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ISO 2953

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Mechanical vibration — Balancing machines — Description and evaluation

Vibrations mécaniques — Machines à équilibrer — Description et évaluation

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Contents

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International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 2953 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock,* Subcommittee SC 1, *Balancing, including balancing machines.*

This third edition cancels and replaces the second edition (ISO 2953:1985). It contains revised and more detailed recommendations for testing the capability of balancing machines, including outboard proving rotors and overhung test planes. It replaces the previous edition of this document.

Annex A is an integral part of this International Standard. Annexes B to F are for information only.

Mechanical vibration — Balancing machines — Description and evaluation

1 Scope

This International Standard gives requirements for the evaluation of the performance and characteristics of machines for balancing rotating components. It stresses the importance attached to the form in which the balancing machine characteristics should be specified by the manufacturers and also outlines criteria and tests for evaluating balancing machines. Adoption of the format suggested in 4.1 and 4.2 makes it easier for the user to compare products of the different manufacturers. Guidance as to the manner in which users should state their requirements is given in annex B.

Details of proving rotors, test masses and performance tests to be employed to ensure compliance with specified unbalance indicating capability are given. Tests for other machine capacities and performance parameters are not contained in this International Standard.

Annex E describes recommended modifications of old ISO proving rotors.

This International Standard does not specify balancing criteria; these are specified in ISO 1940-1.

This International Standard is applicable to balancing machines that support and rotate workpieces which are rigid at balancing speed, and that indicate the amounts and angular locations of required unbalance corrections in one or more planes. It covers both the machines that measure out-of-balance effects on soft bearings and those that measure this on hard bearings.

Technical requirements for such balancing machines are included, however, special features, such as those associated with automatic correction, are excluded.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1925:1990, *Mechanical vibration — Balancing — Vocabulary.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 1925 and those given in annex A apply.

4 Capacity and performance data of the machine

The manufacturer shall specify the data listed in 4.1 for horizontal or 4.2 for vertical machines respectively, as applicable, and in a similar format.

4.1 Data of horizontal machines

4.1.1 Rotor mass and unbalance limitations

4.1.1.1 The maximum mass of rotor which can be balanced shall be stated over the range of balancing speeds.

The maximum moment of inertia [(mass × (radius of gyration)^2] of a rotor with respect to the shaft axis which the machine can accelerate in a stated acceleration time shall be given for the range of balancing speeds (n_1, n_2, ...) together with the corresponding cycle rate (see table 1).

Table 1 — Data of horizontal machines

Manufacturer:		**Model..**					
Balancing speeds or speed ranges (see also 4.1.3.1)			n_1	n_2	n_3	n_4	n_5
Rotor mass (see note 1)	kg	maximum					
		minimum					
Occasional overload force per support (see note 1)	N						
Maximum negative force per support (see note 1)	N						
Maximum rotor moment of inertia with respect to the shaft axis (see note 2)	kg·m^2						
Cycle rate (see note 2)							
Maximum unbalance (see note 3)	g·mm/kg or g·mm	measurable					
		permissible					
a) For inboard rotors Minimum achievable residual specific unbalance, e_{mar}, g·mm/kg (see note 4 and clause 6)		maximum mass					
		0,2 × max. mass					
		minimum mass					
Corresponding deflection of analog amount-of-unbalance indicator, mm Number of digital units (see note 4)		maximum mass					
		0,2 × max. mass					
		minimum mass					
b) For outboard rotors Minimum achievable residual specific unbalance, e_{mar}, g·mm/kg (see note 4 and clause 6)		maximum mass					
		0,2 × max. mass					
		minimum mass					
Corresponding deflection of analog amount-of-unbalance indicator, mm Number of digital units (see note 4)		maximum mass					
		0,2 × max. mass					
		minimum mass					

4.1.1.2 Production efficiency (see clause 7) shall be stated, as follows.

4.1.1.2.1 Time per measuring run:

a) Time for mechanical adjustment: .... s

b) Time for setting indicating system: .... s

c) Time for preparation of rotor: .... s

d) Average acceleration time: .... s

e) Reading time (including time to stabilize): .... s

f) Average deceleration time: .... s

g) Relating readings to rotor: .... s

h) Other necessary time: .... s

i) Total time per measuring run [a) to h) above]: .... s

4.1.1.2.2 Unbalance reduction ratio for inboard rotors: .... %

4.1.1.2.3 Unbalance reduction ratio for outboard rotors: .... %

4.1.2 Rotor dimensions

4.1.2.1 Adequate envelope drawings of the pedestals and of other obstructions, such as belt-drive mechanism, shroud mounting pads, thrust arms and tie bars, shall be supplied to enable the user to determine the maximum rotor envelope that can be accommodated and the tooling and/or adaptors required.

A combination of large journal diameter and high balancing speed may result in an excessive journal peripheral speed. The maximum journal peripheral speed shall be stated.

When belt drive is supplied, balancing speeds shall be stated for both the maximum and minimum diameters over which the belt can drive, or other convenient diameter.

The manufacturer shall state if the axial position of the drive can be adjusted.

4.1.2.2 Rotor envelope limitations (see figure 1) shall be stated.

4.1.2.3 Rotor diameter:

a) Maximum diameter over bed: .... mm

b) Maximum diameter over which belt can drive: .... mm

c) Minimum diameter over which belt can drive: .... mm

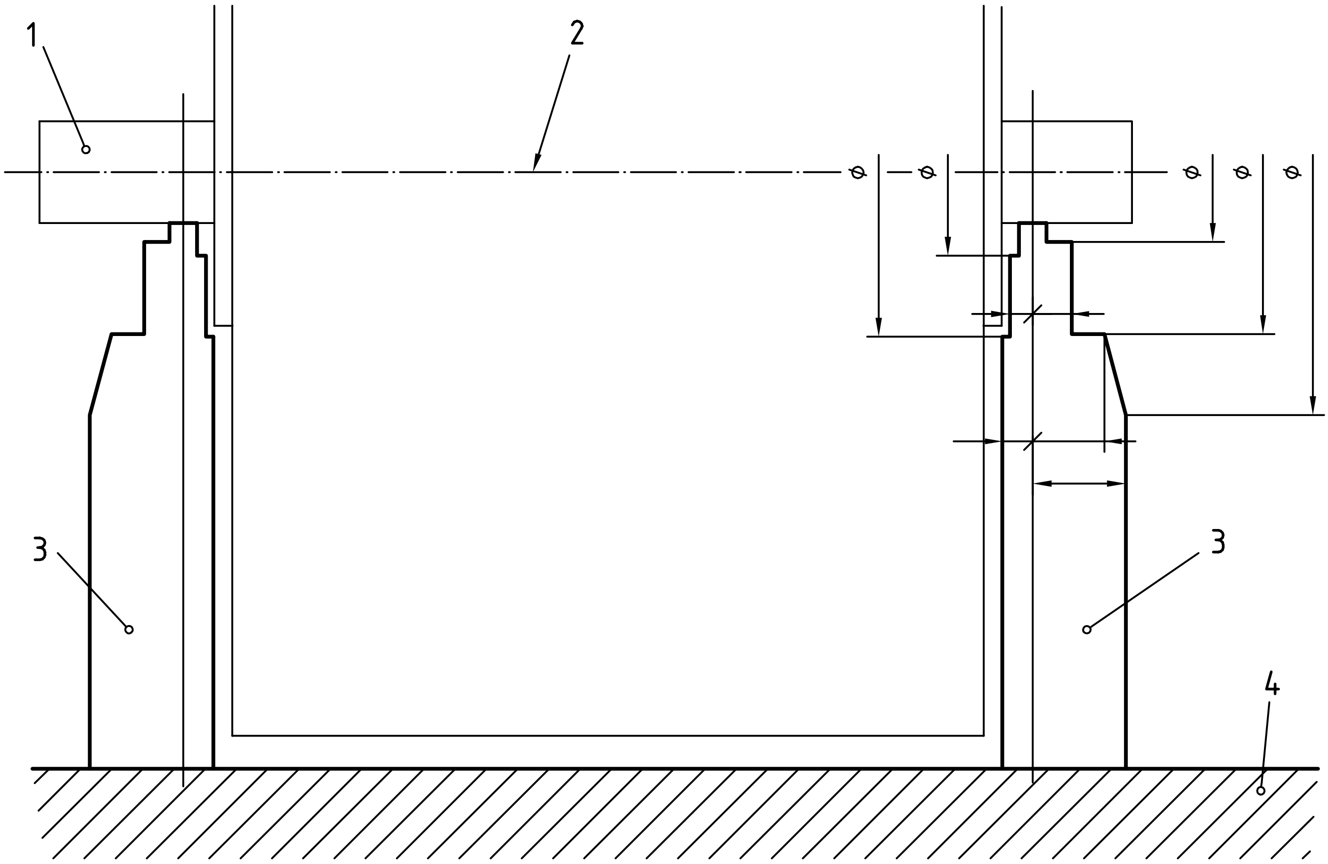
4.1.2.4 Distance between journal centrelines:

a) Maximum: .... mm

b) Minimum: .... mm

c) Maximum distance from coupling flange to centreline of farthest bearing: .... mm

d) Minimum distance from coupling flange to centreline of nearest bearing: .... mm



Key

1 Shaft
2 Rotor
3 Support
4 Bed

NOTE 1 If the left-hand support is not a mirror image of the right-hand support, separate dimensions shall be shown.

NOTE 2 The profile of the belt-drive equipment shall be shown, if applicable.

Figure 1 — Example of machine support drawing illustrating rotor envelope limitations

4.1.2.5 Journal diameter:

a) Maximum: .... mm

b) Minimum: .... mm

Maximum permissible peripheral journal speed .... m/s

4.1.2.6 Correction plane limitations (consistent with the statements in 5.4) shall be stated.

4.1.2.7 Correction plane interference ratios (consistent with the statements in 5.4 and based on the proving rotor) shall be stated.

4.1.3 Drive

4.1.3.1

	Balancing speed	Rated torque on workpiece
	r/min	N·m
n_1	....	....
n_2	....	....
n_3	....	....
n_4	....	....
n_5	....	....
n_6	....	....
n_7	....	....
n_8	....	....
	or	or
	steplessly variable	steplessly variable
from	....	....
to	....	....

4.1.3.2 Torque (see note 5):

a) Zero-speed torque: .... % rated torque on workpiece

b) Run-up torque adjustable from .... to .... % rated torque on workpiece

c) Peak torque .... % rated torque on workpiece

4.1.3.3 Type of drive to workpiece (see note 6): ....

4.1.3.4 Prime mover (type of motor): ....

a) Rated power: .... kW

b) Motor speed: .... r/min

c) Power supply, voltage / frequency / phase: ....

4.1.3.5 Brake

a) Type of brake: ....

b) Braking torque adjustable from .... to .... % of rated torque

c) Can brake be used as a holding device? Yes / No

4.1.3.6 Motor and controls in accordance with the following standard(s): ....

4.1.3.7 Speed regulation provided:

Accurate or constant within ...... % of .... r/min, or .... r/min

4.1.4 Couple unbalance interference ratio (g·mm/g·mm^2) .... % (see note 7)

4.1.5 Air pressure requirements: .... Pa; .... m^3/s

NOTE 1 The occasional overload force need only be stated for the lowest balancing speed. It is the maximum force per support that can be accommodated by the machine without immediate damage.

The negative force is the static upward force resulting from a workpiece having its centre of mass outside the bearing support.

NOTE 2 Cycle rate for a given balancing speed is the number of starts and stops which the machine can perform per hour without damage to the machine when balancing a rotor of the maximum moment of inertia.

NOTE 3 In general, for rigid rotors with two correction planes, one-half of the stated value pertains to each plane; for disc-shaped rotors, the full stated value holds for one plane.

NOTE 4 Limits for soft-bearing machines are generally stated in gram millimetres per kilogram (specific unbalance), since this value represents a measure of rotor displacement and, therefore, motion of the balancing machine bearings. For hard-bearing machines, the limits are generally stated in gram millimetres, since these machines are usually factory-calibrated to indicated unbalance in such units (see clause 6). For two-plane machines, this is the result obtained when the minimum achievable residual unbalance is distributed between the two planes.

NOTE 5 In most cases, maximum torque is required for accelerating a workpiece. However, in the case of a workpiece with high windage and/or friction loss, maximum torque may be required at balancing speed. When there is axial thrust, it is necessary that provisions be made to take this into account.

NOTE 6 Examples of the type of drive to the workpiece are:

— end drive by universal joint driver,

— end drive by band,

— belt drive,

— magnetic field,

— driven bearing rollers,

— air jet, etc.

NOTE 7 This value is only applicable for single-plane balancing machines. It describes the influence of couple unbalance in the rotor on the indication of static unbalance.

4.2 Data of vertical machines

4.2.1 Rotor mass and unbalance limitations

4.2.1.1 The maximum mass of rotor which can be balanced shall be stated over the range of balancing speeds.

The maximum moment of inertia [mass × (radius of gyration)^2] of a rotor with respect to the shaft axis which the machine can accelerate in a stated acceleration time shall be given for the range of balancing speeds (n_1, n_2, ...) together with the corresponding cycle rate (see table 2).

Table 2 — Data of vertical machines

Manufacturer:	**Model ....**					
Balancing speeds or speed ranges (see also 4.2.3.1)		n_1	n_2	n_3	n_4	n_5
Rotor mass kg (see note 1)	maximum					
	minimum					
Occasional overload force up to (see note 1) N						
Maximum rotor moment of inertia with respect to the shaft axis (see note 2) kg·m²						
Cycle rate (see note 2)						
Maximum unbalance (see note 3) g·mm/kg or g·mm	measurable					
	permissible					
Minimum achievable residual specific unbalance, e_{mar}, (see note 4 and clause 6) g·mm/kg	maximum mass					
	0,2 × max. mass					
	minimum mass					
Corresponding deflection of analog amount-of-unbalance indicator mm Number of digital units (see note 4)	maximum mass					
	0,2 × max. mass					
	minimum mass					

4.2.1.2 Production efficiency (see clause 7) shall be stated, as follows.

4.2.1.2.1 Time per measuring run:

a) Time for mechanical adjustment: .... s

b) Time for setting indicating system: .... s

c) Time for preparation of rotor: .... s

d) Average acceleration time: .... s

e) Reading time (including time to stabilize): .... s

f) Average deceleration time: .... s

g) Relating readings to rotor: .... s

h) Other necessary time: .... s

i) Total time per measuring run [a) to h) above]: .... s

4.2.1.3 Unbalance reduction ratio: .... %

4.2.2 Rotor dimensions

4.2.2.1 If the machine is equipped with two or more speeds, this information shall be stated for each speed. If the machine is equipped with steplessly variable balancing speeds, then the information shall be given in the form of a table, formula or graph.

Adequate drawings of the support surface of the spindle or mounting plate, and of obstructions, such as drill heads, electrical control cabinets, etc. above the mounting plate, shall be supplied to enable the user to determine the maximum rotor envelope that can be accommodated and the tooling and/or adaptors required.

4.2.2.2 Maximum diameter: .... mm

4.2.2.3 Rotor height:

a) Maximum overall height: .... mm

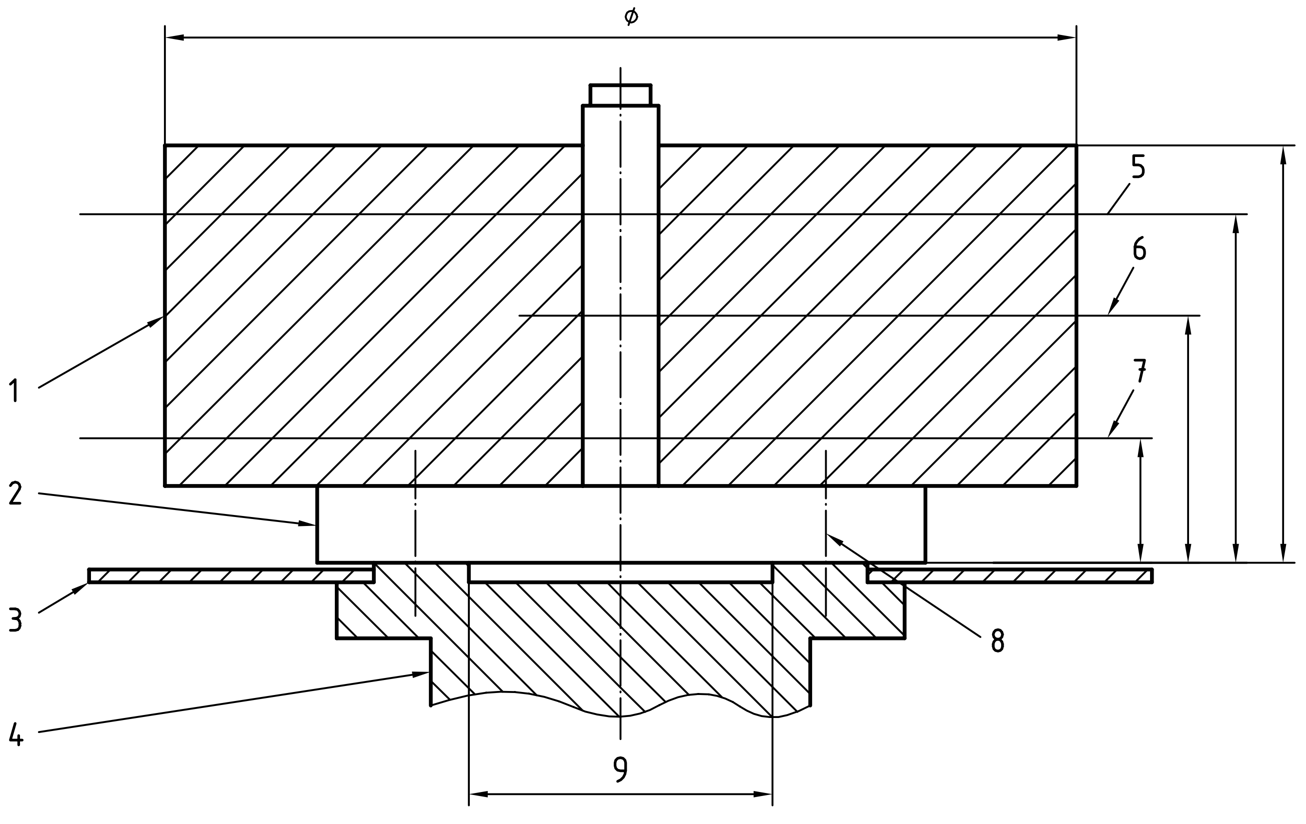
b) Maximum height of centre of gravity: .... mm

at 100 % of maximum mass: .... mm

at 50 % of maximum mass: .... mm

at 25 % of maximum mass: .... mm

4.2.2.4 Rotor envelope limitations, including machine spindle or mounting plate interface (see figure 2) shall be stated.



Key

1 Rotor
2 Adapter
3 Protractor
4 Spindle
5 Upper correction plane
6 Centre of mass plane
7 Lower correction plane
8 Mounting holes for adapter
9 Pilot ∅

Figure 2 — Example of vertical machine mounting interface illustrating rotor envelope limitations

4.2.2.5 Correction plane limitations (consistent with the statements in 5.4) shall be stated.

4.2.3 Drive

4.2.3.1

	Balancing speed r/min	Rated torque on workpiece N·m
n_1	....	....
n_2	....	....
n_3	....	....
n_4	....	....
n_5	....	....
n_6	....	....
n_7	....	....
n_8	....	....

4.2.3.2 Torque (see note 5):

a) Zero-speed torque: .... % of rated torque on workpiece

b) Run-up torque adjustable from .... to .... % of rated torque on workpiece

c) Peak torque: ...... % of rated torque on workpiece

4.2.3.3 Prime mover (type of motor):

a) Rated power: .... kW

b) Motor speed: .... r/min

c) Power supply, voltage / frequency / phase: .... / .... / ....

4.2.3.4 Brake

a) Type of brake:

b) Braking torque adjustable from .... to .... % of rated torque

c) Can brake be used as a holding device ? Yes / No

4.2.3.5 Motor and controls in accordance with the following standard(s): ....

4.2.3.6 Speed regulation provided:

Accurate or constant within .... % of .... r/min, or .... r/min

4.2.4 Couple unbalance interference ratio, g·mm / g·mm^2 (see note 6)

4.2.5 Air pressure requirements: .... Pa; .... m^3/s

NOTE 1 The occasional overload force need only be stated for the lowest balancing speed. It is the maximum force that can be accommodated by the machine without immediate damage.

NOTE 2 Cycle rate for a given balancing speed is the number of starts and stops which the machine can perform per hour without damage to the machine when balancing a rotor of the maximum moment of inertia.

NOTE 3 In general, for rigid rotors with two correction planes, one-half of the state value pertains to each plane; for disc-shaped rotors, the full stated value holds for one plane.

NOTE 4 Limits for soft-bearing machines are generally stated in gram millimetres per kilogram (specific unbalance), since this value represents a measure of rotor displacement and, therefore, motion of the balancing machine bearings. For hard-bearing machines, the limits are generally stated in gram millimetres, since these machines are usually factory-calibrated to indicate unbalance in such unit. (See also clause 6.) For two-plane-machines, this is the result obtained when the minimum achievable residual unbalance is distributed between the two planes.

NOTE 5 In most cases, maximum torque is required for accelerating a workpiece. However, in the case of workpieces with high windage and/or friction loss, maximum torque may be required at balancing speed.

NOTE 6 This value is only applicable for single-plane balancing machines. It describes the influence of couple unbalance in the rotor on the indication of static unbalance.

5 Machine features

5.1 Principle of operation

An adequate description of the principle of operation of the balancing machine shall be given; for example, motion measuring, force measuring, resonance, compensation.

5.2 Arrangement of the machine

5.2.1 The manufacturer shall describe the general configuration of this machine and the principal features of design, for example:

— horizontal or vertical axis of rotation;

— soft- or hard-bearing suspension system;

— resonance-type machine with mechanical compensator.

5.2.2 The manufacturer shall provide details of the following, as applicable.

5.2.2.1 Components designed to support the rotor, for example:

— vee blocks;

— open rollers;

— plain half-bearings;

— closed-ball, roller or plain bearings;

— devices to accommodate rotors in their service bearings;

— devices to accommodate complete units.

NOTE Details of bearing lubrication requirements shall be given, where applicable.

5.2.2.2 The mechanical adjustment and functioning of the means provided to take up axial thrust from the rotor (horizontal machines only).

5.2.2.3 Type(s) of transducers used to sense unbalance effects.

5.2.2.4 The drive and its control.

5.3 Indicating system

5.3.1 General

A balancing machine shall have means to determine the amount of unbalance and its angular location; such means shall be described, for example:

— wattmetric indicating system;

— voltmetric indicating system with phase-sensitive rectifier (including systems with frequency conversion);

— voltmetric system with stroboscope and filter;

— voltmetric indicating system with marking of angular position on the rotor itself;

— compensator with mechanical or electrical indication.

5.3.2 Amount indicators

The manufacturer shall describe the means of amount indication provided, for example:

— wattmetric or voltmetric component meters;

— wattmetric or voltmetric amount meters;

— wattmetric or voltmetric vector meters;

— mechanical or optical indicators;

— analog or digital readout.

5.3.3 Angle indicators

The manufacturer shall describe the means of angle indication provided, for example:

— wattmetric or voltmetric component meters;

— wattmetric or voltmetric vector meters;

— direct angle indication in degrees on a scale meter;

— oscilloscope, stroboscopic indicators;

— mechanical or optical indicators;

— analog or digital readout.

5.3.4 Operation of the indicating system

The manufacturer shall describe the procedure by which readings are obtained, taking into account at least the following points.

a) How many measuring runs are required to obtain:

   — the two readings for single-plane balancing?

   — the four readings for two-plane balancing?

b) Is an indicator provided for each reading or is it necessary to switch over for each reading?

c) Are readings retained after the end of the measuring run?

d) Is an individual plus-and-minus switch provided for each plane which permits the indication of a heavy or light spot?

5.4 Plane separation system

5.4.1 This subclause is not applicable to single-plane machines; see.5.4.2.

The manufacturer shall state whether plane separation is provided. If it is provided, at least the following details shall be given.

a) How is it operated for single rotors of a type not previously balanced?

b) How is it operated for single rotors in a series, with identical dimensions and mass?

c) The limits of workpiece geometry over which plane separation is effective shall be defined with the effectiveness stated on the basis of the correction plane interference ratio, stating the following:

   — the ratio of bearing distance to plane distance for which plane separation is effective;

   — whether either or both correction planes can be between or outside the bearings;

   — whether the centre of mass can be between or outside the two selected correction planes and/or bearings.

d) Whether the indicator system can also be used to measure directly static unbalance and couple unbalance.

5.4.2 On single-plane horizontal or vertical machines, the manufacturer shall state to what extent the machine is able to suppress effects of couple unbalance (see 11.8).

5.5 Setting and calibration of indication

5.5.1 General

The manufacturer shall describe the means of setting and calibration and the means provided for checking these.

The manufacturer shall state whether setting is possible for indication in any desired unit, whether practical correction units and/or standard weight or unbalance units.

The manufacturer shall state the number of runs required for calibrating the machine:

— for single-plane balancing;

— for two-plane balancing.

The manufacturer shall state the maximum permissible change, in percentage terms, in repeatability of speed during calibration and operation.

5.5.2 Soft-bearing machines

The manufacturer shall state how calibration is accomplished on the first rotor of a particular mass and configuration, for example, does the rotor have to be balanced by a trial-and-error procedure or is a compensator provided, are calibration masses required, etc., and whether total or partial re-calibration is required when changing the balancing speed.

If a compensator is provided, the limits of initial unbalance, of rotor geometry and speed for which compensation is effective shall be stated.

5.5.3 Hard-bearing machines

The manufacturer shall state whether the machine is permanently calibrated and can be set according to the workpiece or shall be calibrated by the user for different balancing speeds, rotor masses and/or dimensions.

5.6 Other devices

Special devices which influence the efficient functioning of the balancing machine shall be described in detail, for example:

— indication in components of an arbitrary coordinate system;

— indication of unbalance resolved into components located in limited sectors in more than two correction planes;

— correction devices;

— devices to correlate the measured angle and/or amount of unbalance with the rotor;

— suitable output for connection to a computer printer or other peripherals.

6 Minimum achievable residual unbalance

The minimum residual unbalance that can be achieved with a balancing machine shall be specified in terms of specific unbalance in gram millimetres per kilogram (see definition in annex A) together with the corresponding deflection of the amount-of-unbalance indicator.

This minimum achievable residual specific unbalance shall be stated for the full range of workpiece masses and balancing speeds of the machine.

In achieving the stated residual unbalance, the manufacturer shall consider whether the accuracy of the following is adequate for the purpose:

— amount indication,

— angle indication,

— plane separation,

— scale multiplier,

— drive, bearings, etc.

It should be noted that the stated minimum achievable residual unbalance value applies to the machine as delivered, but if out-of-round journals, excessively heavy or loose adaptors or other tooling are employed by the user, the minimum achievable residual unbalance may be affected.

7 Production efficiency

7.1 General

Production efficiency is the ability of the machine to assist the operator in balancing a rotor to a given residual unbalance in the shortest possible time. It shall be assessed by using a proving rotor or, alternatively, a test rotor to be specified by the user.

To find the production rate for a specific rotor (number of pieces per time unit or the reciprocal of the floor-to-floor time), the time per measuring run, the necessary number of runs, the time for loading, unbalance correction and unloading have to be taken into consideration. The necessary number of measuring runs depends on the average initial unbalance, the tolerance and the unbalance reduction ratio (URR).

7.2 Time per measuring run

For the proving rotor or rotors specified by the user, the manufacturer shall describe the procedure in detail and state the average time for each of the operations listed under a) to h):

a) mechanical adjustment of the machine, including the drive, tooling and/or adaptor;

b) setting of the indicating system;

c) preparation of the rotor for the measuring run;

d) average acceleration time;

e) the reading time, i.e. the normal total time between the end of the acceleration run and the start of the deceleration run;

f) average deceleration time;

g) any further operations necessary to relate the readings obtained to the actual rotor being balanced;

h) time for all other required operations, for example, safety measures.

NOTE 1 Items a) and b) are of primary interest for single rotor balancing.

NOTE 2 The time per measuring run is the total time required for steps a) to h) for the first run, but for subsequent measuring runs on the same rotor, only steps d) to h) are required. In the case of mass production rotors, only steps c) to h) are required.

If special tools, not supplied as part of the standard equipment, are necessary to accommodate a rotor, this shall be specified; for example, bearing inserts, couplings for drive shafts, shrouds, etc.

7.3 Unbalance reduction ratio

The manufacturer shall state the unbalance reduction ratio (see definition in annex A). It shall be assumed that the addition or subtraction of mass is made without error and that normal skill and care are exercised in the operation of the machine.

Where indicator systems that rely heavily on operator judgement are used, for example, stroboscopes, mechanical indicators, etc., realistic values based on experience and related to the rotor to be balanced shall be given.

8 Performance qualifying factors

The manufacturer shall state the range of the following factors within which the machine is capable of achieving the guaranteed performance, for example:

- temperature,
- humidity,
- balancing speed variation,
- line voltage and frequency fluctuations.

The manufacturer shall also state whether the performance of the machine is significantly changed by the use of ball bearings on the rotor journals.

In addition, the manufacturer shall state whether the unbalance indication of the rotor is significantly affected if the rotor bearing thrust face is not square to the axis.

9 Installation requirements

9.1 General

In considering the siting of a balancing machine, the manufacturer shall state what precautions shall be observed to obtain satisfactory performance in the presence of the following environmental factors:

— extraneous vibration,

— electromagnetic radiation,

— condensation, fungus and other factors, such as those referred to in clause 8.

9.2 Electrical and pneumatic requirements

Balancing machines shall be provided with standard input connections that are plainly marked with the required supply voltage and frequency, air pressure, hydraulic pressure, etc.

9.3 Foundation

The manufacturer shall state the overall dimensions and mass of the machine, and the type and size of foundation required for the machine under which its specified performance is assured; for example, concrete blocks, workbench, etc.

10 Proving rotors and test masses

10.1 General

This clause specifies technical requirements for a range of proving rotors for use in testing balancing machines. It specifies rotor masses, materials. dimensions, limits, tapped hole dimensions, rotor balancing requirements and details of test masses. The extent and costs of tests and the rotor size(s) may be negotiated between the manufacturer and the user.

10.2 Proving rotors

10.2.1 Three types of proving rotors are defined, named A, B and C (Figure 3). Typical workpieces, which are intended to be represented by the proving rotors, are characterized as follows.

— Type A: Rotors without journals, balanced on a vertical machine[1)], in one or two correction planes.

Service bearing planes may be anywhere; i.e. one on each side, or both on one side of the main rotor body. For the tests it is assumed that one bearing is on each side of the rotor.

— Type B: Inboard rotors with journals, balanced on a horizontal machine, mostly with two correction planes between the bearings.

Service bearings are positioned on either side of the rotor.

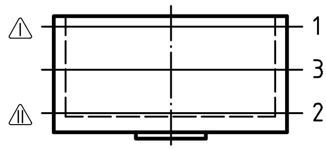
— Type C: Outboard rotors with journals, balanced on a horizontal machine, with two overhung correction planes.

Service bearing positions are similar to those on the proving rotor.

NOTE 1 Type C proving rotor is composed of a shaft and a proving rotor type A.

NOTE 2 Calculations for U_{mar} for type C proving rotor are based on the total mass (shaft and proving rotor type A).

[1)] They may be balanced on a horizontal machine with integrated spindle.



Type A

a) Vertical balancing machine

Type B

Type C

b) Horizontal balancing machines

NOTE 1 Mass centre position is inboard in Types A and B but outboard in Type C (shaft plus type A rotor).

Figure 3 — Proving rotors type A, B, C with test planes 1, 2, 3 and assumed bearing planes I, II

Each type of proving rotor has three planes for attachment of test masses.

The same proving rotor and test masses will be used for tests in one or two planes.

10.2.2 The manufacturer shall state whether or not a proving rotor is supplied with the machine.

10.2.3 Proving rotors shall be manufactured of steel and shall be similar to those shown in figure 4 and table 3 for vertical machines, figure 5 and table 4 for horizontal machines (inboard rotor), and figure 6 and table 5 for outboard rotors (see 10.2.5).

10.2.4 For machines covered by this International Standard, the manufacturer shall have available proving rotors that may be used to confirm the performance of each machine prior to shipment from the plant.

10.2.5 If a horizontal machine is to be used for balancing outboard rotors (or inboard rotors with correction planes overhanging on one side), additional tests have to be agreed upon (see 11.1). These require a proving rotor type C.

NOTE 1 Older style rotors with only eight holes per plane may be modified to this International Standard (see annex E).

NOTE 2 The shipment of proving rotors to the user is the subject of individual negotiation.

10.2.6 Clear and permanent angle markings shall be provided on every proving rotor every 10° and enumerated at intervals of 30°. Two such scales with a clockwise and anticlockwise enumeration may be provided.

For testing stroboscopic machines, the proving rotor shall be equipped with a numbered standard band delivered with the machine. The middle of the first number shall coincide with one set of tapped holes. Angle readout for the tests shall be made from the numbered band and recalculated in the 360° circle.

10.2.7 For multi-purpose machines, a standard proving rotor shall be used whose mass falls within the lower third of the the mass capacity range of the machine.

10.2.8 For machines which are intended to be used near the lower limit of the mass capacity range, a proving rotor having a mass near the lower mass capacity limit is recommended for an additional test.

10.2.9 For special-purpose machines, or by agreement between the manufacturer and the user, a user's own rotor may be used, provided the balance errors introduced by such rotors are negligible.

10.3 Test masses

10.3.1 General

Test masses are used to create defined unbalances in the proving rotor test planes.

Since the test positions have threaded holes, the test masses may be in the form of bolts, screws, etc. A recommended solution is to have studbolts permanently fixed into all positions, protruding from the surface of the rotor by a certain height, and to screw the test masses onto them. In this case, test masses are rings and the precise location of their centres of mass (radius) can easily be identified.

The unbalance value of a test mass is always expressed in units of U_{mar}, i.e. multiples of the minimum achievable residual unbalance.

If the claimed minimum achievable residual unbalance is specified per plane, U_{mar} is calculated as follows:

$$U_{mar} = 2\ U_{mar\ per\ plane}$$

If e_{mar}, the claimed minimum achievable residual specific unbalance is stated, U_{mar} is gained by multiplying e_{mar} by the total mass m of the proving rotor:

$$U_{mar} = e_{mar}\ m$$

NOTE The required value for the mass of a particular test mass is derived from the required unbalance and the radius of its centre of mass, when attached to the proving rotor.

10.3.2 Test mass for U_{mar} test

10.3.2.1 For the U_{mar} test (see 11.6) the following test mass is required for plane 3 (see table 7):

— one test mass producing 10 times U_{mar}.

NOTE For proving rotors of type A or B, 2 test masses of $5U_{mar}$ each for planes 1 and 2 could be used instead. There is no recommended alternative for proving rotors type C.

10.3.2.2 For proving rotors type A and B for U_{mar} tests:

— on vertical machines and on horizontal machines with integrated spindles (A),

— on horizontal machines for inboard rotors (B).

EXAMPLE: Horizontal machine, proving rotor type B,

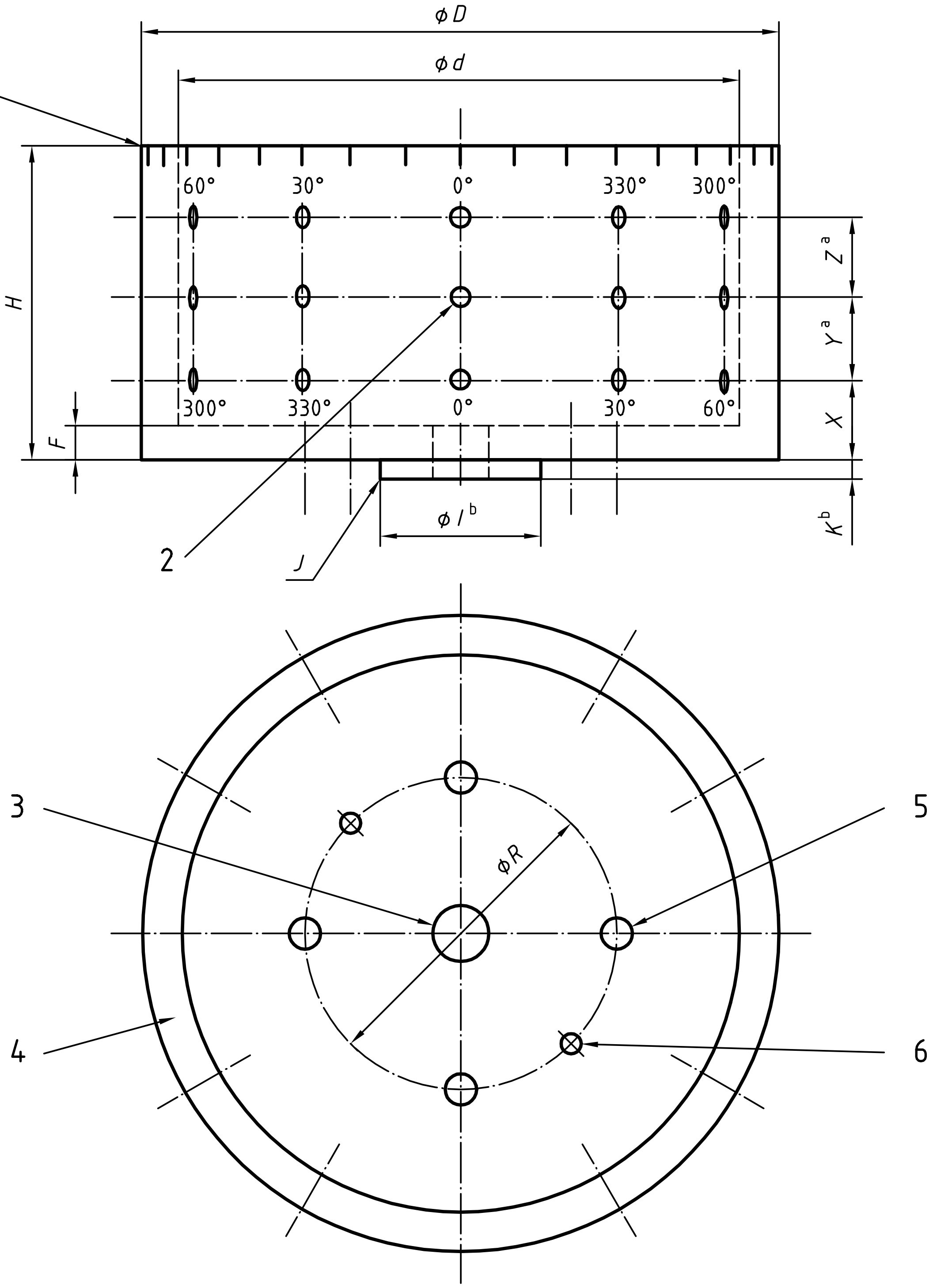
Table 4, No. 5, 50 kg.

Claimed in table 1:

e_{mar} = 0,000 5 mm or 0,5 g·mm/kg.

Calculation: $U_{mar} = 50 \times 0{,}5 = 25$ g·mm.

U_{mar} test mass to produce: $10 \times U_{mar} = 250$ g·mm.



Key

1 36 equal divisions of 10°, enumerated at 30° intervals, clockwise, anticlockwise

2 12 equally spaced threaded holes G in each of three test planes

3 Threaded hole for lifting eye

4 Holes in this face to balance rotor (optional)

5 Four through holes O, equally spaced

6 Two threaded holes G

[a] Dimensions may be varied, except *Y* and *Z* .

[b] Interface dimensions (spigot) comply with SAE ARP 4162 proving rotors (where existing).

NOTE 1 All tolerances and residual unbalance shall be in accordance with the the test aims.

NOTE 2 Proving rotors from SAE ARP 4162 may be used instead with test masses modified to suit the ISO tests.

NOTE 3 For dimensions see table 3.

Figure 4 — Proving rotors Type A for tests on vertical machines (for dimensions, see table 3)

Table 3 — Suggested dimensions, masses and speeds for proving rotors type A for tests on vertical machines (see figure 4)

Rotor No.	**Rotor mass** *M*	**Major diameter** *D*	**Minor diameter** *d*	**Height** *H*	*X*	*Y* [a]	*Z* [a]	*F*	*G*	*I* [b]	*J* [b]	*K* [b]	*R* [b]	*O*	**Highest test speed** [c]
		D	0,9 *D*	0,5 *D*	0,075 *D*	0,175 *D*	0,175 *D*	0,06 *D*							
Metric values															
	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	r/min
1	1,1	110	99	55	8	20	20	6,5	M3	50,8	0,4 × 45°	4,2	76,2	6,6	20 000
2	3,5	160	144	80	12	30	30	9,5	M4	50,8	0,4 × 45°	4,2	76,2	6,6	14 000
3	11	230	206	127	19	45	45	13	M5	114,3	0,4 × 45°	4,2	133,35	10,3	10 000
4	35	345	310	170	25	60	60	20	M6	114,3	0,4 × 45°	4,2	133,35	10,3	6 000
5	110	510	460	255	38	90	90	30	M8	114,3	0,4 × 45°	4,2	133,35	10,3	4 000
Inch/pound values															
	lb	in	in	in	in	in	in	in	in	in	in	in	in	in	r/min
1	2,5	4,3	3,875	2,2	0,375	0,75	0,75	0,250	No.5UNF	2	0,015 × 45°	0,165	3	0,266	20 000
2	8	6,3	5,650	3,2	0,5	1,125	1,125	0,375	No.8UNF	2	0,015 × 45°	0,165	3	0,266	14 000
3	25	9	8,125	5	0,75	1,75	1,75	0,510	No.10UNF	4,5	0,015 × 45°	0,165	5,25	0,406	10 000
4	80	13,5	12,125	7	1	2,375	2,375	0,800	1/4UNF	4,5	0,015 × 45°	0,165	5,25	0,406	6 000
5	250	20	18	10	1,5	3,5	3,5	1.186	5/16UNC	4,5	0,015 × 45°	0,165	5,25	0,406	4 000

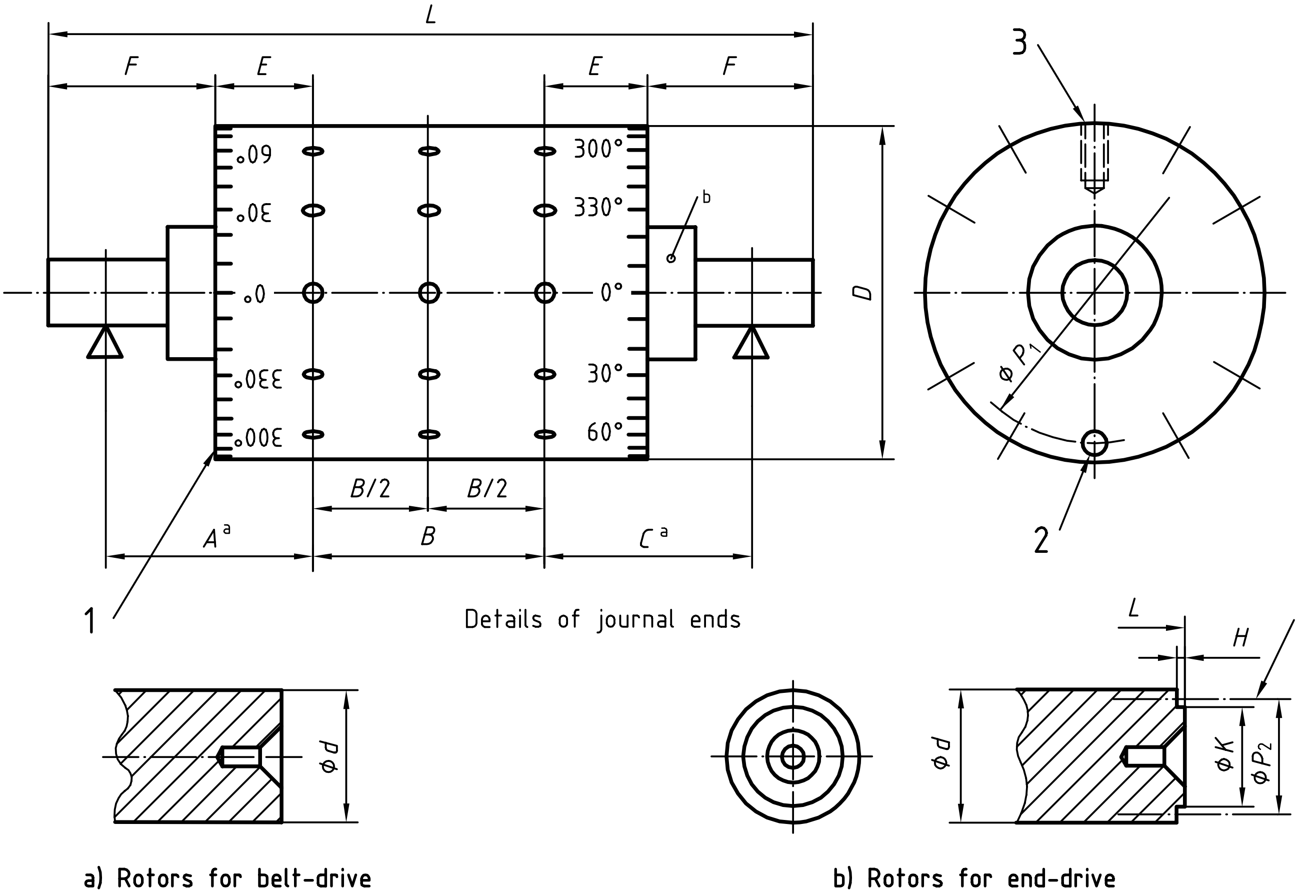
NOTE 1 All tolerances and residual unbalance shall be in accordance with the test aims.

NOTE 2 Proving rotors from SAE ARP 4162 may be used instead with test masses modified to suit the ISO tests.

a Dimensions may be varied, except *Y* and *Z*.

b Interface (spigot) dimensions comply with SAE ARP 4162 proving rotors (Rotor Nos. 2 to 5).

c Refers to rotors. Test mass design may limit highest speed.



Key

1 36 equal divisions of 10°, enumerated at 30° intervals, clockwise, anticlockwise
2 12 equally spaced threaded holes N on each end for trim balancing
3 12 equally spaced threaded holes N in each test plane
4 Number and size of threads as requested

a Dimensions *A*, *B* and *C* may be varied provided they meet the requirements: $A \approx B/2$; $C \approx B/2$.

b If the shafts are used as ball bearing seatings, a shoulder should be provided so that bearings are square to the shaft axis and the centres are at the prescribed axial location.

NOTE 1 End-drive interface dimensions comply with typical drive shafts.

NOTE 2 All tolerances and residual unbalance shall be in accordance with the test aims.

NOTE 3 Proving rotors from SAE ARP 4162 may be used instead with test masses modified to suit the ISO tests.

NOTE 4 Older style rotors with only 8 holes per plane may be modified to this International Standard (see annex E).

NOTE 5 For dimensions see table 4.

Figure 5 — Proving rotors Type B for tests on horizontal machines (for dimensions, see table 4)

Table 4 — Suggested dimensions, masses and speeds for proving rotors type B for inboard tests on horizontal machines (see figure 5)

Rotor No.	Rotor mass M	Major diameter D	Overall length $L \approx 2{,}5D$	Shaft diameter $d \approx 0{,}3D$[b]	Bearing distance $A+B+C \approx 2D$	A[a] C[a] $\approx 0{,}5D$	B[a] $\approx 1D$	E $\approx 0{,}25D$	F $\approx 0{,}5D$	P_1	H[b]	K[b]	P_2[b]	N	Critical speed[c] $\approx 7\,600\,000/D$	Highest test speed[d] $\approx 760\,000/D$
Metric values																
	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	r/min	r/min
1	0,5	38	95	11	76	19	38	9,5	19	31	—	—	—	M2	200 000	20 000
2	1,6	56	140	17	112	28	56	14	28	46	—	—	—	M3	140 000	14 000
3	5	82	205	25	164	41	82	20,5	41	72	—	—	—	M4	95 000	9 500
4	16	120	300	36	240	60	120	30	60	108	4	7	30	M5	65 000	6 500
5	50	176	440	58	352	88	176	44	88	160	1,4	30	47	M6	45 000	4 500
6	160	260	650	78	520	130	260	65	130	240	1,8	42	62	M8	30 000	3 000
7	500	380	950	114	760	190	380	95	190	350	2,2	57	84	M10	20 000	2 000
Inch/pound values																
	lb	in	in	in	in	in	in	in	in	in	in	in	in	in	r/min	r/min
1	1,1	1,5	3,75	0,433	3	0,75	1,5	0,375	0,75	1,25	—	—	—	No. 2UN	200 000	20 000
2	3,5	2,2	5,5	0,669	4,4	1,1	2,2	0,55	1,1	1,8	—	—	—	No. 5UNF	140 000	14 000
3	11	3,2	8	0,984	6,4	1,6	3,2	0,8	1,6	2,8	—	—	—	No. 8UNF	95 000	9 500
4	35	4,8	12	1,417	9,6	2,4	4,8	1,2	2,4	4,25	0,157	0,276	1,181	No.10UNF	65 000	6 500
5	110	7	17,5	2,283	14	3,5	7	1,75	3,5	6,25	0,05	1,181	1,850	1/4UNF	45 000	4 500
6	350	10,2	25,5	3,071	20,4	5,1	10,2	2,55	5,1	9,25	0,071	1,654	2,441	5/16UNC	30 000	3 000
7	1 100	15	37,5	4,488	30	7,5	15	3,75	7,5	13,75	0,087	2,244	3,307	3/8UNC	20 000	2 000

NOTE 1 All tolerances and residual unbalance are in accordance with the test aims.

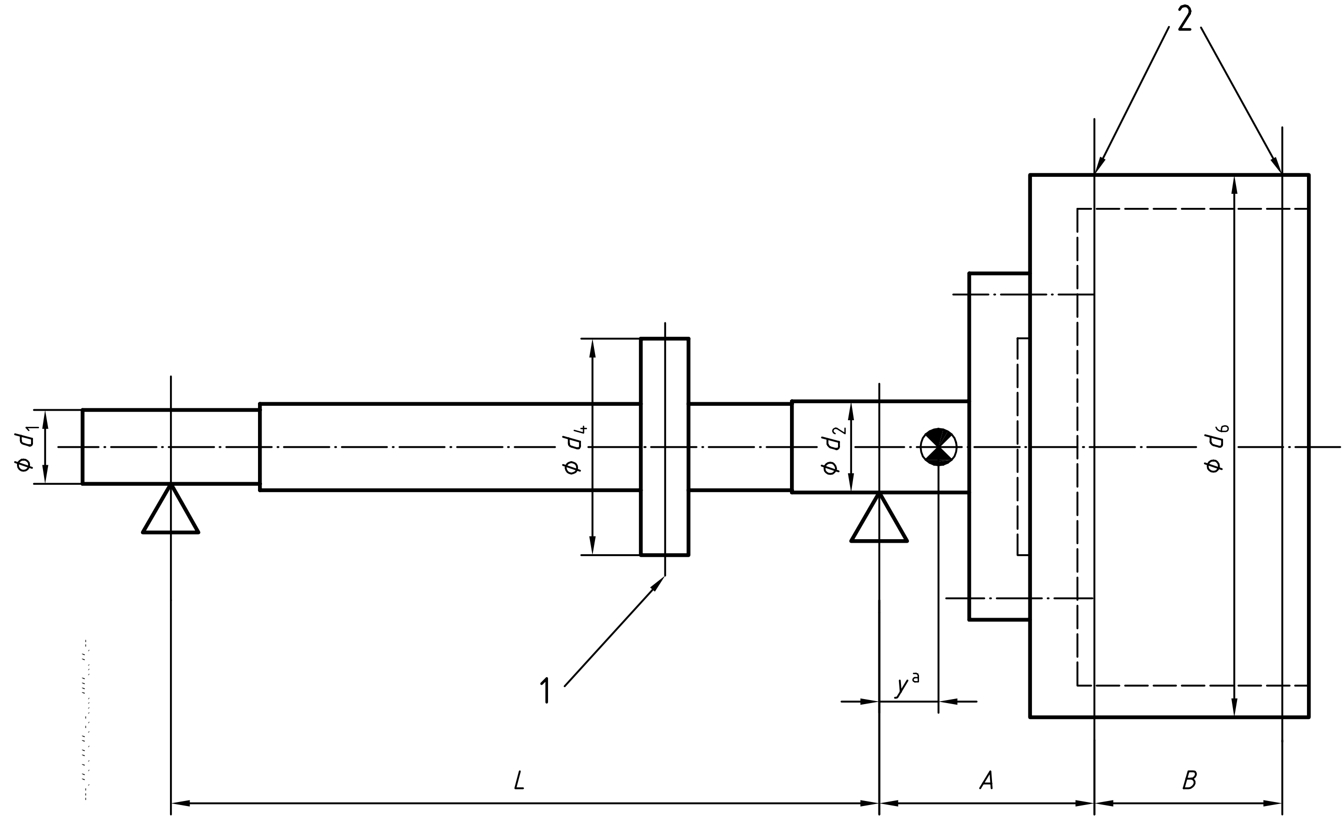
NOTE 2 Proving rotors from SAE ARP 4162 may be used instead with test masses modified to suit the ISO test.

a Dimensions A, B and C may be varied provided they meet the requirements: $A \approx B/2$; $C \approx B/2$.

b End-drive interface dimensions comply with typical drive shafts.

c Critical speeds are calculated for rotors running in rigid bearings.

d Refers to rotors. Test mass design may limit highest speed.



Key

1 12 equally spaced threaded holes, N

2 12 equally spaced threaded holes, N

[a] Dimensions may be varied provided the centre of mass stays outboard with the same overhang and the position of holes N between bearings is maintained.

NOTE 1 Examples for detailed dimensions of shafts (for end-drive), fitting proving rotors type A are given in annex D.

NOTE 2 Proving rotor type C is made up from a shaft (see figure D.1 and table D.1) and a proving rotor type A.

NOTE 3 Interface dimensions (spigot) comply with proving rotors type A.

NOTE 4 End-drive interface dimensions for Nos. 3 to 5 are in accordance with proving rotors type B, Nos. 4 to 6.

NOTE 5 All tolerances and residual unbalance shall be in accordance with the test aims.

NOTE 6 Proving rotors from SAE ARP 4162 may be used instead of proving rotor type A with test masses modified to suit the ISO tests.

Figure 6 — Proving rotors type C for outboard tests on horizontal machines (for dimensions see table 5)

Table 5 — Suggested dimensions, masses and speeds of proving rotors type C for outboard tests on horizontal machines (see figure 6)

Shaft	Proving rotor Type A	Assembly														
No.	No.	No.	Mass	Bearing load on rotor						N [a]	Major diameter	Bearing dist.	A	B	Critical speed [c]	Highest test speed [d]
			M	A	B	Y [a]	d_1 [b]	d_2	d_4		d_6	L				
Metric values																
			kg	N	N	mm	mm	mm	mm		mm	mm	mm	mm	r/min	r/min
1	1	1	2,2	– 3	24	20	17	21	50	M3	110	164	41	40	25 000	4 000
2	2	2	6,2	– 8	70	30	25	30	72	M4	160	240	60	60	17 000	2 800
3	3	3	19,5	– 25	220	45	36	45	106	M5	230	352	90	90	14 500	1 900
4	4	4	60	– 75	700	65	58	65	156	M6	345	520	140	120	8 000	1 300
5	5	5	190	– 230	2 100	95	78	95	230	M8	510	760	203	180	5 500	900
Inch/pound values																
			lb	lbf	lbf	in	in	in	in		in	in	in	in	r/min	r/min
1	1	1	5	– 0,6	5,6	0,8	0,67	0,83	2	No.5UNF	4,3	6,4	1,68	1,5	25 000	4 000
2	2	2	14	– 1,8	16	1,2	0,98	1,2	2,8	No.8UNF	6,3	9,6	2,45	2,25	17 000	2 800
3	3	3	45	– 6	51	1,75	1,42	1,8	4,2	No.10UNF	9	14	3,25	3,5	14 500	1 900
4	4	4	135	– 17	150	2,55	2,28	2,55	6,2	1/4UNC	13,5	20,4	5,55	4,75	8 000	1 300
5	5	5	430	– 54	480	3,75	3,07	3,7	9	5/16UNC	20	30	8	7	5 500	900

NOTE 1 All tolerances and residual unbalance are in accordance with the test aims.

NOTE 2 Proving rotors from SAE ARP 4162 may be used instead of proving rotor type A with test masses modified to suit the ISO test.

a Dimensions may be varied provided the centre of mass stays outboard with the same overhung and the position of holes N between bearings is maintained.

b End-drive interface dimensions for Nos. 3 to 5 are in accordance with proving rotors type B, Nos. 4 to 6.

c Critical speeds are calculated for rotors running in rigid bearings.

d Refers to rotors. Test mass design may limit highest speed.

10.3.2.3 For proving rotors type C on horizontal machines for outboard tests:

— same calculation (principle) as above.

NOTE This will lead to masses different from the inboard test because:

— the mass of rotor type C is different from type B,

— the value claimed in table 1 as e_{mar} for inboard rotors may differ from that for outboard rotors,

— the mass is attached to a different rotor diameter and thus has a different effective radius.

EXAMPLE: Horizontal machine, outboard proving rotor type C,

Table 5, No. 3, 19,5 kg.

Claimed under Table 1:

e_{mar} = 0,002 mm or 2 g·mm/kg

Calculation: $U_{mar} = 19{,}5 \times 2 = 39$ g·mm

U_{mar} test mass to produce: $10 \times U_{mar} = 390$ g·mm

10.3.3 Test masses for URR tests (see 11.7)

10.3.3.1 For proving rotors types A and B:

— one (for a single-plane test) or two (for a two-plane test) stationary masses, each producing 20 to 60 × U_{mar}:

$U_{station} = 20 \text{ to } 60 \times U_{mar}$

— one (for a single-plane test) or two (for a two-plane test) travelling masses, each producing five times the unbalance of the stationary masses

$U_{travel} = 5 \times U_{station}$

EXAMPLE

Using the same proving rotor and claimed value of e_{mar} as in 10.3.2.1, and test masses producing 30 times and 150 times the minimum achievable residual unbalance leads to:

URR stationary test masses produce:

$U_{station} = 30 \times U_{mar} = 30 \times 25$ g·mm = 750 g·mm.

URR travelling test masses produce:

$U_{travel} = 5 \times U_{station}$ = 3 750 g·mm.

10.3.3.2 For proving rotor type C:

— same calculation (principle) as above, however, in order to use the same URR evaluation diagram:

$U_{station} = 60 \text{ to } 100 \times U_{mar}$.

NOTE The test masses differ from those for proving rotor type A.

On proving rotors type C (outboard), as an alternative the URR test could be performed with resultant/couple test masses. According to the principles and rules as stated in ISO 1940-1, the following is suggested.

For resultant:

- one stationary mass, producing: $U_{\text{res station}} = 20 \text{ to } 60 \times U_{\text{mar}}$
- one travelling mass, producing: $U_{\text{res travel}} = 5 \times U_{\text{res station}}$

For couple:

- two stationary masses, each producing: $U_{\text{c station}} = 4 \times U_{\text{res station}}$
- two travelling masses, each producing: $U_{\text{c travel}} = 5 \times U_{\text{c station}}$

10.3.4 Permissible errors of test masses

10.3.4.1 Masses

The permissible error in the test mass is directly related to the task and should not influence the test by more than 10 %.

a) For the U_{mar} test, the permissible mass error is ± 1 %.

b) For the URR test, the permissible mass error (percentage) is directly related to the claimed URR. The percentage is equal to:

$$\pm 0{,}1 \times (100\ \% - \text{URR}_{\text{claim}})$$

EXAMPLE

For a URR test with 95 % $\text{URR}_{\text{claim}}$, the permissible mass error is

$$\pm 0{,}1 \times (100 - 95)\ \% = \pm 0{,}5\ \%$$

10.3.4.2 Position

The mounting position for test masses shall be at 30° intervals in each plane.

NOTE Older style rotors with only eight holes per plane may be modified to this International Standard (see annex E).

The zero degree reference in each test plane shall be at the same angular orientation (in the same plane through the axis of rotation).

The mounting positions shall be located relative to the true position in each of three directions with the following permissible errors:

a) in the axial direction: within the same percentage as determined for the mass tolerance in 10.3.4.1 for URR test (e.g. ± 0,5 %) but applied to the correction plane distances;

b) in the radial position: within the same percentage as above (e.g. ± 0,5 %), but applied to the radius;

c) in the angular position: within the same percentage as above, but applied to the unit of angle (1 rad = 57,3°); for example ± 0,5 % equals ± 0,3°.

In order to facilitate tests with proving rotors types B and C, it is advisable to line up the thread pattern for the end drive to the 0° position of the proving rotor.

10.3.5 Material

For medium and small proving rotors, some test masses may become difficult to design and inconvenient to handle because of their small size. In these cases, it is preferable to make the test masses from lightweight material (aluminum or plastic material).

11 Verification tests

11.1 Requirements for performance and parameter verification

To verify the claimed performance of a balancing machine in general, two to four separate tests are required:

— the U_{mar} test (test for minimum achievable residual unbalance);

— the URR test (test for unbalance reduction ratio);

— the ISC test (test for interference from couple unbalance with static unbalance indication), required only for single-plane machines;

— the test of the compensator, used for index balancing.

These tests are described in 11.6 to 11.9, and shall be conducted by the manufacturer either at his/her plant or after installation on site; the location to be agreed between the manufacturer and user.

Proving rotors types A and B are choosen according to the type of balancing machine (see 10.2). Proving rotors type C shall be used only if outboard rotors are to be balanced on the horizontal machine and upon prior agreement between the manufacturer and user.

NOTE Figure 7 gives an overview of U_{mar} tests and the URR test for proving rotors types A, B and C.

These tests represent a minimum test procedure designed to establish essential compliance with the requirements for:

— minimum achievable residual unbalance (U_{mar}), and for

— combined accuracy of amount-of-unbalance indication, angle indication and plane separation (URR),

— suppression of couple unbalance (ISC),

— accuracy of the compensator.

The test procedures will not prove compliance with all requirements over the full range of variables, nor will they define the exact reason when the machine fails to comply.

In addition, equipment parameters shall be verified. This includes physical inspection of various dimensions, features, instrumentation, tooling and accessories.

11.2 Duties of manufacturer and user

11.2.1 Examiner

For these tests, the user shall provide an examiner trained in the use of balancing machines. The manufacturer shall instruct the examiner in the use of the machine. The examiner may either operate the machine or satisfy him/herself that he/she could obtain the same results as the operator. The manufacturer shall ensure that the written instructions are followed by the examiner.

11.2.2 Readings

The examiner shall print or read off the unbalance indication from the machine's instrumentation, log the values, convert them into units of U_{mar}, and subsequently plot them. The manufacturer shall be entitled to check the accuracy of the examiner's work.

11.2.3 Condition of proving rotor and test masses

The manufacturer shall be responsible for the condition of the proving rotor, the correctness of the test masses, and the location of the test masses. The examiner shall be entitled to verify this.

NOTE Older style rotors with only eight holes per plane may be modified to this International Standard (see annex E).

11.3 Requirement for weighing scale

A weighing scale shall be available having sufficient accuracy to meet the requirements of 10.3.4.1.

11.4 Test and rechecks

When a machine fails to conform in a test, the manufacturer shall be entitled to adjust or modify the machine, after which the complete test shall be repeated and the machine shall conform in that test in order to qualify as being acceptable.

11.5 Test speed

The appropriate test speed for the proving rotor may be determined in the following ways and agreed upon between manufacturer and user:

a) a typical speed of the machine to be tested, based on specification data of the manufacturer;

b) 1/10 up to 1/5 of the heighest permissible test speed of the proving rotor (see tables 3 to 5), adapted to the specification data of the manufacturer;

c) a typical speed the users intends to balance rotors at;

d) in the case where a user's own rotor is prepared as a proving rotor (see 10.2.7), the intended balancing speed of this rotor.

11.6 Test for minimum achievable residual unbalance (U_{mar} test)

11.6.1 General

This test is intended to check the ability of the machine to balance a rotor to the claimed minimum achievable residual unbalance (U_{mar}).

A two-plane test is described in detail, deviations for a single-plane test are mentioned.

11.6.2 Starting-point

11.6.2.1 Plane setting for balancing

For the particular rotor under consideration perform the mechanical adjustment of the machine. Calibration and/or setting is done for balancing in plane(s) (which are **not** the test planes); see tables 6 and 7.

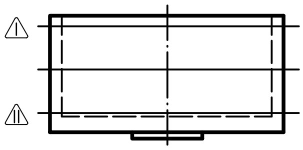
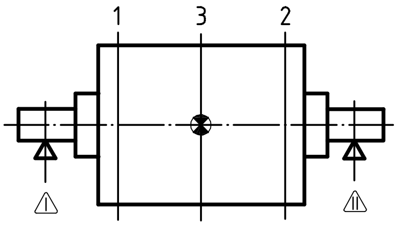
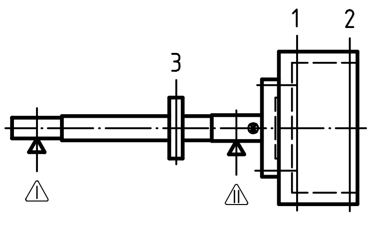
11.6.2.2 Initial unbalance

Make sure that the unbalance in each plane of the proving rotor is smaller than five times the claimed minimum achievable residual unbalance (10 times for a single-plane test). If necessary, correct for these unbalances. Use locations which do not interfere with the following test steps.

EXAMPLE

For correction planes on a proving rotor type B: rotor body end-faces.

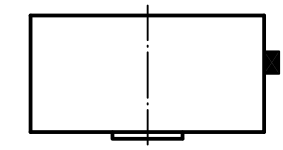
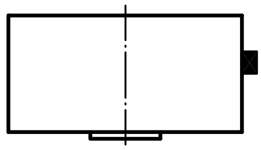
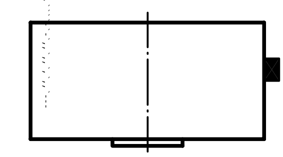
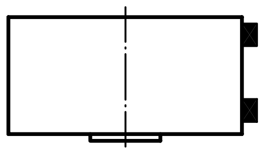
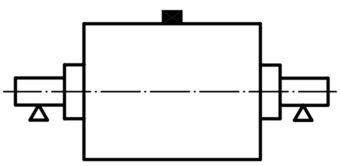
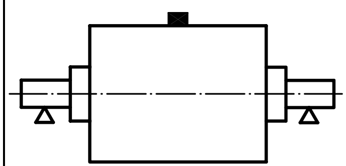
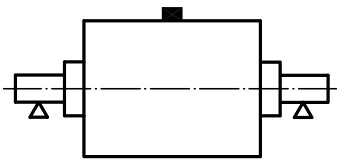
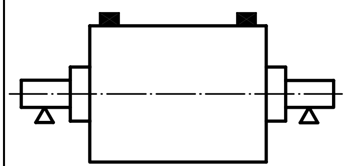
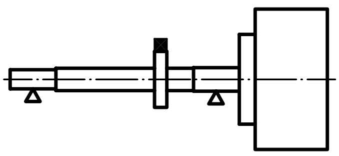
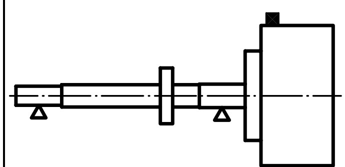
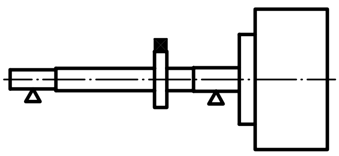
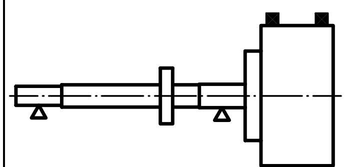
Table 6 — Test planes

Machine axis	Centre of mass location	Proving rotor (see 10.1)	No. of test planes
Vertical	—	 Type A	single-plane
			two-plane
Horizontal	inboard	 Type B	single-plane
			two-plane
	outboard	 Type C	single-plane
			two-plane

1, 2, 3 Test planes;

⚠, ⚠ Measuring planes for U_{mar}.

Table 7 — Overview of U_{mar} and URR tests

U_{mar} test (see 11.6)	**URR test** (see 11.7)
Balancing with plane setting: static  Test mass producing $10 \times U_{mar}$ in plane 3 Measuring: static	Test masses in plane 3  U_{stat} = 20 to 60 × U_{mar} U_{trav} = 5 × U_{stat} Measuring: static
Balancing with plane setting: to correction planes near to 1, 2  Test mass producing $10 \times U_{mar}$ in plane 3 Measuring: planes △I, △II	Test masses in each plane 1, 2  U_{stat} = 20 to 60 × U_{mar} U_{trav} = 5 × U_{stat} Measuring: planes 1, 2
Balancing with plane setting: static  Test mass producing $10 \times U_{mar}$ in plane 3 Measuring: static	Test masses in plane 3  U_{stat} = 20 to 60 × U_{mar} U_{trav} = 5 × U_{stat} Measuring: static
Balancing with plane setting: to correction planes near to 1, 2  Test mass producing $10 \times U_{mar}$ in plane 3 Measuring: planes △I, △II	Test masses in each plane 1, 2  U_{stat} = 20 to 60 × U_{mar} U_{trav} = 5 × U_{stat} Measuring: planes 1, 2
Balancing with plane setting: static  Test mass producing $10 \times U_{mar}$ in plane 3 Measuring: static	Test masses in plane 1  U_{stat} = 20 to 60 × U_{mar} U_{trav} = 5 × U_{stat} Measuring: static
Balancing with plane setting: to correction planes near to 1, 2  Test mass producing $10 \times U_{mar}$ in plane 3 Measuring: planes △I, △II	Test masses in each plane 1, 2  U_{stat} = 20 to 60 × U_{mar} U_{trav} = 5 × U_{stat} Measuring: planes 1, 2

1, 2, 3 Test planes;

△I, △II Measuring planes for U_{mar}.

11.6.3 Unbalance added

Add two unbalance masses (such as balancing clay) to the rotor. They shall be equivalent to 5 to $10 \times U_{mar}$ each. The unbalance masses shall **not** be:

a) in the same radial plane,

b) in a correction plane,

c) in a test plane,

d) at the same angle,

e) displaced by 180°.

EXAMPLE

For planes on a proving rotor type B to add these unbalances: rotor body surface near to the test planes.

NOTE In the case of a single-plane test, one unbalance mass of 10 to $20 \times U_{mar}$ is used.

11.6.4 Readings

Readings of these initial unbalances (and after each correction step, see 11.6.5) are recorded in table 8.

11.6.5 Correction

Balance the rotor as well as possible (following the standard procedure for the machine) in a maximum of four runs. Apply corrections in the correction plane(s). Take readings and record them in table 8.

EXAMPLE

For correction planes on a proving rotor type B: rotor body end-faces.

NOTE If residual unbalance is not well below 0,5 U_{mar} in each plane (two-plane test) or below U_{mar} (single-plane test), the machine will probably not pass the test.

11.6.6 Reference change

In the case of horizontal machines, after performing the actions described in 11.6.2 to 11.6.5, change the angular reference system of the machine by 60°:

— on end-drive machines, turn the drive shaft with respect to the rotor;

— on belt-drive machines, shift the angle reference.

NOTE 1 If a 60° change is not possible, a 90° change may be made.

NOTE 2 If, after the reference system has been changed, the next reading (run 6) is unsatisfactory (see note under 11.6.5), the problems should be remedied before continuing with the test.

11.6.7 Plane setting for U_{mar} test

Set the instrument to read in measuring plane(s) according to tables 6 and 7.

11.6.8 Test runs

Attach in test plane 3 a test mass producing $10 \times U_{mar}$ (see 10.3.2). Run rotor, measure and record unbalance readings (amounts only) in table 9.

Attach this mass in all available holes in plane 3 using a sequence that is arbitrary.

Run rotor, measure and record readings in both planes for each position of the mass in table 9.

11.6.9 U_{mar} evaluation (see table 9)

11.6.9.1 Calculation

Calculate the arithmetic mean value per plane by adding the values of all readings per plane, and dividing the result by 12. Record the arithmetic mean value in table 9 under: "Mean value".

Divide each reading by the "Mean value" of the respective plane and record the results in table 9 under "Multiples of mean value".

11.6.9.2 Plot

Plot the calculated values (multiples of mean value) in figure 7.

11.6.9.3 Lines

In figure 7 the horizontal middle-line represents the arithmetic mean of the readings in each plane. Two dotted lines (0,88 and 1,12) represent the limit lines: ± 12 % of the arithmetic mean for each plane, which account for 1 times the claimed U_{mar} + 20 % for the effects of variation in the position of the masses and scatter of the test data.

11.6.9.4 Assessment

The machine is considered to have passed the U_{mar} test, i.e., the claimed minimum achievable residual unbalance has been reached, if the following condition is met:

All plotted points are within the range given by the two dotted lines (0,88 and 1,12), with one exception allowed.

11.7 Test for unbalance reduction ratio (URR test)

11.7.1 URR tests on single-plane balancing machines

On horizontal and vertical single-plane balancing machines, designed to indicated static unbalance only, the unbalance reduction test is intended to check only the combined accuracy of amount-of-unbalance indication and angle indication.

For test planes and reading planes see tables 6 and 7.

11.7.2 URR tests on two-plane balancing machines

On horizontal and vertical two-plane balancing machines, designed to indicated dynamic unbalance, the unbalance reduction test is intended to check the combined accuracy of amount-of-unbalance indication, angle indication and plane separation.

For test planes and reading planes see tables 6 and 7.

NOTE On outboard proving rotors type C, the URR test could be performed as an alternative with resultant/couple unbalance test masses. Deviations from the two-plane test are described.

11.7.3 General

The test and the method of recording the machine indications are designed to prevent the machine operator from knowing in advance what the readings should be, and thereby prevent him/her from influencing the outcome.

The test consists of a set of 11 measuring runs. The test is run with a stationary test mass and a travelling test mass (see 10.3.3) in each test plane.

Unbalance readings are recorded on the test sheet and subsequently plotted and evaluated.

There are different URR test data sheets for two-plane (table 10) and single-plane (table 11) tests. Prepare the test data sheet prior to making the actual test runs so that test data are entered in the proper order.

Table 8 — Data sheet for balancing of the proving rotor

Date of test: ....

Location of test: ....

Machine operated by: ....

Readings taken and recorded by: ....

Machine tested, make: ....

Model: ....

Proving rotor, type: ....

No. .... Mass: .... kg

U_{mar} = ... g·mm; 10 U_{mar} = ... g·mm

Test mass .... g; effective radius: .... mm

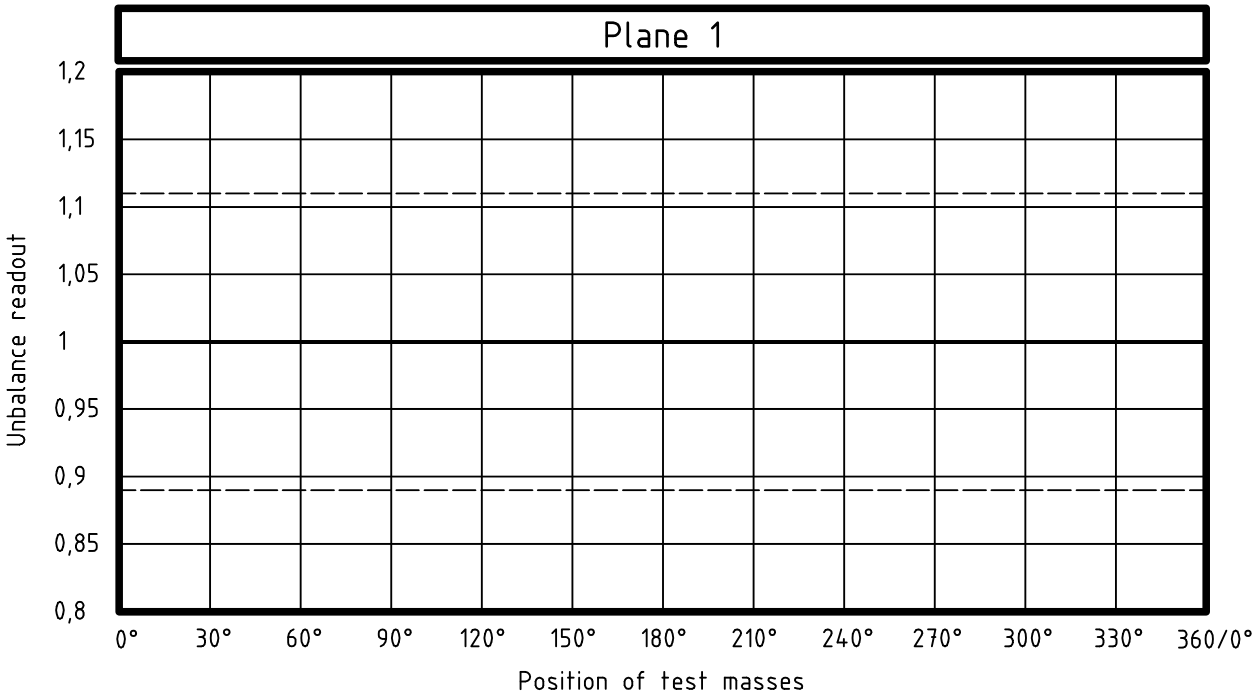
Test speed:.............................. r/min

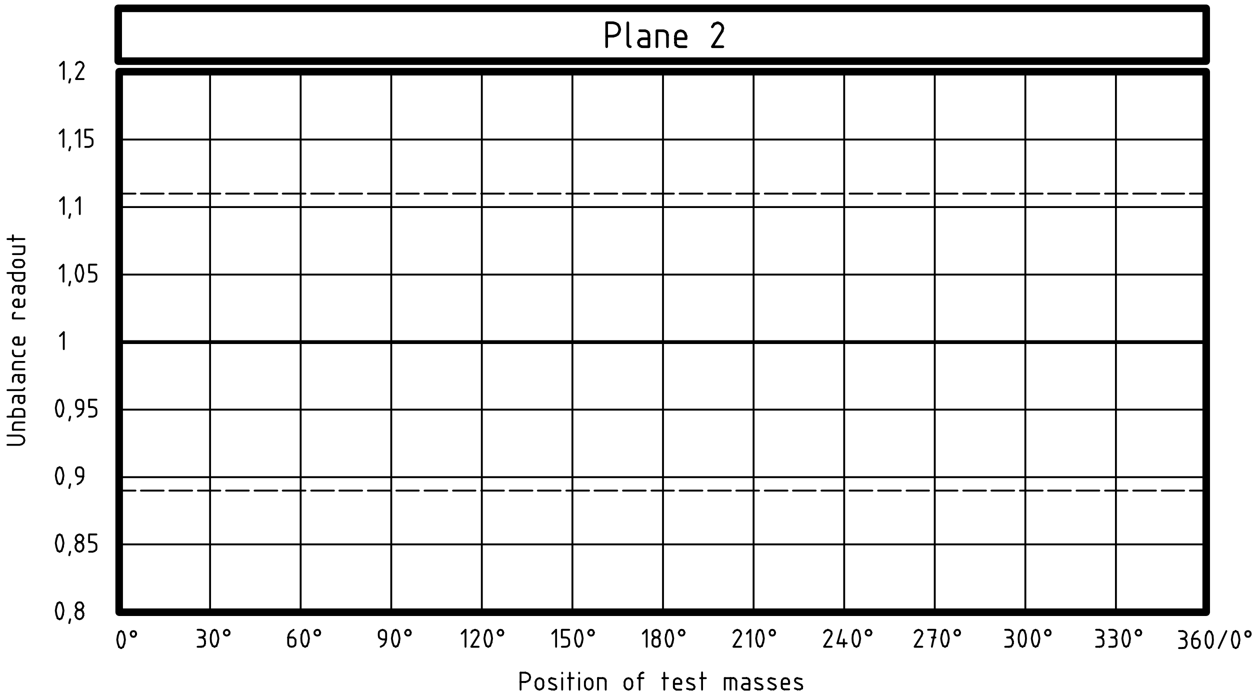
Plane reading unit	1		2		Correction
	Amount U_{mar}	**Angle** degrees	**Amount** U_{mar}	**Angle** degrees	
Run 1 initial unbalance					No. 1
Run 2					No. 2
Run 3					No. 3
Run 4					No. 4
Run 5 residual unbalance					not allowed
Run 6 after 60° reference change					not allowed

Table 9 — Test data sheet for U_{mar} test

Position of test mass	**Amount of unbalance**	**Amount of unbalance**	**Multiples of mean value**	**Multiples of mean value**
degrees	Plane 1	Plane 2	Plane 1	Plane 2
0°				
30°				
60°				
90°				
120°				
150°				
180°				
210°				
240°				
270°				
300°				
330°				
Sum				
Mean value				

NOTE For single-plane machines, use plane 1 columns to record the readings for the resultant unbalance.





NOTE Unbalance readout is in multiples of arithmetic mean values.

Figure 7 — Diagram for evaluation of U_{mar} test

11.7.4 Preparation of test sheets

11.7.4.1 Two-plane test

Preparation of a test data sheet (table 10) entails the following steps.

a) Enter at the top of the data sheet the requested data so that the test conditions are permanently recorded.

b) Arbitrarily choose in plane 1 one of the 12 possible test mass positions for the stationary test mass and enter the degree value in the "Run No. 1" line on the "plane 1, stationary" column of the data sheet.

c) Choose in plane 2 a position for the stationary test mass. This should neither be the same position nor opposite to the stationary test mass in plane 1. Enter the degree value in the "Run No. 1" line on the "plane 2, stationary" column of the data sheet.

d) Arbitrarily choose in plane 1 one of the remaining 11 positions as the starting position for the travelling test mass and enter the degree value in the "Run No. 1" line on the "plane 1, travelling" column of the data sheet.

e) Arbitrarily choose in plane 2 a starting position for the travelling test mass. Enter the degree value in the "Run No. 1" line on the "plane 2, stationary" column of the data sheet.

f) Enter successive positions for successive runs in the data sheet for both travelling test masses, letting them travel

   — in plane 1 in ascending 30° intervals,

   — in plane 2 in descending 30° intervals.

   Skip the stationary test mass positions, since two test masses cannot occupy the same position.

For a resultant/couple test use table 10 with the following modifications.

— Mark plane 1 as the left-hand couple plane. This means positions and readings for couple test masses in plane 1 (couple test masses in plane 2 are always 180° apart).

— Mark plane 2 as the middle plane (between planes 1 and 2). This means positions and readings for resultant test masses.

11.7.4.2 Single-plane test

Table 11 is for only one plane. The rules to chose positions for the stationary and travelling test masses are identical to plane 1 of the two-plane test.

11.7.5 Plane setting

The machine is set to read in the test planes (see tables 6 and 7).

For a resultant/couple test on a proving rotor type C, the machine is set to read the couple unbalance in planes 1 and 2 and resultant unbalance in the middle plane (between planes 1 and 2).

11.7.6 URR test runs

11.7.6.1 Starting-point

Unless a U_{mar} test has immediately preceded this one, perform steps described in 11.6.2 through 11.6.6.

11.7.6.2 Test planes

Test planes are according to tables 6 and 7.

For a resultant/couple test, planes 1 and 2 are used for the couple test masses, the middle plane (between planes 1 and 2) for the resultant test masses.

11.7.6.3 Procedure

Add the stationary and travelling test masses in starting position (Run No. 1 line) to the test planes of the proving rotor as shown in the data sheet.

Make a run, measure and record the amount and angle readings for the planes on the data sheet.

Advance the travelling test masses to the next positions as shown in the data sheet, make a run, measure and record the amount and angle readings for the planes in the data sheet, until 11 successive runs have been performed.

Divide amount readings by the unbalance value of the stationary mass (both in terms of unbalances) to obtain values in multiples of the stationary unbalance. Enter these in the appropriate columns of the data sheet.

11.7.7 Plotting URR test data

11.7.7.1 Evaluation diagrams

Each evaluation diagram (figure 8 for two-plane tests and figure 9 for single-plane tests) contains a diagram with 11 sets of concentric URR limit circles. From the inside outwards, the concentric circles designate the limits for URR values of 95 %, 90 %, 85 % and 80 %.

Instructions for drawing these diagrams are given in annex C.

11.7.7.2 Two-plane test (figure 8)

a) Enter the angular position of plane 1 stationary test mass on the short line above the arrow in the appropriate URR evaluation diagram. Mark radial lines in 20° intervals by entering degree markings in 20° increments (rising clockwise) on all short lines around the periphery of the diagram.

b) Since the stationary test mass in the plane 2 has a different angular position, enter a second angular reference system into the diagram for plane 2. To avoid interference with the degree markings for plane 1, enter the degree markings for plane 2 in the oval circles provided halfway between the degree markings for plane 1.

c) Using the amount (multiples of U_{mar}) and angle values from the data sheet, plot the plane 1 readings in the form of test points (dots) on the appropriate URR diagram, using the amount scale as shown next to the vertical arrow.

d) Next plot the plane 2 readings, but in order to avoid confusing plane 1 test points with plane 2 test points, circle all test points for plane 2.

For a resultant/couple test, plane 1 means couple unbalance, plane 2 means resultant unbalance (see 11.7.4.1).

11.7.7.3 Single-plane test (figure 9)

Enter only one angular reference system into the diagram.

11.7.8 Evaluation

If a test point falls within the innermost circle (or on its line), the reading qualifies for a 95 % circle. If a test point falls between the 95 % circle and the 90 % circle (or on its line), the reading qualifies for a 90 % URR, and so on.

NOTE If a URR value other than 95 %, 90 %, 85 % or 80 % is specified, an intermediate circle of appropriate diameter may be inserted (see annex C).

All test points on a URR Evaluation Diagram shall fall within the URR limit circles that correspond to the claimed value for the URR with one exception per correction plane allowed. If not, the machine fails the test, in which case the rules given in 11.4 apply.

Table 10 — URR test data sheet for two-plane tests

Company: ....

Location of test: ....

Machine tested, make: .... Model: ....

Machine operated by: ....

Readings taken and logged by: .... Date of test: ....

Proving rotor, Type: .... No.: .... Mass: .... kg

Claimed e_{mar} = ... g·mm/kg

Claimed U_{mar} = ... g·mm

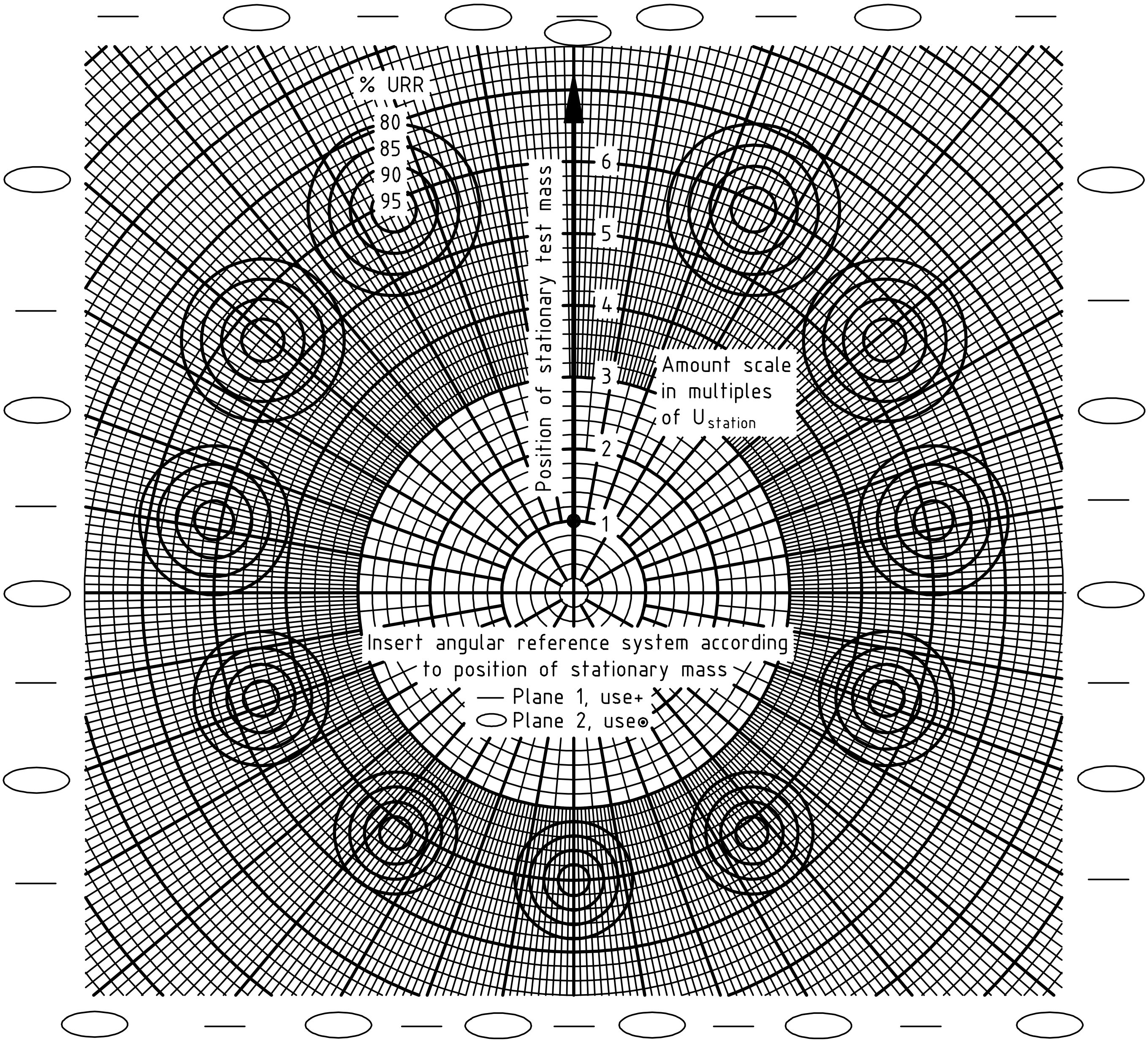
$U_{station}$ = ... × U_{mar} = ... g·mm

effective radius: .... mm; stationary mass: .... g

$U_{travel} = 5 \times U_{station}$ = ... g·mm

effective radius: .... mm; travelling mass: .... g

Run	Test mass positions (angles)				Unbalance readout		Amount	Unbalance readout		Amount
	Plane 1		Plane 2		Plane 1		Reading pl.1 divided by $U_{station}$ Multiple of $U_{station}$	Plane 2		Reading pl.2 divided by $U_{station}$ Multiple of $U_{station}$
	Stationary	Travelling	Stationary	Travelling	Amount g·mm	Angle degrees		Amount g·mm	Angle degrees	
1										
2	″		″							
3	″		″							
4	″		″							
5	″		″							
6	″		″							
7	″		″							
8	″		″							
9	″		″							
10	″		″							
11	″		″							



URR achieved: ....

Test points plotted by: ....

Figure 8 — URR evaluation diagram for two-plane tests

Table 11 — URR test data sheet for single-plane tests

Company: ....

Location of test: ....

Machine tested, make: .... Model: ....

Machine operated by: ....

Readings taken and logged by: .... Date of test: ....

Proving rotor, Type: .... No.: .... Mass: .... kg

Claimed e_{mar} = ... g·mm/kg

Claimed U_{mar} = ... g·mm

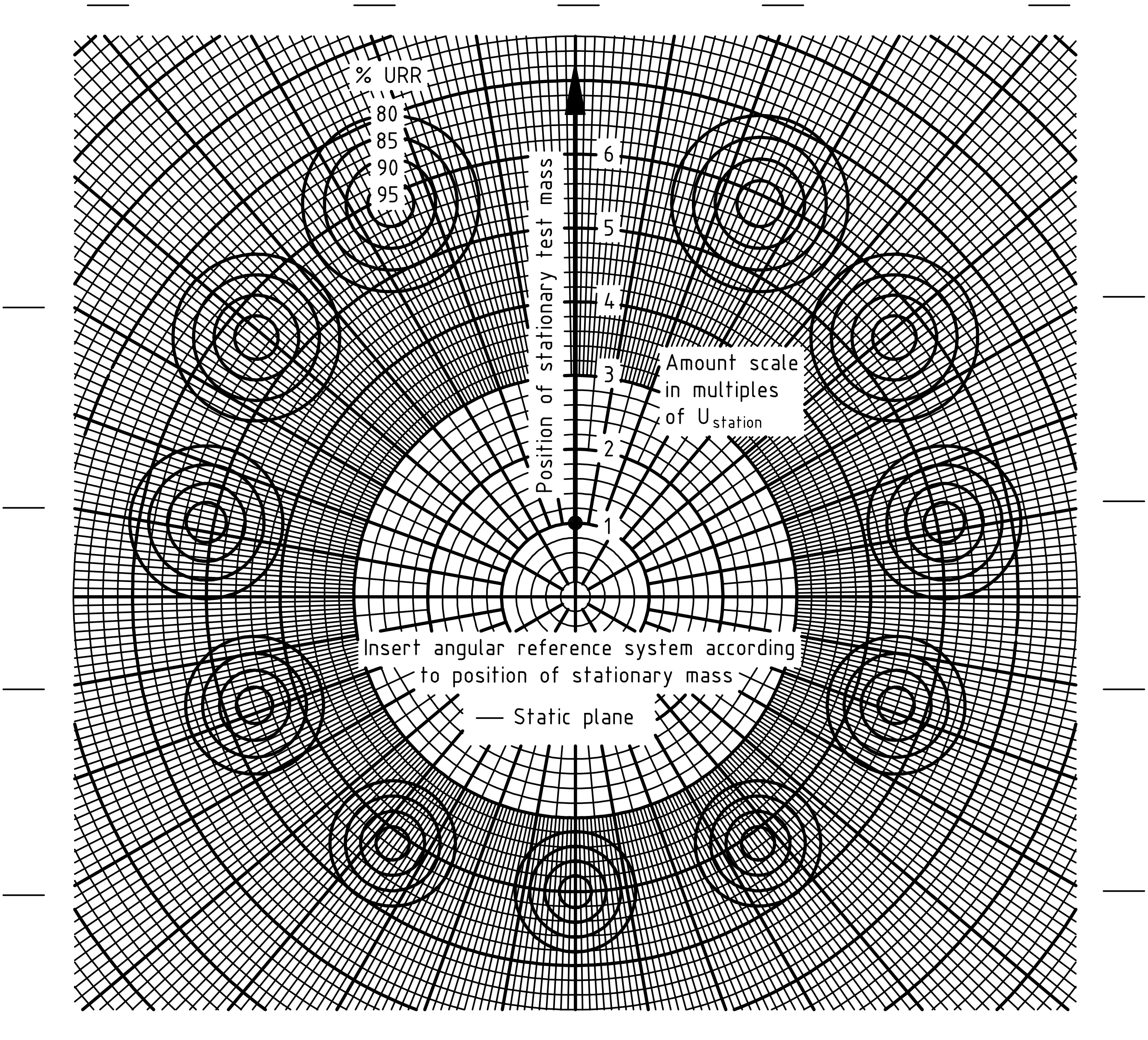
$U_{station}$ = ... × U_{mar} = ... g·mm

effective radius: .... mm; stationary mass: .... g

$U_{travel} = 5 \times U_{station}$ = ... g·mm

effective radius: .... mm; travelling mass: .... g

Run	**Test mass positions (angles)** Plane 3		**Unbalance readout** Plane 3		**Amount** Reading plane 3 divided by $U_{station}$
	Stationary	Travelling	Amount g·mm	Angle degrees	Multiple of $U_{station}$
1					
2	″				
3	″				
4	″				
5	″				
6	″				
7	″				
8	″				
9	″				
10	″				
11	″				



URR achieved: ....

Test points plotted by: ....

Figure 9 — URR evaluation diagram for single-plane tests

11.8 Test for couple unbalance interference on single-plane machines

11.8.1 Starting point

On horizontal and vertical single-plane balancing machines, the ability to suppress indication of couple unbalance shall be checked.

Balance the rotor as stated in 11.6.5.

11.8.2 Procedure

Add one test mass each (e.g. the travelling mass of the URR test) in planes 1 and 2 of the rotor, exactly 180° apart, and take a reading of the static unbalance. Shift the couple unbalance test masses by 90° three times in succession, each time taking a new reading.

11.8.3 Evaluation

None of the four readings may exceed the value of the attached couple unbalance multiplied by the claimed couple unbalance interference ratio, plus the claimed minimum achievable residual unbalance.

11.9 Compensator test

11.9.1 Starting-point

The compensator (used for the indexing procedure) shall provide a consistent readout at the end of the test procedure.

NOTE This test checks the compensator by simulating the indexing of the rotor by only moving test masses.

Use the balanced proving rotor (11.6.5) or ensure, that the unbalance is smaller than five times U_{mar} in each plane (11.6.3).

11.9.2 Procedure

Add in plane 1

— a 'stationary test mass' $U_{station}$ at 30° and

— a 'travelling test mass' U_{travel} at 150°.

Add in plane 2

— a 'travelling test mass' U_{travel} at 30° and

— a 'stationary test mass' $U_{station}$ at 150°.

Run the balancing machine and set the compensator for the first step according to the manufacturer's manual.

Move

— in plane 1 the 'travelling test mass' U_{travel} from the 150° position to 330° (180° shift),

— in plane 2 the 'travelling test mass' U_{travel} from the 30° position to 210° (180° shift), to simulate the indexing procedure.

Run the balancing machine and set the compensator for the second step according to the manufacturer's manual.

Remove

— in plane 1 the 'travelling test mass' U_{travel} located at 330° and

— in plane 2 the 'travelling test mass' U_{travel} located at 210°.

Run the machine and set the compensator to read rotor unbalance.

11.9.3 Evaluation

The compensator clears the test if readings in both planes are 0,02 $U_{station}$ or less.

NOTE The 'stationary test masses' in plane 1 at 30° and in plane 2 at 150° are still in place.

11.10 Simplified tests

11.10.1 General

If a balancing machine has been type-tested thoroughly before, or a machine in operation periodically is undergoing tests, a reduced effort will suffice.

Both the U_{mar} and the URR test may be simplified in reducing the number of test runs.

11.10.2 Simplified U_{mar} test

a) Follow procedures 11.6.2 to 11.6.7.

b) In 11.6.8, skip every second angular position, thus reducing the number of runs to 6.

NOTE The remaining angles are evenly spread around the rotor, e.g. 0°, 60°, 120°, 180°, 240°, 300°.

c) Follow 11.6.9.1 to 11.6.9.3, but calculate the arithmetic mean value per plane by dividing the sum by 6.

d) The machine has passed the test if all plotted points are within the range given by the two dotted lines (0,88 and 1,12).

No exception is allowed.

11.10.3 Simplified URR test

a) Follow 11.7.4 to 11.7.8, but skip all positions being 60° or multiples apart from the stationary test masses in each plane. This reduces the number of runs to six.

b) Enter for the travelling test masses 60° ascending/descending intervals in the log [11.7.4.1 f)].

c) Make six successive runs (11.7.6.3).

d) All test points on the test sheet shall fall within the URR limit circles (or on their lines) that correspond to the claimed value for the URR.

No exception is allowed.

Annex A
(normative)

Definitions

NOTE 1 For the convenience of users of this International Standard, some definitions from ISO 1925 are quoted.

NOTE 2 Modified definitions as agreed upon in WG 1 for a future edition of ISO 1925 are marked *).

A.1
centre of mass
point assiociated with a body which has the property that an imaginary particle placed at this point with a mass equal to the mass of a given material system has a first moment with respect to any plane equal to the corresponding first moment of the system *)

A.2
rotor
body capable of rotation *)

A.3
journal
that part of a rotor which is supported radially and/or guided by a bearing in which it rotates *)

A.4
shaft (rotor) axis
straight line joining the journal centres *)

A.5
inboard rotor
two-journal rotor which has its centre of mass between the journals

A.6
outboard rotor
two-journal rotor which has its centre of mass located other than between the journals

A.7
unbalance vector
vector whose magnitude is the amount of unbalance and whose direction is the angle of unbalance *)

A.8
amount of unbalance
product of the unbalance mass and the distance (radius) of its centre of mass from the shaft axis *)

A.9
angle of unbalance
polar angle at which an unbalance mass is located with reference to the given coordinate system, given a polar coordination system in a plane perpendicular to the shaft axis and rotating with the rotor *)

A.10
unbalance mass
mass whose centre is at a distance from the shaft axis *)

A.11
residual (final) unbalance
unbalance of any kind that exists in the rotor after balancing

A.12
initial unbalance
unbalance of any kind that exists in the rotor before balancing

A.13
resultant unbalance, V_r
vector sum of all unbalance vectors distributed along the rotor *)

A.14
specific unbalance, e
amount of static unbalance U divided by the mass m of the rotor

A.15
correction (balancing) plane
plane perpendicular to the shaft axis of a rotor in which correction for unbalance is made

A.16
measuring plane
plane perpendicular to the shaft axis in which the unbalance vector is determined

A.17
test plane
plane perpendicular to the shaft axis in which test masses may be attached

A.18
test mass
precisely defined mass used in conjunction with a proving rotor to test a balancing machine

NOTE 1 The use of the term "test weight" is deprecated; the term "test mass" is accepted in international usage.

NOTE 2 The specification for a test mass should include its mass and its centre-of-mass location; the aggregate effect of the errors in these values should not have a significant effect on the test results.

A.19
single plane (static) balancing machine
gravitational or centrifugal balancing machine that provides information for accomplishing single-plane balancing

A.20
dynamic (two-plane) balancing machine
centrifugal balancing machine that furnishes information for performing two-plane balancing

A.21
balancing machine accuracy
limits within which a given amount and angle of unbalance can be measured under specified conditions

A.22
couple unbalance interference ratio
interference ratio I_{SC} is defined by the relationship

$$I_{SC} = U_S/U_C$$

where U_S is the change in static unbalance indication of a balancing machine when a given amount of couple unbalance U_C is introduced to the rotor

NOTE This ratio is generally used in the testing of single-plane balancing machines and may be expressed by multiplying it by the maximum distance between the test planes on a proving rotor.

A.23
plane separation
capability of a balancing machine to minimize the correction plane interference ratio.

NOTE The term is also used for the related process. *)

A.24
unbalance reduction ratio (URR)
ratio of the reduction in the unbalance by a single unbalance correction to the initial unbalance

$$\text{URR} = \frac{U_1 - U_2}{U_1} = 1 - \frac{U_2}{U_1}$$

where

U_1 is the amount of initial unbalance;

U_2 is the amount of unbalance remaining after one correction

NOTE 1 The unbalance reduction ratio is a measure of the overall efficiency of the unbalance correction.

NOTE 2 The ratio is usually given as a percentage.

A.25
minimum achievable residual unbalance
smallest value of residual unbalance that a balancing machine is capable of achieving

A.26
claimed minimum achievable residual unbalance
smallest value of residual unbalance stated by the manufacturer for the machine, and measured in accordance with the procedure specified in this International Standard

A.27
proving (test) rotor
rigid rotor of suitable mass designed for testing balancing machines and balanced sufficiently to permit the introduction of exact unbalance by means of additional masses with high reproducibility of the magnitude and angular position

Annex B
(informative)

Information to be supplied to the balancing machine manufacturer by the user

B.1 General

This annex indicates the type of information that a user should provide to enable a manufacturer of a balancing machine to meet his requirements. Adoption of the format suggested below makes it easier for the manufacturer to assess the user's requirements.

B.2 Rotor to be balanced

B.2.1 Essential rotor data

Give limiting factors, such as mass, dimensions, tolerances, etc).

If the machine is to be used for series balancing of a limited number of specific rotors, detailed information, including manufacturer's drawings, should be supplied in lieu of table B.1. If the machine is to be used for many types of rotors, table B.1 should be completed for each type. The extreme sizes of rotors that the machine would be required to balance should be indicated.

B.2.2 Other rotor requirements

B.2.2.1 Include detail drawings. If possible, the user should send drawings of typical parts to be balanced. This is particularly important for rotors with unusual geometry.

B.2.2.2 If correction planes are located other than between the journals, describe their locations.

B.2.2.3 Is the balancing machine to be used with outboard rotors? If so, what is load B and negative load at A? (See figure B.1.)

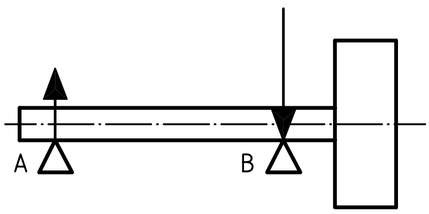


Figure B.1 — Loads

B.2.2.4 Is there a thrust load? If so, give value and direction expected during balancing operation (applicable to horizontal machines only).

B.2.2.5 Will the user require the manufacturer to supply the necessary fixtures and attachments, such as driving adaptors, pulleys, mounting adaptors, mandrels, etc.?

B.2.2.6 What is the journal finish, roundness and hardness?

Table B.1 — Rotor data

Typical rigid workpiece to be balanced						Units[a]
Mass						kg
Type [b]						
Quantity [c]						
Production rate required [d]						per hour/day
Dimensions [e]						
Maximum diameter *D*						mm
Belt-drive diameter *Q* [f, g]						mm
Maximum length *L*						mm
Journal diameters *d* [f]						mm
Distance between journal centres *W* [f]						mm
Correction plane location *A*						mm
B						mm
C						mm
End clearance on driven end *P* [f]						mm
Service speed						r/min
Critical speed [h]						r/min
Moment of inertia [i]						$kg \cdot m^2$
Air resistance [j]						
Power and speed						kW; r/min
Maximum initial unbalance [k]						g·mm
Unbalance tolerance [l]						g·mm
Number of correction planes [m]						
Drive [f, n]						
Correction means [o]						

a Circle the units to be used.

b Type(s) of rotor(s) and use: for example 4-cylinder crankshaft, flywheel, ventilator, electric rotor, fan.

c Approximately how many rotors of the same type are to be balanced in succession before changing over to another type?

d If applicable, state the desired production rate in pieces per hour or day at 100 % efficiency.

e See figures B.2 and B.3.

f Generally applicable only to horizontal machines.

g If applicable, state the diameter over which the belt shall drive.

h For multi-bearing rotors, for example crankshafts, state the approximate frequency value of the first flexural critical speed of the rotor, simply supported in rigid bearings on the two end journals.

i Moment of inertia is $\int r^2 dm$ over the entire body, where d*m* is an increment of mass and *r* is the distance from the shaft axis.

j Will the part offer substantial air resistance uring the balancing operation? If so, give expected power required and the corresponding speed.

k What is the maximum initial unbalance (g·mm) for each selected correction plane?

l Unbalance tolerance (g·mm) for each selected correction plane.

m State the number of planes in which correction is to be made. If correction in more than two planes is required, explain separately.

n State the means by which the rotor may be rotated: belt drive, end drive, either belt or end drive, air drive, roller drive, self-powered drive, band drive, etc.

o State the means of correction intended, for example drilling, milling, etc., or addition of correction masses.

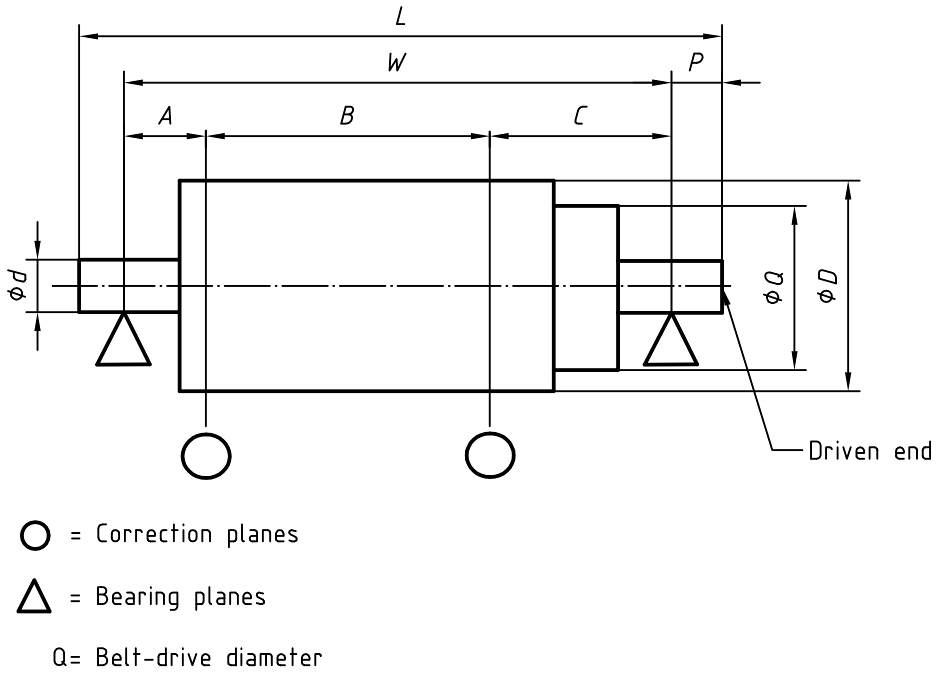
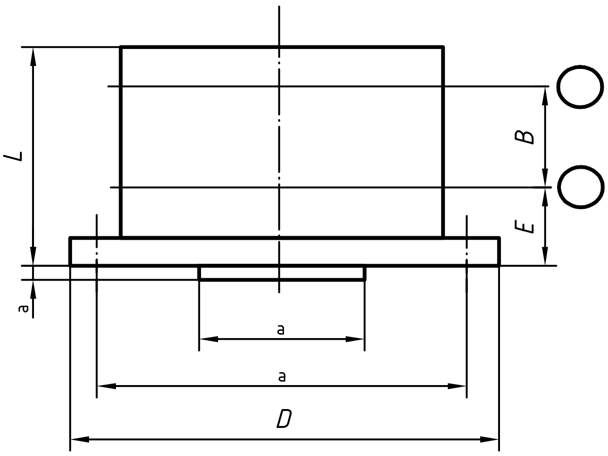


Figure B.2 — Example of a horizontal machine



a Mounting dimensions, including number of bolt holes and their diameter, or central bore or taper used to mount the rotor in assembly should be stated.

Figure B.3 — Example of a vertical machine

B.2.2.7 Are the rotors to be balanced in their own bearings? If so, give details, for example type of bearings, maximum outside diameter of bearings, etc.

B.2.2.8 Is a specific balancing speed desired? If so, explain.

B.2.2.9 Does the user expect the manufacturer to supply the means of correction (drills, milling cutters, etc.)?

B.2.2.10 Are there any other special workpiece properties, for example rotating magnetic fields, aerodynamic effects, etc.?

B.3 Other requirements

B.3.1 Is the main electrical supply three- or single-phase voltage? Give frequency and maximum possible deviation (%). If the three-phase system is grounded, is there a neutral lead available? Should the electrical equipment meet any particular standard or specification?

B.3.2 Is tropical insulation required?

B.3.3 Is compressed air available? At what pressure? With what maximum variation?

B.3.4 Is the floor rigid where the machine will be located, that is, equivalent to a concrete slab laid on compacted earth? How thick is the concrete floor?

B.3.5 State possible sources of vibration in the vicinity: for example hammers, heavy vehicles, etc. State their average rate of occurrence.

B.3.6 Who will inspect and accept the machine and where? Where are the applicable specifications?

B.3.7 In which language should the operating instructions and leaflets accompanying the machine preferably be written? What other languages are also acceptable?

B.3.8 What units should be marked on indicating devices?

B.4 Administrative requirements

B.4.1 Does the user require the services of a balancing machine service engineer to install and calibrate the machine?

B.4.2 Does the user require the services of a balancing machine service engineer to instruct the personnel?

B.4.3 What are the names and addresses of people in user's organization in charge of balancing?

B.4.4 Is the user prepared to send an operator for training by the manufacturer?

B.4.5 Is the user interested in a maintenance contract?

B.4.6 To whom shall the quotation be addressed?

B.4.7 State address to which the machine is to be shipped.

B.4.8 Give any box markings.

B.4.9 Give insurance instructions.

B.4.10 State, as applicable: FOB (free on board)... (loading port agreed); FAS (free alongside ship)... (loading port agreed); CIF (cost insurance freight)... (designation port agreed), etc.

B.4.11 Requested delivery date.

Annex C
(informative)

URR limit diagrams

C.1 Basic data

Underlying data for the URR limit diagrams shown in figures 8 and 9 are listed in tables C.1 and C.2. Even though they are calculated for $U_{station} = 30 \times U_{mar}$, they may be used with sufficient accuracy in the range of $U_{station} = 20$ to $60 \times U_{mar}$.

Table C.1 — Two-plane URR limit diagram data

Origin of URR limit circles			**Radii** r [c] **of URR limit circles**			
α [a] degrees	γ [b] degrees	R [c] $U_{station}$	80 %	85 %	90 %	95 %
30	25,1	5,89	1,19	0,900	0,605	0,311
60	51,1	5,57	1,13	0,852	0,573	0,295
90	78,7	5,10	1,04	0,782	0,527	0,272
120	109,1	4,58	0,93	0,704	0,475	0,246
150	143,1	4,16	0,85	0,641	0,433	0,225
180	180,0	4,00	0,82	0,617	0,417	0,217

a α is the angle between the stationary mass and the travelling mass.

b γ is the angle of the resultant vector R.

c R and r are in multiples of $U_{station}$.

Table C.2 — Single-plane URR limit diagram data

Origin of URR limit circles			**Radii** r [c] **of URR limit circles**			
α [a] degrees	γ [b] degrees	R [c] $U_{station}$	80 %	85 %	90 %	95 %
30	25,1	5,89	1,21	0,916	0,622	0,328
60	51,1	5,57	1,15	0,868	0,590	0,312
90	78,7	5,10	1,05	0,798	0,543	0,288
120	109,1	4,58	0,95	0,721	0,492	0,262
150	143,1	4,16	0,87	0,658	0,450	0,242
180	180,0	4,00	0,83	0,633	0,433	0,233

NOTE For footnotes, see table C.1.

C.2 Instructions for drawing URR limit circle diagrams

Proceed as follows (see figure C.1):

a) use commercially available polar diagram paper or design your own;

b) select a suitable scale so that all circles are within the diagram part of the paper;

c) determine the URR limit circle origin; it is a distance equivalent to 1 ($1 \times U_{station}$) vertically above the graph paper origin;

d) draw 12 equally spaced radial lines (30° apart) from the URR limit circle origin outwards;

e) determine the centre of each URR limit circle, omitting the one in vertical direction (towards the top of the page); the centres are located on each radial line, a distance equivalent to 5 ($5 \times U_{station}$) from the URR limit circle origin;

f) draw concentric circles around each URR limit circle centre, with radii r (in units of $U_{station}$) as shown in the columns of the selected URR values in tables C.1 or C.2;

g) insert an arrow from the graph origin in a vertical direction to designate the position of the stationary test masses;

h) along the arrow, mark off the amount-of-unbalance scale in units of $U_{station}$ and insert the appropriate values 1 to 6; the diagram is now ready for evaluating the logged URR test data.

C.3 Other URR limits

If the URR limit diagrams given in figures 8 and 9 are insufficient, i.e. a machine with another unbalance reduction ratio is to be tested, an appropriate URR limit diagram can be made up with the help of the instructions given in clause C.4.

C.4 Instruction for calculating URR limit circles

C.4.1 The radii and positions of URR limit circles for commonly used unbalance reduction ratios may be taken directly from tables C.1 and C.2 The equations given below may serve mainly to substantiate the data in tables C.1 and C.2, but may also be used to calculate values for R, r and γ, if different URR values or angles between test masses are used.

C.4.2 The equation for determining the distance R between the graph origin and the centre of a URR limit circle is as follows:

$$R = \sqrt{m_S{}^2 + m_T{}^2 + 2\left(m_S\ m_T\ \cos\alpha\right)}$$

where

m_S is the stationary test mass ($1 \times U_{station}$);

m_T is the travelling test mass ($5 \times U_{station}$);

R is the resultant of m_S and m_T (amount of unbalance indication) or distance from graph origin to centre of URR limit circle;

α is the angle between the stationary and travelling test masses;

γ is the angle between m_S and R;

r is the radius of the URR limit circle;

URR is the unbalance reduction ratio.

C.4.3 The equation for determining the angle γ between the stationary test mass m_S and the resultant R is as follows:

$$\cos\gamma = \frac{{m_S}^2 + R^2 - {m_T}^2}{2\, m_S\, R}$$

C.4.4 For dimensions of m_S, m_T, R and r in multiples of $U_{station}$ and $m_T = 5 \times m_S$, the equations for R and γ are as follows:

$$R = \sqrt{26 + 10\cos\alpha}$$

$$\cos\gamma = \frac{R^2 - 24}{2R}$$

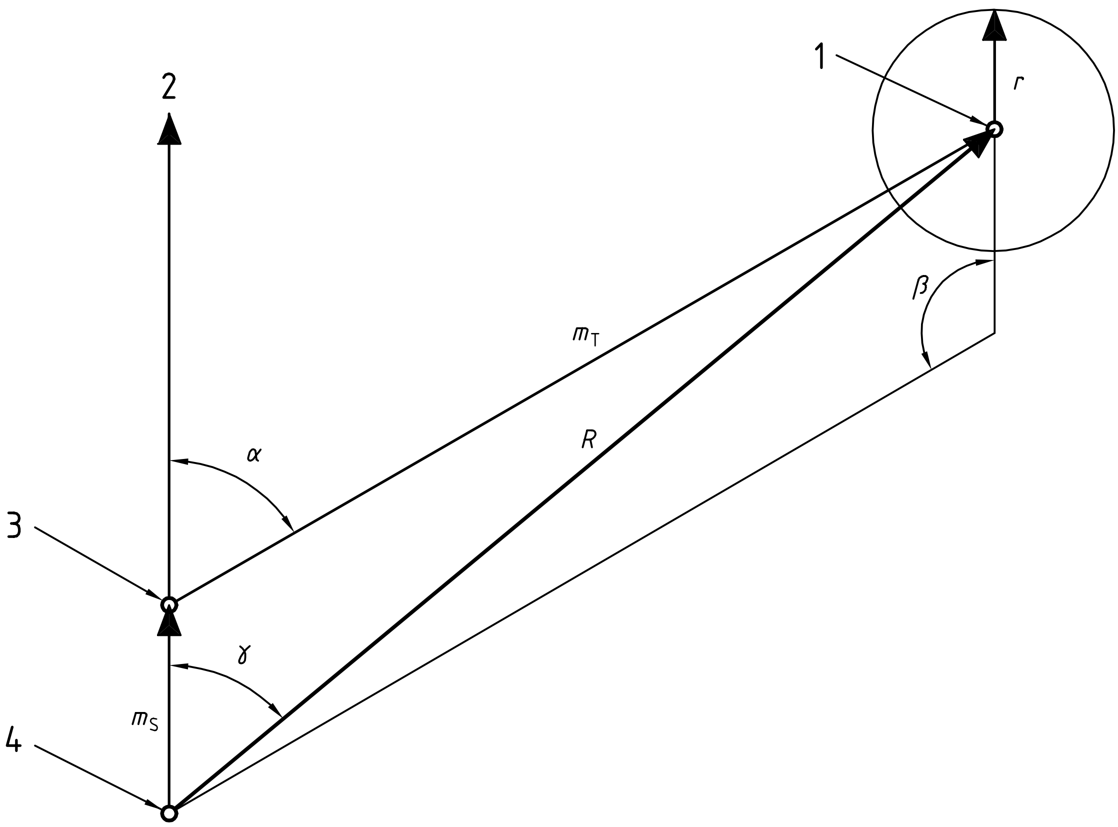
C.4.5 The equation for determining r the radius of a URR limit circle is as follows:

a) Two-plane

$$r = R(1 - \text{URR}) + \frac{U_{mar}}{2\, U_{station}}$$

b) Single-plane

$$r = R(1 - \text{URR}) + \frac{U_{mar}}{U_{station}}$$



Key

1 Origin of URR limit circles

2 0° axis

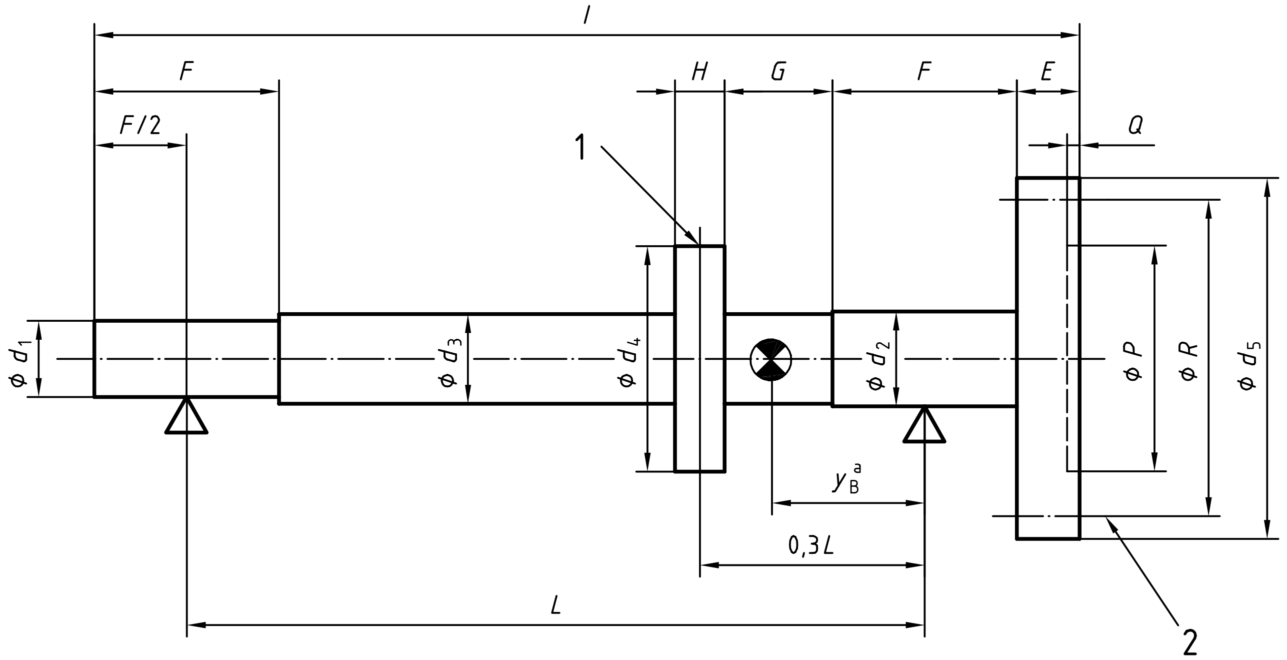
3 Origin of travelling mass

4 Graph origin (origin of stationary mass)

Figure C.1 — Graphical determination of R and γ from m_S, m_T and α

Annex D
(informative)

Shafts of outboard proving rotors type C



Key

1 12 equally spaced threaded holes, N
2 4 equally spaced threaded holes, O

[a] Distance of centre of mass to right-hand bearing plane.

NOTE 1 For dimensions see table D.1.

NOTE 2 Dimensions may be varied (e.g. by addition of a belt pulley) provided the mass, position of centre of mass and position of N between bearings are maintained.

NOTE 3 Interface dimensions (spigot) comply with proving rotors type A.

NOTE 4 End-drive interface dimensions for Nos. 3 to 5 shall be in accordance with proving rotors type B, Nos. 4 to 6.

NOTE 5 All tolerances and residual unbalance shall be in accordance with the test aims.

Figure D.1 — Shafts of proving rotors type C for outboard tests on horizontal machines

Table D.1 — Suggested dimensions and masses of shafts of proving rotors type C for outboard tests on horizontal machines (see figure D.1)

No.	Mass	Bearing distance	Overall length	Journals				Major diam.		Shaft length				Flange [b]				
	M_S	L	l	d_1 [c]	d_2	d_3	d_4	d_5	E	F	G	H	N	P	Q	R	O	Y_S [a, d]
				≈ 0,1 l	≈ 0,125 l		≈ 0,3 l			≈ 0,25 l								
Metric values																		
	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm		mm	mm	mm		mm
1	1,1	164	217	17	21	20	50	85	12	41	24	11	M3	50,8	5	76,2	M6	30
2	2,7	240	320	25	30	28	72	85	20	60	34	16	M4	50,8	5	76,2	M6	60
3	8,5	352	460	36	45	42	106	156	30	88	50	24	M5	114,3	6	133,35	M10	90
4	25	520	700	58	65	62	156	156	50	130	74	34	M6	114,3	6	133,35	M10	135
5	80	760	1 020	78	95	91	230	230	70	190	108	50	M8	114,3	6	133,35	M10	200
Inch/pound values																		
	lb	in	in	in	in	in	in	in	in	in	in	in		in	in	in		in
1	2,5	6,4	8,5	0,67	0,83	0,8	2	3,4	0,5	1,6	1	0,4	No.5 UNF	2	0,2	3	1/4 UNF	1,2
2	6	9,6	12,75	0,98	1,2	1,1	2,8	3,4	0,75	2,4	1,3	0,6	No.8 UNF	2	0,2	3	1/4 UNF	2,4
3	20	14	18,25	1,42	1,8	1,65	4,2	6,2	1,18	3,5	2	0,9	No.10 UNF	4,5	0,25	5,25	3/8 UNC	3,5
4	55	20,4	27,5	2,28	2,55	2,4	6,2	6,2	2	5,1	3	1,3	1/4 UNC	4,5	0,25	5,25	3/8 UNC	5,3
5	180	30	40,25	3,07	3,7	3,5	9	9	2,75	7,5	4,25	2	5/16 UNC	4,5	0,25	5,25	3/8 UNC	8

NOTE All tolerances and residual unbalance shall be in accordance with the test aims.

a Dimensions may be varied provided the mass and position of centre of mass are maintained.

b Interface dimensions (spigot) comply with proving rotors type A.

c End-drive interface dimensions for Nos. 3 to 5 are in accordance with proving rotors type B, Nos. 4 to 6.

d Distance of centre of mass to right-hand bearing plane.

Annex E
(informative)

Modification of old (ISO 2953:1985) proving rotors to this International Standard

E.1 Proving rotors type A

The main differences are the size of threads and test masses.

The easiest adaptation to this International Standard is to use bolts with stepped threads: one end for the tapped holes in the proving rotor, the other end for the test masses (rings) with the thread recommended now.

E.2 Proving rotors type B

The main differences are threads, middle plane (3), number of holes, test masses, shaft diameter and interfaces to cardan shafts. A few comments follow.

a) Test planes

It is recommended to machine all holes in the three planes in one set up.

The new test planes (1 and 2) are arranged best adjacent to and inside of old planes (old holes may be closed by set screws). Add middle plane (3).

b) Interfaces to end drives

The interface may be adapted to this International Standard by an adapter, which becomes an integral part of the proving rotor (too large a mass on the cardan shaft side may jeopardize the U_{mar} test).

E.3 Proving rotors type C

The main differences are the special shaft and modifications on the proving rotor type A. The shaft is a new item; for modification of proving rotor type A, see E.1.

Annex F
(informative)

Bibliography

[1] ISO 1940-1:1986, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance.*

[2] ISO 1940-2:1997, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 2: Balance errors.*

[3] ISO 7475:1984, *Balancing machines — Enclosures and other safety measures*.

[4] SAE ARP 4162, *Balancing Machine Proving Rotors*.

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