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International Standard ISO 2953

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Balancing machines — Description and evaluation

Machines à équilibrer — Description, caractéristiques et possibilités

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 2953 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*.

ISO 2953 was first published in 1975. This second edition cancels and replaces the first edition, of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Annexes

Balancing machines — Description and evaluation

1 Scope

This International Standard sets out standards for the evaluation of performance and characteristics of machines for balancing rotating components where correction is required in one or more planes perpendicular to the shaft axis. It stresses the importance attached to the form in which the balancing machine characteristics should be specified by the manufacturer and also outlines methods of evaluating balancing machines. Adoption of the format suggested in 4.1 and 4.2 makes it easier for the user to compare one manufacturer's product with another's. Guidance as to the manner in which users should state their requirements is given in annex A.

It should be noted that the terminology used throughout this International Standard is in accordance with ISO 1925 and this terminology should be employed by manufacturers and users when applying this International Standard.

2 Field of application

This International Standard is applicable to balancing machines that support and rotate rigid workpieces (that is, workpieces that are rigid at balancing speeds) and that indicate the amounts and angular locations of unbalance corrections required.

It covers both those machines that measure out-of-balance effects on soft bearings and those that measure out-of-balance effects on hard bearings. It also relates to resonance-type machines, provided that mechanical compensators are incorporated.

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

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 A gives an indication of the information a user might supply to a manufacturer and a suggested method of tabulating it. Annex B gives some of the definitions relevant to the provisions of this International Standard.

This International Standard does not specify balancing criteria; these will be found in ISO 1940.

3 References

ISO 1925, *Balancing — Vocabulary.*

ISO 1940, *Balancing quality of rotating rigid bodies.*

4 Capacity and performance data of the machine

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

4.1 Capacity and performance data of horizontal machines (See page 4 for notes)

Manufacturer : .... Model : ....

4.1.1 Rotor mass and unbalance limitations

4.1.1.1	Balancing speeds or speed ranges (see also 4.1.3.1)		Min.	n_2	n_3	n_4	n_5
4.1.1.2[1)]	Rotor mass kg (lb)	maximum					
		minimum					
	Occasional overload force per support : N (kgf, lbf)						
	Maximum negative force per support : N (kgf, lbf)						
4.1.1.3[2)]	Maximum rotor moment of inertia with respect to the shaft axis kg·m^2 (lb·ft^2)						
	Cycle rate						
4.1.1.4[3)]	Maximum unbalance g·mm/kg or g·mm (lb·in/lb or oz·in)	measurable					
		permissible					
4.1.1.5[4)] For inboard rotors	Minimum achievable residual specific unbalance, e_{mar} (see clause 6) g·mm/kg (lb·in/lb)	maximum mass					
		0,2 × maximum mass					
		minimum mass					
	Corresponding deflection of analogue amount-of-unbalance indicator : mm (in), respectively number of digital units	maximum mass					
		0,2 × maximum mass					
		minimum mass					
4.1.1.5.1[4)] For outboard rotors	Minimum achievable residual specific unbalance, e_{mar} (see clause 6) g·mm/kg (lb·in/lb)	maximum mass					
		0,2 × maximum mass					
		minimum mass					
	Corresponding deflection of analogue amount-of-unbalance indicator : mm (in), respectively number of digital units	maximum mass					
		0,2 × maximum mass					
		minimum mass					

4.1.1.6 Production efficiency (see clause 7)

4.1.1.6.1 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: .... s

f) Average deceleration time: .... s

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

h) Other necessary time: .... s

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

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

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

4.1.2 Rotor dimensions

4.1.2.1[5] Rotor envelope limitations (see figure 1)

4.1.2.2 Rotor diameter

Maximum diameter over bed : .... mm (in)

Maximum diameter over which belt can drive : .... mm (in)

Minimum diameter over which belt can drive : .... mm (in)

4.1.2.3 Distance between journal centrelines

Maximum : .... mm (in)

Minimum : .... mm (in)

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

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

4.1.2.4 Journal diameter

Maximum : .... mm (in)

Minimum : .... mm (in)

4.1.2.4.1[6] Maximum permissible peripheral journal speed .... m/s (ft/s)

4.1.2.5 Correction plane limitations (consistent with the statements in 5.4)

4.1.2.6 Correction plane interference ratios (consistent with the statements in 5.4 and based on the proving rotor)

4.1.3 Drive

4.1.3.1[7]

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

4.1.3.2[8] Zero-speed torque : .... % of rated torque on workpiece

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

Peak torque .... % of rated torque on workpiece

4.1.3.3[9] Type of drive to workpiece : ....

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

4.1.3.4.1 Rated power : .... kW (hp)

Motor speed : .... rev/min

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

4.1.3.5 Brake

4.1.3.5.1 Type of brake : ....

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

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 .... rev/min, or .... rev/min

4.1.4[10] **Couple unbalance interference ratio** [g·mm/g·mm^2 (oz·in/oz·in^2)] .... %

4.1.5 **Air pressure requirements :** .... Pa (psi) ; .... m^3/s (ft^3/s)

NOTES TO 4.1

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

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 gravity outside the bearing support.

2) 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. 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.

) 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.

) Limits for soft-bearing machines shall generally be 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 shall generally be stated in gram millimetres, since these machines are usually factory-calibrated to indicate 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.

) 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.

6) 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.

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

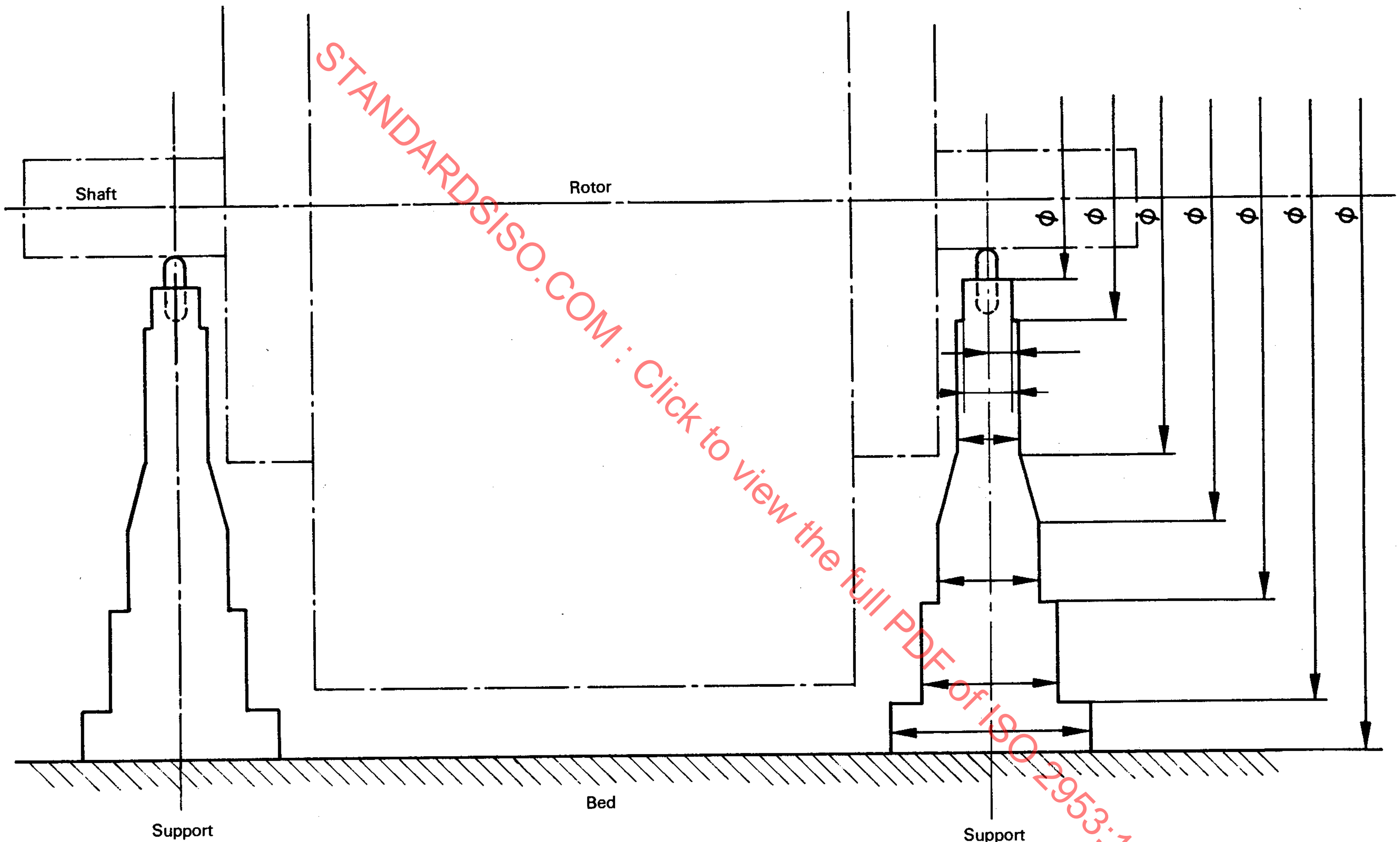
8) In most cases, maximum torque is required for accelerating a workpiece. However, in the case of workpieces with high windage and/or friction loss, maximum torque may be required at balancing speed. When there is axial thrust, it is necessary that provisions be made to take this into account.

9) 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.

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

10) 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.



NOTES

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

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

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

4.2 Capacity and performance data of vertical machines (See page 8 for notes)

Manufacturer : .... Model : ....

4.2.1 Rotor mass and unbalance limitations

			Min.	n_2	n_3	n_4	n_5
4.2.1.1	Balancing speeds or speed ranges (see also 4.2.3.1)						
4.2.1.2 1)	Rotor mass (kg/lb)	maximum					
		minimum					
	Occasional overload force up to : N (kgf, lbf)						
4.2.1.3 2)	Maximum rotor moment of inertia with respect to the shaft axis kg·m^2 (lb·ft^2)						
	Cycle rate						
4.2.1.4 3)	Maximum unbalance g·mm/kg or g·mm (lb·in/lb or oz·in)	measurable					
		permissible					
4.2.1.5 4)	Minimum achievable residual specific unbalance, e_{mar} (see clause 6) g·mm/kg (lb·in/lb)						
	Corresponding deflection of analogue amount-of-unbalance indicator : mm (in), respectively number of digital units						

4.2.1.6 Production efficiency (see clause 7)

4.2.1.6.1 Time per measuring run: .... s

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: .... s

f) Average deceleration time: .... s

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

h) Other necessary time: .... s

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

4.2.1.6.2 Unbalance reduction ratio: .... %

4.2.2 Rotor dimensions

4.2.2.1 Maximum diameter: .... mm (in)

4.2.2.2 Rotor height :

a) Maximum overall height : .... mm (in)

b)[5] Maximum height of centre of gravity : .... mm (in)

at 100 % of maximum mass : .... mm (in)

at 50 % of maximum mass : .... mm (in)

at 25 % of maximum mass : .... mm (in)

4.2.2.3[6] Rotor envelope limitations, including machine spindle or mounting plate interface (see figure 2)

4.2.2.4 Correction plane limitations (consistent with the statements in 5.4)

4.2.3 Drive

4.2.3.1

	Balancing speed rev/min	Rated torque on workpiece N·m (lbf·ft)
n_1	....	....
n_2	....	....
n_3	....	....
n_4	....	....
n_5	....	....
n_6	....	....
n_7	....	....
n_8	....	....

4.2.3.2[7] Zero-speed torque : .... % of rated torque on workpiece

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

Peak torque .... % of rated torque on workpiece

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

4.2.3.3.1 Rated power : .... kW (hp)

Motor speed : .... rev/min

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

4.2.3.4 Brake

4.2.3.4.1 Type of brake : ....

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

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 .... rev/min, or .... rev/min

4.2.4[8] **Couple unbalance interference ratio** [g·mm/g·mm^2 (oz·in/oz·in^2)] : .... %

4.2.5 Air pressure requirements : .... Pa (psi) ; .... m^3/s (ft^3/s)

NOTES TO 4.2

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

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.

2) 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. 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.

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.

4) Limits for soft-bearing machines shall generally be 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 shall generally be stated in gram millimetres, since these machines are usually factory-calibrated to indicate unbalance in such units. (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.

5) 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.

6) 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 plates, shall be supplied to enable the user to determine the maximum rotor envelope that can be accommodated and the tooling and/or adaptors required.

7) 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.

8) 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.

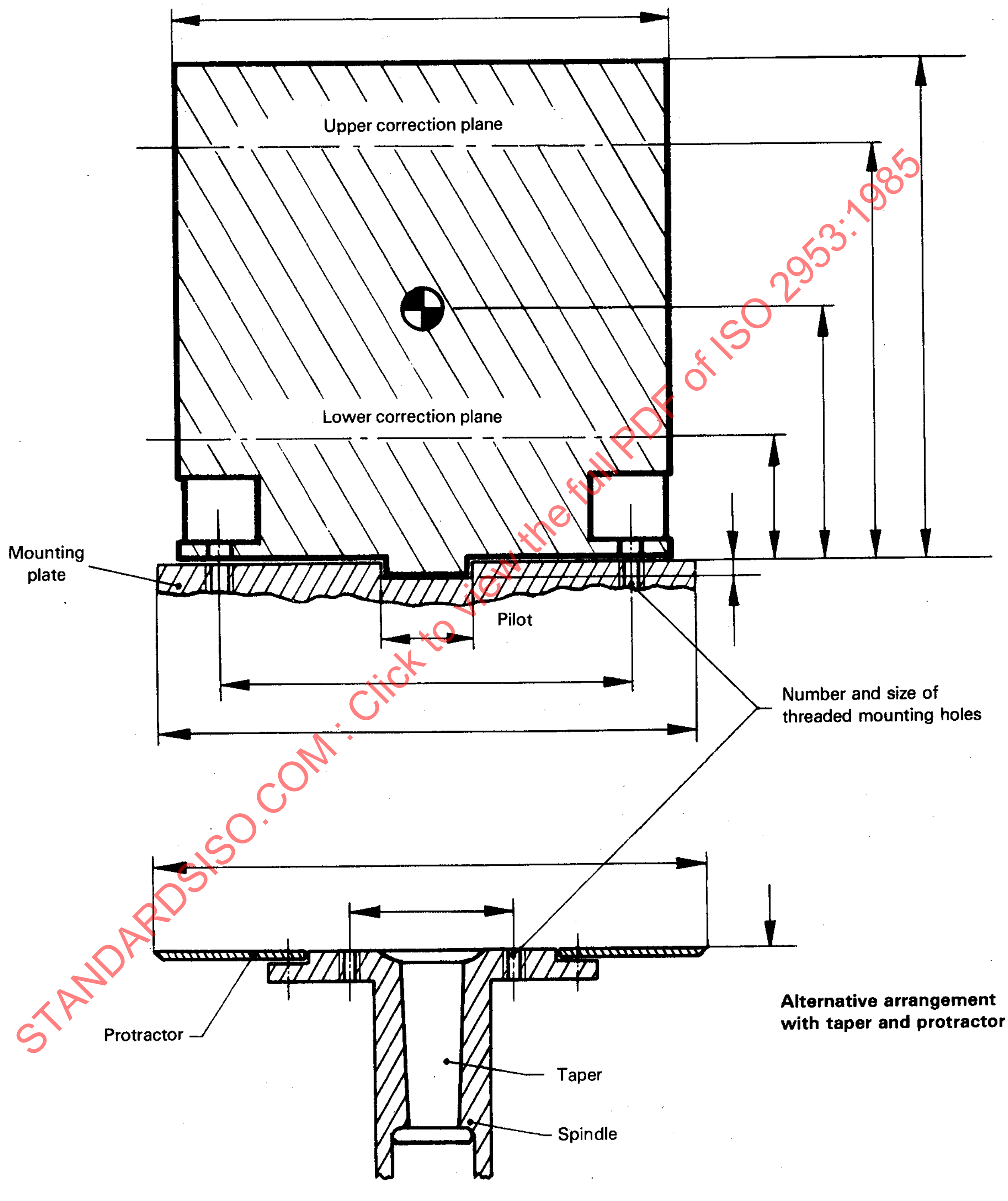


Figure 2 — Example of vertical machine mounting interface illustrating rotor envelope limitations

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, etc.

5.2 Arrangement of the machine

5.2.1 The manufacturer shall describe the general configuration of his 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

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.

5.3.1 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;
- analogue or digital readout.

5.3.2 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;
- analogue or digital readout.

5.3.3 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) What is the maximum retention period?

e) 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 (not applicable to single-plane machines; see also note below)

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

NOTE — 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 11.7.9).

5.5 Setting and calibration of indication

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.

He shall state the number of runs required for calibrating the machine :

— for single-plane balancing;

— for two-plane balancing.

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

5.5.1 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.

5.5.2 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 co-ordinate 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 (see definition in annex B) in gram millimetres per kilogram (pound inches per pound $\times 10^{-6}$) 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

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.

Unless otherwise specified, "proving rotor" shall be understood to mean the heaviest rotor described in table 1 which falls within the capacity of the machine.

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).

7.1 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) overleaf.

NOTE — 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.

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

b) setting of the indicating system;

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

c) preparation of the rotor for the measuring run;

NOTE — 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.

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.

7.2 Unbalance reduction

The manufacturer shall state the unbalance reduction ratio (see definition in annex B). 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.

NOTE — In certain circumstances, the unbalance reduction ratio can and does depend on the relation between the initial amount of unbalance and the desired residual unbalance. Values shall therefore be given for the initial unbalances in the ranges 20 to 50 times and 100 to 500 times the specified achievable residual unbalance.

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 weight of his machine and the type and size of foundation required for his machine under which its specified performance is assured, for example, concrete blocks, workbench, etc.

10 Proving rotors and test masses

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.

10.1 Proving rotors

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

10.1.2 Proving rotors shall be manufactured of steel and shall be similar to those shown in table 1 and figure 3 for horizontal machines and in table 2 and figure 4 for vertical machines; some of the latter are used as outboard proving rotors on horizontal machines (see note 3 below).

NOTES

1 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 his plant.

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

3 If a horizontal machine is to be used for balancing outboard rotors, additional tests, if agreed upon, require a horizontal machine rotor, a vertical machine rotor, and an adaptor by means of which the vertical rotor is mounted on one end of the horizontal rotor. (See also figure 5 and 11.7.1.)

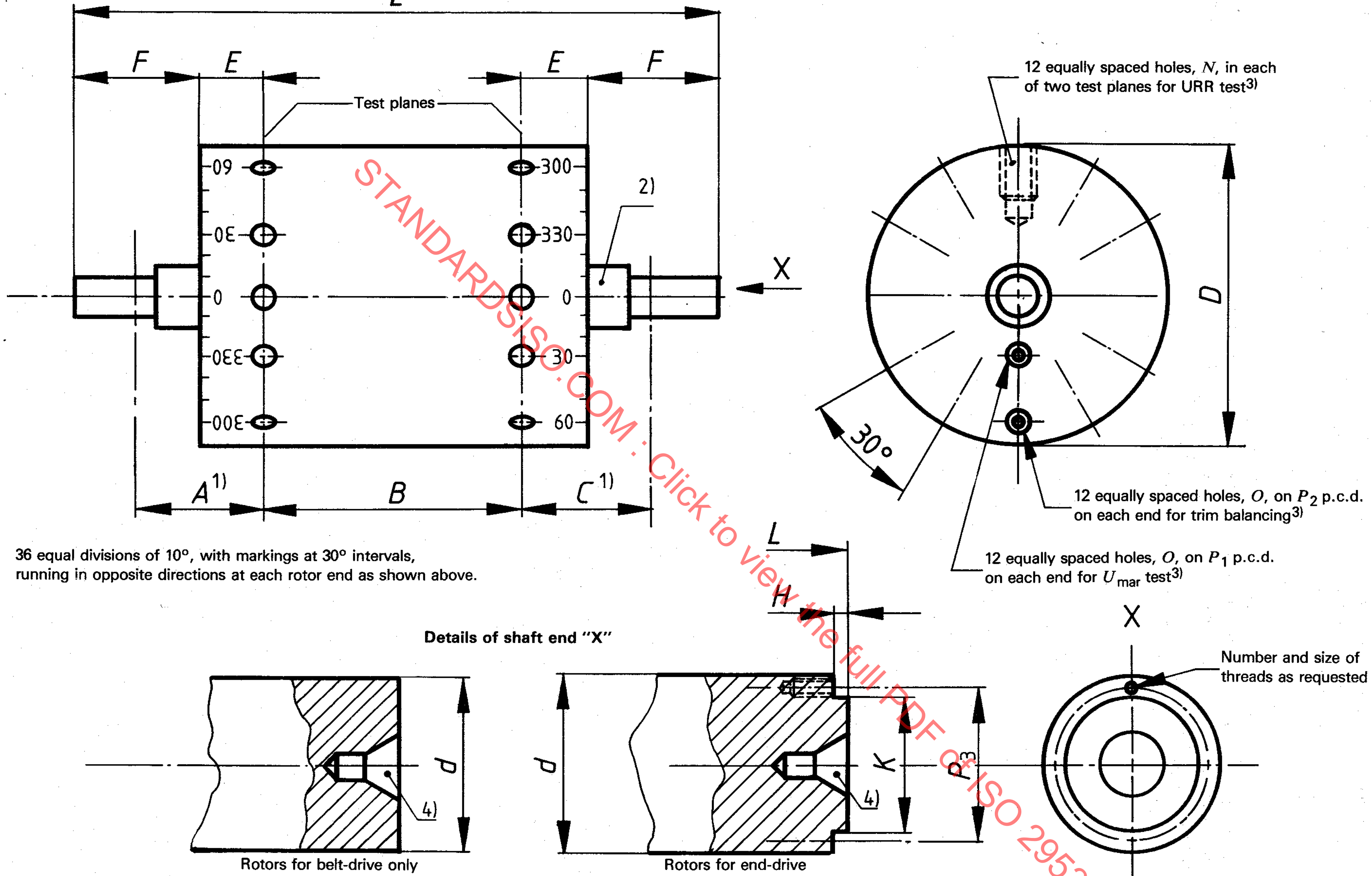
10.1.3 Clear and permanent angle markings shall be provided on every proving rotor every 10° and enumerated at intervals of 30°. Rotors conforming to SAE ARP 588 A with 15° markings shall also be acceptable.

10.1.3.1 For testing stroboscopic machines, the proving rotor shall be equipped with an enumerated standard band delivered with the machine. The middle of the first number on the band shall coincide with one set of tapped holes. No other middle of a number shall coincide with a set of tapped holes as far as this can be avoided.

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

10.1.5 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 to determine the machine capability in a mass range where the parasitic mass of supporting members has a significant influence on the test results.

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



1) Test plane limitations : $A \geqslant B/2$; $C \geqslant B/2$

2) If the shafts are used as ball bearing seatings, a shoulder ring shall be provided so that the centres of the ball bearings are at the prescribed distance.

3) Older style proving rotors with only eight holes and angular spacing may also be used.

4) Replace with tapped hole if an outboard rotor is to be attached.

Figure 3 — Inboard proving rotors for horizontal machines
(for dimensions, see table 1)

Table 1 — Dimensions, masses and speeds of inboard proving rotors for horizontal machines

Metric values

Rotor No.	Rotor mass M	Moment of inertia $I \approx Mk^2$	Major diameter D	Overall length L	Shaft diameter d	Bearing distance $A + B + C$	A 1) C 1)	B 1)	E	F	P_1	P_2	H 1)	K 2)	P_3 2)	N	O	Critical speed 3)	Highest test speed 4)
	$9{,}5 \times 10^{-6}\ D^3$		D	$2{,}5\ D$	$0{,}2\ D$	$2\ D$	$0{,}5\ D$	$1\ D$	$0{,}25\ D$	$0{,}5\ D$	$0{,}5\ D$							$\frac{7\ 600\ 000}{D}$	$\frac{760\ 000}{D}$
	kg	kg·m²	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	rev/min	rev/min
1	0,5	0,000 1	38	95	8	76	19	38	9,5	19	19	31	—	—	—	M 3	M 2	200 000	20 000
2	1,6	0,000 6	56	140	12	112	28	56	14	28	28	46	—	—	—	M 3	M 2	140 000	14 000
3	5	0,004	82	205	17	164	41	82	20,5	41	41	72	—	—	—	M 6	M 3	95 000	9 500
4	16	0,03	120	300	25	240	60	120	30	60	60	108	—	—	—	M 6	M 3	65 000	6 500
5	50	0,2	176	440	35	352	88	176	44	88	88	160	—	—	—	M 12	M 6	45 000	4 500
6	160	1,3	260	650	50	520	130	260	65	130	130	240	—	—	—	M 12	M 6	30 000	3 000
7	500	9	380	950	75	760	190	380	95	190	190	350	1,4	30	47	M 20	M 12	20 000	2 000

Inch/pound values

Rotor No.	Rotor mass M	Moment of inertia $I \approx Mk^2$	Major diameter D	Overall length L	Shaft diameter d	Bearing distance $A + B + C$	A 1) C 1)	B 1)	E	F	P_1	P_2	H 1)	K 2)	P_3 2)	N	O	Critical speed 3)	Highest test speed 4)
	$0{,}33\ D^3$		D	$2{,}5\ D$	$0{,}2\ D$	$2\ D$	$0{,}5\ D$	$1\ D$	$0{,}25\ D$	$0{,}5\ D$	$0{,}5\ D$							$\frac{300\ 000}{D}$	$\frac{30\ 000}{D}$
	lb	lb·ft²	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	rev/min	rev/min
1	1.1	0.002	1.5	3.75	0.315 0	3	0.75	1.5	0.375	0.75	0.75	1.25	—	—	—	No. 5 UNF	No. 2 UNF	200 000	20 000
2	3.5	0.015	2.2	5.5	0.433 1	4.4	1.1	2.2	0.55	1.1	1.1	1.8	—	—	—	No. 5 UNF	No. 2 UNF	140 000	14 000
3	11	0.1	3.2	8	0.669 3	6.4	1.6	3.2	0.8	1.6	1.6	2.8	—	—	—	1/4 UNF	No. 5 UNF	95 000	9 500
4	35	0.7	4.8	12	0.984 3	9.6	2.4	4.8	1.2	2.4	2.4	4.25	—	—	—	1/4 UNF	No. 5 UNF	65 000	6 500
5	110	4.7	7	17.5	1.378 0	14	3.5	7	1.75	3.5	3.5	6.25	—	—	—	1/2 UNF	1/4 UNF	45 000	4 500
6	350	31	10.2	25.5	1.968 5	20.4	5.1	10.2	2.55	5.1	5.1	9.25	—	—	—	1/2 UNF	1/4 UNF	30 000	3 000
7	1 100	220	15	37.5	2.952 0	30	7.5	15	3.75	7.5	7.5	13.75	0.058	1.181	1.850	3/4 UNF	1/2 UNF	20 000	2 000

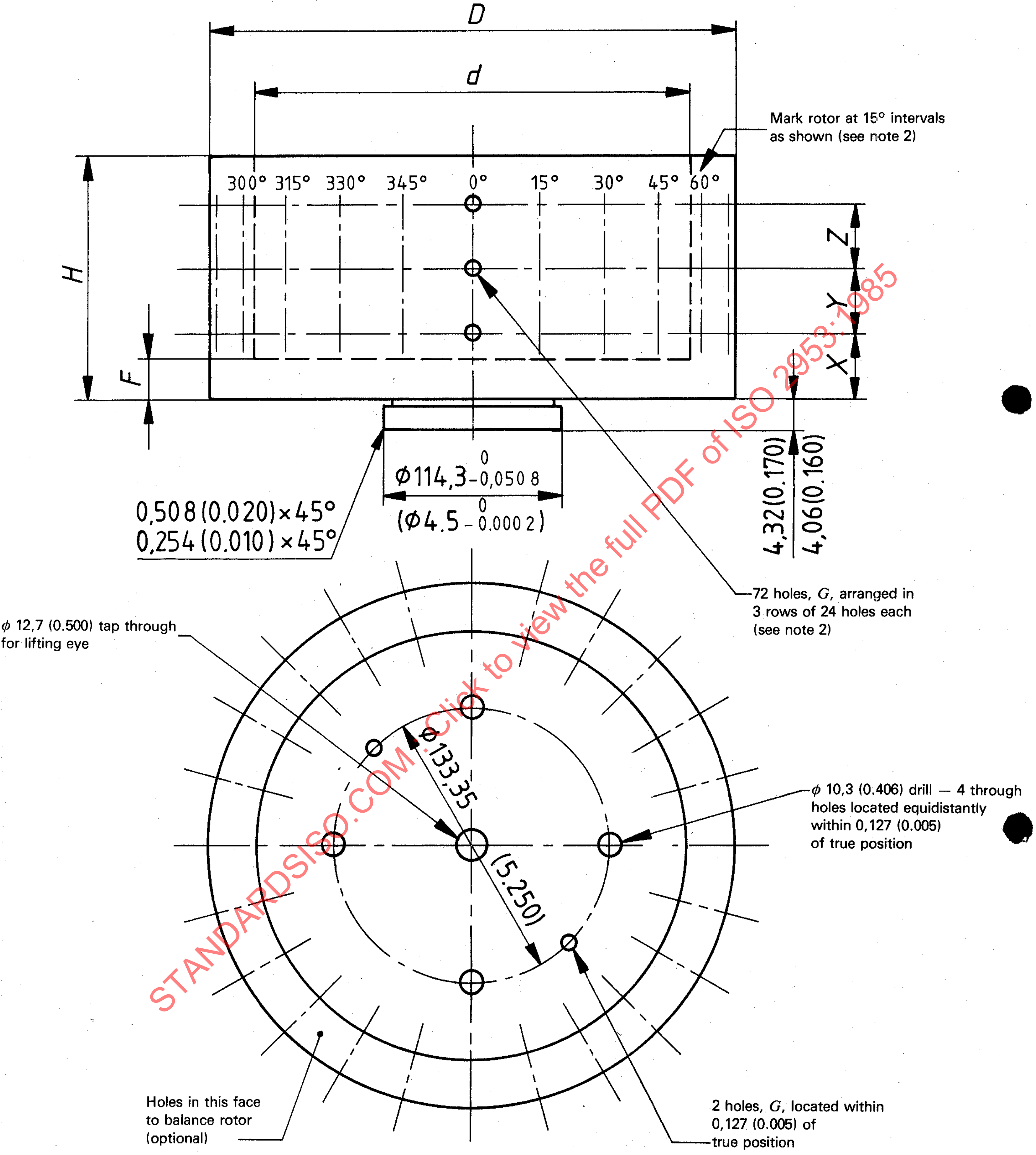
1) Dimensions A, B and C may be varied provided they meet the requirements of $A > B/2$; $C > B/2$

2) End-drive interface dimensions for rotor No. 7 conform with SAE ARP 1382. Other end-drive interfaces have not as yet been standardized.

3) The critical speeds are calculated for rotors running in rigid bearings.

4) Refers to rotor without test masses. Test mass weight and design may limit highest test speed to a lower value.

Dimensions in millimetres (Inch values in parentheses)



NOTES

1 Interface dimensions are identical to those given in SAE ARP 588 A for rotor numbers 3 and 5. Interface dimensions for the other rotors have not been standardized.

2 The rotor shown is a typical SAE rotor as taken from SAE ARP 588 A. It has three bolt hole circles of 24 holes each, with markings every 15°. For ISO 2953 tests, only twelve holes are required in top and bottom bolt circles. The middle bolt circle may be deleted or used for trim balancing the rotor. Markings are only needed at 30° intervals.

Figure 4 — Proving rotors for vertical machines and for outboard tests on horizontal machines
(for dimensions, see table 2)

Table 2 — Dimensions and masses of proving rotors for vertical machines and for outboard rotors on horizontal machines

Metric units

Rotor No.	Rotor mass M	Moment of inertia $I \approx Mk^2$	Major diameter D	Minor diameter d	Height H	X	Y	Z	F	G	Number of hori-zontal rotors[2)]
	$8{,}5 \times 10^{-7}\,D^3$		D	$0{,}9\,D$	$0{,}5\,D$	$0{,}075\,D$	$0{,}175\,D$	$0{,}175\,D$	$0{,}06\,D$		
	kg	kg·mm²	mm	mm	mm	mm	mm	mm	mm	mm	
1	1,1	0,002 5	110	99	55	8	20	20	6,5	M 3	3
2	3,5	0,017	160	144	80	12	30	30	9,5	M 3	4
3	11[1)]	0,12	230	206	127	19	45	45	13	M 6	5
4	35	0,8	345	310	170	25	60	60	20	M 10	6
5	110[1)]	5,5	510	460	255	38	90	90	30	M 10	7

Inch/pound values

Rotor No.	Rotor mass M	Moment of inertia $I \approx Mk^2$	Major diameter D	Minor diameter d	Height H	X	Y	Z	F	G	Number of hori-zontal rotors[2)]
	$3{,}1 \times 10^{-2}\,D^3$		D	$0{,}9\,D$	$0{,}5\,D$	$0{,}075\,D$	$0{,}175\,D$	$0{,}175\,D$	$0{,}06\,D$		
	lb	lb·ft²	in	in	in	in	in	in	in	in	
1	2.5	0.06	4.3	3.875	2.2	0.375	0.75	0.75	0.250	No.5UNF	3
2	8	0.41	6.3	5.650	3.2	0.5	1.125	1.125	0.375	No.5UNF	4
3	25[1)]	2.7	9	8.125	5	0.75	1.75	1.75	0.510	1/4UNF	5
4	80	20	13.5	12.125	7	1	2.375	2.375	0.800	3/8UNF	6
5	250[1)]	130	20	18	10	1.5	3.5	3.5	1.186	3/8UNF	7

1) These rotors are the same as those described in SAE ARP 588 A.

2) Horizontal rotor number on which the vertical machine rotor may be mounted to serve as an outboard rotor.

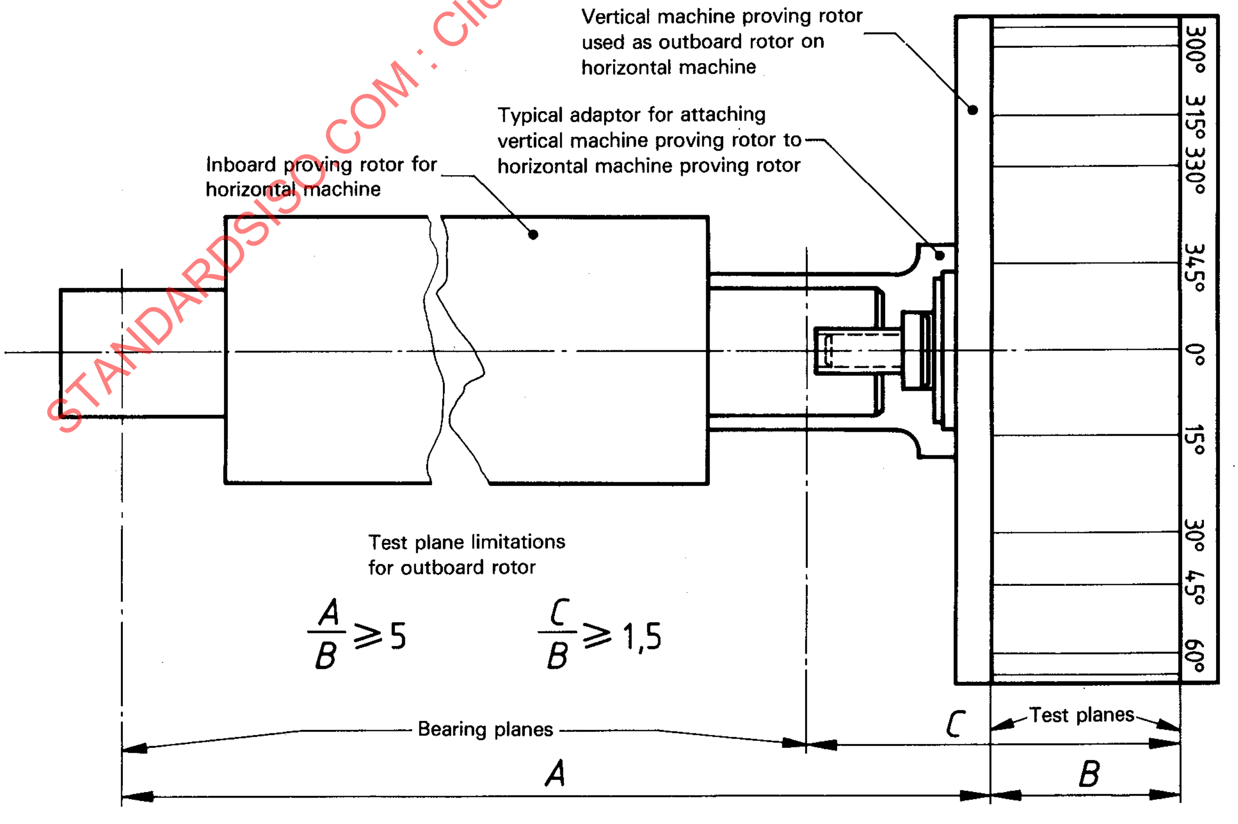


Figure 5 — Typical attachment of vertical machine rotor to horizontal machine rotor for outboard tests

10.2 Test masses

10.2.1 Test masses shall be provided for attachment in the proving rotor test planes. The test masses shall be in the form of bolts, screws, etc. and the precise location of their centres of gravity shall be identified in the manufacturer's test procedure. The value of a test mass is always expressed in units of U_{mar}, i.e. multiples (or fractions) of the minimum achievable residual unbalance.

10.2.2 For the U_{mar} test (see 11.6), the following test masses are required:

a) for a single-plane machine: one test mass of 10 U_{mar}.

The value of 1 U_{mar} (for a single-plane rotor) is ascertained by multiplying the claimed minimum achievable residual specific unbalance (1 e_{mar}) (see 4.2.1.5) by the total mass of the proving rotor. See also figures 6a) and 6b) and the example.

Example:

Vertical machine, proving rotor No. 3, 11 kg

Claimed under heading 4.2.1.5:

$$1\ e_{mar} = 0{,}001 \text{ mm or } 1 \text{ g·mm/kg}$$

Therefore

$$1\ U_{mar} = 11\ 000 \times 0{,}001 = 11 \text{ g·mm}$$

Hence

$$10\ U_{mar} = 110 \text{ g·mm}$$

b) for a two-plane machine using a proving rotor with two test planes: two test masses of 10 U_{mar} each, based on one half of the rotor mass.

Since 4.1.1.5 states e_{mar} in relation to the entire rotor mass, it is necessary to use only one half of the proving rotor mass when calculating the weight of a test mass for each of the two test planes. See also figure 6c) and the following example.

Example

Horizontal machine, proving rotor No. 5, 50 kg

Claimed under heading 4.1.1.5:

$$1\ e_{mar} = 0{,}000\ 5 \text{ mm or } 0{,}5 \text{ g·mm/kg}$$

Therefore

$$1\ U_{mar} = \frac{50\ 000}{2} \times 0{,}000\ 5 = 12{,}5 \text{ g·mm}$$

Hence

$$10\ U_{mar} = 125 \text{ g·mm}$$

NOTES

1 Test masses for a two-plane vertical rotor are calculated in a similar way in 10.2.2b).

2 Only when both test masses have the same angular location do they create a specific unbalance in the plane of the centre of gravity equivalent to 10 e_{mar}.

3 There is no separate U_{mar} test for outboard rotors.

10.2.3 For the unbalance reduction test (see 11.7), the following test masses are required:

a) for inboard rotors: two equal test masses each equivalent to a value of 5, 25 and 125 times the calculated minimum achievable residual unbalance (U_{mar}).

Example

Using the same proving rotor and claimed value of e_{mar} calculated as in 10.2.2b), and a test mass equivalent to 25 times the calculated minimum achievable residual unbalance:

$$\text{Test mass } (25\ U_{mar}) = 25 \times 12{,}5 \text{ g·mm} = 312{,}5 \text{ g·mm}$$

b) for outboard rotors: two equal test masses, each equivalent to a value of 5, 25 and 125 U_{mar}. Note, however, that these will be of different sizes from the inboard test masses because

1) they are attached to a different (larger) rotor diameter and thus have a different effective radius;

2) the value claimed for e_{mar} in 4.1.1.5.1 may differ from that claimed in 4.1.1.5;

3) the value of 1 U_{mar} has to be recalculated using the total mass of the inboard rotor, adaptor and outboard rotor, since almost the total mass rests on one support.

Example

No. 3 outboard proving rotor, assembled to the No. 5 inboard rotor

No. 3 outboard rotor mass:	11 kg
Adaptor mass (assumed):	2 kg
No. 5 inboard rotor mass:	50 kg
Total mass of rotor assembly:	63 kg

Claimed under heading 4.1.1.5.1:

$$1\ e_{mar} = 0{,}001 \text{ mm}$$

Therefore

$$1\ U_{mar} = 63\ 000 \times 0{,}001 = 63 \text{ g·mm}$$

Hence

$$25\ U_{mar} = 1\ 575 \text{ g·mm}$$

NOTE — If both inboard and outboard tests are to be run, the inboard test (using the inboard rotor only) may be limited to the low level test, and the outboard test to the high level test. This shortened procedure reduces the required number of test masses to two of 5 U_{mar} and two of 25 U_{mar} for the inboard test, and two of 25 U_{mar} and two of 125 U_{mar} for the outboard test.

c) for single-plane machines: only one test mass each of 5, 25 and 125 U_{mar} is required.

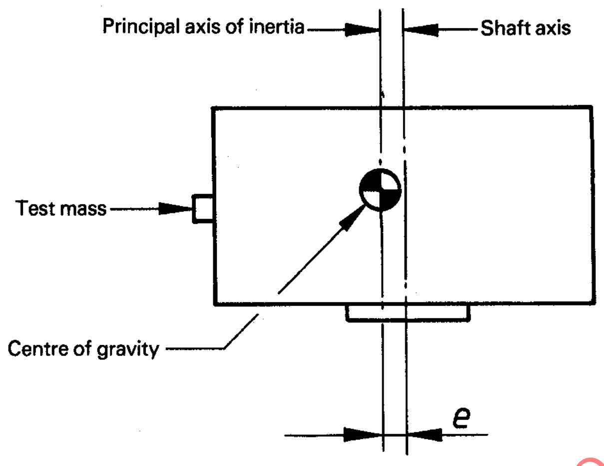


Figure 6a) — Test mass on a single-plane vertical rotor

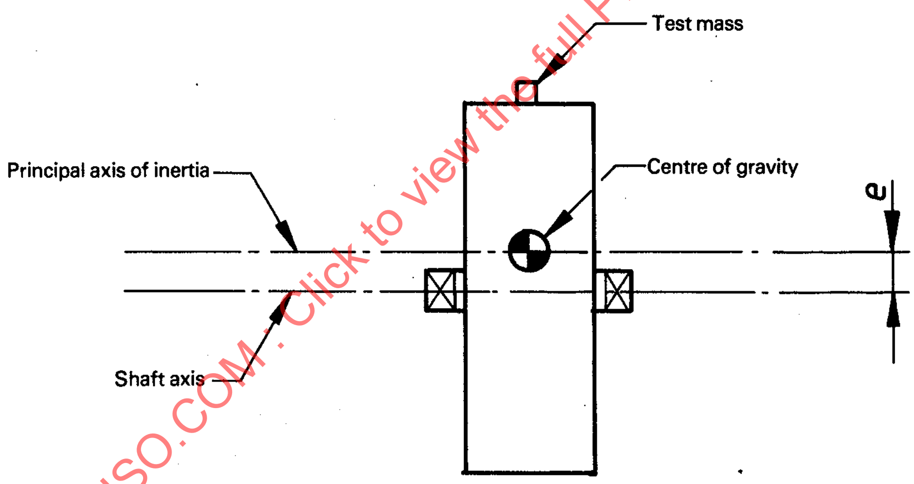


Figure 6b) — Test mass on a single-plane horizontal rotor

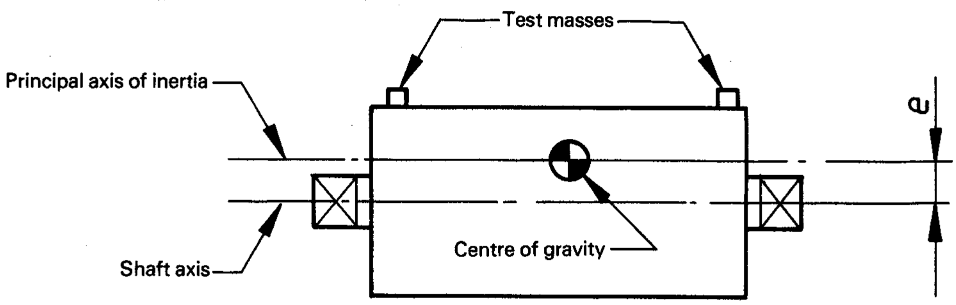


Figure 6c) — Test masses on a two-plane horizontal rotor

10.2.3.1 The weight of all test masses shall be accurate to within a percentage directly related to the specified unbalance reduction ratio. This percentage is equal to:

0,1 × (100 % − specified unbalance reduction ratio)

For example, with a 95 % unbalance reduction ratio, the weight tolerance is 0,1 × (100 − 95) % = 0,5 %.

10.2.3.2 The mounting position for test masses shall be at 30° intervals (45° on old style inboard rotors) at the same radius in each plane. 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 accuracy:

a) in the axial direction : within the same percentage as determined for the weight tolerance in 10.2.3.1 but applied to the correction plane separation distance;

b) in the radial direction : within the same percentage as above, 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 % = 0,29°.

10.2.4 For medium and small proving rotors, test masses may become inconvenient to handle because of their small size. In these cases, differential test masses may have to be used. Alternatively, it may be preferable to make small, single test masses from lightweight material since differential test masses require considerably higher dimensional accuracies.

11 Verification tests

11.1 Requirements for three tests

To verify the claimed performance of a balancing machine, three separate tests are required. The first one is the traverse test, also called the U_{mar} test, and the second is the unbalance reduction test (URR test). These tests are described in 11.6 and 11.7, respectively, and shall be conducted by the manufacturer either at his works or after installation on site; the location to be agreed between the manufacturer and user. These tests represent a minimum test procedure designed to establish essential compliance with the requirements for minimum achievable residual unbalance and for combined accuracy of amount-of-unbalance indication, angle indication and plane separation. The test procedure will not prove compliance with all requirements over the full range of variables nor will it define the exact reason in case the machine fails to comply.

A third test, namely verification of equipment parameters, includes physical inspection of various dimensions, features, instrumentation, tooling and accessories.

11.2 Duties of manufacturer and user

11.2.1 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 himself that he could obtain the same results as the operator. The manufacturer shall ensure that his written instructions are followed by the examiner.

11.2.2. The examiner shall 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 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.

11.3 Requirement for weighing scale

A weighing scale shall be available having sufficient accuracy to meet the requirements of 10.2.3.1.

11.4 Test and rechecks

When a machine fails to conform in a test, the manufacturer shall be entitled to adjust the machine, after which a repeat test shall be made and the machine shall conform in that test in order to qualify as acceptable.

11.5 Balancing speeds

The balancing speeds for tests are:

— the lowest speed specified by the manufacturer for the proving rotor mass;

— the highest speed specified for the heaviest rotor, if specifically agreed to between manufacturer and user.

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

11.6.1 Perform the mechanical adjustment, calibration and/or setting of the machine for the particular rotor under consideration, ensuring that the unbalance in the proving rotor is smaller than five times the claimed minimum achievable residual unbalance for the machine.

11.6.2 Add two unbalance masses (such as balancing clay) to the rotor. They shall be equivalent to 10 to 20 times the minimum achievable residual unbalance claimed per plane for the proving rotor mass. The unbalance masses shall not be

a) in the same transverse plane;

b) in a test plane;

c) at the same angle;

d) displaced by 180°.

11.6.3 Balance the rotor as well as possible (following the standard procedure for the machine) in a maximum of four runs at the balancing speed selected for the U_{mar} test. Apply corrections in two planes other than test planes or those used for the unbalance masses.

11.6.4 In the case of horizontal machines, after performing the actions described in 11.6.1 to 11.6.3, change the angular reference system of the machine by 60°, for example, on end-drive machines, turn the drive shaft with respect to the rotor; on belt-drive machines, turn black and white markings, etc. If a 60° change is not possible, a 90° change may be made.

NOTE — If, after the reference system has been changed, the first reading in the U_{mar} test is unsatisfactory, the problem should be remedied before continuing with the test.

11.6.5 For horizontal or vertical machines, attach in each of the two prepared test planes a test mass equal to ten times the claimed minimum achievable residual unbalance (see 10.2.2); attach these masses in phase with one another in all available holes in these planes, using sequences that are arbitrary. Record amount-of-unbalance readings in each plane for each position of the masses in a log similar to the example shown in figure 7.

11.6.6 Evaluate the logged readings from figure 7 as described in 11.6.6.1 to 11.6.6.6.

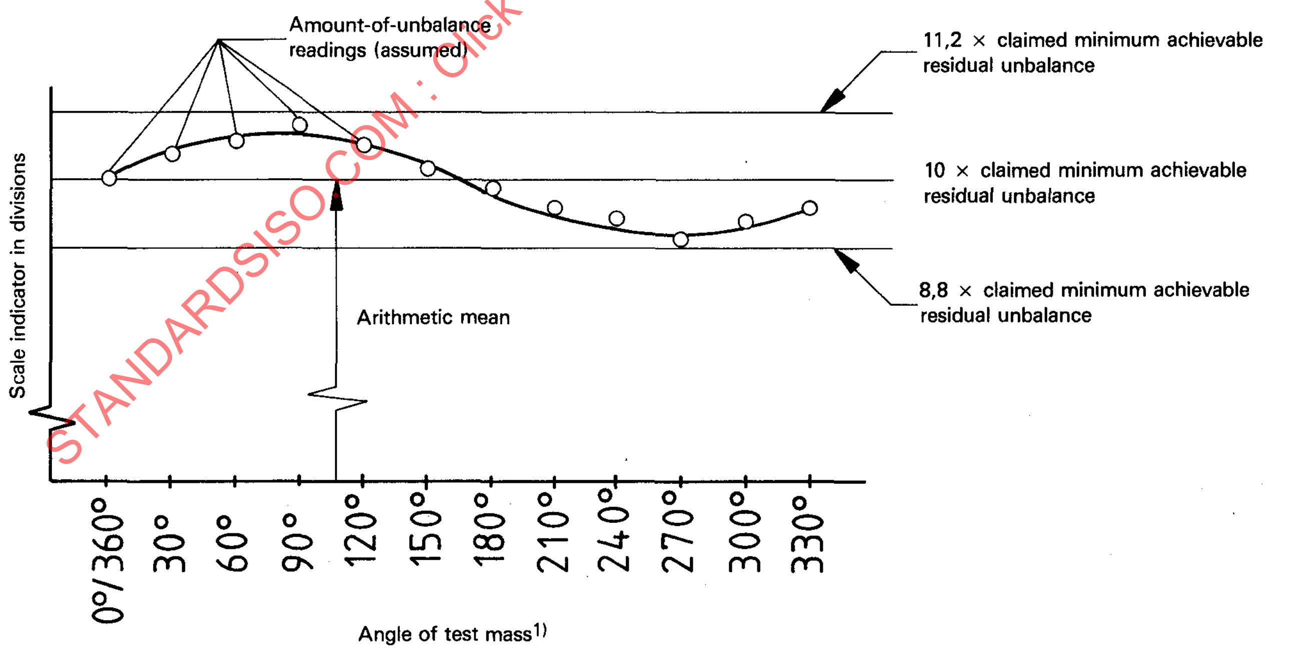
11.6.6.1 Plot results from the log in figure 7 onto diagrams similar to the example shown in figure 8, using separate diagrams for each of the two test planes.

Angle of test mass1)		0°/360°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
Amount of unbalance readings	left plane (lower plane)2)												
	right plane (upper plane)2)												

1) For proving rotors with only eight holes per test plane, only eight columns are needed with headings at 45° intervals.

2) "Upper" and "lower" plane designations apply to vertical machines.

Figure 7 — Example of a log for U_{mar} test



1) For proving rotors with only eight holes per test plane, the results are plotted at 45° intervals.

Figure 8 — Example of a diagram showing residual unbalance in U_{mar} test

11.6.6.2 Connect the points in each diagram by an averaging curve. It shall be of sinusoidal shape and include all test points.

11.6.6.3 If the plotted test data for a given plane are closely scattered above and below the 10 U_{mar} line without discernible sinusoidal shape, the residual unbalance in that plane may be nearly zero. Add an unbalance of 0,5 U_{mar} to that plane at an arbitrary position and repeat the test procedure from 11.6.5 for that plane.

11.6.6.4 If the amount-of-unbalance indication is unstable, read and plot the maximum and minimum amount readings for each angular position of the test mass.

11.6.6.5 Draw a horizontal line representing the arithmetic mean of the scale reading into each diagram and add two further lines representing ± 12 % of the arithmetic mean for each curve, which accounts for 1 U_{mar} plus 20 % for the effects of variation in the position of the masses and scatter of the test data.

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

a) the arithmetic mean line is within ± 10 % of ten times the indicator movement (or digital indication) corresponding to the claimed minimum achievable residual unbalance;

b) all plotted points are within the range given by the two lines drawn in 11.6.6.5 representing ± 12 % of the arithmetic mean line.

11.6.7 On horizontal and vertical single-plane balancing machines designed to indicate static unbalance only, follow the same procedure as described in 11.6.1 to 11.6.6, but use only one test mass, in the left (or lower) plane of the proving rotor.

11.6.8 On vertical machines, the residual unbalance in the spindle shall be checked. Remove the proving rotor and run the machine. The amount of unbalance now indicated should be less than the claimed minimum achievable residual unbalance.

11.7 Unbalance reduction test

11.7.1 Aim of test

This test is intended to check the combined accuracy of amount-of-unbalance indication, angle indication and plane separation. It is divided into an inboard and an outboard test. The inboard test shall be conducted for all machines; in addition, the outboard test shall be conducted for all horizontal two-plane machines on which outboard rotors are to be balanced.

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 from influencing the outcome.

11.7.2 Test procedure

Each test consists of two sets of 11 runs, called "low level" and "high level" tests. The low level tests are run with a stationary 5 U_{mar} test mass and a travelling 25 U_{mar} test mass in each plane, the high level tests with a stationary 25 U_{mar} test mass and a travelling 125 U_{mar} test mass in each plane to test the machine at different levels of unbalance.

NOTES

1 When using older style proving rotors with only eight holes per test plane, only two sets of seven runs can be made.

2 If both inboard and outboard tests are to be conducted, the inboard test (using the inboard rotor only) may be limited to the low level test, and the outboard test to the high level test. [See also the note in 10.2.3b).]

11.7.3 Readings

Unbalance readings for successive runs are recorded on the test sheet copies, i.e. logged and subsequently plotted.

11.7.4 Preparation of test sheets

Make copies of the appropriate test sheets (see figures 9 to 12) and use the copies for recording the test results, thus preserving the blank originals for future use.

Next, prepare the test logs on each test sheet prior to making the actual test runs so that test data is entered in proper order. Two test sheets are required for inboard tests (one for the low level test and one for the high level test); two additional test sheets are required for outboard tests. If the shortened inboard/outboard tests are used as mentioned in note 2 in 11.7.2, only two test sheets are needed.

Another set shall be required if a second proving rotor is to be used.

Preparation of a test log entails the following steps:

a) enter at the top of each log the requested data so that the test conditions are permanently recorded;

b) for the low level test, arbitrarily choose one of the 12 possible test mass positions (eight on 8-hole rotors) in the left test plane for the stationary mass and enter the degree value in the "left plane stationary" column on the "Run No. 1" line of the log. Next, choose a position for the stationary test mass in the right plane. This should neither be the same nor opposite the stationary test mass position in the left plane. Enter the degree value in the "right plane stationary" column on the "Run No. 1" line of the log;

c) arbitrarily choose one of the remaining 11 positions (seven on 8-hole rotors) as the starting position for the travelling test mass in the left plane and enter the degree value in the log. Arbitrarily choose a starting position for the travelling test mass in the right plane. This should neither be the same nor opposite the stationary test mass in the right plane. Enter the degree value in the log;

d) enter successive positions for successive runs in the log for both travelling masses, letting the left one travel in ascending 30° intervals, the right one in descending 30° intervals (45° intervals on 8-hole rotors). Skip the stationary mass position, since both masses cannot occupy the same position. (When differential test masses are used, the position opposite the stationary mass shall also be skipped, thus resulting in one less test run.);

e) similar entries as in a) to d) above are made for the test mass positions in the high level log and the outboard logs, using different positions for stationary masses and different starting positions for travelling masses. Once the logs have been set up, the actual test runs may be conducted.

11.7.5 Unbalance reduction test runs

11.7.5.1 Perform steps described in 11.6.1, 11.6.3 and 11.6.4, unless a U_{mar} test has immediately preceded this one.

11.7.5.2 Add the stationary and travelling test masses in starting position (Run No. 1 Line) to both test planes of the proving rotor as shown in the respective log.

11.7.5.3 Make 11 successive runs (seven on 8-hole rotors; in either case, one run less when differential masses are used). After each run, record the readings for both planes in the log, and advance the travelling test masses to the next position as shown in the log.

NOTE — Test mass positions were pre-planned and entered into the **left** half of the log prior to the test runs in terms of angle markings **on the rotor**. During running of the test, angle readings from the machine's **indicating instruments** are recorded in the **right** half of the log.

11.7.5.4 Divide amount readings, expressed in gram millimetres, by the value of 1 U_{mar}, expressed in gram millimetres, to obtain the equivalent of the readings in units of U_{mar}. Enter these in the appropriate columns of the log.

11.7.6 Plotting the test data

11.7.6.1 Each test sheet contains a diagram with 11 sets of concentric URR limit circles (seven sets for 8-hole rotors). From the inside outwards, the concentric circles designate the limits for URR values of 95, 90, 85 and 80 %. If a test point falls within the innermost circle (or on the line) the reading qualifies for a 95 % URR. If a test point falls between the 95 % circle and the 90 % circle, the reading qualifies for a 90 % URR.

NOTE — If a URR value other than 95, 90, 85 or 80 % is specified, an intermediate circle of appropriate diameter may be inserted or a new diagram made up in accordance with the instructions contained in annex C.

11.7.6.2 Enter the angular position of the left plane stationary test mass on the short line above the arrow in the appropriate URR limit diagrams (see figures 9 to 12). 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.

NOTE — To avoid confusion, it is best to use one and the same direction of angle markings on the rotor and the diagram. The most commonly used convention is to let the degree markings on the rotor (and therefore on the diagram) rise clockwise when looking at the rotor from the left.

11.7.6.3 Since the stationary test mass in the right plane has a different angular position, a second angular reference system shall be entered into the diagram for the right plane. To avoid interference with the degree markings for the left plane, enter the degree markings for the right plane in the oval circles provided halfway between the degree markings for the left plane. (See annex C, figure 14 as an example.)

11.7.6.4 Using the U_{mar} and angle values from the log, plot the left plane readings, and then the right plane readings in the form of test points (dots) on the appropriate URR diagram, using the U_{mar} scale as shown next to the vertical arrow. In order to avoid confusing left plane test points with right plane test points, circle all test points for the right plane.

11.7.7 Evaluation of plotted test points

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

NOTE — It can be expected that for a given machine the manufacturer's claimed URR for the outboard test will be lower than that for the inboard test by 5 % to 10 %. For example, a machine with an inboard URR of 95 % may have an outboard URR of 85 %.

11.7.8 URR tests on single-plane balancing machines

On horizontal and vertical single-plane balancing machines designed to indicate static unbalance only, the unbalance reduction tests in 11.7 are intended to check only the combined accuracy of amount-of-unbalance indication and angle indication. High and low level tests shall be carried out with test masses in only the left (or lower) plane.

11.7.9 Test for couple unbalance suppression on single-plane machines

On vertical (and horizontal) single-plane balancing machines, the ability to suppress indication of couple unbalance shall be checked. Balance the rotor as stated in 11.6.3. Add one test mass equivalent to 125 times the minimum achievable residual unbalance in the upper and lower (left and right) planes of the rotor, exactly 180° apart. Shift the couple by 90° three times in succession, each time taking a new reading. 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.

11.7.10 Special URR limit circle diagram

If machines having unbalance reduction ratios other than those shown in figures 9 to 12 are to be tested, special diagrams can be made up from the information contained in annex C.

Log for inboard and outboard tests

Date of test : ....

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

Location of test : ....

Machine operated by : ....

Readings taken and logged by : ....

Inboard proving rotor type : .... Mass, g : : ....

Outboard proving rotor type (if used) : .... Mass, g : ....

Adaptor mass (for outboard rotor only), g : ....

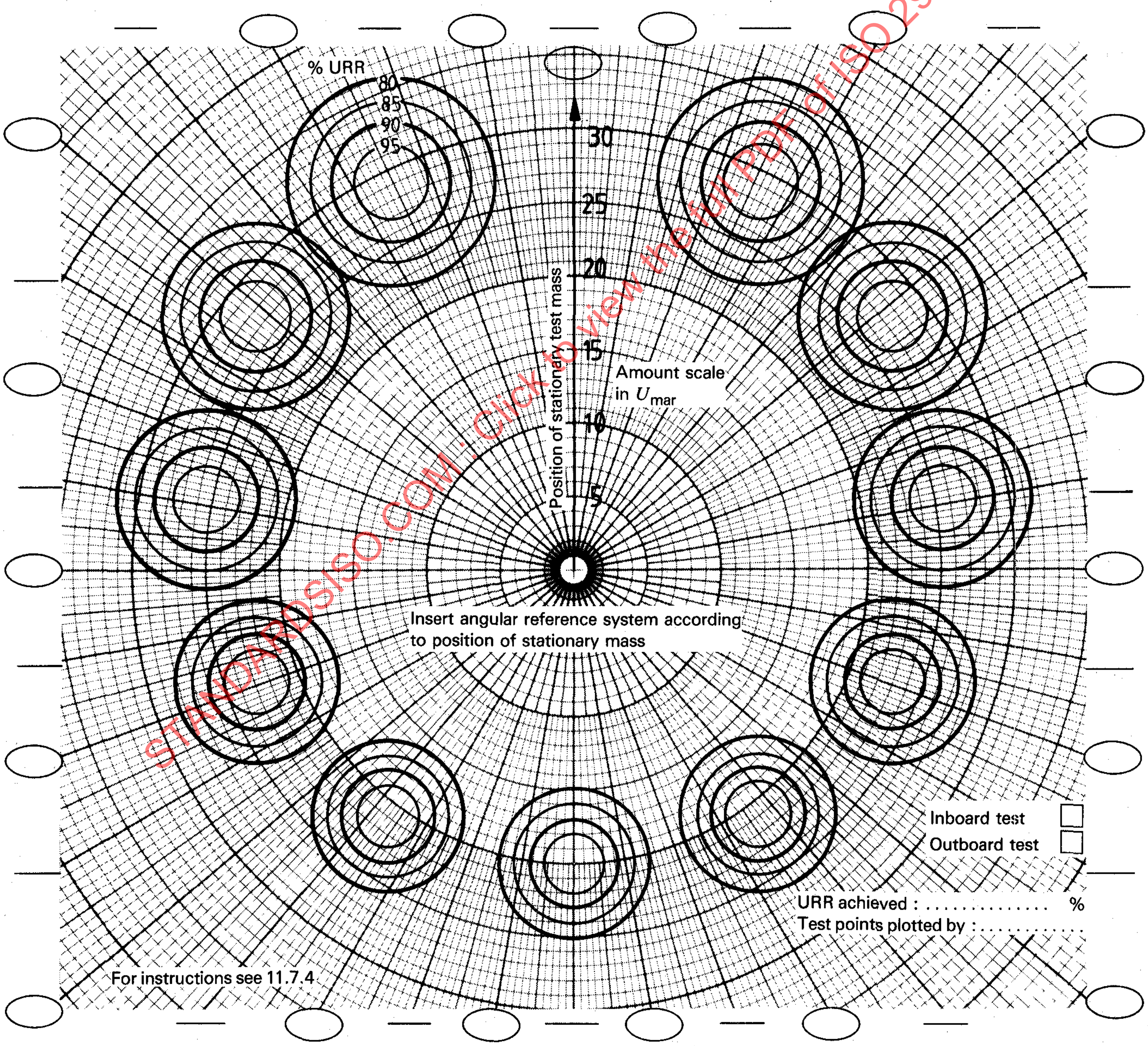
Claimed e_{mar}, mm : ....; 1 U_{mar} per test plane, g·mm : ....

Test mass effective radius, mm : ....

Stationary mass, g (5 U_{mar}/effective radius) : ....

Travelling mass, g (25 U_{mar}/effective radius) : ....

Run No.	Test mass positions				Unbalance readout		Amount (for left plane) divided by 1 U_{mar}	Unbalance readout		Amount (for right plane) divided by 1 U_{mar}
	Left plane		Right plane		Left plane			Right plane		
	Stationary	Travelling	Stationary	Travelling	Amount g·mm	Angle degrees	U_{mar}	Amount g·mm	Angle degrees	U_{mar}
1										
2	"		"							
3	"		"							
4	"		"							
5	"		"							
6	"		"							
7	"		"							
8	"		"							
9	"		"							
10	"		"							
11	"		"							



NOTE — *Left plane angle positions* ______ *; right plane angle positions* ( ).

Figure 9 — Test sheet for URR limit log and diagram for low level test on 12-hole rotor

Log for inboard and outboard tests

Date of test : ....

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

Location of test : ....

Machine operated by : ....

Readings taken and logged by : ....

Inboard proving rotor type : .... Mass, g : : ....

Outboard proving rotor type (if used) : .... Mass, g : ....

Adaptor mass (for outboard rotor only), g : ....

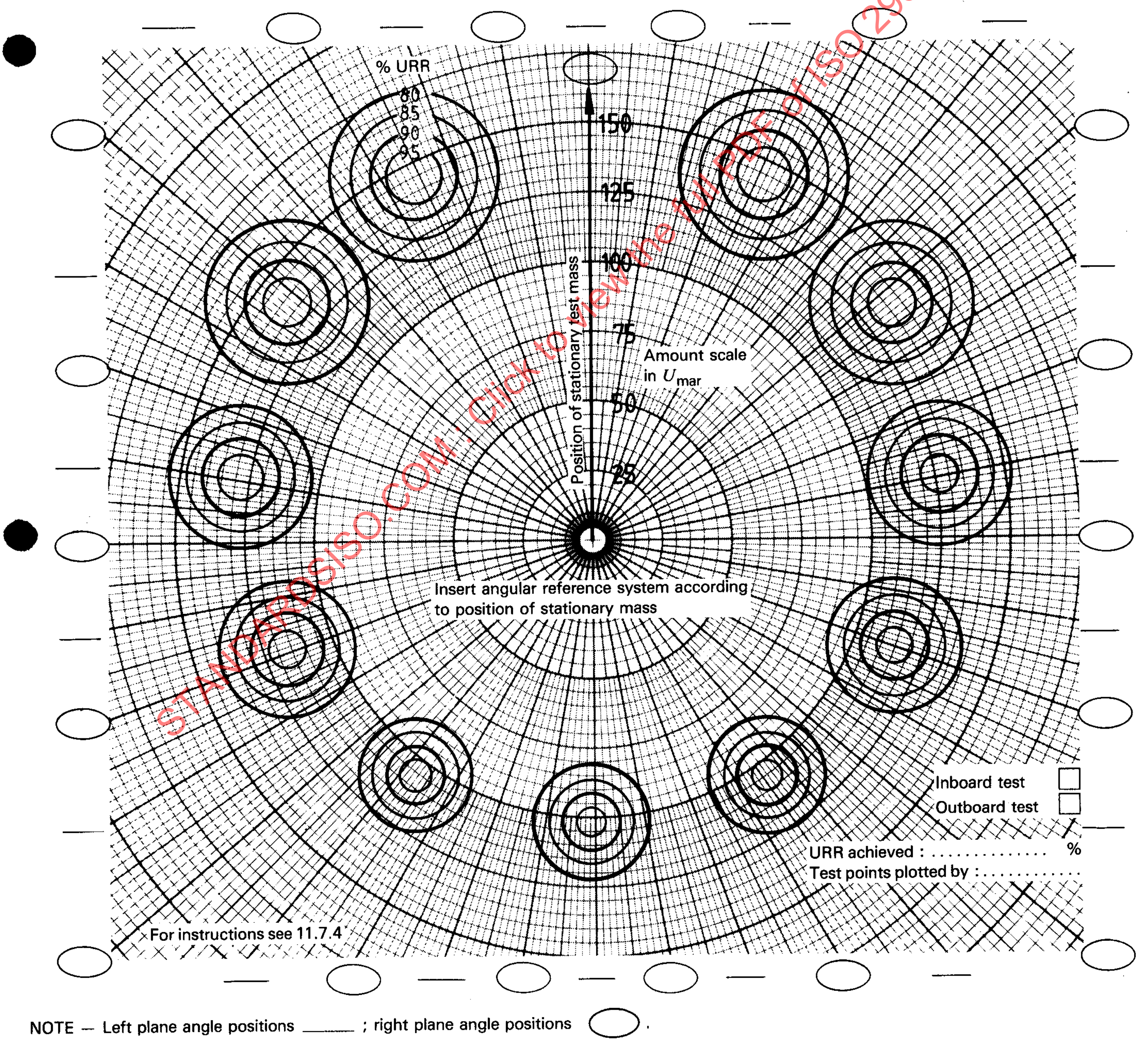
Claimed e_{mar}, mm : ....; 1 U_{mar} per test plane, g·mm : ....

Test mass effective radius, mm : ....

Stationary mass, g (25 U_{mar}/effective radius) : ....

Travelling mass, g (125 U_{mar}/effective radius) : ....

Run No.	Test mass positions				Unbalance readout		Amount (for left plane) divided by 1 U_{mar}	Unbalance readout		Amount (for right plane) divided by 1 U_{mar}
	Left plane		Right plane		Left plane			Right plane		
	Stationary	Travelling	Stationary	Travelling	Amount g·mm	Angle degrees	U_{mar}	Amount g·mm	Angle degrees	U_{mar}
1										
2	"		"							
3	"		"							
4	"		"							
5	"		"							
6	"		"							
7	"		"							
8	"		"							
9	"		"							
10	"		"							
11	"		"							



NOTE — Left plane angle positions ______ ; right plane angle positions ◯ .

Figure 10 — Test sheet for URR limit log and diagram for low level test on 12-hole rotor

Log for inboard and outboard tests

Date of test : ....

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

Location of test : ....

Machine operated by : ....

Readings taken and logged by : ....

Inboard proving rotor type : .... Mass, g : : ....

Outboard proving rotor type (if used) : .... Mass, g : ....

Adaptor mass (for outboard rotor only), g : ....

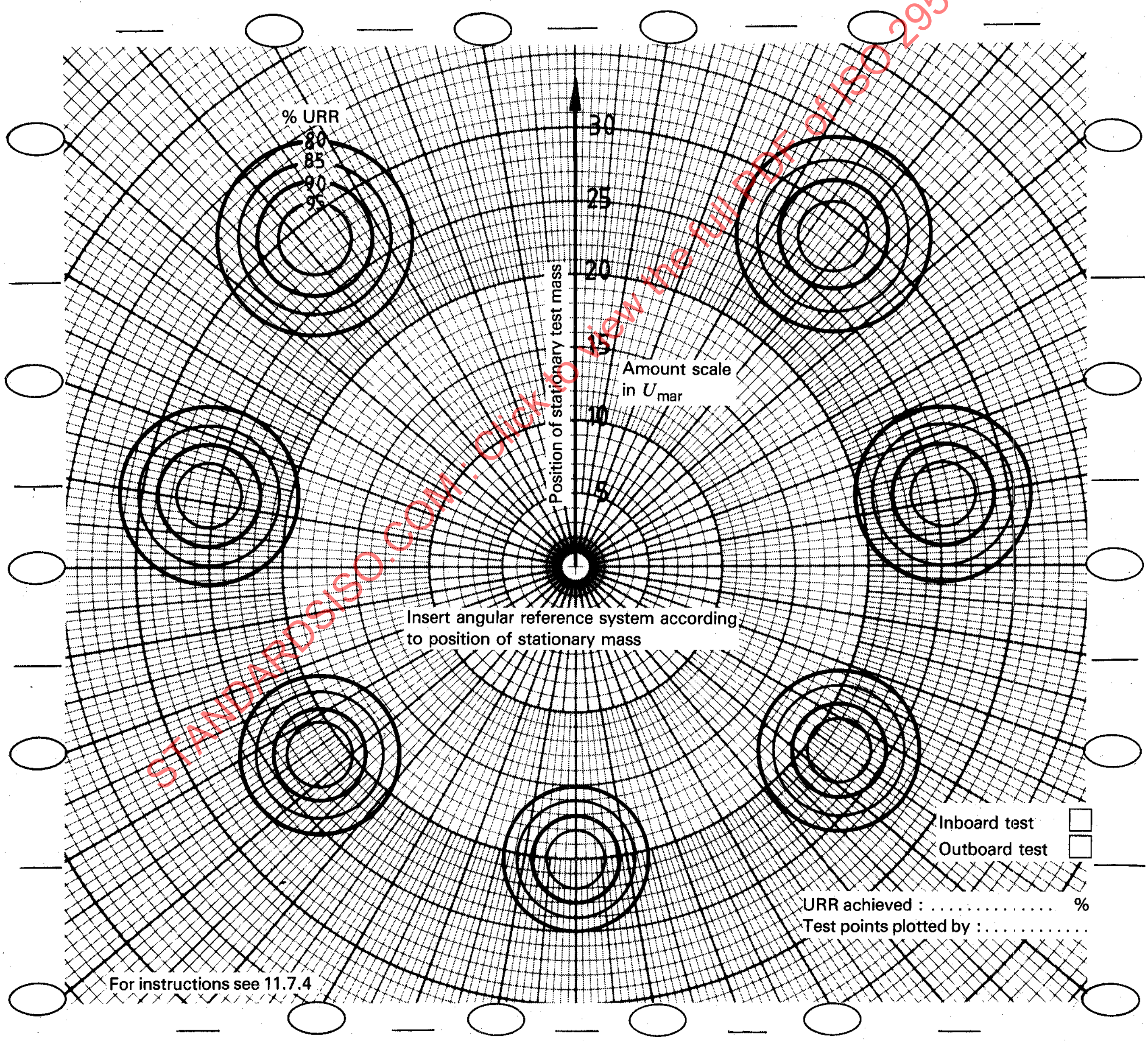
Claimed e_{mar}, mm : ....; 1 U_{mar} per test plane, g·mm : ....

Test mass effective radius, mm : ....

Stationary mass, g (5 U_{mar}/effective radius) : ....

Travelling mass, g (25 U_{mar}/effective radius) : ....

Run No.	Test mass positions				Unbalance readout		Amount (for left plane) divided by 1 U_{mar}	Unbalance readout		Amount (for right plane) divided by 1 U_{mar}
	Left plane		Right plane		Left plane			Right plane		
	Stationary	Travelling	Stationary	Travelling	Amount g·mm	Angle degrees	U_{mar}	Amount g·mm	Angle degrees	U_{mar}
1										
2	"		"							
3	"		"							
4	"		"							
5	"		"							
6	"		"							
7	"		"							
8	"		"							
9	"		"							
10	"		"							
11	"		"							



NOTE — Left plane angle positions ______ ; right plane angle positions ◯ .

Figure 11 — Test sheet for URR limit log and diagram for low level test on 8-hole rotor