

Mixed Capacity Trains

The above maximum permissible errors can be applied to unit trains in which all wagons are the same, or to mixed goods trains with varying size and type of wagons. In the latter case the wagons in the test train should be varied to represent a typical train. The five test wagons are positioned as for the unit train but are a mixture of light and heavy wagons. The worst situation is when weighing a light wagon located at the front of a train and having heavier wagons on either side. Therefore this combination should be included, particularly when the instrument is used for individual wagon masses.

Dual Maximum Permissible Dynamic Errors

The maximum permissible dynamic errors are specified as an absolute mass value or as a percent of the total mass whichever is the larger for a particular load. Test results obtained over a number of installations indicated that there is a limiting mass error which occurs on all weighings no matter what size the load is. For lightly loaded wagons or trains this mass, expressed as a percent error, becomes excessive. Therefore dual errors were determined to overcome this problem and they have been found to be suitable for most installations.

Sample Dynamic Tests

The following two sample results cover two different installations. The first example covers the most typical installation where unit trains with all wagons the same are weighed (Table 1). The total train mass is the value which is in use for trade, but the individual wagon masses are also used for checking for overload. The weighbridge is located on the straight track coming out of a balloon loop.

The second example covers an installation used for weighing goods trains of mixed wagons where the individual mass of each wagon is required for trade purposes (Table 2). The weighbridge is located on a straight section of track with a 1 in 400 gradient. The train can be weighed in either direction.

Tables 1 and 2 give results for one speed only, in the form specified in the National Standards Commission's test procedure. The overall results for total train mass for these two installations, together with other installations, are shown in Table 3.

Some conclusions which can be drawn from the results obtained for a number of different sites are :

Total train mass

(i) In the majority of cases the maximum permissible calibration error of ± 0.1 % can be achieved for the range of speeds encountered in one installation.

(ii) The one exception in the results shown is for the Dry Creek location where the weighbridge can be used in both directions. As one direction is uphill and the other downhill, it proved to be difficult to set the calibration adjustment to suit both directions and all speeds. However, the net result is satisfactory.

(iii) The calibration error is based on the mean dynamic error of the total of the five sample test wagons and is used to set the dynamic calibration adjustment to obtain the best setting for all conditions. From the results there is no obvious difficulty in setting the calibration adjustments irrespective of the number of the wagons, the mass of the train, the speed or the arrangement of wagons.

(iv) As the calibration error does not give any indication of the variation of the total train mass for individual weighings, the total train mass repeatability error is measured. The maximum permissible error is 5 t for total loads up to 2 500 t and 0.2 % over 2 500 t. As can be seen from the results, the actual errors do not exceed 4 t but can approach this value whether the total load is 1 000 t or nearly 4 000 t.

(v) With respect to speed, the repeatability error is consistently low at 3-4 km/h and consistently high for 1-2 km/h and 8 km/h. Apparently 3-4 km/h is the ideal speed irrespective of site conditions and size of train.

(vi) The number of wagons between 20 and 65 appears to have little affect on the overall performance of the instrument. For this reason instruments are tested with the smaller size train if more than one size train is weighed over a weighbridge. For some weighbridges trains of 60, 100 and 150 wagons are weighed.

Individual wagon mass

(i) The maximum permissible error for the individual wagon mass is 1 t or 1.0 %. Therefore for wagons up to 100 t, 1 t applies. For the majority of installations weighing unit trains of similar wagons loaded to the same capacity, the errors on each wagon are well within this limit.

(ii) For mixed wagon trains the errors for individual wagons can be much greater. The worst case is for a lightly loaded wagon in between heavier wagons, located at the front of the train and travelling uphill at about 8 km/h.

Conclusions

Results obtained in the field indicate that the test procedure adopted by the National Standards Commission, in conjunction with the State Weights and Measures Authorities and Government Railways, have proved to be satisfactory.

The procedure was developed because the majority of trains weighed in Australia are quite large and are often located at remote mine sites. The sampling method is the only method possible, even though it still takes three to five days to test a weighbridge. The static tests occupy one day while the dynamic tests take two to four days depending on how many adjustments have to be made before a satisfactory result is obtained.

However this does not preclude using a typical train loaded with the material normally weighed as the test train, provided the number of wagons is small and a weighbridge capable of weighing each wagon in a single weighing is available in the near vicinity. The train would have to be weighed statically and dynamically within a short period to avoid any changes in mass of the material. The actual weighbrige of the weighing-in-motion system cannot be used to determine the static mass of each wagon as it cannot weigh a complete wagon in one weighing.

The National Standards Commission specifies the normal reverification period of two years for the static tests, but dynamic tests need only be repeated every four years. However the tests would have to be repeated within those periods if any alterations or repairs were carried out.

Generally the design rules and test procedures specified in the National Standards Commission's Design Manual No 8, Design Manual for Weighing-in-Motion Systems for Trade Use (Document 117) have proved to be satisfactory on the many sites installed in Australia.

TABLE 1

DYNAMIC TEST REPORT - TOTAL TRAIN MASS

WEIGHING-IN-MOTION WEIGHING INSTRUMENT

Weighing-in-Motion Instrument

NSC no:	-
Max:	50 t
Min:	1 t
e :	0.05 t
T:	-
Max axle or bogie load:	18 t axle
Train speed range:	1-4 km/h
No of wagons in train:	60
Wagon type & no of axles:	WHO-4

Test Wagons

No	Wagon no & type	Mass (t)
1	32129 - WHO	70.87
2	32192 - WHO	71.08
3	32094 - WHO	70.57
4	32134 - WHO	71.46
5	32146 - WHO	70.88
	Total mass	354.86

General

Owner: Queensland Railways
Location: Curragh Coal Mine
Material weighed: Coal
Temperature: 25°C
Date: 2/8/83

	Description	Run 1	Run 2	Run 3	Run 4	Run 5
1	Speed (km/h)	1.4	1.7	1.5	1.6	1.5
2	Mass 1st wagon (t)	70.60	70.90	70.80	70.85	70.70
3	Mass 2nd wagon (t)	70.95	71.15	71.10	71.05	71.00
4	Mass 3rd wagon (t)	70.25	70.65	70.65	70.50	70.40
5	Mass 4th wagon (t)	71.35	71.70	71.40	71.45	71.40
6	Mass 5th wagon (t)	71.05	71.15	71.10	71.00	71.05
7	Total mass of 5 wagons (t)	354.20	355.55	355.05	354.85	354.55
8	True total mass of 5 wagons (t)	354.86	354.86	354.86	354.86	354.86
9	% Error total mass ($\frac{7-8}{8}$ x 100)	-0.186	+0.194	+0.054	-0.003	-0.087
10	Total train mass (t)	1153.15	1154.10	1154.85	1154.50	1151.30

Average % error of total test wagon mass (Σ9/no runs) = -0.0056% at 1.5 km/h (MPE ± 0.1%)

Max repeatability error (max 10 - min 10) t = 3.55 t at 1.5 km/h (MPE 5 t)

TABLE 2

DYNAMIC TEST REPORT - WAGON MASS

WEIGHING-IN-MOTION WEIGHING INSTRUMENT

Weighing-in-Motion Instrument

NSC no:	-
Max:	50 t
Min:	1 t
e :	0.05 t
T:	-
Max axle or bogie load:	40 t bogie
Train speed range:	4-8 km/h
No of wagons in train:	64
Wagon type & no of axles:	various types 4 axle

Test Wagons

No	Wagon no & type	Mass (t)
1	1648 RGC	75.75
2	3171 RGC	31.41
3	1620 RGC	75.05
4	1757 RGC	30.99
5	1774 RGC	75.01
	Total mass	288.21

General

Owner: Australian National Rail
Location: Dry Creek, South Australia
Material weighed: Goods
Temperature: 18°C
Date: 4/6/83

	Description	Run 1	Run 2	Run 3	Run 4	Run 5
1	Speed (km/h)	8	8	8	8	6
2	1st wagon - Mass (t)	75.05	75.70	75.45	75.00	75.45
3	- True mass (t)	75.75	75.75	75.75	75.75	75.75
4	- Error (2-3) (t)	- 0.70	- 0.05	- 0.30	- 0.75	- 0.30
5	2nd wagon - Mass (t)	31.75	31.90	31.75	32.15	31.15
6	- True mass (t)	31.41	31.41	31.41	31.41	31.41
7	- Error (5-6) (t)	+ 0.34	+ 0.49	+ 0.34	+ 0.74	- 0.26
8	3rd wagon - Mass (t)	74.90	75.25	75.00	75.15	75.00
9	- True mass (t)	75.05	75.05	75.05	75.05	75.05
10	- Error (8-9) (t)	- 0.15	+ 0.20	- 0.05	+ 0.10	- 0.05
11	4th wagon - Mass (t)	31.20	31.40	31.10	31.10	31.25
12	- True mass (t)	30.99	30.99	30.99	30.99	30.99
13	- Error (11-12) (t)	+ 0.21	+ 0.41	+ 0.11	+ 0.11	+ 0.26
14	5th wagon - Mass (t)	75.25	75.40	75.05	75.25	75.25
15	- True mass (t)	75.01	75.01	75.01	75.01	75.01
16	- Error (14-15) (t)	+ 0.24	+ 0.39	+ 0.04	+ 0.24	+ 0.24

Max wagon errors +0.74 t and -0.75 t at 8 km/h (MPE ±1 t)

Repeatability error (worst wagon, max error - min error) = 1.0 t for wagon no 2 at 8 km/h (MPE 1 t).

TABLE 3

SUMMARY OF RESULTS FOR VARIOUS INSTALLATIONS

Site location	Number of wagons	Total train mass (t)	Calibration error (%)					Total train mass repeatability error (% or t)			
			Slow speed (1-2 km/h)	Medium speed (3-4 km/h)	Fast speed (8 km/h)	Average error	MPE	Slow speed (1-2 km/h)	Medium speed (3-4 km/h)	Fast speed (8 km/h)	MPE[b]
Oaky Creek, Queensland	61	1155	+ 0.02	- 0.02		0	± 0.1	3.7 t	0.65 t		5 t
Curragh, Queensland	62	1154	- 0.01	+ 0.025		+ 0.008	± 0.1	3.9 t	0.39 t		5 t
Collinsville, Queensland	64	1297	+ 0.07	+ 0.03		+ 0.05	± 0.1	3.75 t	1.25 t		5 t
Boundary Hill, Queensland	61	1203	+ 0.08	- 0.096		- 0.008	± 0.1	1.69 t	1.08 t		5 t
Newlands, Queensland	65	1235	+ 0.07	+ 0.04		+ 0.055	± 0.1	2.65 t	0.95 t		5 t
Port Kembla, NSW	20	1891		+ 0.003		+ 0.003	± 0.1		2.5 t		5 t
Port Waratah, NSW	30	3193		+ 0.06	+0.06	+0.06	± 0.1			0.09% (2.9 t)	0.2%
Dry Creek, South Australia[a]	64	3714		+ 0.05	- 0.15	- 0.05	± 0.1		0.05% (1.75 t)	0.10% (3.8 t)	0.2%
Dry Creek, South Australia	64	3714		+ 0.08	+ 0.10	+ 0.09	± 0.1		0.03% (1.15 t)	0.09% (3.3 t)	0.2%

[a] Operates in two directions - first results downhill (1 in 400), second results uphill (1 in 400)

[b] 5 t up to 2500 t and 0.2% over 2500 t

LITERATURE

VOCABULARY

The International Vocabulary of basic and general terms in metrology which was produced jointly by BIPM, IEC, ISO and OIML and published by ISO in French-English version now exists in an English-German edition produced by Deutsches Institut für Normung (DIN) and edited by Beuth-Verlag GmbH, Berlin.

PTB TEST RULES

Two new guidance brochures have been issued by the Physikalisch-Technische Bundesanstalt :

— « Störfestigkeit » (Procedures for testing the effect of electromagnetic disturbances on measuring instruments)

and

— « Therapiedosimeter mit Ionisationskammern für Photonenstrahlung mit Energien unterhalb 3 MeV » (Ionizing chamber therapy dosimeters for energies lower than 3 MeV).

A new catalogue of foreign language translations of PTB-Test rules and other PTB publications has also been issued (June 1984) and can be obtained from

Physikalisch- Technische Bundesanstalt
Referat « Technische Zusammenarbeit »
Postfach 3345
D-3300 Braunschweig
Fed. Rep. of Germany

ELECTRICAL ENERGY METERS

A statistical examination of results of field inspection of electricity meters has been published by the legal metrology service of CANADA. This brochure « METERS on the ROOF » by M. Romanowski and E. Green is available in both French and English versions from

Consumer and Corporate Affairs of Canada
Legal Metrology Branch
Parc Tunney, Holland Ave.
Ottowa, Ontario K1A OC9
Canada

TECHNICAL SEMINARS IN AUSTRALIA

The National Standards Commission of Australia has published proceedings from two seminars attended by legal metrology staff and industry engineers on 9 May 1984. The first one concerns the subject of

« Electromagnetic compatibility of electronic trade measuring instruments »

and the second

« Calibration of liquid petroleum gas drive away flowmeters »

WEIGHING

A book treating load cells and weighing by electronic means is just out of press :

K.E. Norden : « Electronic Weighing in Industrial Processes »,
1984, 300 pages
Granada Publishing Ltd (Collins Publishers)
8 Grafton Street
London W1X 3LA

The book is written by an international consultant in industrial weighing. The book has chapters on : Load-Cell Principles, Electronics and Data Handling, Application of Static Weighing, Batch-weighing Systems, In-motion weighing, Belt Conveyer Weighing, Checkweighers, Specifications and Regulations.

Reference is made to OIML Recommendations and to NBS Handbook 44. Regretfully there are however practically no other literature references. (A small remark : As regards weighing-in-motion the author seems to have made some confusion or anticipation in the reference to OIML work).

The book is anyhow a good contribution for teaching in a field where there are presently very few books commercially available.

Another book treating industrial weighing has been received by BIML :

A. Schuster (Editor) : Industrielle Wägetechnik
Carl Schenk, Darmstadt, 1983, 123 pages.

This book in German language treats both discontinuous and continuous weighing with chapters on load cells, electronics, gravimetric filling machines, errors in beltweighing, etc. The text is very concise and well illustrated and is well suited for teaching purposes in particular as it is not commercially biased.

The book was issued for the 100 year anniversary of the Carl Schenck company and is not commercially available. Requests may however be addressed to Carl Schenck AG, Abt. Diskontinuerliche Wägetechnik, Postfach 4018, D-6100 Darmstadt 1.

Among the PTB-publications translated into English as mentioned above the following concern weighing :

M. Kochsiek (Editor) : The determination of mass (Part I and II)

B. Meissner, J. Steinhauer : Overload protection for load cells

B. Meissner : Requirements for and investigations of strain gauge load cells.

Finally we have been informed that a new fully revised edition will soon be on the market of the well-known treatise on mechanical and electronic weighing.

H. Colijn : Weighing and proportioning of bulk solids
(2nd edition 1984)

Trans Tech Publications
CH-4711 Aedermansdorf, Switzerland

HARDNESS MEASUREMENTS

The BIML has recently issued a brochure written by F. Petik and carrying the title « Hardness blocks and indenters »

The brochure is a synthesis of essential information contained in numerous papers on the subject. It may be obtained on request from BIML

INFORMATIONS

MEMBRES DU COMITE

La composition du Comité International de Métrologie Légale (CIML) est modifiée ainsi qu'il suit :

SRI LANKA — Monsieur H.L.R.W. MADANAYAKE, Acting Commissioner of Internal Trade, a été officiellement désigné pour représenter son Pays au Comité.

SUISSE — A compter du 1er janvier 1985, Monsieur A. PERLSTAIN, ancien Directeur de l'Office Fédéral de Métrologie, est remplacé comme Membre du Comité par Monsieur P. KOCH, Vice-directeur du même Office.

Monsieur A. PERLSTAIN a été nommé Membre d'Honneur du CIML (voir ci-avant informations sur la Septième Conférence Internationale de Métrologie Légale et la 20ème réunion du CIML).

Nous adressons nos meilleures salutations de bienvenue aux nouveaux Membres du Comité et nos vifs remerciements à Monsieur PERLSTAIN pour sa précieuse participation pendant de très longues années à nos travaux.

ORAN

L'Organisation Régionale Africaine de Normalisation vient de publier un document sur la création d'un réseau africain d'information et de documentation sur les normes, la métrologie, la certification et le contrôle de la qualité (ARSO-DIS).

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INFORMATION

COMMITTEE MEMBERS

The composition of the International Committee of Legal Metrology (CIML) is modified as follows :

SRI LANKA — Mr H.L.R.W. MADANAYAKE, Acting Commissioner of Internal Trade, has been officially appointed as representative of his Country on the Committee.

SWITZERLAND — As from 1st January 1985, Mr A. PERLSTAIN, former Director of the Office Fédéral de Métrologie, is replaced as Committee Member by Mr P. KOCH, Vice-director of the same Office.

Mr A. PERLSTAIN has been elected as Honorary Member of the CIML (see ahead our note on the Seventh International Conference of Legal Metrology and the 20th Meeting of CIML).

We express our best wishes of welcome to the new Committee Members, and warmly thank Mr PERLSTAIN for his valuable participation in our activities for so many years.

ARSO

The African Regional Organization for Standardization has published a document concerning the creation of an African network of information and documentation on standards, metrology, certification and quality control (ARSO-DIS).

IMEKO

RECENT ADVANCES IN WEIGHING TECHNOLOGY AND FORCE MEASUREMENT

IMEKO Technical Committee TC-3 « Measurement of Force and Mass » (Chairman : H. Wieringa) held its 10th International Conference in Kobe, Japan, 11-14 September 1984. The series of TC-3 meetings was started in Braunschweig in 1969, followed by meetings at The Hague, Ostrava, Dresden, Udine, Szeged, London, Odessa, Braunschweig, Moscow, Krakow, Berlin, London.

The International Program Committee of the Kobe Conference succeeded in ensuring papers giving a good cross section of latest development in the field of mass and force measurement.

Two special lectures discussed the Present Status of Mass and Force Measurement in Japan (Iizuka) and Miniature Force Transducers with Strain Gauges (Rohrbach - Lexow).

The first group of lectures was consecrated to problems of load cells and transducers. We can mention only some of the subjects discussed : — New designs of load cells — Magnetoelastic and mechanical resonator principles in load cells — 6-component force transducers — Temperature dependence of Young's Modulus — Creep of load cells — Time division circuitry.

Three papers discussed the state of weighing technology : — State of strain gauge transducers — Problems raised by improvements in load cell accuracy — New results in the scale industry.

Among the applications of scales, several new types for steel plants, cranes, axle weighing and for moving plane applications such as a shipboard were described.

Several advanced instruments for weighing were presented, among others : — Displacement and velocity sensing type mass measurement — Magnetic suspension balance — Electronic analytical balance — Measurement of very small load variations — Automatic rest point reading system — New electronic counting scale.

The development of mass standard laboratories was described in several papers : — Alloys for mass standards — Mass comparison by a hydrostatic weighing method and by electronic comparator — Measuring the density of air and of liquids.

The realization of force standards was another subject group of the Conference, including papers on — Progress in force measurement in various national standards laboratories — Verification of force standard machines — International comparisons of force — New compound lever standard machines — Hydraulic force standard machines — Design of transfer standards.

Numerous papers were presented on force measurement applications, among others : — Weighing of heavy structures — Forces at continuous casting — Load cells for rolling mills — Forces in mechanical switches — Forces on automobile tyres — Ocean bottom gravity meter — Performance evaluation of the verification of testing machines — Automatic Charpy impact testers.

Round table discussions were held on two subjects :

— Scales industry and weighing in the developing countries,

— Parasitic components of force standard machines.

The publication of the proceedings of the Conference is foreseen early 1985 (Editor : Prof. T. Ono, Chairman of the International Program Committee of the TC-3 Conference, University of Osaka Prefecture, 804, Mozo Umemachi 4-cho, Sakai-shi, Osaka 591, Japan).

F.P.

INTERREGIONAL TRAINING COURSE ON ENSURING MEASUREMENT ACCURACY

This Training Course organized by IMEKO TC-8, the Austrian Research Center Seibersdorf and the Austrian Federal Office of Metrology with the financial assistance of the International Atomic Energy Agency and UNIDO from 11 to 21 September 1984 was attended by 75 participants from 34 countries. (Other cooperating partners were the ÖVE/ÖIAV Fachgruppe Messtechnik, Austrian Member Organization of IMEKO, the National Office of Measures Budapest, OIML and BIPM). During the 9 working days 26 lectures were read by highly qualified speakers, there were 4 round table discussions and 6 very interesting technical visits to laboratories and verification offices. A great number of the participants came from developing countries and actively contributed to the program.

The subjects covered were typically

— international cooperation in the field of metrology (BIPM and OIML) — measurement uncertainties — ionisation radiation dosimetry — reference materials — length, mass, force, temperature, pressure — volume and electrical measurements.

The full text of the lectures was published in 3 volumes and distributed to the participants.

A.T.

REUNIONS

	Groupes de travail	Dates	Lieux
SP 5 - Sr 15	Compteurs et ensembles de mesure de liquides cryogéniques	17-19 avril 1985	PARIS, BIML
SP 7 - Sr 5	Instruments de pesage à fonctionnement automatique	29 avril-3 mai 1985	LONDRES ROYAUME-UNI
SP 17 et ses secrétariats-rapporteurs	Mesure des pollutions	21-24 mai 1985	WASHINGTON U.S.A.
SP 21 et ses secrétariats-rapporteurs	Normalisation des caractéristiques métrologiques	20-22 mai 1985	LVOV U.R.S.S.
SP 11 - Sr 4	Manomètres à éléments récepteurs élastiques	23-25 mai 1985	LVOV U.R.S.S.
SP 20 - Sr 1	Contenu informatif de l'étiquetage des produits préemballés	3-7 juin 1985 *(provisoire)*	BERNE SUISSE
SP 20 - Sr 2	Vérification des quantités contenues dans les emballages	3-7 juin 1985 *(provisoire)*	BERNE SUISSE
SP 2 - Sr 6	Instruments électroniques	10-12 juin 1985	COPENHAGUE DANEMARK
SP 7 - Sr 2	Mesure des masses. Dispositifs électroniques	13-14 juin 1985	COPENHAGUE DANEMARK
SP 30	Mesures physico-chimiques	9-14 sept. 1985	BATOUMI U.R.S.S.
SP 12 - Sr 7	Thermomètres médicaux	24-26 sept. 1985	TRIER R.F. D'ALLEMAGNE
SP 27	Principes généraux de l'utilisation des matériaux de référence en métrologie légale	automne 1985 *(provisoire)*	U.R.S.S.

Séminaire OIML sur le contrôle des installations de pesage en vrac	22-25 avril 1985	PARIS FRANCE

CENTRE DE DOCUMENTATION

Documents reçus au cours du 4ème trimestre 1984

BUREAU INTERNATIONAL DES POIDS ET MESURES — BIPM

Comptes Rendus des séances de la 17ème Conférence Générale des Poids et Mesures du 17 au 21 octobre 1983

ORGANISATION DES NATIONS UNIES — ONU

Commission Economique pour l'Europe

ECE/STAND/20/Rev. 1 : Liste CEE des Secteurs appelant une normalisation, Genève 1984 (fr. et angl.)

CONFERENCE DES NATIONS UNIES SUR LE COMMERCE ET LE DEVELOPPEMENT — CNUCED

Rapport sur le Commerce et le Développement, 1983

COMMISSION ELECTROTECHNIQUE INTERNATIONALE — CEI

Secrétariat

Rapport Annuel/Annual Report 1983

INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS — ICRU

ICRU Report No. 35 : Radiation Dosimetry : Electron Beams with Energies Between 1 and 50 MeV, 15 September 1984

INTERNATIONAL MEASUREMENT CONFEDERATION — IMEKO

TC 8 Technical Committee on Metrology

Interregional Training Course on ensuring Measurements Accuracy — Proceedings. Vol. 1, 2, 3 (Sept. 11-21, 1984)

ORGANISATION REGIONALE AFRICAINE DE NORMALISATION — ORAN/ARSO

Annual Report for the year ending December 1982

ARAB ORGANIZATION FOR STANDARDIZATION AND METROLOGY — ASMO

General Secretariat

Arab Standards Catalogue, 1984

REPUBLIQUE FEDERALE D'ALLEMAGNE

Deutsches Institut für Normung

Internationales Wörterbuch der Metrologie/International Vocabulary of Basic and General Terms in Metrology, 1984

AUSTRALIE

National Standards Commission

Proceedings of the Seminar on the Electromagnetic Comptability of Electronic Trade Measuring Instruments (9-5-1984)

Proceedings of the Seminar on the Calibration of liquid Petroleum Gas Driveway Flowmeters (9-5-1984)

BRESIL

Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industriale

Coletanea das Portarias do INPM sobre mercadorias acondicionadas (jusqu'au 13-6-1984)

Participe do SINMETRO

Sintese da Situaçao da Metrologia Legal no Brasil, 1984

DIMEL - Projetos de Recomendaçao a serem apresentados a sançao da 7ª Conferencia

MAN-MEL (Manual de Metrologia Legal)

Institutional View, 1984

CUBA

Comité Estatal de Normalizacion

Traduction en espagnol de :

Liste des Secrétariats de l'OIML, 1984

Etat d'avancement des travaux des Secrétariats de l'OIML

ETATS-UNIS D'AMERIQUE

National Council on Radiation Protection and Measurements — NCRP

NCRP Report No. 78 : Evaluation of occupation and environmental exposures to radon and radon daughters in the United States, May 1984

Lecture No. 8 : Limitation and Assessment in Radiation Protection (by H.H. Rossi, 1-6-1984)

National Bureau of Standards

Proceedings : 1984 Workshop and Symposium of the National Conference of Standards Laboratories (Gaithersburg October 1-4, 1984)

FRANCE

Réglementation métrologique

Arrêtés du 13-2-1984 :

fixant le montant des taxes de vérification primitive

fixant le montant des redevances pour utilisation du matériel de l'Etat

fixant le montant des redevances à l'occasion du contrôle des instruments de mesure, jaugeages, étalonnages et travaux effectués par les fonctionnaires habilités

Arrêtés du 20-3-1984 : Bureau national de Métrologie

Instruction n° 84.1.01.400.0.3 du 30-3-1984 relative à la gestion des groupements d'ensembles de mesurage routiers

Instruction n° 84.1.02.100.0.0 du 4-4-1984 : Assiette des taxes et redevances

Décret n° 84-294 du 12-4-1984 sur les instruments de mesure de pression acoustique

Décret n° 84-948 du 19-10-1984 modifiant le décret n° 79-200 du 5-3-1979 relatif aux alcoomètres, aux aréomètres pour alcool et aux tables alcoométriques

IRAK

Central Organization for Standardization and Quality Control

Law No 42 of 1978 on Stamping Measuring Instrument for the Determination for Weight, Length or Volume for Commercial Purposes

POLOGNE

Polski Komitet Normalizacji, Miar i Jakosci

Katalog Norm Branzowych 1983 (Dodatek)

ROYAUME-UNI DE GRANDE-BRETAGNE ET D'IRLANDE DU NORD

London Her Majesty's Stationery Office

Methods for the Examination of Waters and Associated Materials :

Suspended, Settleable, and Total Dissolved Solids in Waters and Effluents 1980

Colour and Turbidity of Waters, 1981 Tentative methods

Methods for Assessing the Treatability of Chemicals and Industrial Waste Waters and their Toxicity to Sewage Treatment Processes 1982

The Permanganate Index and Permanganate Value Tests for Waters and Effluents 1983

Methods of Biological Sampling : Sampling of Benthic Macroinvertebrate in Deep Rivers 1983

The Sampling of Oils, Fats, Waxes and Tars in Aqueous and Solid System 1983

Statutory Instruments 1984 No 1446 : Weights and Measures. The Weights and Measures (Amendment) Regulations 1984

S.I. 1984 No 1618 : Weights and Measures. The Measuring Instruments (EEC Requirements) (Amendment) Regulations 1984

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 machines

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 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. Méthode de vérification
Glass capillary viscometers for the measurement of kinematic viscosity. Verification method

70 — Méthode pour la détermination des erreurs de base et de reversibilité des analyseurs de gaz
Method for the determination of intrinsic and hysteresis errors of gas analysers

71 — Réservoirs de stockage fixes à pression atmosphérique ou sous pression. Prescriptions générales
Fixed storage tanks at atmospheric pressure or under pressure. 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 référence
Requirements concerning CO, CO_2, CH_4, H_2, O_2, N_2 and Ar pure gases intended for the preparation of reference gas mixtures

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

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

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

Les Recommandations Internationales 3, 35, 44, 51 et 60 à 73 sont en cours d'impression.
The International Recommendations 3, 35, 44, 51 and 60 to 73 are being printed.

ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

BUREAU INTERNATIONAL DE MÉTROLOGIE LÉGALE
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MEMBRES CORRESPONDANTS

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