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Verification equipment for national metrology services

Equipement d'un service national de métrologie

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ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION
OF LEGAL METROLOGY

This publication containing summarized specifications and suggestions for procurement and use of verification equipment is based on work made by the OIML Reporting Secretariat SP 25-Sr 3 "Equipment required for the operation of a Legal Metrology Service" under the responsibility of USSR. After the creation of the OIML Development Council in 1980 this Reporting Secretariat continues to operate as an ad hoc group under the Development Council.

Presently the following lists of verification equipment have been elaborated by the group and reviewed by BIML :

MASS MEASUREMENT

Introduction

The present list of verification equipment is made up with the aim of providing a practical aid to the national metrological services of developing countries in the matters relating to ensuring Uniformity and reliability in mass measurement. The equipment included in the attached list is intended to enable the metrological service to verify mass measuring instruments which are used in all basic fields of legal metrology such as commercial activities, official relations, health, environmental control, etc.

The Annex p.8 contains a summarized description and basic data of the recommended equipment along with references to OIML Recommendations, where applicable. The main use of each item is indicated in the last column "Field of Application".

The equipment described in the list is thought to be versatile so as to enable selection of the required verification means in compliance with the demands of each particular country depending on the actual tasks, which the national metrological service is confronted with.

Part of the reference instruments included in the list will for their appropriate use require special conditions and parameters of the environment (temperature, humidity, vibration, etc.). These requirements are usually stated in the technical documentation for the particular types of instruments needed.

Fig. 1 shows a block diagram of the transfer of the mass unit from the National standard to the ordinary measuring instruments with the help of standard and reference measuring instruments.

Standards (at National central laboratory)

The National standard is a weight with a nominal mass value of 1 kg (A_1) . It shall be made from non-magnetic stainless steel and its mass value shall be adjusted to that of the international prototype kilogram of the International Bureau of Weights and Measures on the basis of an assumed density of weight material equal to $8.0.10^3$ kg/m^3 and on air density equal to 1.2 kg/m^3.

The secondary standards are weights with nominal mass value from 1 mg to 20 kg (A_2 to A_4) and should be in compliance with the requirements specified for weights of class E2 in OIML RI 20.

The tertiary standard set of weights (A_5 to A_7) is similar to the secondary one (A_2 to A_4) and differs only in the identification marking.

The secondary standard weights should be made of non-magnetic stainless steel. These standards should be certified by way of comparing them with the National standard taking into account the actual density of the material which the weights are made of and the actual density of the air at the time of comparison.

The secondary standards should be stored in boxes marked as required. Each set of weights(A_2 to A_4) should preferably be supplied with a verification certificate.

The transfer of mass unit value from the National standard to the secondary standard 1 kg weight (comprised in set A_4) is effected with the use of the primary comparison balance A_{24}- The values of the other secondary standard weights are obtained, through closed-series comparisons using the balances A_{22} to A_{25}.

Though the above-mentioned measuring instruments can also be employed for solving other metrological tasks, their use for other purposes than calibration of fine weights shall always be avoided.

Reference Measuring Instruments (used for verification)

The reference measuring instruments for measurement of small masses (up to 30 kg) should be :

- reference weights ($A_8 - A_{10}$) of accuracy class F_1 used as local standards
- test weights ($A_{11} - A_{16}$) used for the verification of weighing machines
- reference balances (A_{26}- A_{29}) for calibration of class F_2 weights and test weights (class F, and M_1.)
- balances (A 30 - A33) which are used for routine testing of commercial weights .class M_1, M_2 and O.

Technical data and adjustment tolerances of the reference and test weights shall be in compliance with the requirements of the OIML International Recommendation No.20.The number of weights is determined in accordance with actual requirements.

Reference and test weights shall be verified within the time intervals prescribed by the national regulations. It is recommended to verify weights annually.

Sets of gram and milligram reference weights shall be stored inside special boxes lined with soft material and provided with forceps having soft nosepieces.

Reference weights from 1 to 20 kg may be better stored in separate boxes to protect them against corrosion and mechanical damage.

The boxes should have a nameplate carrying the following information :

- national identification sign,
- purpose of weights such as "reference weights for verification officers",
- accuracy class of reference weights,
- name of manufacturer,
- range of nominal mass values of weights.

Additional instructions can also be envisaged in compliance with the National metrological legislation.

Verification of high capacity weighing equipment

The verification of high capacity weighing instruments (above 30 kg) usually requires the following equipment :

- test weights of classes F_2 (A_{11} to A_{13}) and M_1 (A_{14} to A_{16}),
  and
- parallelepiped-shaped reference/test weights (A_{17}, A_{18}) with technical data corresponding to the requirements of OIML RI 2 but adjusted in compliance with requirements stated for weights of classes F_2 and M_1 respectively,
- reference weights for testing of high capacity weighing devices (A_{19}) generally in compliance with OIML RI 47 but with adjustment tolerances of 0.002 %,
- high capacity comparison balance (A_{34}) with maximum weighing capacity of 1000 kg,
- mobile weighbridge verification units (on road vehicle or railway chassis) ($A_{20} - A_{21}$).

National metrological services should pay attention to the necessity of special adjustment and verification of the heavy weights. The required number of heavy test weights is determined in accordance with actual requirements.

Adjustment and verification of reference parallelepiped-shaped 20 kg weights should be effected with a maximum permissible error of 300 mg and of test weights for verification of balances at their place of use with a maximum permissible error of 1000 mg.

Weights from 500 to 5000 kg (i.e. 500, 1000, 2000 and 5000 kg) are required for the verification of high capacity weighing devices. The maximum value of these weights shall be selected taking account of local tasks and conditions as well availability of special lifting transport and auxiliary equipment needed for the handling of such weights.

The mobile test units for verification of high capacity truck, railway, conveyer and other similar scales should only be acquired paying careful attention to the local needs.

The mobile road weighbridge verification unit should contain a set of 500 or 1000 kg test weights arranged on a special vehicle chassis (van-type vehicle or tow-truck with semitrailer-van). It shall also carry a sufficient number (up to 50) of 20 kg test weights (see item A_{18})

The van should be equipped with loading devices (i.e. monorail, electric or hydraulic hoist for lifting of weights, longitudinal-displacement mechanism, weight holders, etc.) for carrying weights of 500 kg or more. The control of the loading/unloading device by electrical or hydraulic means actuated from the vehicle engine as well as the auxiliary devices and appliances should ensure smooth operation of the whole unit.

The 20 kg test weights (25 to 50) should be stored in the mobile verification unit in special cases excluding any displacement and protecting them from mechanical and other kind of damage.

These mobile units, depending on the type of the vehicle and trailer used and their loading capacity can ensure verification of weighbridges with the maximum weighing limit from 10 to 40 t (This limit will in practice also depend on the permissible load on access roads).

Weighbridge verification test units of the railway van type are intended for verification of weighbridges used, for instance, in sea and river ports, railway locations handling heavy freight (such as minerals, etc.).

Depending on the actual conditions and tasks to be solved, units for .the verification of railway weighbridges of a maximum capacity up to 100 or 200 t may be acquired. These units can comprise railway vans equipped with 20 kg test weights (see item A_{18}) and heavy weights of mass 1000, 2000 or 5000 kg adjusted to ± 0.01 % as well as with special trolleys of verified mass.

The van serves for storage and transport of verification trolleys and test weights. It is also possible to use a railway van as ballast for verification.

The van should contain from 20 to 40 heavy weights, their total mass being at least equal to 50 % of the maximum capacity of the verified scales. The number of verification trolleys can be limited to 2.

The van should be equipped with a diesel power plant, ,1 hoist for lifting, displacing and lowering of weights and trolleys, electric motors actuating displacement of the van and verification trolleys, external power supply sources, control systems and devices. The use of verification trolleys allows displacement of the weights to the verified scales and along the scale platform.

The the site of automatic and semi-automatic belt weighers and other heavy weighing scales of discontinuous or continuous action is usually done using the material normally weighed with the machines. The mass of this material is determined on a static weighbridge which must be available close to the location and which is previously verified.

The verification of heavy crane scales (from 5000 kg and upwards) may require the use of a materials tension testing machine equipped with a calibrated dynamometer. When such a testing machine is not available in the central metrology laboratory the calibration may take place in some other materials testing laboratory provided the metrology service has a suitable set of certified tension dynamometers or load cells ranging from 50 kN to 1 MN and which can be used as comparison standards.

Other equipment which is occasionally necessary for pattern approval of mechanical weighing machines such as a Rockwell hardness tester and surface roughness comparison patterns may also be available in a materials testing laboratory cooperating with the mass measuring laboratory of the metrology service.

Auxiliary equipment

Equipment for measuring the levelling of weighbridges may also be required as well as small block levels for inspection of balances of medium and higher accuracy class.

The metrology service must of course also be equipped with sealing and stamping equipment for weights and weighing machines (see OIML RI 42).

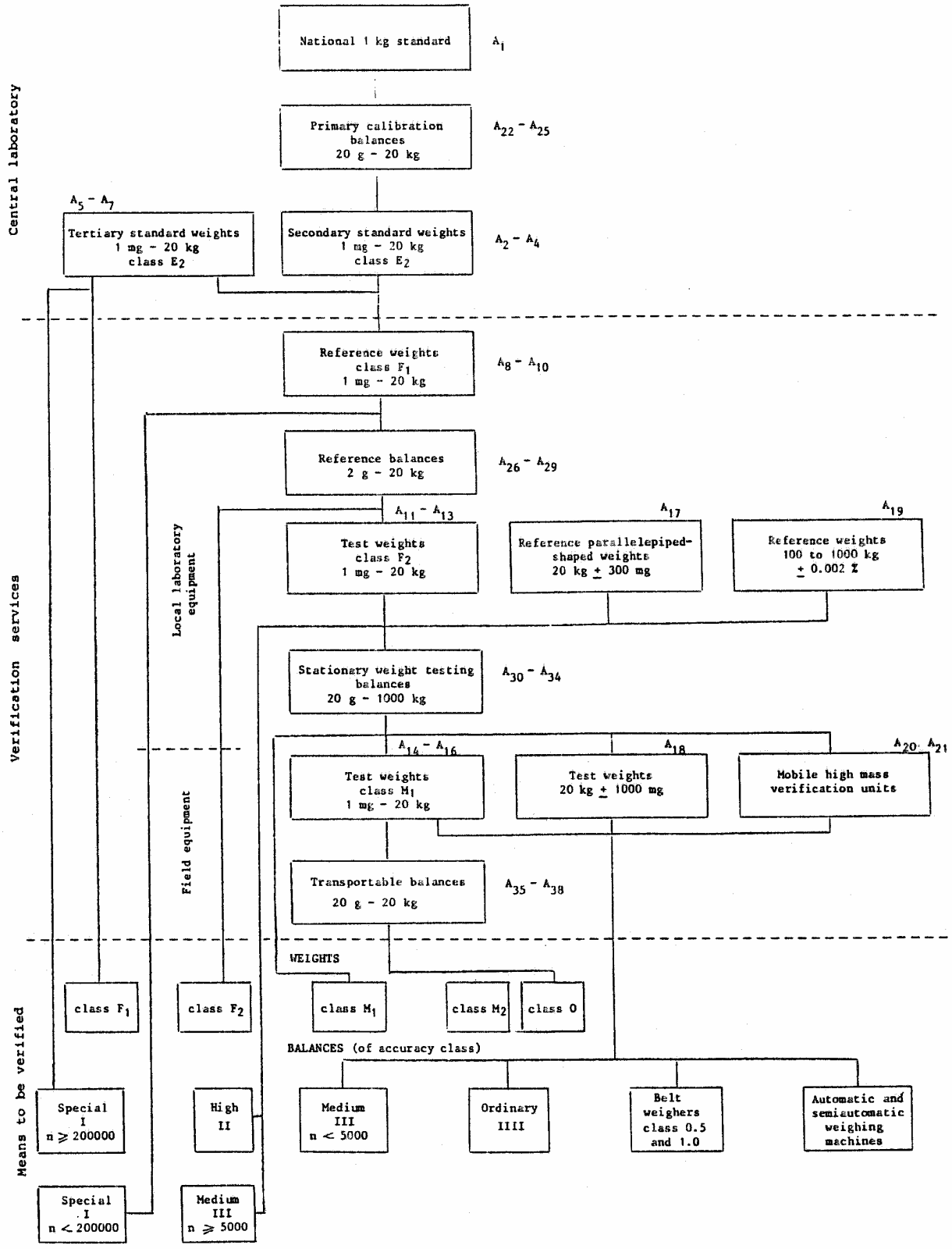


Fig. 1 - Block diagram of interrelation of verification equipment in the field of mass measurement

ANNEX

MASS MEASUREMENT

Item	Description	Basic data	Field of application
		1. Standards (Highest level)	
A_1	National standard	Nominal mass value 1 kg. Made from non-magnetic stainless steel. Cylindrical shape, h = d. True material density to be indicated. Admissible deviation from nominal mass value ± 1 mg. To be supplied with BIPM calibration certificate with uncertainty to ± 0.1 mg	Initial means of reproduction and maintaining of the unit of mass
A_2 - A_4	Sets of secondary standard weights, composed of :	Material : non-magnetic stainless steel. Composition of sets and adjustment according to OIML class E_2	Closed series comparisons of secondary standard weights with 1 kg national standard. Verification of tertiary set of weights A_5 - A_7 and of weights used as local standards.
	A_2 Set of milligram weights	1 - 500 mg	
	A_3 Set of gram weights	1 - 500 g	
	A_4 Set of kilogram weights	1 - 20 kg	
A_5 - A_7	Set of tertiary standard weights for current calibrations at high accuracy level	Identical to sets A_2 - A_4 except for identification markings	Verification of class F_1 weights and of balances of special accuracy class with n ≥ 200 000
		2. Local reference and test weights	
		2.1. Mass measurements up to 30 kg	
A_8 - A_{10}	Set of reference weights (Local standards)	Composition of sets, material and adjustment tolerances in accordance with OIML class F_1	Reference standards for local offices. Verification of weights class F_2 and of specially adjusted parallelepipedic weights of 20 kg (item A_{17}). Verification of balances of special accuracy class with n < 200 000
	A_8 Set of milligram weights	1 - 500 mg	
	A_9 Set of gram weights	1 - 500 g	
	A_{10} Set of kilogram weights	1 - 20 kg	
A_{11} - A_{13}	Set of test weights	Composition of sets, material and adjustment tolerances in accordance with OIML class F_2	Verification of weights class M_1 (and M_2) Verification of weighing machines class II and III
	A_{11} Set of milligram weights	1 - 500 mg	
	A_{12} Set of gram weights	1 - 500 g	
	A_{13} Set of kilogram weights	1 - 20 kg	
A_{14} - A_{16}	Set of test weights	Same data as for A_{11} - A_{13} but OIML class M_1	Verification of weights class M_2 and 0. Field verification of weighing machines of class III and class IIII.
		2.2. Mass measurements above 30 kg	
A_{17}	Set of 20 kg reference weights	50 cast iron (or cast steel) parallelepipedic weights of nominal mass 20 kg generally according to OIML RI 2 but provided with means for easy adjustment to error limits of ± 300 mg	Verification of reference high mass weights of 100, 200, 500 or 1000 kg nominal value (A_{19}).
A_{18}	Set of 20 kg test weights	Specifications as for A_{17} but with sealed adjustment to error limits of ± 1000 mg	Verification of large capacity weighing machines of medium and ordinary accuracy class up to 1000 kg on the site of installation.

Item	Description	Basic data	Field of application
		4. Local office balances	
A_{26} - A_{29}	Set of local office reference balances :	Mechanical or electronic balances with the following data :	Verification of weights class F_2 and test weights items A_{11}-A_{13} and A_{17} and A_{18} using set A_8-A_{10} as reference.
	A_{26} Microanalytical balance	Maximum capacity 20 g. Scale interval 0.01 mg Standard deviation $\leq$ 0.02 mg	
	A_{27} Analytical balance	Maximum capacity 200 g Scale interval 0.1 mg Standard deviation $\leq$ 0.2 mg	
	A_{28} Verification office reference balance	Maximum capacity 2 kg Scale interval 1 mg Standard deviation $\leq$ 2 mg	
	A_{29} Verification office reference balance	Maximum capacity 20 kg Scale interval 10 mg Standard deviation $\leq$ 50 mg	
A_{30} - A_{33}	Set of stationary weight testing balances :	Mechanical or electronic balances suitable for rapid comparisons of weights having the following data :	Verification and stamping at the local office of commercial weights class M_1 M_2 (and 0).
	A_{30} Analytical balance	Maximum capacity 20 g Scale interval 0.1 mg	
	A_{31} Analytical balance	Maximum capacity 200 g Scale interval 1 mg	
	A_{32} Analytical balance	Maximum capacity 2 kg Scale interval 10 mg	
	A_{33} Precision balance	Maximum capacity 20 kg Scale interval 100 mg	
A_{34}	High capacity comparison balance	Maximum capacity 1000 kg Standard deviation 10 g	Comparison of item A_{19} to A_{17} and verification of test weights A_{20} using A_{19} as reference
		5. Transportable balances (if required)	
A_{35} - A_{38}	Set of transportable balances :	Pack-away balances in boxes (or sturdy electronic balances installed in a mobile van) with the following data :	In-service verification of weights (classes M_2 and 0) at their place of use (supervision)
	A_{35} Jewellery type balance	Maximum capacity 20 g Scale interval 1 mg	
	A_{36} Transportable precision balance	Maximum capacity 200 g Scale interval 10 mg	
	A_{37} Transportable precision balance	Maximum capacity 5 kg Scale interval 100 mg	
	A_{38} Transportable precision balance	Maximun capacity 20 kg Scale interval 1000 mg	

Item	Description	Basic data	Field of application
		4. Local office balances	
$A_{26} - A_{29}$	Set of local office reference balances :	Mechanical or electronic balances with the following data :	Verification of weights class F_2 and test weights items A_{11}-A_{13} and A_{17} and A_{18} using set A_8-A_{10} as reference.
	A_{26} Microanalytical balance	Maximum capacity 20 g. Scale interval 0.01 mg Standard deviation $\leq$ 0.02 mg	
	A_{27} Analytical balance	Maximum capacity 200 g Scale interval 0.1 mg Standard deviation $\leq$ 0.2 mg	
	A_{28} Verification office reference balance	Maximum capacity 2 kg Scale interval 1 mg Standard deviation $\leq$ 2 mg	
	A_{29} Verification office reference balance	Maximum capacity 20 kg Scale interval 10 mg Standard deviation $\leq$ 50 mg	
$A_{30} - A_{33}$	Set of stationary weight testing balances :	Mechanical or electronic balances suitable for rapid comparisons of weights having the following data :	Verification and stamping at the local office of commercial weights class M_1 M_2 (and 0).
	A_{30} Analytical balance	Maximum capacity 20 g Scale interval 0.1 mg	
	A_{31} Analytical balance	Maximum capacity 200 g Scale interval 1 mg	
	A_{32} Analytical balance	Maximum capacity 2 kg Scale interval 10 mg	
	A_{33} Precision balance	Maximum capacity 20 kg Scale interval 100 mg	
A_{34}	High capacity comparison balance	Maximum capacity 1000 kg Standard deviation 10 g	Comparison of item A_{19} to A_{17} and verification of test weights A_{20} using A_{19} as reference
		5. Transportable balances (if required)	
$A_{35} - A_{38}$	Set of transportable balances :	Pack-away balances in boxes (or sturdy electronic balances installed in a mobile van) with the following data :	In-service verification of weights (classes M_2 and 0) at their place of use (supervision)
	A_{35} Jewellery type balance	Maximum capacity 20 g Scale interval 1 mg	
	A_{36} Transportable precision balance	Maximum capacity 200 g Scale interval 10 mg	
	A_{37} Transportable precision balance	Maximum capacity 5 kg Scale interval 100 mg	
	A_{38} Transportable precision balance	Maximun capacity 20 kg Scale interval 1000 mg	

MEASUREMENT OF VOLUME OF LIQUIDS

Introduction

This list of equipment for the verification of measures and meters of volume of liquids covers most of the common activities of legal metrology services over a wide range of measured values : from one millilitre or less to hundreds of cubic metres, See Annex p. 17.

The accuracy of the measures and measuring instruments used in the field of volume measurement is ensured by following the procedure for the transfer of the unit of volume from the standards to the test measures and from there to the ordinary measures and meters as shown in Fig. 1.

Calibration by weighing

The standard volume measures are verified by way of accurate weighing of the mass of distilled water with the use of class F_2 weights (OIML, RI 20) and converting subsequently this mass into volume of water at the moment of weighing using accepted (or measured) values for the density of water (*) and taking into account the air buoyancy correction with respect to the weights used with (or to calibrate) the balance.

The temperature of the water used shall be measured with thermometers having a maximum error of 0.1 °C. (If a standard or test measure is calibrated or used at a temperature very different from the normal temperature of 20 or 27 °C it is also necessary to take into account the coefficient of cubical expansion of the material of the measures).

The weighing shall take place under good laboratory conditions (preferably in the central laboratory) in a room with stable temperature.

The balances used shall have sufficient capacity so as to take account of the mass of the empty measures (as proposed in items V_{12} to V_{15} in the list). They shall furthermore provide for sufficient free space to accommodate the standard measures. Electronic top loading balances are usually suitable for this purpose but the weighing procedure must then make use of the substitution with weights so as to eliminate any scale or drift errors.

(*) Values of the density of distilled water may be found in OIML RI 22 International Alcoholometric Tables, Table 1 for p-values = 0.

The weighing method makes it possible to determine the amount of water contained in ,or delivered by the vessel. The accuracy of measurement of volume delivered by the vessel depends on the amount of liquid retained by the walls of the vessel and on the time interval allowed for drainage. The waiting time for drainage is generally specified in the relevant standards or OIML Recommendations (for flasks, burettes and pipettes). For standard flasks of volume greater than 2 L it may be taken equal to 1 minute. When test flasks are used for verification of ordinary measures the drainage time is usually prescribed in national regulations and is frequently 30 s.

Standard measures

The standard measures are intended for the calibration of test measures used by verification officers.

The main set of standard measuring flasks V_1| is made of stainless steel and comprises vessels of capacity 2, 5, 10, 20, (50) 100 and 200 L. As to the form each flask consists of a cylindrical body closed by cones in the upper and the lower parts. Attached to the upper cone is a neck and attached to the lower one is a drain valve. The capacity of the standard flask is in the lower part limited by a drain valve and in the upper part by a neck to fill the vessel up to the upper edge level. The standard flasks are positioned on rubber shock absorbers placed, in turn, on a tripod made of steel pipes. The lower ends of the steel pipes are provided with adjustable supports for levelling. The tripod is designed to protect the flask against mechanical damage.

The standard flasks should preferably be filled through an additional bottom valve to prevent formation of air bubbles on the walls which otherwise may effect the accuracy.

The standard flask is provided with a spirit level and is adjusted to the temperature of 20°C for the delivered volume. It is verified by the weighing method and should be supplied with a certificate of the national metrological service of the country of manufacture with indication of nominal and real volume, year of manufacture and the manufacturing plant. The statutory verification stamp is applied to the end-face part of the neck. The maximum error for the determination of volume of the standard gauging vessel should be lower than ± 0.03 %.

The set of standard one-mark glass flasks V_3 shall comply with OIML RI 4. The set consists of flasks of the following nominal capacities: 0.1, 0.2, 0.5, 1 and 2 L.

The nominal volumes are chosen in compliance with the national regulations.

The flasks are calibrated (*) by the method of weighing distilled water in delivered volume (wetted walls) at a temperature of 20 °C (or 27 ° C)

The set of standard burettes V_5 of nominal capacity 10, 25, 50 and 100 ml should be in compliance with OIML RI 41 which also describes the method of verification by weighing.

Standard burettes are mainly used for calibration at a fixed location of laboratory glassware, whereby the range may be extended down to 1 ml if required.

If the amount of laboratory or other glassware to be verified is great, the standard glass flasks and the standard burettes may be substituted by a fixed installation of automatic burettes with fixed-volume overflow devices.(It is foreseen that a Recommendation for such standard instruments will be drafted by OIML SP 5- Sr 3) .

Test measures

Test measures are designed for the verification of ordinary measures and meters.

The set of test flasks, item V_2 is generally similar to the standard test flasks but have a graduated inspection neck. The smaller test flasks of 20 L and below do, however, not have drain valves, at the bottom. The material to be used is preferably stainless steel but can be any other suitably corrosion-protected metal. The set consists of gauging vessels of capacities 2, 5, 10, 20, (50) 100, 200, (500) and 1000 L.

The capacity of the test flasks is verified by the volumetric method, i.e. the method of draining water from a standard flask into the verified measure.

(*) An applicable method of calibration is described in the annex to OIML RI 34.

The value of the capacity is reduced to the reference temperature of 20 °C. The neck is graduated by means of standard flasks and pipettes. The test flask is supplied with the national metrological service certificate containing the following data :

(a) capacity,

(b) serial number,

(c) year of manufacture,

(d) name of manufacturing plant.

These data should be provided on the nameplate attached to the test flask. A place should also be provided for the stamp of the national metrological service.

The maximum permissible error of determination of volume of the test flasks is ± 0. 1 %.

The test vessels of 500 and 1000 L should be equipped with a release valve and a drain tube and installed on a truck (or car) trailer. The calibration should be effected in the central laboratory with the use of standard test flasks of capacity 100 and 200 L. Quantity : one for the central laboratory and as may be required for other individual laboratories (verification of proving tanks for water and petroleum, flow meters, gauging of tanks, reservoirs, etc.).

Sets of test glass flasks item V_4 shall also be provided ranging from 0.01 to 2 L in compliance with OIML RI 43. They shall be packed in suitable transport boxes. These sets are used for verification of trade measures (for milk, beverages and other liquids) by the mobile verification units.

The set of graduated pipettes, item V_6, complying to OIML RI 40 and having capacities of 1, 2, 5, 10 and 25 ml shall be used by verification officers as a complement to the test glass flasks. They shall also be packed in suitable transport boxes.

The geometric method should be used for gauging of stationary horizontal and vertical steel reservoirs.

The mobile units responsible for gauging of tanks and reservoirs can as a minimum be equipped with the set of means described under item V_7 of the present list. For gauging the bottom of reservoirs it may be appropriate to use a calibrated tank truck having a capacity of 10 000 L.

If a great number of tank wagons or tank trucks have to be gauged a special installation may be used which is equipped with proving tanks of fixed capacity of 1000 L and one graduated measure of capacity 200 L. The proving tanks are placed on a metallic trestle having a platform for the operator located at a height suitable for the tank trucks or tankwagons.

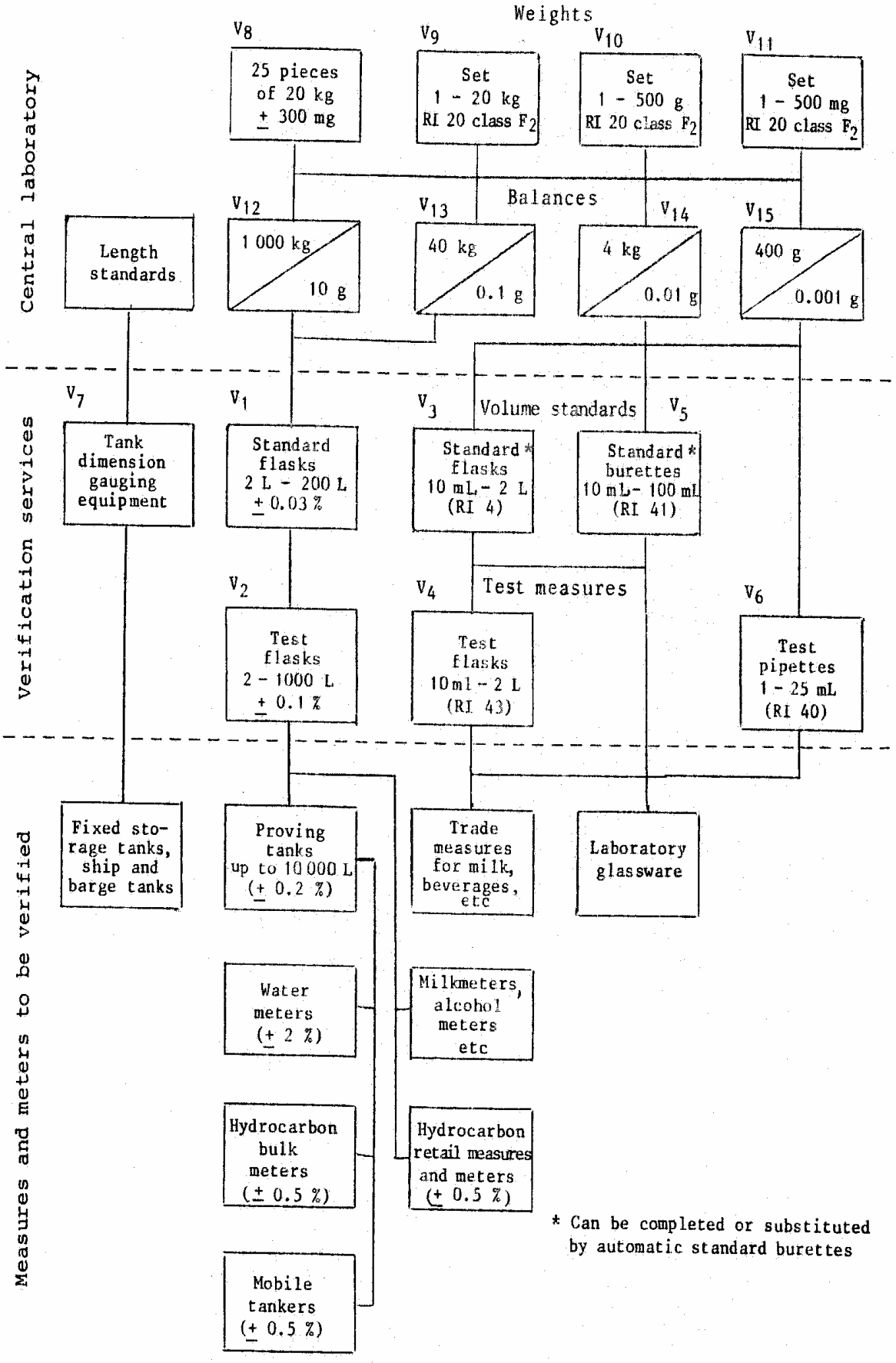


Fig. 1 - Block diagram of equipment for the verification of volume of liquids

VOLUME MEASUREMENTS OF LIQUIDS

Item	Description	Basic data	Field of application
V_1	Standard flasks	Capacity : 2, 5, 10, 20, (50), 100 and 200 L Limits of error : ± 0.03 % Material : stainless steel Quantity : one of each	Verification of test flasks item V_2
V_2	Test flasks	Capacity : 2, 5, 10, 20, (50), 100, 200, (500), 1000 L Limits of error : ± 0.1 % Material : corrosion protected metal. Transportable execution Quantity : as required by the verification service by taking into account field of application and liquids used.	Verification of measures, proving tanks and meters for water and hydrocarbon products. Verification of milk meters, alcohol meters etc.
V_3	Standard flasks, with one mark	Capacity : 10 mL to 2 L Material : borosilicate glass Form and tolerances according to OIML RI 4 (or ISO 1042, grade A)	Verification of test flasks (item V_4) and laboratory glassware
V_4	Test flasks, graduated	Capacity : 10 mL to 2 L Material : hard glass Form and tolerances according to OIML RI 43.	Verification of trade measures for milk, beverages, etc.
V_5	Standard burettes	Capacity : 10 mL to 100 mL Material : glass Form and tolerances according to OIML RI 41 (or ISO 385, grade A). (The capacity may be extended down to 1 mL if needed).	Verification of laboratory glassware.
V_6	Test pipettes, graduated	Capacity : 1 mL to 25 mL Material : glass Form and tolerances according to OIML RI 40 (or ISO 835, grade A).	Verification of trade measures as a complement to item V_4 and verification of low-capacity measures
V_7	Tank dimension gauging equipment	Length measures and accessories as follows : 1 Measuring tape of stainless steel with wind-up handle length 20 m interval 1 mm 1 Do. length 50 m 1 Do. length 100 m 2 Non-graduated measuring tapes of stainless steel with wind-up devices length 200 m 4 Tape tensioning springs 3 Telescopic poles for displacing the tapes 1 Folding 3 m measure 1 Sliding telescopic measure of 3 m 1 Flexible double metre 1 Folding double metre 1 T-shaped dip stick to measure water level 1 Height measuring tape of 20 m with bob on rewind device 4 Thermometers 8-38 °C, scale interval 0.1 °C	Verification of fixed storage tanks or of tanks installed in ships and barges
V_8	Set of reference test weights	25 (or 50) cast iron or cast steel parallelepipedic weights of nominal mass 20 kg generally according to OIML RI 2 but adjusted to error limits of ± 300 mg (same as item A_{17} in mass list)	For use with high capacity platform balance item V_{12} in calibrations (by substitution) of standard test flasks in the range from 50 L to 200 L
$V_9 - V_{11}$	Set of test weights	Composition of sets, material and adjustment tolerances in accordance with OIML RI 20 class F_2 (same as items $A_{11} - A_{13}$ in mass list)	For use with balances items V_{13}, V_{14} and V_{15} in calibrations (by substitution) of standard flasks, burettes and pipettes in the range from 1 mL to 20 L
	V_9 kilogram weights	1 - 20 kg	
	V_{10} gram weights	1 - 500 g	
	V_{11} milligram weights	10 - 1000 mg	

Item	Description	Basic data	Field of application
V_{12}	High mass balance	Capacity : 1000 kg (min. 500 kg) Repeatability s = 10 g Free height and size of loading platform chosen so as to accept standard flasks up to at least 200 L. (May be the same balance as item A_{34} in mass list)	Verification of standard flasks in the range from 50 to 200 L by weighing using clean (filtered) tap water
V_{13}	Laboratory balance	Capacity : 40 kg (minimum) Scale interval : 0.1 g Repeatability s = 0.2 g Top loading electronic type (or mechanical with free height over pan of at least 600 mm).	Verification of standard flasks in the range from 5 to 20 L by weighing using distilled water
V_{14}	Laboratory balance	Capacity : 4 kg (minimum) Scale interval and repeatability s = 0.01 g Top loading electronic type (or mechanical with free height over pan of at least 400 mm)	Verification of standard flasks in the range from 0.5 to 2 L by weighing using distilled water
V_{15}	Laboratory balance	Capacity : 400 g (minimum) Scale interval and repeatability s = 0.001 g Top loading electronic type (or mechanical with free height over pan of at least 250 mm).	Verification of standard flasks in the range from 10 to 200 mL and of standard burettes and pipettes by weighing using distilled water
V_{16}	Laboratory thermometers	Range : - 2 to 32 °C Division and accuracy : 0.1 °C Certified.	Determination of density of water by using temperature to density relation expressed in tables (e.g. OIML RI 22)

MEASUREMENT OF LENGTH AND ANGLE

The field of angle and linear measurements applies to a great variety of objects of different use, geometrical size, shape, type of measurement, accuracy, etc.

The list of means used for verification of linear and angle measures is therefore long and the number of standards required for the verification of these means, although not so great, is still quite considerable.

These guidelines are intended to serve as a basis which, depending upon the real needs, can be supplemented and specified in more detail.

The list does not comprise any standard means relating to gear-engineering, geodesy, range finding, thin films, coatings, deviations in form, kinematic drives, etc.

The Annex p.22 contains the list of suggested verification means for equipping metrology services of developing countries with a metrological central laboratory for linear and angle measurements.

If all the standard verification means described in the list are available, the laboratory can ensure verification of the majority of length and angle measures and instruments used in mechanical engineering, civil engineering and trade.

If an interferometric comparator for absolute measurements of block gauges equipped with the corresponding light source (L« in the list) is available, the laboratory can ensure the transfer of the unit of length through all stages of the transfer diagram (see Fig. 1).

In the absense of an interferometric comparator the laboratory shall choose a class of end measures to be accepted as the primary one. In this case the original sets of end measures shall be certified by a country having the corresponding means at its disposal. The measures of the lower orders can be certified by the laboratory using the means described in the list,

The divided H-shaped line standard (L_{19}) serves as the primary one for certification of machines used for measurement of length measuring rules. This standard shall itself be calibrated periodically in a country which has such facilities.

The primary means for verification of angle measurements may consist of a set of optical polygons certified in a country having the necessary facilities.

The column "Field of Application" in the Annex illustrates examples of practical use of the verification means. It does however not comprise all metrological tasks that can be solved by means of the equipment described. The solution of metrological tasks on certification of the end measures is illustrated in Fig. 1.

The list includes only the primary means used for verification, there are however in a. number of cases also other measuring or auxiliary instruments which are required (for example, in the course of verification of the end measures a micrometer is required for measurement of the sizes of the sections of measures and in other cases fastening or other appliances are required). These devices are not mentioned but described in detail in the corresponding practical instructions for verification.

These instructions describing the conduct of the verification, suitable premises and personnel of required qualification shall, jointly with the present list of standard means ,serve as a background for the organization of the laboratory work.

If it is impossible to ensure standard climatic (temperature) conditions for the conduct of measurements the results of verification must be converted in accordance with recommendations of the relevant standards or methodological documents.

In addition to the special equipment described in the list, the organizations of the national metrological services should be provided with the means for applying the specified marks to the verified measuring instruments (stamping) as well as for cancellation of these marks.

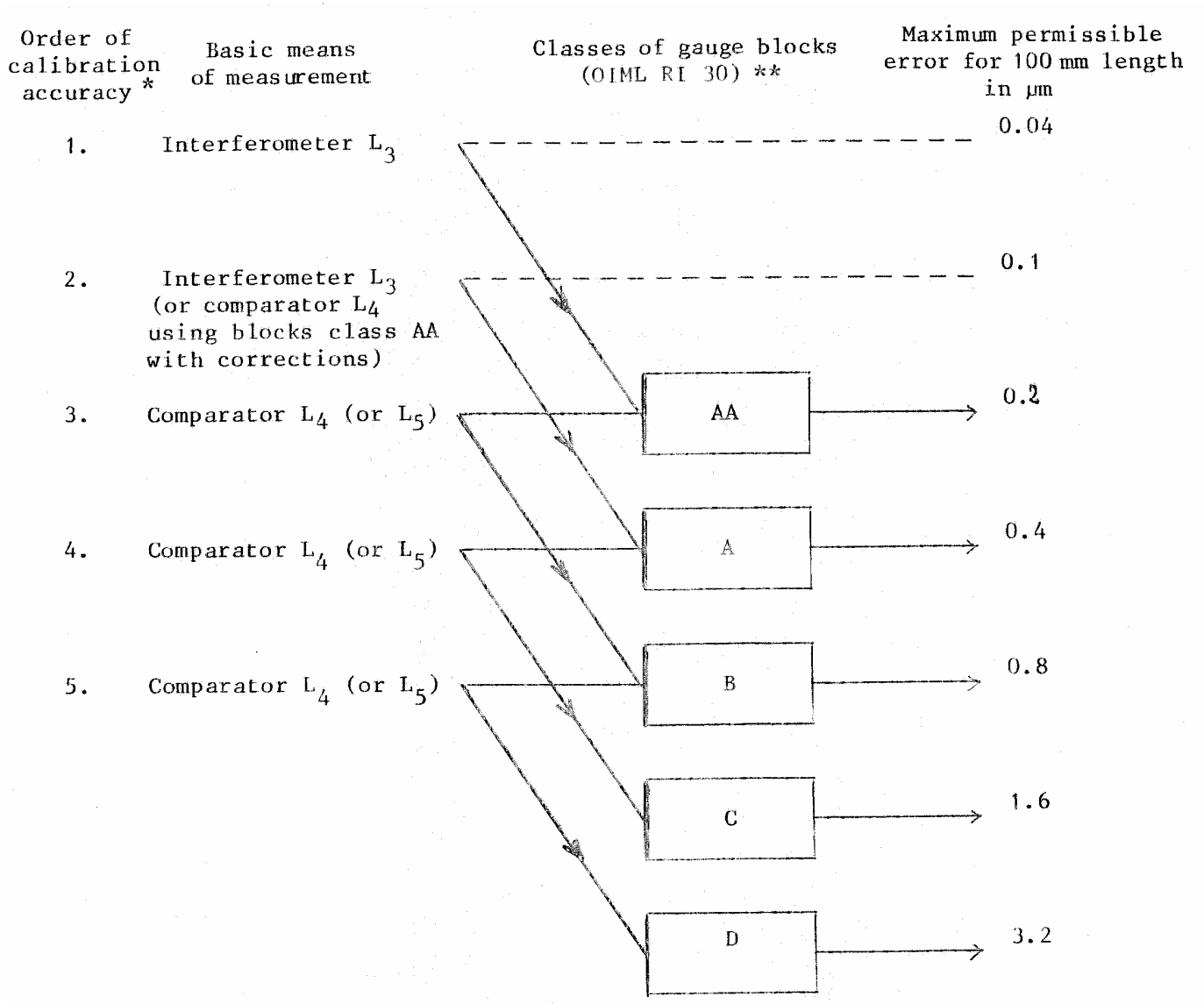


Fig. 1 - Transfer diagram of end gauges

* The order of calibration accuracy is determined by the limits of permissible errors in measuring the length of the gauge blocks (see OIML RI 30, point 10) illustrated by following the inclined arrows in the diagram.

** The class is determined by the permissible deviations of the values of the length of end gauges (used as standards).

— Class AA gauge blocks are used as basic laboratory reference measures and should be delivered with individually certified corrections (for at least every 10 mm) .

— Class A (and B) gauge blocks are used for direct calibration of other gauge blocks and instruments of lower accuracy (usually two orders lower without corrections and at least one order if corrections of the reference gauge blocks are taken into account).

— The accuracy classes AA, A, B and C of OIML RI 30 correspond to ISO 3650 classes 00, 0, 1 and 2 respectively.

ANNEX

LENGTH and ANGLE MEASUREMENT

Item	Description	Basic data	Field of application
L_1	Gauge blocks (end gauges)	Length : from 0.5 to 100 mm (OIML RI 30) Class according to needs (AA or A).	Transfer of length measurement unit from primary to reference and ordinary measuring instruments, see Fig. 1.
L_2	Gauge blocks (end gauges)	Length : from 200 to 1000 mm (OIML RI 30) Class according to needs (A or B).	(as for L_1)
L_3	Interferometric comparator for measurement of end measures by absolute (and comparison) methods	Range of measurement : up to 100 (or 200) mm Supplied with secondary standard light source	Verification of end measures class AA and A (by absolute method of measurement) see Fig. 1.
L_4	Vertical comparator, mechanical contact type with optical or electrical indication	Range of measurement : up to 200 mm Scale interval : 0.1 µm (or less)	Verification of end measures (by method of relative measurement)
L_5	Optical-mechanical universal measuring machine for length measurement	Range of measurement : up to 1000 mm Scale interval : 0.001 mm or less	Verification of end measures (by method of absolute and relative measurements)
L_6	Optical flats	Diameter : 60, 80, 100 and 120 mm Tolerance of interference fringe surface flatness : 0.1 - 0.2	To be used for verification of end measures and for measurement of deviations from planeness of finished surfaces
L_7	Plane-parallel optical flats (4-flat sets, dimensions of flats depend on the measurement limits of the verified instrument)	Permissible tolerance of interference fringe surface flatness : 0.3	To be used for measurement of deviations from alignment and planeness of anvils of micrometers, lever and indicating gauges, etc.
L_8	Thermometer	Scale interval : 0.1 °C Range of measurement : from + 10 to + 35 °C	To be used for verification of end measures and other length measuring instruments
L_9	Profilometer-profilograph (universal)	Range of measurement of surface roughness parameter R_a : from 0.02 to 100 µm according to ISO 3274	Verification of surface roughness (comparison) patterns. To be used for verification of measures, gauges, instruments, tools, or when measuring surface roughness of products
L_{10}	Surface roughness reference standards	Set according to manufacturer's catalogue	Verification of profilometers, profilographs and optical instruments used for the checking of surface roughness
L_{11}	Surface roughness (comparison) patterns	Limit deviations of the mean value of parameter R_a from the nominal value $(^{+10}_{-20}\ \%)$ R_a = 0.025 - 12.5 µm R_a = 0.2 - 400 µm according to ISO 2632/I and ISO 2632/III	To be used for tactile and visual verification of measures, gauges, instruments, tools, surfaces of products
L_{12}	Tool-room microscope with projection headpiece or "universal" microscope	Scale interval : 0.005 mm or less	To be used for verification of threaded and conical gauges, different types of scales, parts of complex shape

Item	Description	Basic data	Field of application
L_{13}	Accessories to plane-parallel end measures	Set in accordance with end gauge manufacturer's catalogue	To be used for verification of internal gauges as well as for measurement and marking of different parts
L_{14}	Comparator for internal and external measurements	Range of measurement : from 0 to 200 mm Scale interval : 0.001 mm and less	Verification of reference and adjusting rings to internal gauges. To be also used for measurement of precision parts
L_{15}	Comparator for the verification of reference standard line measures	Range of measurement : up to 1000 mm Scale interval : 0.001 mm and less (may be combined with item L_5)	Verification of reference graduated length measures. To be also used for measurement of precision parts
L_{16}	Reference rings	Sets according to manufacturer's catalogue	Verification and adjustment of internal gauges
L_{17}	Reference stainless steel measuring tape	Length of scale : 20 m Scale interval : 10 mm with first 100 mm divided in mm	Verification of graduated length measures using a long flat bench
L_{18}	Reference steel rule	Length of scale : 1 m Scale interval : 1 mm	Verification of graduated trade measures by direct comparison (using a magnifying glass).
L_{19}	Reference H-shaped precision steel rule	Length of scale : 1 m Scale interval : 1 mm (first millimeter divided in 0.1 mm)	Verification of length measuring machines
L_{20}	Object-micrometer	Length of scale : 1 mm Scale interval : 0.01 mm	Calibration of ocular micrometers
L_{21}	Surface plate	Preferably of hard granite, dimensions for example 1500 x 1000 mm	To be used for measurement of flatness of parts, instruments and measures
L_{22}	Toolmaker's straight-edges	Dimensions - with for example knife edge 200 mm, others 500 and 1000 mm	To be used for measurement of flatness of parts, instruments and measures as well as for checking of articles
L_{23}	Feeler gauges (sets)	Sets - according to manufacturer's catalogue	To be used for measurement of rectilinearity and planeness of parts of instruments and measures as well as for checking of articles
L_{24}	Special micrometer for verification of dial indicators (with a special rack to attach indicator)	Scale interval : 0.01 mm Maximum error : $\pm$ 0.002 mm (Measuring range 10 mm)	Verification of dial indicators
L_{25}	Dial comparators	Scale interval : 0.001 mm and less Mounting bore diameter : 28 mm and 8 mm Type to be selected from manufacturer's catalogue	To be used for verification of different gauges, measurement of misalignment and perpendicularity of lines, and surfaces of measures, parts of instruments and articles

Item	Description	Basic data	Field of application
L_{26}	Comparator stands	For comparators with mounting bore diameters : 28 and 8 mm Type to be selected from manufacturer's catalogue	For use with L_{25}
L_{27}	Roundness measuring machine	The minimum width of working field for recording on the diagram disk : 30 mm (the maximum increase error in the course of recording : $\pm$ 3 %)	To be used for verification of gauges, reference rings and for measurement of precision parts
L_{28}	Prismatic angle standards and optical polygons	Sets - according to manufacturer's catalogue	Verification of protractors and similar devices
L_{29}	Goniometer	Scale interval : 1"	Verification of angle measures, measurement of precision parts
L_{30}	Autocollimator	Scale interval : 1" and less	To be used for measurement of rectilinearity of travel of parts of instruments, machines; also for measurement of alignment
L_{31}	Reference wedges (angle standards)	Set - according to manufacturer's catalogue	Verification of autocollimators
L_{32}	Precision level (for use in level checking device)	Scale interval : 1"	Verification of levels
L_{33}	Optical dividing head	Scale interval : 5" (or less)	Verification of theodolites, etc.
L_{34}	Sine bars	Bases of sine bars 100 (or 200) mm	To be used for verification of conical gauges as well as for measurement of angles of articles

MEASUREMENT OF TEMPERATURE
(thermal contact methods)

Introduction

Temperature is one of the most widely spread and important physical parameters in biology and medicine; it characterizes the various processes in power engineering, in petroleum and gas extraction and refinery industries as well as in chemical, metallurgical, food and other industries.

The field of temperature measurements is extensive both in the range of temperatures and requirements for accuracy and in the variety of types and kinds of technical means used for temperature measurement. In consequence, it is difficult to organize properly the state metrological supervision over the entire field of temperature measurements covering engineering, commercial, medical and other activities.

At the same time, it seems possible to limit at first the scope of tasks to be solved by the legal metrology services and, hence, the range of temperature measurements and the number of metrological means to be used for this purpose.

Temperatures ranging from - 50 (or 190) to + 1200 °C may be chosen as such an immediate temperature range. The present list of verification means is worked out specially for this range covering the basic temperature measurements using thermal contact methods, see Annex p. 29.

The following three main categories of equipment are included in the list of verification means :

measurement standards,
reference means,
additional equipment.

Standards (primary)

The standards comprise :

1. Sets of standard platinum resistance thermometers and standard thermocouples to be subjected to primary calibration by international or national metrology services of countries delivering this equipment,

2. Set of high-accuracy electric measuring equipment comprising preferably on automatic bridge for resistance thermometry and a digital voltmeter for thermocouple measurements.

3. Fixed points

The necessity of regular calibration abroad of the standard resistance thermometers and standard thermocouples may be avoided if fixed points according to the International Practical Temperature Scale (IPTS-68) are procured. This, however, requires a certain amount of scientific skill and availability of pure materials for operation and replacement as well as a small computer facility for establishment of calibration tables.

The equipment list includes, as a possible extension, a suggestion for some of these fixed points in the following order of priority

- triple point of water
- freezing point of tin
- freezing point of zinc
- triple point of argon (for IPTS below 0 °C)

(The standard thermocouples may be calibrated by the melting wire method using wire of pure noble metals.)

The temperature unit within the adopted range is transferred from the national standards to the reference means of temperature measurement through calibration at selected reference points of IPTS-68 and comparison performed in thermostated baths (or if necessary in cryostats at temperatures below - 50 °C).

When required for reasons of accuracy the temperature unit may be transferred from national standards directly to the high-accuracy working means of temperature measurements.

<u>Reference means</u> (calibration equipment)

The set of reference means indicated in this list comprises :

- set of reference platinum resistance thermometers,
- set of reference mercury-in-glass thermometers,
- set of reference platinum - platinum / rhodium thermocouples,
- set of secondary fixed points used within the IPTS-68 such as

  the ice melting point and a number of baths or furnaces with specified properties (temperature, size, homogeneity, etc.)

in which the comparison and calibration of thermometers are performed,

- associated electrical measuring equipment (identical or similar to that for the standards).

The reference measuring means are intended for the verification of measuring means for direct use (medical, scientific, industrial and so on) through their calibration in reference points and through the direct comparison in cryostats, thermostats and in high-temperature furnaces,

The set of additional equipment contains a number of devices, appliances and instruments required either for preparation of the coolant (such as ice) and for the use or control of the verification equipment.

The complete composition of the verification means indicated in the list of means for equipping the national legal metrology services of developing countries is presented in the Annex. This table also gives the basic metrological data and technical characteristics of the suggested equipment and specifies the field of application.

Fig. 1 shows the simplified diagram of the interrelation of equipment indicated in the list for verification of ordinary temperature measuring means (industrial, medical, laboratory and scientific) and the transfer of the temperature unit from the primary national standards to the ordinary instruments.

When purchasing equipment for the national services of legal metrology in the field of temperature measurements one must bear in mind that the majority of calibrations and verifications of thermometers of various types, intended for measurements in various ranges (including high-temperature thermocouples) requires the use of the ice melting point (0 °C). For this reason, it is recommended to pay special attention to the purchase of "zero" thermostats and machines for ice preparation (crushing, screaping) and for maintainance of the above—mentioned means in appropriate condition.

As a whole, the suggested list of verification equipment aims at solving many metrological problems by ensuring harmonization and confidence of temperature measurements using many types of thermometers over a wide range of temperatures and accuracies.

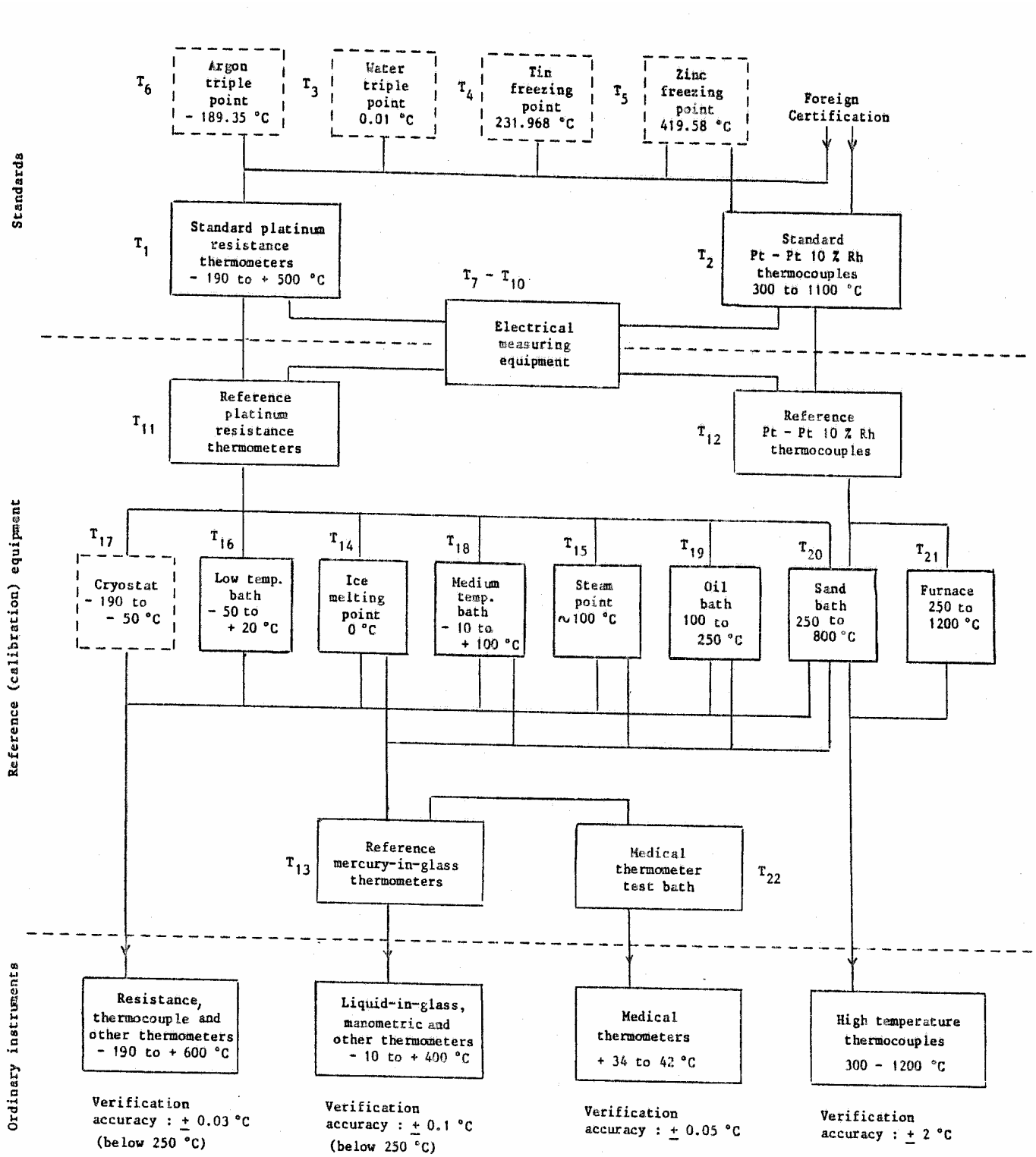


Fig. 1

Simplified diagram of temperature verification equipment showing the transfer from standards to ordinary instruments

ANNEX

TEMPERATURE MEASUREMENTS

Item	Description	Basic data	Field of application
		STANDARD MEANS	
T_1	Set of standard platinum resistance thermometers	Range of temperature measurement : - 190 to + 630 °C Permissible error (at 0 °C) : max. ± 1 mK Thermometer nominal resistance at 0 °C : 25 or 10 ohm Ratio of thermometer resistance at 100 °C to its resistance at 0 °C not less than 1.3925 Measuring current flowing through thermometer : 1 mA Insulation resistance not less than 10^8 ohm Quartz sheath length : minimum 400 mm Platinum wire 4-lead terminals. Set consists of 3 thermometers delivered in separate cases and furnished with certificate of the official metrology service (calibration at the following fixed points of IPTS-68 : oxygen boiling point, water triple point, tin freezing point, zinc freezing point).	Use as national reference instrument in the range from - 190 to + 500 °C
T_2	Set of standard platinum - platinum 10 % rhodium thermocouples	Temperature measurement range : + 300 to 1200 °C Permissible errors : max. 0.5 K Diameter of wires : 0.5 mm Wire length : 1600 mm Insulation of wire : two-channel tube made of aluminium oxide and having the length of not less than 500 mm. Length of free (non-protected by electro-insulating pipe) part of thermal electrodes : 50 mm Values of the thermal EMF between the reference junction at 0 °C and the temperature of working junction as well as other characteristics shall be within limits specified by BIPM for IPTS-68. The set consists of 3 platinum-platinum 10 % rhodium thermocouples delivered in separate cases and furnished with certificate of official metrology service with calibration of at least 3 reference points IPTS-68. It is advisable to include the following equipment in the delivery set : - additional reinforcing two-channel tubes (with the length of 5-10 cm and bore diameter corresponding to wire diameter of 0.5 mm, - tubes made of aluminium oxide with the length of up to 500 to 600 mm intended for accommodation of twin-bore insulating tubes.	Use as national reference in the range from 500 to 1100 °C

Item	Description	Basic data	Field of application
		Set of IPTS-68 fixed points (extension)	
T_3	Water triple point cell	Represented value of temperature : 273.16 K (0.01 °C) Error less than ± 0.5 mK. The equipment shall consist of at least 2-3 vessels containing water of required isotopic composition and at least 2 respective Dewar flasks	Calibration of standard resistance thermometers, comparison of standard and reference resistance thermometers
T_4	Tin freezing point cell	Represented value of temperature : 505.118 K (231.968 °C) Purity of tin used : 99.999 % Commercial version consisting of : - furnace - ampoule with highly pure tin - graphite crucible - ampoule lifting device - thermal automatic control system	- idem -
T_5	Zinc freezing point cell	Represented value of temperature : 692.73 K (419.58 °C) Purity of zinc used 99.999 % Commercial version consisting of - furnace - ampoule with highly pure zinc - crucible - thermal automatic control system	- idem -
T_6	Argon triple point apparatus	Represented value of temperature : 83.798 K (- 189.35 °C)	- idem -
		Electrical measuring equipment	
T_7	Measuring system for resistance thermometers (automatic or semi-automatic)	Suitable for connection of four-terminal platinum resistance thermometers with 25 or 10 ohm ice resistance Resistance range : 10^{-5} to 110 ohm minimum (preferably extendable to 500 ohm for use with industrial Pt 100 sensors) Accuracy (linearity) better than 10.10^{-6} May consist of fully automatic bridge with digital indication or Six-decade potentiometer, resolution 0.1 µV with highly stabilized current supply, null detector and suitable stable standard resistors (10, 25 and 100 ohm with very low temperature coefficient or mounted in thermostat)	Measurement of temperatures by platinum resistance thermometers. Calibration in fixed points or comparison of resistance thermometers. (Potentiometer version may also be used for thermocouple measurements and calibration of digital voltmeters)
T_8	Set of special two-pole switches with low thermal emf	Parasitic EMF less than 0.1 µV. Contacts of suitable material with very low thermal EMF against copper. Supplied in boxes with copper or gold-plated pole screw connections. Suggested number : 4 each of 12-way, 2 pole 2 each of 24-way, 2 pole 2 each of 4-way, 4 pole (for resistance thermometers)	Connection of resistance thermometers and thermocouples to their respective electrical measuring instruments

Item	Description	Basic data	Field of application
T_9	Universal digital electronic voltmeter	Measurement range : 0.1, 1, 10 and 100 V Resolution (sensitivity) limit : 1 µV or better) Stability (long-term) and linearity : 0.005 %. The instrument shall have : - self-verification facility to externally connected (or built-in) saturated standard cell - insulated output to printers - four-terminal resistance measuring facility in the range from 10 MΩ to 0.01 ohm It is preferable to purchase at least two voltmeters (including one spare voltmeter)	Precise measurement of voltage of thermocouples. Resistance measurement of industrial resistance temperature sensors (platinum wire or semi-conducting)
T_{10}	Digital printer	The equipment shall comprise : - interface ensuring the matching of potentiometric unit or digital voltmeter with electrically controlled printing device - digital printing device - required amount of consumable printing material	
		Reference means (calibration equipment)	
T_{11}	Set of reference platinum resistance thermometers	Secondary standard platinum resistance thermometers with range : - 190 °C to + 630 °C Permissible error maximum ± 0.01 K (between - 50 and 250 °C) The nominal resistance at 0 °C shall be 25 or 10 ohm The ratio of thermometer resistance at 100 °C to resistance at 0 °C should not be less than 1.3925 Measuring current : max 2 mA Insulation resistance should not be less than 10^8 ohm. Length of quartz sheath not less than 400 mm Platinum terminals ensuring the measurements with a four-wire circuit The set shall consist of 2 or more thermometers having the calibration tables established by direct comparison with the standards.	Verification of resistance thermometers, liquid-in-glass, thermocouples and other types of thermometers by direct comparison in cryostats and thermostats within the range - 190 to + 600 °C
T_{12}	Set of reference (secondary standard) platinum-platinum 10 % rhodium thermocouples	Temperature measurement range : + 300 to 1200 °C Permissible errors : ± 1.0 K Remaining characteristics and accessories are similar to those specified for item T_2 The set consists of 3 (or more) thermocouples in separate boxes.	Verification of ordinary thermocouples made of noble metals in the range from 300 to 1200 °C and base metals in the range of 300 to 800 °C

Item	Description	Basic data	Field of application
T_{13}	Set of reference mercury-in-glass thermometers	Temperature measurement range : - 30 to + 400 °C Scale interval depends on a range and permissible error of measurements. The number and type of thermometers in the set depend on the particular problems to be solved by official national metrology agencies. It is desirable to have at least 5 thermometers with the same scale interval for the solution of each problem	Verification of mercury-in-glass thermometers, including medical thermometers
		Set of temperature calibration baths	
T_{14}	Ice melting point apparatus (zero thermostat)	Zero thermostat consisting of - ice melting bath - device for water agitation and saturation with air for preparation of water-ice mixture - Dewar flask - thermometer holder The thermostat shall ensure representation of ice melting temperature 0 °C with maximum error of + 0.01 °C Suitable dimensions of working volume : diameter:70-150 mm, depth:300-400 mm	Verification and calibration of the zero point of liquid-in-glass thermometers and other thermometers.
T_{15}	Water boiling point apparatus (vapour thermostat)	The represented point of temperature scale is about 100 °C (depending on the external barometric pressure).	Verification and calibration of liquid-in-glass thermometers about 100 °C by comparison to reference standards
T_{16}	Bath for comparison of thermometers at temperatures below 0 °C	Low temperature bath for calibration and comparison of liquid-in-glass or electrical thermometers, range - 70 °C (or more) to ambient room temperature Immersion depth minimum 300 mm Immersion diameter : 70 to 120 mm Equipped with mechanical refrigeration, bottom agitation and accurate resistance sensor controlled temperature regulation having a setting resolution of 0.1 K or better and a stability better than 0.01 K The uniformity of temperature in test zone shall be better than 0.005 K at ambient temperature. The bath shall be of such construction from safety point of view to allow use with inflammable liquids such as alcohol. To be supplied with suitable holders for thermometers and resistance thermometer.	Verification and calibration of thermometers at low temperatures (0 °C to - 50 °C) by comparison to reference platinum resistance thermometers
T_{17}	Cryostat	Using liquid nitrogen as working fluid : temperature range - 210 to + 20 °C. Stability of the temperature in the cryostat should be better than ± 0.05 °C within the time of 15 min. The time of cooling from + 20 °C down to - 180 °C should not be more than 2 hours.	As for T_{16} but at temperatures lower than - 50 °C

Item	Description	Basic data	Field of application
T_{18}	Medium temperature bath	Range : - 20 to + 100 °C using silicon oil or using water between + 2 and 95 °C, immersion depth minimum 300 mm, immersion zone diameter 70 to 120 mm. Equipped with mechanical refrigeration, bottom agitation and accurate resistance sensor controlled temperature regulation with setting resolution of 0.1 K or better and a stability better than 0.01 K. Uniformity of temperature to be better than 0.005 K in the test zone at ambient temperature. Delivered with programmer for very slow increase of temperature.	Verification and calibration of liquid-in-glass thermometers and other thermometers by comparison with platinum resistance reference thermometers or with reference mercury-in-glass thermometers in the range - 10 to + 100 °C.
T_{19}	Oil thermostat	Working temperature range : + 50 to + 250 °C. Working fluid : oil with flash point exceeding the upper value of working temperature by at least 50 °C. Temperature stability and uniformity in the working volume to be better than 0.05 K	- idem - in the range 100 to 250 °C
T_{20}	Pneumatic sand bath	Working temperature range : + 100 to 800 °C Working medium : alumin powder or other suitable material. The dimensions of the working space should not be less than 100 mm in diameter and 500 mm in depth. The temperature stability in the working volume (employing equalizing block for the thermometers) to be better than 0.5 K at 500 °C. Electronic temperature regulator. Air blower for agitating the working substance.	Verification and calibration of thermometers and thermocouples by comparison with reference standard platinum resistance thermometers in the range from 250 to 500 °C and to reference thermocouples in the range from 250 to 800 °C
T_{21}	Furnace for comparison of thermocouples	Range of temperatures : up to 1200 °C (or higher) Error of adjusting and maintaining the temperature in the working volume lower than ± 1 K. Tubular furnace length : 500 to 600 mm Tube diameter : 25 to 40 mm Supplied with temperature controller and stabilized mains power supply.	Verification and calibration of thermocouples by comparison to reference thermocouples in the range from 300 to 1100 °C
T_{22}	Bath for verification of medical thermometers	Bath for testing medical thermometers with fully electronic control of two set-points. Accuracy of temperatures 0.01 K. Range 34 to 43 °C settable.	Verification of medical thermometers.

Electrical measuring equipment

(The same type of electrical equipment as indicated in items $T_7 - T_{10}$ is used with the reference calibration equipment).

Item	Description	Basic data	Field of application
		ADDITIONAL EQUIPMENT	
T_{23}	Demineralizer of water	Ion-exchange type with regeneration system. The capacity should not be less than 10 litres of water per hour. Equipped with means of control of water composition and characteristics (electrical conductivity).	
T_{24}	Machine for ice preparation	Capacity up to 20 kg/day. It is usually possible to use domestic supply, refrigeraters or freezers.	
T_{25}	Machine for ice crushing and shaving		
T_{26}	Universal glass thermometers of high accuracy	Thermometers of full immersion type for general uses (see also item T_{13})	For temperature measurements outside the standards laboratory (on request)
T_{27}	Set of technical thermocouples	Materials : - platinum - platinum-rhodium (10 % of rhodium), - platinum - platinum-rhodium (30 % of rhodium), - copper-constantan, - iron-constantan etc.	For temperature measurements outside the standards laboratory (on request)
T_{28}	Portable digital voltmeter-thermometer	It should fit for use with thermocouples.	
T_{29}	Portable megohmmeter	Range up to 10^9 ohm.	Measurement of thermometer insulation resistance.

ELECTRICAL MEASUREMENTS

This list contains suggestions of equipment for the verification of measuring instruments for the measurement of the most common AC and DC electrical quantities within the most frequently used ranges.

The list includes the equipment used for the verification of measuring instruments intended for the measurement of :

- direct voltage,

- direct current,

- resistance,

- alternating voltage (frequencies 50 or 60 Hz),

- alternating current (frequencies 50 or 60 Hz).

The following devices are recommended for use as basic standards :

- standard cells for electromotive force,

- standard resistors,

The method of thermoelectrical comparison to direct voltage and current is supposed to be used for the verification of instruments measuring alternating voltage and current,.

The diagrams of transfer of the units of measurement realized with the equipment contained in the list are given in :

Figure 1 - direct voltage
Figure 2 - direct current
Figure 3 - resistance
Figure 4 - alternating voltage, current and power.

In addition to standards and reference measuring instruments the list contains additional equipment used for verification.

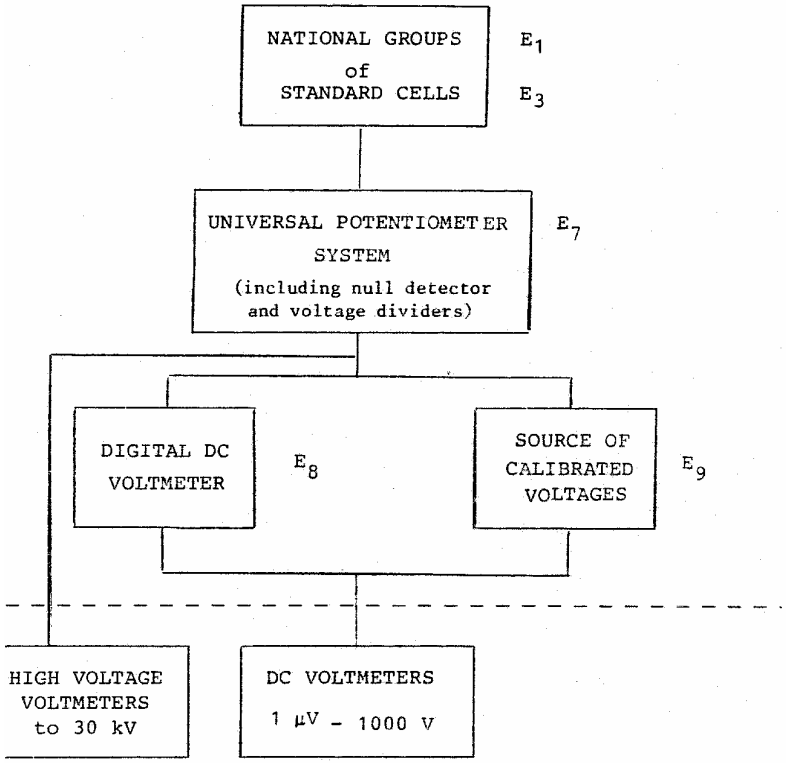


Fig. 1

Block-diagram of transfer of the unit of electromotive force from standards

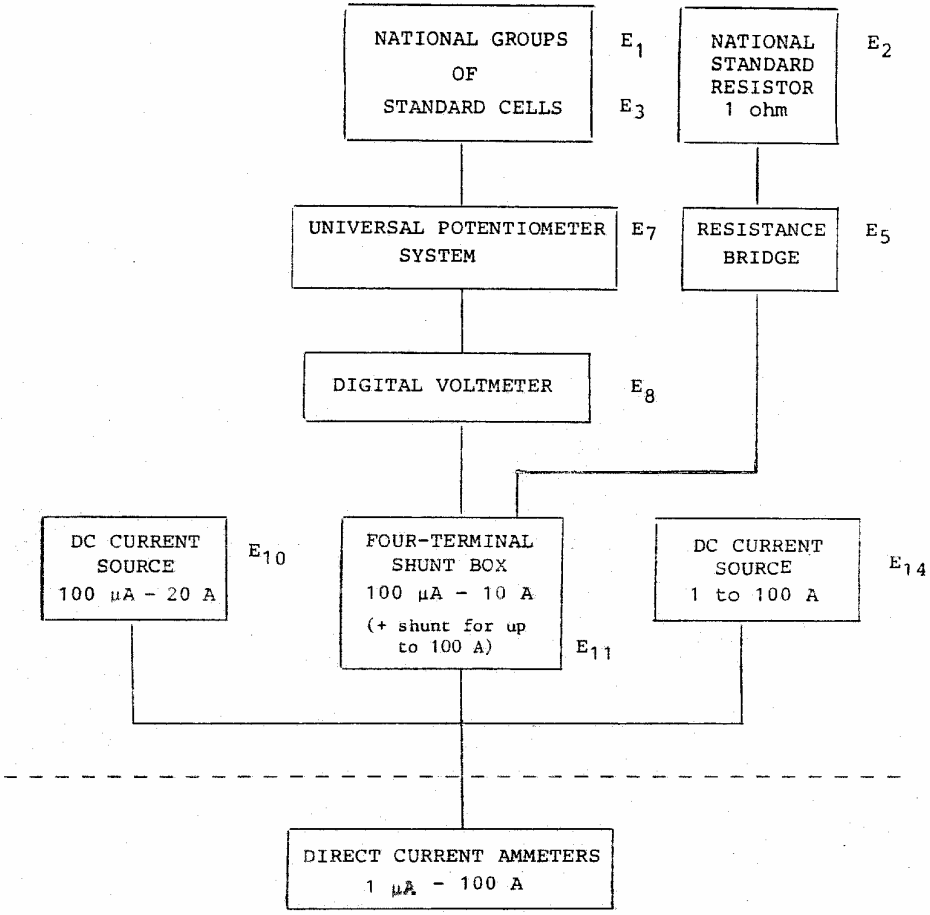


Fig. 2

Block-diagram of transfer of the unit of direct current intensity from standards

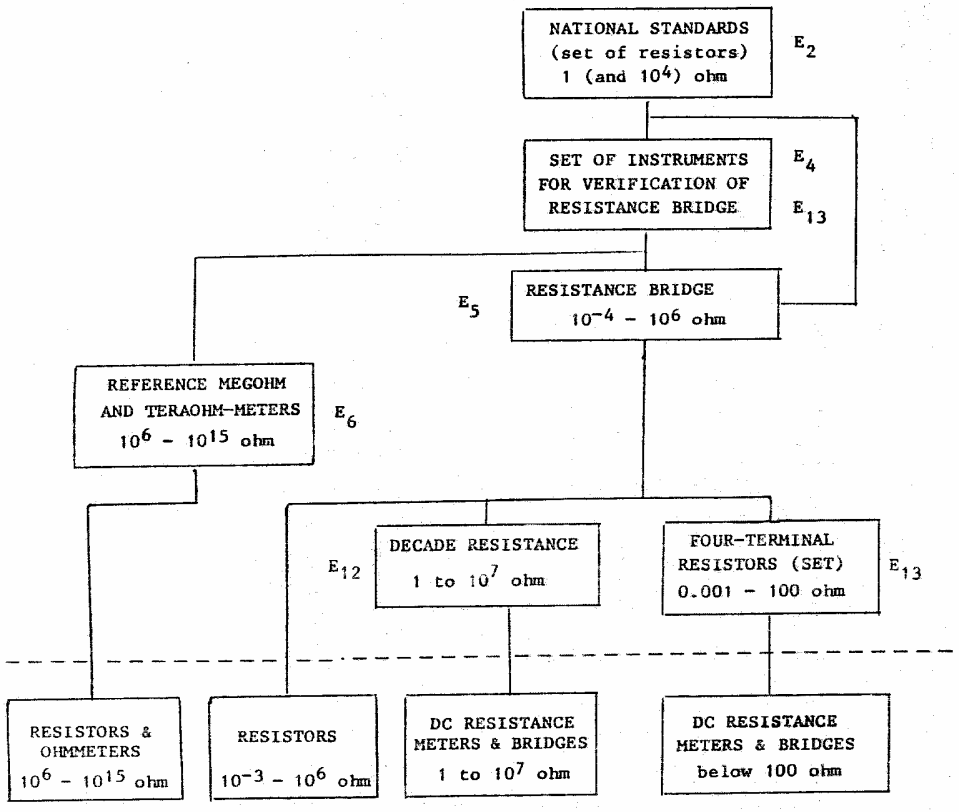


Fig. 3

Block-diagram of transfer of the unit of resistance
from standards to ordinary measuring instruments

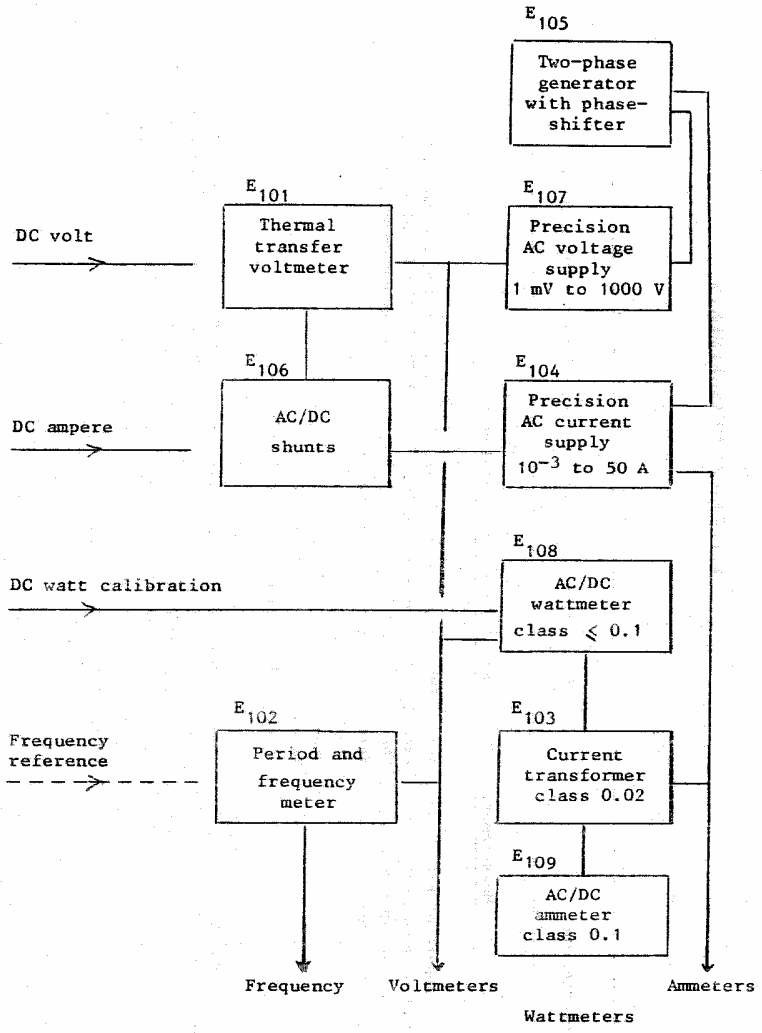


Fig. 4

Block-diagram of calibration equipment
for AC voltage, current and power

ANNEX

ELECTRICAL MEASUREMENTS

Item	Description	Basic data	Field of application
	Measurement of DC voltage, current and resistance		
E_1	Travelling standard of EMF consisting of 4 saturated standard cells in a portable thermostated enclosure	Annual EMF variation should not exceed $2 \cdot 10^{-6}$ (mean value for the group) Temperature in the thermostatic chamber set to 32 °C. Stability : 0.01 °C. To be calibrated at BIPM (or accredited foreign laboratory)	Ensuring the traceability to BIPM in the field of electrical measurements.
E_2	National standard of resistance (set of resistors)	1 ohm (or 10^4 ohm) Four-terminal execution. Instability of resistance per year not more than $2 \cdot 10^{-6}$. To be calibrated at BIPM (or accredited foreign laboratory).	Ensuring the traceability to BIPM of the unit of resistance. Maintenance on national level of the unit of resistance. (Preferably group of 3 resistors).
E_3	Reference group of saturated standard cells (set of 10 or more) in thermostatic chamber	Annual EMF variation should not exceed $1 \cdot 10^{-5}$ (for individual cells). Temperature in thermostatic chamber set to 32 °C, Stability $\pm$ 0.01 °C.	Maintenance on national level of the unit of electromotive force.
E_4	Set of instruments for verification of resistance bridges consisting of :		Standards for use with resistance bridge E_5 and for verification of two-terminal resistance bridges.
E_{4-1}	Reference resistors (set)	1 kohm, 10 kohm, 100 kohm, 1 Mohm. Annual stability : $2 \cdot 10^{-5}$	
E_{4-2}	Special resistance boxes with increasing range and individual engagement of sub-ranges	Range : 1 to 10^8 ohm. in decades allowing series or parallel connections.	Ensuring transfer of the unit of resistance from 1 ohm and upwards
E_5	Direct current bridge unit (comparator)	Range : 10^{-4} to 10^6 ohm Resolution : $1 \cdot 10^{-6}$ Four-terminal connection up to 100 ohm and two-terminal above. Maximum permissible error : $2 \cdot 10^{-5}$ (for 1 to 10^3 ohm) $1 \cdot 10^{-3}$ (for 10^6 ohm)	Calibration of standard (and other) resistors.
E_6	Reference megohm- and teraohmmeter	Range : 10^6 to 10^{15} ohm Maximum permissible error 1 % (Including stabilized voltage source up to	Calibration of high value resistors (above 1 megohm) and testing of insulation resistance measuring instruments

Item	Description	Basic data	Field of application
E_7	Universal potentiometer system consisting of :		Calibration of standards cells and precision voltage sources, potentiometers and digital voltmeters
E_{7-1}	Direct current potentiometer (six-decade)	Direct connection range up to 1.6 or 2 V, resolution 1 µV Maximum permissible error : 0.001 %	
E_{7-2}	Zero-indicator	Detection limit equal to or less than 0.1 µV on 5 kohm source resistance and minimum 1 µV on 50 kohm source resistance. Ranges : ± 500 mV to ± 10 µV.	
E_{7-3}	Source of stabilized current	Power supply with low ripple content for potentiometer item E_{7-1} Stability : $1 \cdot 10^{-5}$. Fully insulated output.	Potentiometer supply (as replacement for storage battery)
E_{7-4}	Voltage divider	Nominal output : 1 or 1.5 V Nominal input range up to 1500 V with intermediate ranges : 150, 300, 450, 600, 750 V. Annual instability not more than $1 \cdot 10^{-5}$	Widening of potentiometer measuring range to 1500 V
E_{7-5}	High voltage DC divider	Nominal output voltage : 1 V for input voltage of 30 kV (current 0.1 - 1 mA) Maximum permissible error 0.1 %	Calibration of DC voltmeters up to 30 kV
E_8	Direct current digital voltmeter	Ranges : 0.11, 1.1, 11, 110, 1100 V Maximum permissible error ± 0.005 %	Calibration of DC voltmeters and ammeters.
E_9	Precision DC voltage source (DC voltage calibrator)	Ranges : 0 - 1.1 V, 0 - 11 V, 0 - 110 V. 0 - 1100 V Error maximum ± 0.005 % Minimum output current : 50 mA for ranges 110 and 1100 V.	Calibration of DC voltmeters.
E_{10}	Precision DC current source	Range : 100 µA - 20 A Instability maximum 0.01 %	Calibration of DC ammeters to 20 A
E_{11}	Four-terminal shunt box (for DC)	Range : 100 µA - 10 A extended with separate shunt to 100 A. Maximum permissible error 0.01 % (0.05 % for the range of 100 A)	Calibration of DC ammeters by connection to E_{10} or E_{15} and to E_8
E_{12}	Decade resistance box	Range : 1 to 10^7 ohm covered by box or set of boxes : 10 x (1, 10, 100 ohm, 1, 10, 100 kohm, 1 Mohm) Maximum permissible error 0.01 %	Calibration of ohmmeters and resistance bridges
E_{13}	Standard four-terminal resistors (set)	Range : 0.001 to 100 ohm with the following values and maximum currents : 0.001 ohm (100 A in oil or oil-filled) 0.01 ohm (30 A in oil or oil-filled) 0.1 ohm (3 A) 1 ohm (1 A) 10 ohm (0.3 A)	Standards of low resistance for u with resistance bridge E_5 or for verification of this bridge below 100 ohm. Calibration of ohmmeters and brid for measuring low resistance.

Item	Description	Basic datat	Field of application
E_{14}	Stabilized current source	Range of smooth regulation from 1 to 100 A. Output voltage up to 8 V	Calibration of current measuring instruments and shunts using E_8 and E_{11}
E_{15}	Oil bath	Thermostated bath with useful space of approximately 40 x 60 cm and 20 cm deep. Temperature controlled for operation between 0 to 60 °C. Long-term stability : ± 0.02 °C	Calibration of standard resistors (including temperature coefficient)
	Measurement of alternating voltage, current and power		
E_{101}	AC-DC thermal transfer voltmeter	0.5 - 1000 V, 0.5 Hz - 500 kHz Maximum permissible error, 0.01 % (within the range of 5 Hz - 20 kHz)	Verification of AC voltmeters, ammeters, wattmeters and precision AC voltage and current sources (such as items E_{104} and E_{107})
E_{102}	Digital meter of frequency and time intervals	Period counter : 10 Hz - 20 kHz, Frequency meter : 10 kHz - 10 MHz Maximum permissible error $1 \cdot 10^{-6}$	Verification of frequency meters Measurement of frequency of generators used for instrument verification
E_{103}	Measuring current transformer	0.1 - 50 A (primary current) 5 A (secondary current) Class 0.02 % Output power 10 VA	Verification of AC ammeters and wattmeters
E_{104}	Precision source of alternating current	1 mA - 50 A, 40 - 500 Hz Stability : 0.02 % Internal and external frequency control.	Verification of AC ammeters and wattmeters
E_{105}	Two-phase AC voltage generator	1 - 10000 Hz, continuous phase variation within 360 ° Instability of output voltage not more than 0.01 %	External generator to control precision current and voltage sources
E_{106}	Direct and alternating current shunts (set)	1 mA to 20 A for use with AC/DC thermal transfer voltmeter (item E_{101})	Verification of AC ammeters and wattmeters and of precision AC current sources (such as item E_{107})
E_{107}	Precision source of AC voltage	1 mV - 1000 V, 40 - 500 Hz Stability : 0.01 % Internal and external frequency control	Verification of AC voltmeters and wattmeters
E_{108}	Precision AC and DC wattmeter	100, 250 and 500 V, 5 A Class 0.1	Verification of AC wattmeters and cosphimeters.
E_{109}	Precision AC and DC ammeter	5 A, class 0.1	Verification of AC ammeters (using item E_{103})

ADDITIONAL EQUIPMENT for ELECTRICAL LABORATORIES

1. Two- beam oscillograph with memory	Pass - band: 0 – 2 MHz Sensitivity: 1 mV – 5V
2. Variable transformers	
3. Stabilized mains supplies	
4. Connection cables	Lengths: 50, 100, 150 m
5. Variable resistors	0.1, 1, 10, 25, 50 ohm, dissipation 1000 W 250 ohm, 2 kohm, 5 kohm, dissipation 250 W
6. Decade resistance boxes (8 boxes)	4 boxes 10 × (0.1 – 1000 ohm) 4 boxes 10 × (10 – 100000 ohm) Maximum permissible error in use 0.1%
7. Analogue or digital multimeters	(two or more)
8. Milliammeters	0 – 60 mA AC/ DC , class 0.5
9. Ammeters	0 – 6 A "
10. Voltmeters	0 – 600 V "
11. Shunts for high currents	30, 60, 150, 300, 750 and 1500 A Voltage drop: 100 or 30 mV Maximum permissible error 0.1%

PRESSURE MEASUREMENTS

The equipment described in this list is intended to enable selection of the required verification means in the field of pressure measurements in compliance with the demands of each particular country depending on the actual tasks, which the national metrological service is confronted with.

Precision calibration of pressure measuring equipment requires knowledge of the local value of the acceleration due to gravity. Calibration equipment is normally manufactured using the conventional value of gravity 9.80665 m/s^2. The reference temperature is usually 20 °C except for mercury columns (barometers) where the reference is 0°C for both scale and mercury. The true values of pressure at the site of the calibration will thus have to be found from calculation or correction tables.

In the pressure calibration scheme we have included the calibration of barometers. However as the installation needed is somewhat costful and requires attention as regards temperature stability it is advised that its procurement and necessary characteristics are analyzed in cooperation with the local meteorological and aviation services so as to avoid unnecessary duplications of equipment.

The National Metrology Service may typically be required to verify pressure gauges used in industry, boilers, etc, whereby the main problem is usually the need for demounting such gauges on installations (this should be the responsibility of its owner) and of fitting the gauges to the available test equipment which may require various types of adaptors. It is advised that a preliminary survey be made of the ranges, pressure media and fittings normally used in the country so as to enable the procurement of the correct test equipment and the necessary adaptors. (*)

(*) Note : The most commonly used connections for pressure gauges are

1/8 -1/4 - 3/8 - 1/2 " BSP and M 20 x 1.5

where BSP refers to Whitworth threads for tubes designated by R in Germany and by G in France. The symbol M refers to the new ISO fine thread.

Standard connections in the USA are 1/8- 27 NPT, 1/4- 18 NPT arid 1/2 - 14 NPT where NPT stands for American Standard taper pipe thread which is slightly different from BSP (be careful not to destroy the threads!!),

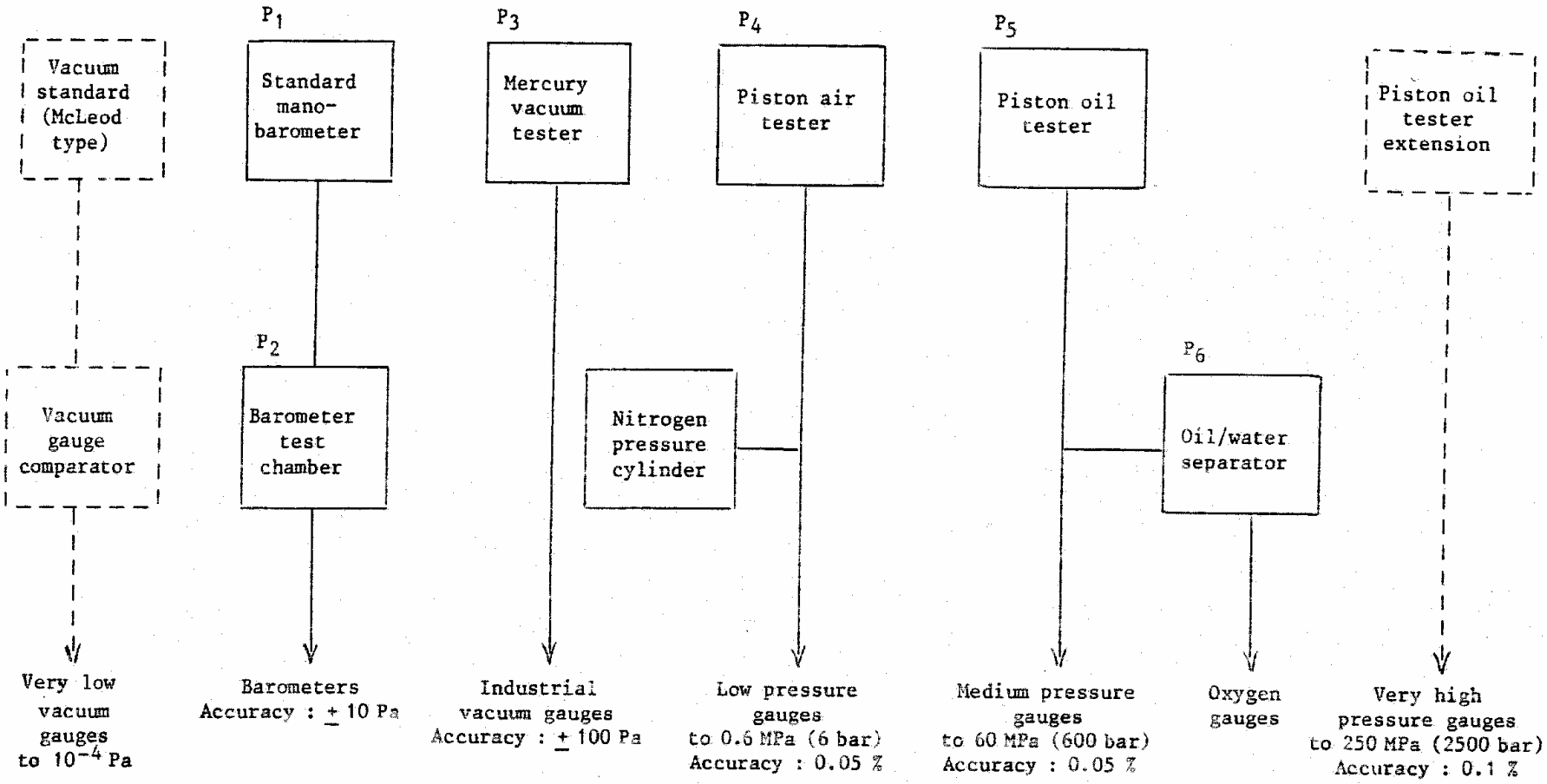
Concerning suitable execution of pressure seals, see OIML Bulletin No. 94, p.27, 1984.

Easily portable dead-weight testers are usually available up to at least 6 MPa (60 bar). For higher pressures the pressure gauge has to be brought to the central metrology laboratory. In exceptional cases and when such provisions exist in the installation, pressure gauges can be checked on the spot to secondary standard (or inspection type) gauges. A set of such gauges has been included in the list below. Dead-weight piston testers should hot/ever be preferred from the point of view of accuracy and reliability.

The problem of the test medium has also to be considered. Pressure gauges with a maximum range of SOO kPa (5 bars) should always be tested with air or a inert gas (like nitrogen). Piston testers using air or gas are also currently available for much higher pressures which however may require safety precautions. Pressure generating dead-weight piston testers using oil as test medium typically range from about 100 kPa (1 bar) up to 100 MPa (1000 bar) arid more. Special precautions must be taken as regards gauges which are to be used with other pressure media than oil for instance oxygen. Such gauges can exceptionally be tested with water on an oil-type piston tester by using a special oil/water separator which can be supplied by some manufacturers. (The practical aspects of series testing of oxygen gauges, if required, should however be treated separately from the standard equipment of the laboratory).

The cost of rotating piston testers varies greatly depending on the accuracy and the quality of the parts used. For many services and especially local offices, a so-called industrial quality may be sufficient and the required ranges may be covered with only a few testers (double-piston types are available). It is preferable that the various weights used are individually marked and weighed to enable regular controls and that at least the reference equipment in the central laboratory has weights which are of stainless steel or suitably corrosion protected.

The following list and the synoptic diagramme includes as examples only a few Pimple piston testers required for the central metrology laboratory to cover the ranges and test media normally required. More elaborate and higher precision systems do however exist sometimes in the form of complete test benches with pressure multipliers (and demultipliers). The amount of heavy weights needed and their ease of handling should be taken into account when making the final choice of piston tester especially for equipment which is intended for frequent use.



SYNOPTIC DIAGRAM OF PRESSURE CALIBRATION EQUIPMENT

ANNEX

PRESSURE MEASUREMENTS

Item	Description	Basic data	Field of application
P_1	Standard barometer	Standard mano-barometer for connection to external test chamber Accuracy ± 5 Pa (0.05 mbar) or approaching Range 0 to 110 kPa (1100 mbar) Suitable for calibration of other barometers or manometers. Two-position reading on precision scale of upper and lower mercury level to ± 0.05 mm, inner diameter of tube at least 11 mm. Certified by official institute.	Calibration of barometers
P_2	Test chamber	Barometer test chamber for connection to item P 1 comprising chamber for installation of mercury barometers and horizontal and vertical aneroid type precision barometers and low pressure gauges. Equipped with vacuum and overpressure pumps, pressure regulating valves, all required supplies, such as oil, fuses etc. for mono-phase operation on ... V ... Hz supply.	Calibration of barometers
P_3	Vacuum tester	Mercury column vacuum tester with scale graduated in mm and second scale graduated in kPa. Equipped with the following connections : 1/4 " - 3/8 " - 1/2 " BSP - M 20 x 1.5 for vertical and angle mounting. To be delivered with hand pump or with electrical vacuum pump and regulating needle valves. The connection to external vacuum system should be possible through suitable connector.	Verification of industrial vacuum gauges
P_4	Air pressure calibrator	Rotating piston dead-weight pressure gauge calibrator for air or gas Accuracy ± 0.02 % Range 10 to 600 kPa (0.1 to 6 bar) or more To be delivered with official certificate from a recognized national laboratory and all adaptors as follows 1/8 " - 1/4 " - 3/8 " - 1/2 " BSP and angle connector 1/4 " - 1/2 " NPT and M 20 x 1.5 as well as triplicate sets of gaskets.	Calibration of pressure gauges at low pressure
P_5	Oil pressure calibrator	Rotating piston dead-weight pressure gauge calibrator for oil Accuracy ± 0.02 % with two (or more) piston assemblies to cover the ranges 0.1 to 6 MPa (1 to 60 bar) and 1 to 60 MPa (10 to 600 bar) To be delivered with official certificate from a recognized national laboratory (piston mass and diameter), connectors and gaskets as for item P 4.	Calibration of pressure gauges at intermediate pressures (above 0.4 MPa)
P_6	Oil/water separator	Oil to water separator for use with item P 5 in particular for testing of oxygen gauges To be delivered with all suitable connectors. Range of use to 40 MPa (400 bar).	Accessory to item P 5 for calibration of special gauges requiring no contamination by oil (such as oxygen gauges)
P_7	Directly indicating standard test gauges	Two (or more) sets of secondary standard test gauges Accuracy 0.1 % Consisting of 0 - 400 kPa (0 - 4 bar) for use on air, connection 1/2 " BSP 0 - 1 MPa (0 - 10 bar) for use on air, connection 1/2 " BSP 0 - 2.5 MPa (0 - 25 bar) for use on oil, connection 1/2 " BSP 0 - 6 Mpa (0 - 60 bar) for use on oil, connection 1/2 " BSP 0 - 10 MPa (0 - 100 bar) for use on oil, connection 1/2 " BSP 0 - 60 MPa (0 - 600 bar) for use on oil, connection 1/2 " BSP All manometers to be delivered in suitable transport boxes.	Comparison and verification of pressure gauges in laboratories and industries (field use)

PHYSICO-CHEMICAL MEASUREMENTS

This list of verification equipment includes basic types of physico-chemical measurements and enables to select for each particular case the necessary equipment which different countries are in need of taking into account the peculiarities of their development and the scientific-technical tasks.

For some types of measurements (for example, hygrometry, spectrometric measurements, instruments to measure composition of substances, refractometry, etc.) it is possible to follow a single-stage diagram of verification.

The countries which utilize these measuring instruments may address themselves directly to the countries supplying verification equipment for all the matters relating to the calibration or verification of reference measuring instruments.

For other types of physico-chemical measurements double-stage diagrams of verification can be used (viscometers, Fig. 1) or combination diagrams consisting of single-stage and double-stage diagrams of verification (densimetry and saccharimetry, Fig. 2 and Fig. 3).

In practically all countries water-alcohol solutions and water solutions of acids, salts, alkalis, liquid products, sugar solutions are either manufactured or utilized, and in many countries it is an essential task to check the viscosity and density of petroleum products, chemical solutions, varnishes, paints, semi-finished food products, and other media. The solution of these problems is achieved by means of different types of viscometers and densimeters,

A block diagram for transfer of the unit of viscosity to ordinary viscometers is shown in Fig. 1. As is seen from this diagram, verification of ordinary viscometers can be made either by the method of comparison (reference viscometers) or by the method of direct measurements using calibration liquids.

The corresponding sets of equipment are shown in the Annex p. 50. Because of the low useful life of calibration liquids (not more than 1 month in a hot climate) it may be preferable to use reference viscometers instead of calibration liquids, which have to be certified.

The certification of calibration liquids and verification of reference viscometers require the use of reference viscometers of higher accuracy (together with special and auxiliary equipment and consumable substances and materials). These operations require observance of special conditions (such as very accurate control and measurement of temperature). These requirements can be found in the respective standards in which the verification methods are described.

Checks of the quality of certain products are frequently made by means of hydrometers. General-purpose glass hydrometers for petroleum products, milk (high and low resolution), alcohol (alcoholometers) and saccharimeters are most extensively used and statutory verification is prescribed in many countries for such instruments.

This verification requires the use of reference hydrometers and suitable verification baths.

The verification of all types of hydrometers is made using special verification liquids (petroleum ether, gasoline, water-alcohol solutions, benzene, mixture or sulphuric acid and ethyl alcohol, water solutions of sulphuric acid and water solutions of mercurous nitrate and potassium iodide) by the method of direct comparison with the reference hydrometers or with high accuracy reference hydrometers, as required. The corresponding block diagram for transfer of the unit of density to ordinary measuring instruments is shown in Fig. 2.

Fig. 3 and Fig. 4 show block diagrams for the verification of saccharimeters (by means of checking the mass concentration in sugar solutions) and alcoholometers (by means of checking the alcohol concentration in water-alcohol solutions) respectively.

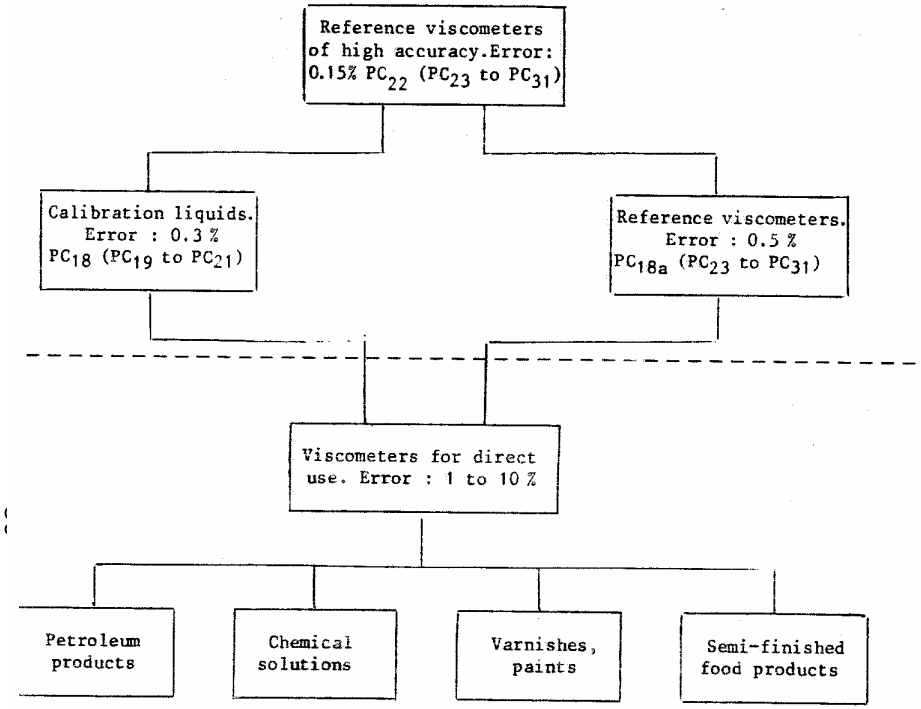


Fig. 1

Block diagram for the transfer of the unit of viscosity to ordinary viscometers and to the products to be measured

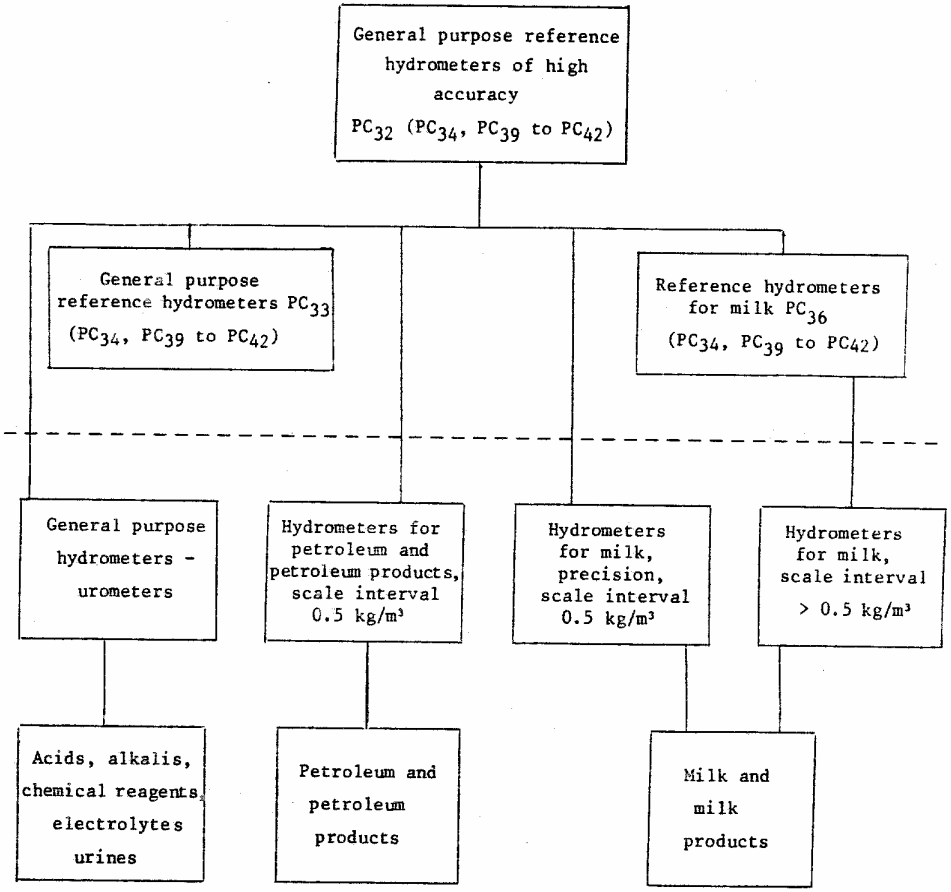


Fig. 2

Block diagram for transfer of the unit of density to ordinary hydrometers and to the products to be measured

Item	Description	Basic data	Field of application
		Polarimeters. Saccharimeters	
PC_{14}	Reference polarimetric plates. Sets	Range : - 17 to + 41 ° Error : ± 0.005 ° Range : - 40 to + 100 ° Error : 0.02 °	Verification of laboratory visual and photoelectric polarimeters and saccharimeters
		Dioptrometers and Ophthalmological Optics	
PC_{15}	Visual dioptrometers	- 30 to + 25 diopters Error : 0.1 diopter	Verification of ophtamological optics (spectacle test lenses)
PC_{16}	Sulphuric ether	Purified for analysis	
		Photoelectric Colorimeters (and spectrophotometers)	
PC_{17}	Set of 8 certified neutral light filters	Transmission range : 1 to 92 % T Error : 0.3 to 0.5 % T	Verification of indication of photoelectric colorimeters and spectrophotometers
		Measurement of Viscosity	
PC_{18}	Graduation liquids (reference samples of viscosity)	0.6 to 34000 mm²/s (cSt) Error : ± 0.15 % (as per ISO 3104-1976) Note : Liquids of limited storage time (usually one month)	Verification of reference viscometer (or ordinary viscometers) according to ISO 3105-1976
PC_{18a}	Reference capillary viscometers for measurement of kinematic viscosity of Newtonian fluids	Range of measurement : 0.6 to 34000 mm²/s (cSt) Error : ± 0.5 %	Verification of glass capillary viscometers in the range from 0.6 to 34000 mm²/s (cSt) as alternative to item PC_{18} (see ISO 3105-1976)
PC_{19}	Glass thermometers, equi-graduated. Set or quartz electronic thermometer with digital readout	Allowing readings to 0.02 °C or better Ranges of measurement : 16 to 20 °C 20 to 24 °C 24 to 28 °C	- idem -
PC_{20}	Stopwatch	Range of measurement : 0 to 30 min, scale interval 0.2 s	- idem -
PC_{21}	Water thermostat	For maintaining temperature in the range of 20 to 30 °C Stability : ± 0.02 °C	- idem -
PC_{22}	Glass capillary reference viscometers of high accuracy, set of 9	Length of viscometer capillary 300 mm Diameter of capillary : from 0.4 to 6 mm Range of measurement : from 0.6 to 34000 mm²/s (cSt) Error of measurement method : ± 0.15 %	Calibration of standard viscosity liquids or of reference capillary viscometers for measurement of kinematic viscosity of Newtonian fluids
PC_{23} - PC_{24}	Electronic pulse counter / timer	Counter range : from 0.1 to 99999.9 s Scale interval : 0.001 s	- idem -
PC_{25}	Water thermostat for reference viscometers	For maintaining temperature in the range of 20 to 30 °C Error : ± 0.01 °C	- idem -
PC_{26}	Water still	Capacity : 3 to 4 L/h	- idem -
PC_{27}	Drying oven for reference viscometers	Length of drying chamber : 600 mm	- idem -

Item	Description	Basic data	Field of application
PC_{28}	Glass chemical vessels :		- idem -
	Measuring glasses,	Capacity : 50, 100, 250, 500, 1000 mL	
	Buchner funnels,	Nos 1 - 6	
	Flasks for filtering in vacuum medium,	5000 mL	
	Tischenko flasks,	250, 500 and 1000 mL	
	Flasks with lapped stoppers	Capacity : 1, 2, 5 and 10 L	
PC_{29}	Consumable substances and materials :	Kinematic viscosity at 20 °C :	For preparation of viscosity calibration liquids
	aviation gasoline, benzene,	0.7 mm²/s	
	kerosene,	1.6	
	transformer oil,	21.0	
	oil,	280.0	
	oil,	1400	
	oil,	1900	
	cable synthetic oil,	100000	
	ethyl alcohol (C_2H_5OH)	Rectified	
PC_{30}	Rubber tubes, medical	Diameter : 5 to 10 mm	
PC_{31}	Glass funnels for filtering with enclosed partition	50 and 500 mL	
	Measurement of density and concentration		
PC_{32}	General-purpose reference hydrometers, set, of high accuracy class	Capacity : 650 to 2000 kg/m³ Fiducial error : 0.1 kg/m³ according to ISO R 649 type L 20	Verification of hydrometers
PC_{33}	General-purpose reference hydrometers, set	650 to 2000 kg/m³ Fiducial error : 0.3 kg/m³ according to ISO R 649 type L 50	Verification of hydrometers for batteries, general purposes, urometers etc.
PC_{34}	Thermostated jacket for hydrometer verification	Temperature control range : from 10 to 50 °C Temperature maintaining error : ± 0.1 °C	Verification of hydrometers by comparison
PC_{35}	Reference glass alcoholometers, set	0 to 100 % of alcohol in volume Fiducial error : ± (0.02 to 0.01) %	Verification of alcoholometers
PC_{36}	Reference hydrometers for milk, set	(1010 to 1040) kg/m³ Fiducial error : 0.1 kg/m³	Verification of hydrometers for milk
PC_{37}	Reference saccharimeters of high accuracy class, set	(0 to 90) % of sugar in mass. Fiducial error (0.01 to 0.03) % of sugar in the mass	Verification of saccharimeters (based on density)
PC_{38}	Reference saccharimeters, set	(0 to 90) % of sugar in mass. Fiducial error : 0.1 % in the mass	- idem -
PC_{39}	Laboratory mercury-in-glass thermometer	Range : 0 to 50 °C Scale interval : 0.1 °C	
PC_{40}	Flasks with lapped plugs	Capacity : 5 L	
PC_{41}	Magnifying glass	Magnification 4 to 7x Diameter : 60 mm	
PC_{42}	Consumable substances and materials :		
	sulphuric acid (H_2SO_4)	Chemically pure	
	potassium bichromate	Chemically pure	
	calcium chloride	Chemically pure	
	filtering paper		
	gasoline		
	alcohol		
	distilled water		

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