INTERNATIONAL STANDARD **ISO** 2953

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 institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

International Standard ISO 2953 was drawn up by Technical Committee ISO/TC 108, *Mechanical vibration and shock,* and circulated to the Member Bodies in May 1973.

It has been approved by the Member Bodies of the following countries :

Australia	Italy	Spain
Austria	Japan	Sweden
Belgium	Netherlands	Thailand
Bulgaria	New Zealand	Turkey
Czechoslovakia	Portugal	United Kingdom
France	Romania	U.S.A.
Germany	South Africa, Rep. of	U.S.S.R.

No Member Body expressed disapproval of the document.

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 3.1 and 3.2 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 document is in accordance with ISO 1925[1] and this terminology should be employed by manufacturers and users when applying the present 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 mechanical compensators are incorporated.

Technical requirements for such balancing machines are also dealt with. Details of performance and other tests to be employed to ensure compliance with these requirements are given; however, special features such as those associated with automatic correction are excluded.

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 new definitions relevant to the provisions of this document.

This International Standard does not specify balancing criteria; these will be found in ISO 1940[2].

3 CAPACITY AND PERFORMANCE DATA OF THE MACHINE

The manufacturer shall specify the data listed in 3.1 or 3.2 for horizontal or vertical machines respectively, as applicable and in a similar format.

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1) ISO 1925, *Balancing — Vocabulary.*

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

1

3.1 CAPACITY AND PERFORMANCE DATA OF HORIZONTAL MACHINES (See page 4 for notes)

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

3.1.1 Rotor mass and unbalance limitations

		Min.	n_2	n_3	n_4	n_5
3.1.1.1	Balancing speeds or speed ranges					
3.1.1.2[1]	Rotor mass max. : kg (lb)					
	min. : kg (lb)					
	Occasional overload force per support : N (kgf, lbf)					
	Maximum negative force per support : N (kgf, lbf)					
3.1.1.3[2]	Maximum rotor moment of inertia with respect to the shaft axis $kg \cdot m^2$ ($lb \cdot ft^2$)					
	Cycle rate					
3.1.1.4[3]	Maximum unbalance Measurable					
	$g \cdot mm/kg$ or $g \cdot mm$					
	($lb \cdot in/lb$ or $oz \cdot in$) Permissible					
3.1.1.5[4]	Minimum achievable residual specific unbalance (see clause 5) $g \cdot mm/kg$ ($lb \cdot in/lb$)					
	Corresponding deflection of analogue amount-of-unbalance indicator : mm (in)					

3.1.1.6 Production efficiency (see clause 6)

3.1.1.6.1 Time per balancing run

3.1.1.6.2 Time for mechanical adjustment

3.1.1.6.3 Time for setting indicating system

3.1.1.6.4 Time for preparation of rotor

3.1.1.6.5 Average acceleration time

3.1.1.6.6 Reading time

3.1.1.6.7 Average deceleration time

3.1.1.6.8 Other necessary time

3.1.1.7 Unbalance reduction ratio

3.1.2 Rotor dimensions

3.1.2.1[5] Rotor envelope limitations (see figure 1)

3.1.2.2 Rotor diameter : . . . . mm (in)

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

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

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

3.1.2.3 Distance between journal centre lines :

    a)   Max. : . . . . mm (in)

    b)   Min. : . . . . mm (in)

    c)   Maximum distance from coupling flange to centre line of farthest bearing : . . . . mm (in)

    d)   Minimum distance from coupling flange to centre line of nearest bearing : . . . . mm (in)

3.1.2.4 Journal diameter :

    Max. : . . . . mm (in)

    Min. : . . . . mm (in)

3.1.2.4.1[6]   Maximum permissible peripheral speed   . . . . m/s (ft/s)

3.1.2.5 Correction plane limitations (consistent with the statements in 4.4)

3.1.2.6 Correction plane interference ratios (consistent with the statements in 4.4 and based on the proving rotor)

3.1.3   **Drive**

3.1.3.1[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

   . . . .

3.1.3.2[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

3.1.3.3[9]   Type of drive to workpiece : . . . .

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

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

    Motor speed : . . . . rev/min

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

3.1.3.5 Brake

3.1.3.5.1   Type of brake : . . . .

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

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

3.1.3.6   Motor and controls in accordance with ISO . . .

3.1.3.7   Speed regulation provided :

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

3.1.4[10)]   **Couple unbalance interference :**   . . . . g·mm/g·mm^2 (oz·in/oz·in^2)

NOTES TO 3.1

1) The maximum mass of rotor that 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 supports.

2) The maximum moment of inertia [mass × (radius of gyration)^2] of a rotor with respect to the shaft axis that 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 that 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 disk-shaped rotors, the full stated value holds for one plane.

4) Limits for soft-bearing machines will 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 will generally be stated in gram millimetres since these machines are usually factory calibrated to indicate unbalance in such units. (See clause 5.) For two-plane machines, this is the result obtained when the minimum achievable residual unbalance is distributed between the two planes.

5) 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 furnished 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 furnished, balancing speeds shall be stated 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.

FIGURE 1 — Example of machine pedestal drawing illustrating rotor envelope limitations
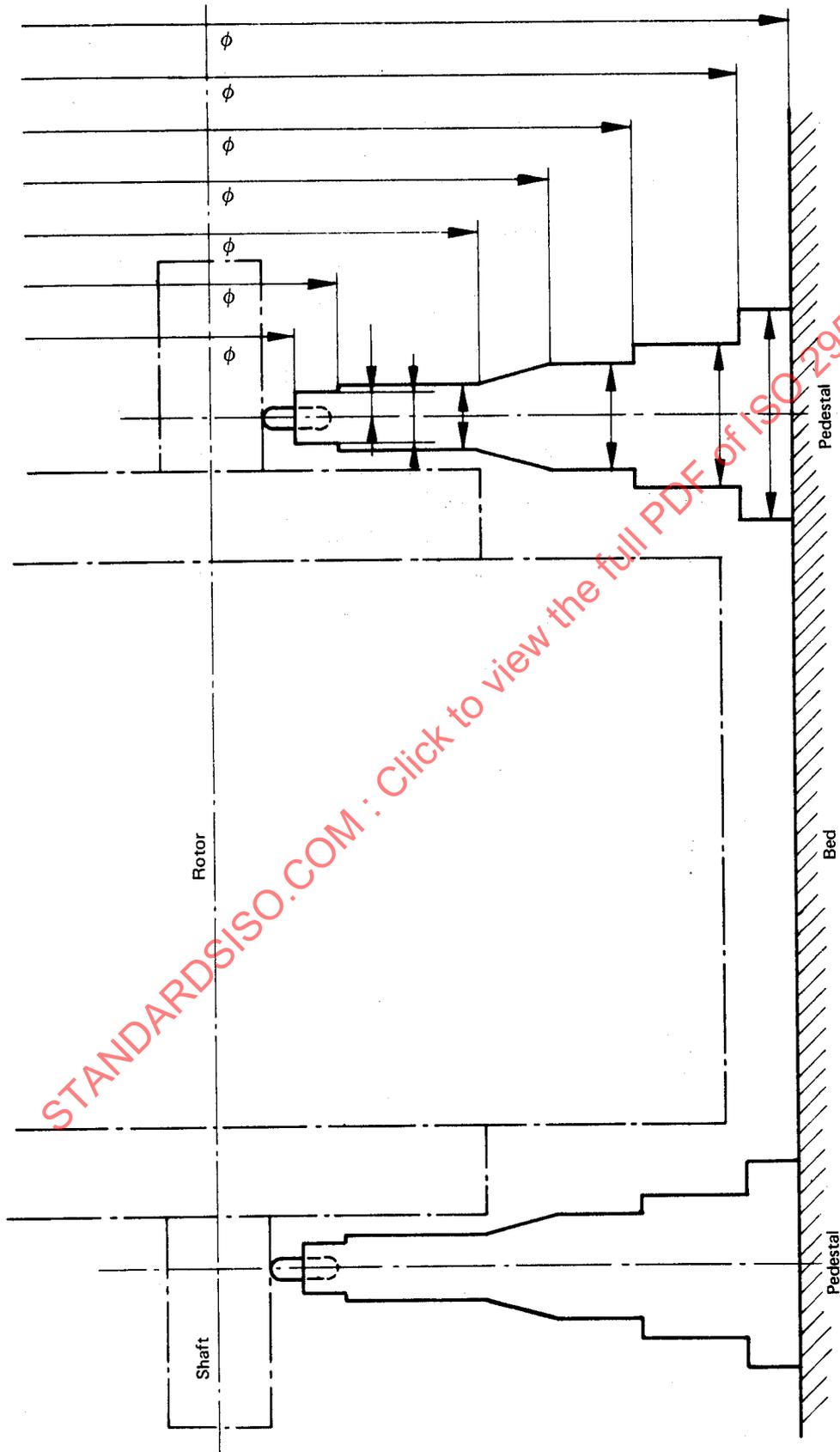
NOTES

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

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

3.2 CAPACITY AND PERFORMANCE DATA OF VERTICAL MACHINES (See pages 7 and 8 for notes)

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

3.2.1 Rotor mass and unbalance limitations

3.2.1.1	Balancing speeds or speed ranges	Min.	n_2	n_3	n_4	n_5
3.2.1.2[1]	Rotor mass max. : kg (lb) min. : kg (lb) Occasional overload force up to : N (kgf, lbf)					
3.2.1.3[2]	Maximum rotor moment of inertia with respect to the shaft axis $kg \cdot m^2$ ($lb \cdot ft^2$) Cycle rate					
3.2.1.4[3]	Maximum unbalance Measurable $g \cdot mm/kg$ or $g \cdot mm$ ($lb \cdot in/lb$ or $oz \cdot in$) Permissible					
3.2.1.5[4]	Minimum achievable residual specific unbalance (see clause 5) $g \cdot mm/kg$ ($lb \cdot in/lb$) Corresponding deflection of analogue amount-of-unbalance indicator : mm (in)					

3.2.1.6   Production efficiency (see clause 6)

3.2.1.6.1   Time per balancing run

3.2.1.6.2   Time for mechanical adjustment

3.2.1.6.3   Time for setting indicating system

3.2.1.6.4   Time for preparation of rotor

3.2.1.6.5   Average acceleration time

3.2.1.6.6   Reading time

3.2.1.6.7   Average deceleration time

3.2.1.6.8   Other necessary time

3.2.1.7   Unbalance reduction ratio

3.2.2 Rotor dimensions

3.2.2.1   Rotor diameter : . . . . .mm (in)

3.2.2.2   Rotor height :

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

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

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

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

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

3.2.2.3[6] Rotor envelope limitations, including machine spindle or mounting plate interface (see figure 2)

3.2.2.4 Correction plane limitations (consistent with the statements in 4.4)

3.2.3 Drive

3.2.3.1

	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	. . . .	. . . .

3.2.3.2[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

3.2.3.3 Prime mover (type of motor) . . . .

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

Motor speed : . . . . rev/min

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

3.2.3.4 Brake

3.2.3.4.1 Type of brake :

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

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

3.2.3.5 Motor and controls in accordance with ISO . . .

3.2.3.6 Speed regulation provided :

Accurate or constant within . . . . % of . . . . rev/min or . . . . rev/min

3.2.4[8] Couple unbalance interference : . . . . g·mm/g·mm^2 (oz·in/oz·in^2)

NOTES TO 3.2

1) The maximum mass of rotor that 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 that the machine can accelerate in a stated acceleration time shall be given for the range of balancing speeds $(n_1, n_2, \ldots)$ together with the corresponding cycle rate.

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

Both the above assume negligible windage (see note 7).

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

4) Limits for soft-bearing machines will 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 will generally be stated in gram millimetres since these machines are usually factory calibrated to indicate unbalance in such units. (See also clause 5.) 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 curve.

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 plate shall be furnished 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.
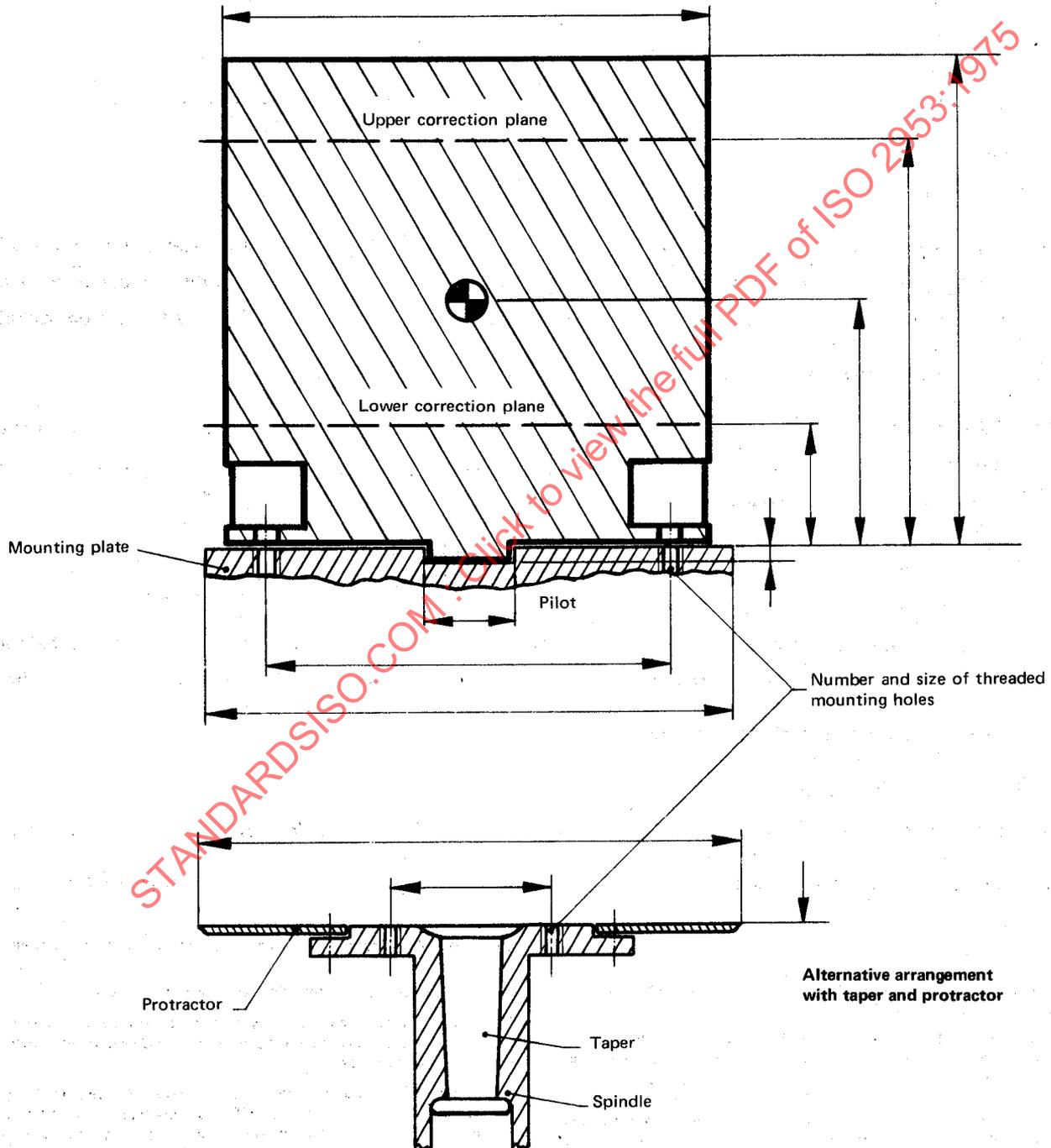
FIGURE 2 — Example of machine mounting interface illustrating rotor envelope limitations

4 MACHINES FEATURES

4.1 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.

4.2 Arrangement of the machine

4.2.1 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.

4.2.2 The manufacturer shall provide details of the following, as applicable :

4.2.2.1 Components designed to support the rotor, for example :

— vee blocks;

— open rollers;

— plain half-bearings;

— closed-ball, roller or plain bearings;

— device to use the service bearings;

— device to accommodate complete units.

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

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

4.2.2.3 Elements by which the vibrational effects (force, velocity, acceleration, or displacement) are sensed.

4.2.2.4 The means (mechanical, electrical, electromechanical, optical, etc.) by which the vibration signals are analysed, measured and displayed.

4.2.2.5 The drive and its control.

4.3 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.

4.3.1 *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.

NOTE — It shall be specified if values given are peak-to-peak, r.m.s., etc.

4.3.2 *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.

NOTE — It shall be specified if values given are peak-to-peak, r.m.s., etc.

4.3.3 *Operation of the indicating system*

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

How many measuring runs are required to obtain :

— the two readings for single-plane balancing ?

— the four readings for two-plane balancing ?

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

Are readings retained after the end of the balancing run ?

What is the maximum retention period ?

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

4.4 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 weight ?

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, and

— 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 9.8.9).

4.5 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 per cent) in repeatability of speed during calibration and operation.

4.5.1 Soft-bearing machines

The manufacturer shall state how calibration is accomplished on the first rotor of a particular mass and configuration, for example, by means of a compensator, trial-and-error method, 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.

4.5.2 Hard-bearing machines

The manufacturer shall state whether the machine is permanently calibrated and can be set according to the

workpiece geometry or must be calibrated by the user for different balancing speeds, rotor masses and/or dimensions.

4.6 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.

5 MINIMUM ACHIEVABLE RESIDUAL UNBALANCE

The minimum residual unbalance that can be achieved with a balancing machine shall be specified in terms of specified 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 unbalance shall be stated for the full range of workpiece weights 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.

6 PRODUCTION EFFICIENCY

Production efficiency is the ability of the machine to assist the operator to balance 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 tolerance and the unbalance reduction ratio.

6.1 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) below.

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 balancing 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.

6.2 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.

7 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.

8 INSTALLATION REQUIREMENTS

8.1 General

In considering the siting of a balancing machine, the manufacturer shall state what precautions must 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 7.

8.2 Power supply

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

8.3 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.

9 PROVING ROTORS AND VERIFICATION TESTS

9.1 Proving rotors

This section 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 unbalance masses.

9.1.1 The manufacturer shall state whether or not a proving rotor is furnished with the machine.

9.1.2 Proving rotors shall be manufactured of steel and shall be in accordance with table 1 and figure 3 for horizontal machines and with table 2 and figure 4 for vertical machines.

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

FIGURE 3 — Dimensions of proving rotors for horizontal machines
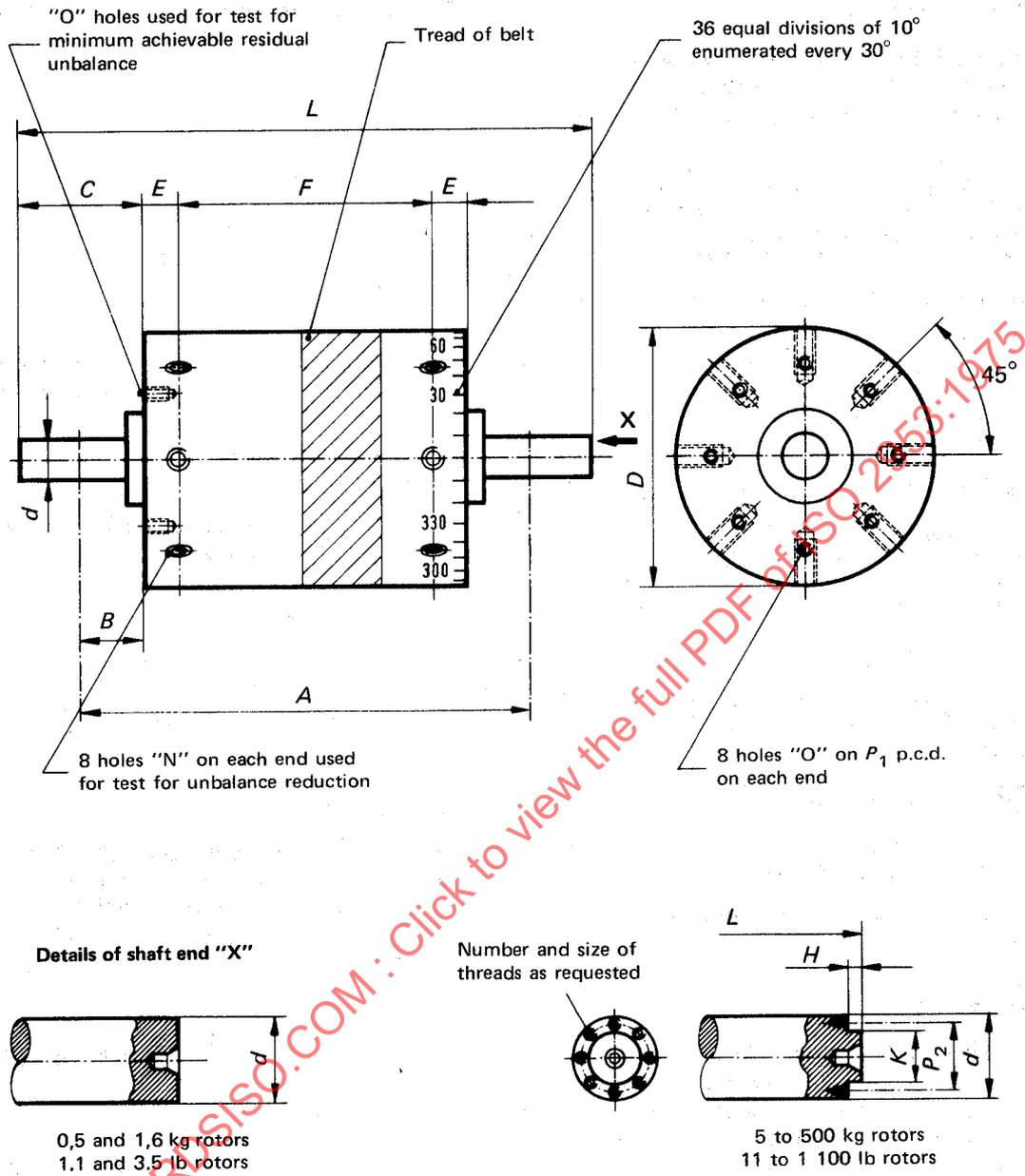
NOTE — If the shafts are used as ball bearing seatings, a shoulder ring shall be provided so that the centres of the ball bearings are at the prescribed distance.

TABLE 1 – Dimensions, masses and speeds of proving rotors for horizontal machines*

METRIC VALUES

No.	Rotor mass M 9,5 × 10⁻⁶ D³ (kg)	Moment of inertia I ≈ Mk² (kg·m²)	Major diameter D = D (mm)	Overall length L = 2,5 D (mm)	Shaft diameter d = 0,2 D (mm)	Bearing distance A = 2 D (mm)	B = 0,25 D (mm)	C = 0,5 D (mm)	E = 0,15 D (mm)	F = 1,2 D (mm)	P₁ = 0,5 D (mm)	H** (mm)	K** (mm)	P₂** (mm)	N	O	Critical speed *** 7 600 000/D (rev/min × 1 000)	Highest test speed 760 000/D (rev/min × 1 000)
1	0,5	0,000 1	38	95	8	76	9,5	19	6	45	19	—	—	—	M 3	M 2	200	20
2	1,6	0,000 6	56	140	12	112	14	28	9,5	65	28	—	—	—	M 3	M 2	140	14
3	5	0,004	82	205	17	164	20,5	41	11,5	100	41	2	4	10	M 6	M 3	95	9,5
4	16	0,03	120	300	25	240	30	60	15	150	60	3	8	16	M 6	M 3	65	6,5
5	50	0,2	176	440	35	352	44	88	27	210	88	4	10	24	M 12	M 6	45	4,5
6	160	1,3	260	650	50	520	65	130	40	310	130	5	25	40	M 12	M 6	30	3
7	500	9	380	950	75	760	95	190	60	450	190	5	25	60	M 20	M 12	20	2

INCH/POUND VALUES

No.	Rotor mass M 0,33 D³ (lb)	Moment of inertia I ≈ Mk² (lb·ft²)	Major diameter D = D (in)	Overall length L = 2,5 D (in)	Shaft diameter d = 0,2 D (in)	Bearing distance A = 2 D (in)	B = 0,25 D (in)	C = 0,5 D (in)	E = 0,15 D (in)	F = 1,2 D (in)	P₁ = 0,5 D (in)	H** (in)	K** (in)	P₂** (in)	N	O	Critical speed *** 7 600 000/D (rev/min × 1 000)	Highest test speed 760 000/D (rev/min × 1 000)
1	1.1	0.002	1.5	3.75	0.315 0	3	0.375	0.75	0.25	1.75	0.75	—	—	—	No. 5 UNF	No. 2 UNF	200	20
2	3.5	0.015	2.2	5.5	0.433 1	4.4	0.55	1.1	0.4	2.5	1.1	—	—	—	No. 5 UNF	No. 2 UNF	140	14
3	11	0.1	3.2	8	0.669 3	6.4	0.8	1.6	0.45	4	1.6	0.1	0.15	0.4	1/4 UNF	No. 5 UNF	95	9.5
4	35	0.7	4.8	12	0.984 3	9.6	1.2	2.4	0.6	6	2.4	0.1	0.3	0.65	1/4 UNF	No. 5 UNF	65	6.5
5	110	4.7	7	17.5	1.378 0	14	1.75	3.5	1	8.5	3.5	0.2	0.4	1	1/2 UNF	1/4 UNF	45	4.5
6	350	31	10.2	25.5	1.968 5	20.4	2.55	5.1	1.65	12	5.1	0.2	1	1.5	1/2 UNF	1/4 UNF	30	3
7	1 100	220	15	37.5	2.952 0	30	3.75	7.5	2.25	18	7.5	0.2	1	2.5	3/4 UNF	1/2 UNF	20	2

* For balancing machines with capacities greater than the test rotors of this table, a rotor furnished by the user may be used.

** These dimensions are only suggestions.

*** The critical speeds are calculated for rotors running in rigid bearings.
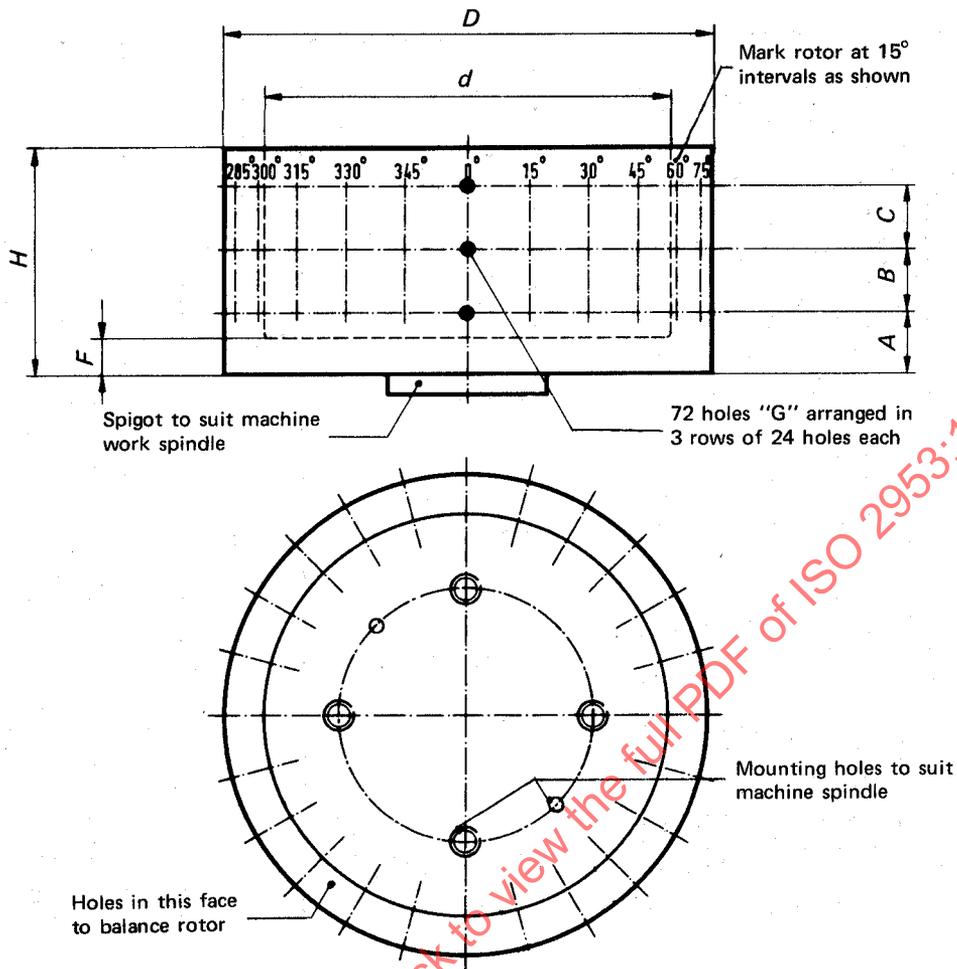
**** Diameter D in millimetres.

FIGURE 4 — Dimensions of proving rotors for vertical machines

TABLE 2 — Dimensions and masses of proving rotors for vertical machines*

METRIC UNITS

No.	Rotor mass M	Moment of inertia $I \approx Mk^2$	Major diameter D	Minor diameter d	Height H	A	B	C	F	G
	$8,5 \times 10^{-7} D^3$		D	$0,9\,D$	$0,5\,D$	$0,075\,D$	$0,175\,D$	$0,175\,D$	$0,06\,D$	
	kg	kg·m²	mm	mm	mm	mm	mm	mm	mm	mm
1	1,1	0,002 5	110	99	55	8	20	20	6,5	M 3
2	3,5	0,017	160	144	80	12	30	30	9,5	M 3
3	11	0,12	230	206	127	19	45	45	13	M 6
4	35	0,8	345	310	170	25	60	60	20	M 10
5	110	5,5	510	460	255	38	90	90	30	M 10

INCH/POUND VALUES

No.	Rotor mass M	Moment of inertia $I \approx Mk^2$	Major diameter D	Minor diameter d	Height H	A	B	C	F	G
	$3,1 \times 10^{-2} D^3$		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. 5 UNF
2	8	0.41	6.3	5.650	3.2	0.5	1.125	1.125	0.375	No. 5 UNF
3	25	2.7	9	8.125	5	0.75	1.75	1.75	0.510	1/4 UNF
4	80	20	13.5	12.125	7	1	2.375	2.375	0.800	3/8 UNF
5	250	130	20	18	10	1.5	3.5	3.5	1.186	3/8 UNF

* For balancing machines with capacities greater than the test rotors of this table, a rotor furnished by the user may be used.

9.1.3 Clear and permanent angle markings shall be provided

— at every 10° and enumerated at intervals of 30° in the case of proving rotors for horizontal machines;

— at every 15° and enumerated at every marking in the case of proving rotors for vertical machines.

9.1.3.1 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.

9.2 Test masses

9.2.1 Test masses shall be in the form of bolts, screws, etc. and their centre of gravity shall be identified in the manufacturer's test procedure.

9.2.2 The following test masses are required to conduct the test for minimum achievable residual unbalance as described in 9.7 :

— Two test masses, each equivalent to five times the specified minimum achievable residual unbalance.

For example : Proving rotor : 50 kg

Specified minimum achievable residual specific unbalance : 1 g·mm/kg

Minimum achievable residual unbalance : 50 kg × 1 g·mm/kg = 50 g·mm

Radius for test mass : 44 mm

$$\text{Test mass} = \frac{5 \times 1\ \text{g·mm/kg} \times 50\ \text{kg}}{44\ \text{mm}} = 5{,}682\ \text{g}$$

NOTES

1 For single-plane machines, only one test mass of ten times the specified minimum achievable residual unbalance is required.

2 This example is for soft-bearing machines (see note 4 in notes to 3.1 and 3.2).

The mass of the test masses shall be accurate to within 0,5 %.

9.2.3 The following test masses are required to conduct the unbalance reduction test described in 9.8.

9.2.3.1 Two equal test masses equivalent to a value in the range from 10 to 25 times the specified minimum achievable residual unbalance.

For example : Using the same proving rotor as in 9.2.2, but with a 100 mm test mass radius and a test mass equivalent to 25 times the specified minimum achievable residual unbalance :

$$\text{Test mass} = \frac{25 \times 1\ \text{g·mm/kg} \times 50\ \text{kg}}{100\ \text{mm}} = 12{,}5\ \text{g}$$

NOTES

1 For single-plane machines, only one test mass of 20 to 50 times the minimum achievable residual unbalance is required.

2 This example is for soft-bearing machines (see note 4 in notes to 3.1 and 3.2).

9.2.3.2 Two equal test masses equivalent to a value in the range from 50 to 250 times the specified minimum achievable residual unbalance.

For example : Using the same proving rotor as in 9.2.2, but with 100 mm test mass radius and test mass equivalent to 200 times the specified achievable residual unbalance :

$$\text{Test mass} = \frac{200 \times 1\ \text{g·mm/kg} \times 50\ \text{kg}}{100\ \text{mm}} = 100\ \text{g}$$

NOTES

1 For single-plane machines, only one test mass of 100 to 500 times the minimum achievable residual unbalance is required.

2 The examples given in 9.2.3.1 and 9.2.3.2 are shown in figure 6.

9.2.3.3 The mass of the test masses in 9.2.3.1 and 9.2.3.2 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 94 % unbalance reduction ratio, the mass tolerance is 0,1 × (100 − 94) % = 0,6 %

NOTES

1 The centre of gravity of each test mass shall be located in such a way that its true position meets the requirements for the mounting position in note 2 below.

2 The mounting position of each test mass shall be at 45° intervals at the same radius in each plane. The zero degree reference in each correction plane shall be at the same angular orientation (in the same plane through the axis of rotation). The mounting positions are to 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 masses in 9.2.3.3 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 0,6 % = 0,35° approx.

9.3 Verification tests

The tests prescribed in the following paragraphs 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 combined accuracy of amount-of-balance indication, angle indication and plane separation. The test procedure will not prove all requirements over the full range of variables nor will it define the exact reason in case the machine fails to comply. In cases where a user has additional requirements such as the ability to plane separate for ratios of bearing span to distance between planes of greater than 5 : 1 and/or to

operate with the rotor having its correction planes or main mass outside the bearing span, verification tests should be agreed between the manufacturer and the user.

NOTES

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.

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 permitted to check any of his work.

2 Verification tests shall also include physical inspection of various machine dimensions, features, instrumentation, tooling and accessories.

9.3.1 A weighing scale shall be available having sufficient accuracy to meet the requirements of 9.2.2 and 9.2.3.

9.4 Test and rechecks

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

9.5 Test conditions

For multi-purpose machines, the following tests shall be performed, using two standard proving rotors representing as nearly as possible the two extremes of the weight capacity range of the machine.

For special purpose machines, a single rotor may be suitable. By agreement between the manufacturer and the user, a user's own rotor may be used.

9.6 Balancing speeds

The balancing speeds for the following tests are :

— the lowest speed specified for the lightest rotor;

— the highest speed specified for the heaviest rotor.

9.7 Test for minimum achievable residual unbalance

9.7.1 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.

9.7.2 Put 10 to 20 times the claimed minimum achievable residual unbalance on the rotor by adding two artificial masses (such as balancing clay). These artificial masses shall not be :

a) in the same transverse plane;

b) in a balancing plane;

c) at the same angle;

d) displaced by 180°.

9.7.3 Balance the rotor, following the standard procedure for the machine, by applying corrections in each plane in a maximum of four runs.

9.7.4 In the case of horizontal machines, after performing the actions described in 9.7.1 to 9.7.3, change the angular reference system of the machine by 60°, turn the end drive shaft with respect to the rotor, turn black and white markings, etc.

9.7.5 Attach in each of the two prepared planes a test mass equal to five times the claimed achievable residual unbalance (see 9.2.2); 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.

Example :

Angle of test mass		0°	45°	90°	135°	180°	225°	270°	315°
Amount of unbalance readings	Left plane (Lower plane)								
	Right plane (Upper plane)								

NOTE — "Upper" and "Lower" plane designations apply to vertical machines.

9.7.6 Plot results as shown in figure 5.

Connect the points by averaging curves. Draw a straight line representing the arithmetic mean of the scale reading through each of the curves and add two further lines representing ± 12 % of the arithmetic mean for each curve, which accounts for the effects of variation in the position of the masses and scatter of the test data.

If all the plotted points are within the range given by those two latter lines for each curve, the claimed minimum achievable residual unbalance has been reached.

If the amount-of-unbalance indication is unstable, read and plot the maximum and minimum values for all angular positions of the test mass. Again, all points must be within the range given.

9.7.7 On horizontal and vertical single-plane balancing machines designed to indicate static unbalance only, proceed in the same way as described in 9.7.1 and 9.7.6 but use only one test mass, in the left (or lower) plane of the proving rotor.
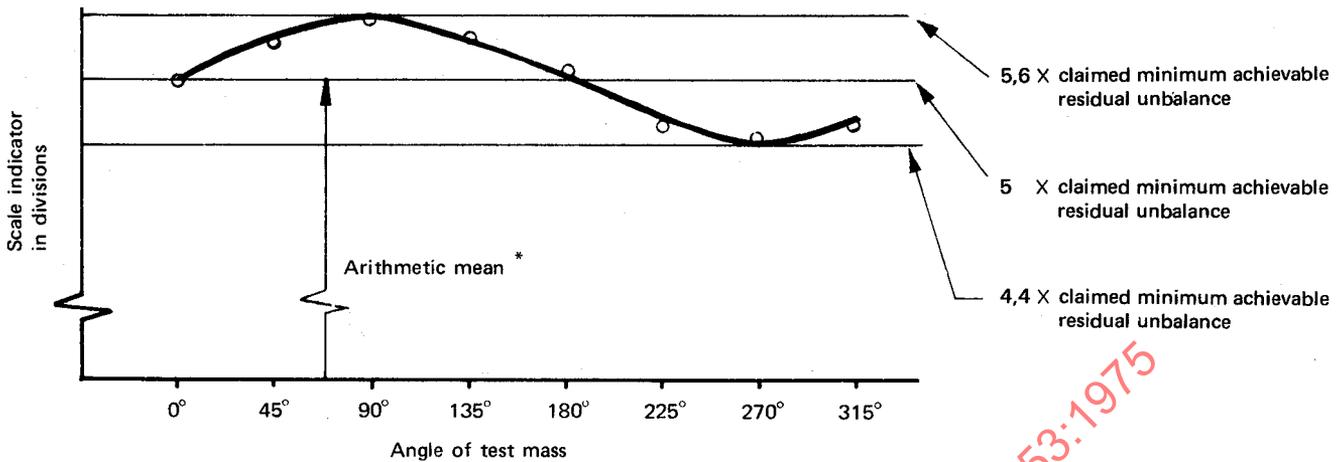
* Equal to five times the indicator movement corresponding to the claimed minimum achievable residual unbalance.

FIGURE 5 — **Diagram showing residual unbalance**

9.7.8 On vertical machines, the spindle balance 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.

9.8 Unbalance reduction test

9.8.1 This test is intended to check the combined accuracy of amount-of-unbalance indication, angle indication and plane separation.

9.8.2 Prepare polar diagram paper (see figure 6), drawing tolerance circles at $0°$, $90°$, $180°$ and $270°$ around points. These points have a distance from the centre of the graph equivalent to the value in the range of 10 to 25 times the minimum achievable residual unbalance for which the manufacturer has stated the unbalance reduction ratio and for which test masses have been prepared in accordance with 9.2.3.1 (see also 6.2). The radius of the tolerance circles is equivalent to half the specified minimum achievable residual unbalance plus the amount to which the test unbalance is reduced by applying the reduction ratio. Units of measurement shall be consistent, such as gram, gram millimetre, ounce or ounce inch.

9.8.3 Add one test mass in accordance with 9.2.3.1 in the left plane of a balanced proving rotor at $0°$ and another mass of the same size in the right plane at $90°$. Take unbalance readings in both planes and plot on the polar diagram as shown in figure 6. (1st run.)

9.8.4 Move the left mass to $90°$ and the right mass to $180°$ so that they are again $90°$ apart and take unbalance readings in both planes. (2nd run.)

9.8.5 Move the right mass to $270°$ so that the masses are now $180°$ apart and take unbalance readings in both planes. (3rd run.)

9.8.6 Prepare polar diagram paper (see figure 6), drawing tolerance circles at $45°$, $135°$, $225°$ and $315°$ around unbalance points, this time at a distance equivalent to the value in the range 50 to 250 times the claimed minimum achievable residual unbalance for which the manufacturer has stated the unbalance reduction ratio and for which test masses have been prepared in accordance with 9.2.3.2.

9.8.7 Repeat the series of runs in 9.8.3 to 9.8.5 by using test masses in accordance with 9.2.3.2. Add these always $45°$ ahead of the locations called for in 9.8.3 to 9.8.5.

All readings in 9.8.3 to 9.8.5 and 9.8.7 shall fall within the tolerance circles to be acceptable, but see note below.

NOTE — If not more than one reading falls outside the tolerance circles shown in figure 6, a further test may be performed, in which case all the readings must be inside the circles. If more than one reading falls outside in the initial test, the machine may be adjusted and retested under the same conditions.

9.8.8 On horizontal and vertical single-plane balancing machines designed to indicate static unbalance only, the tests in 9.8.1 to 9.8.4 and in 9.8.7 are intended to check only the combined accuracy of amount-of-unbalance indication and angle indication. Tests shall be carried out with only one test mass of each size in the left (or lower) plane. For sizes of masses, see 9.2.2 and 9.2.3.

9.8.9 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 9.7.3. Add one test mass equivalent to the value in the range 50 to 250 times the minimum achievable residual unbalance in the upper and lower 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 times the claimed couple unbalance interference ratio plus the claimed minimum achievable residual unbalance.