International Standard ISO 7475

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Balancing machines — Enclosures and other safety measures

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Foreword

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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.

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Balancing machines — Enclosures and other safety measures

0 Introduction

In designing balancing machines, efforts are made to minimize hazards arising from the use of the machines themselves. Rising demand for still greater safety in the working environment, however, requires additional protection, especially with respect to the rotor to be balanced. Potential hazards to the operator or the surrounding workshop area may exist, for example, by personnel coming into contact with machine components or the rotor, by rotor components or unbalance correction masses detaching and flying off, or by the rotor lifting from the supports or disintegrating. Particular dangers are posed by protruding rotor components or those which may become detached during rotation in the balancing machine. These potential hazards may theoretically increase with rotor size and balancing speed, but they are generally minimized by appropriate rotor design.

Special purpose balancing machines, for example those used in the mass production automotive industry, normally incorporate all necessary safety measures because the workpiece, as well as the operating conditions of the machine, are known and can be taken into account by the machine manufacturer. For multi-purpose balancing machines, however, where the workpieces to be balanced are generally unknown to the machine manufacturer, and are thus beyond his control, normal safety measures are limited to obvious hazards, for example end-drive coupling and/or drive belt covers.

1 Scope and field of application

This International Standard specifies requirements for enclosures and other safety measures used to minimize hazards associated with the operation of balancing machines under a variety of rotor and balancing conditions. It defines different classes of protection that enclosures and other protective features have to provide and describes the limits of applicability for each class of protection.

Special enclosure features, such as noise reduction, windage reduction or vacuum (which is required to spin certain rotors at the balancing speed), are not covered by this International Standard.

2 References

ISO 1925, *Balancing — Vocabulary.*

ISO 2041, *Vibrations and shock — Vocabulary.*

ISO 4849, *Personal eye-protectors — Specifications.*

3 Definitions

For the purpose of this International Standard, the definitions given in ISO 1925 and ISO 2041 apply.

4 Accident probability and its effect on safety measures

Most local or national regulations require certain minimum safety measures to be taken. Observance of such requirements in conjunction with the recommendations contained in this International Standard will generally provide an adequate measure of protection to the balancing machine operator and surrounding workshop personnel. There may be applications, however, where the recommended enclosures or other safety measures are so costly, or their use so time-consuming, that other safety precautions, such as vacating the surrounding area for a sufficient distance, remote control of the balancing facility, or work outside normal hours, etc., have to be considered.

The consideration of accident probability may be important if a rotor needs to be balanced or spin-tested at or above its service speed, where major rotor failure cannot be excluded with as much certainty as during low speed balancing. Maximum service and spin-test speeds are generally well below the speed where major rotor failure can be expected.

On the other hand, a rotor being balanced at low speed may consist of an assembly of several components, such as a bladed turbine wheel. It is then important to consider whether an enclosure for low speed balancing should withstand penetration of a turbine blade, or whether it is sufficient to protect against unbalance correction masses that might fly off during balancing. If the probability of blade separation is practically non-existent, a light enclosure, which just protects against correction masses, may be sufficient.

Since this International Standard deals with balancing machines and safety measures in general, no details of the risk can be stated for specific rotor types and balancing facilities. Individual investigations, based on actual rotor parameters, will probably be required in each specific case. In this connection, risk analysis of possible accidents should include the characteristics of the balancing machine itself. For the extent of the ensuing damages, it may be of decisive importance to know how much unbalance can be endured by its supports and bearings due to partial rotor failure, for example rotor components becoming detached.

5 Possible hazards and precautionary measures

Hazards from machine components are generally covered by local and national safety regulations. Hazards associated with the spinning rotor in a balancing machine may be separated into several different categories and precautions may be taken in a variety of ways. Generally recognized hazards and the appropriate precautions are as follows.

5.1 Disengagement or failure of the end-drive coupling

One end of the universal-joint driver may remain coupled to the balancing machine drive or the spinning rotor, with the free end whipping around. The common device for protection in such a case is an enclosure around the universal-joint shaft.

5.2 Operator becoming entangled in the belt-drive

The usual protective devices are belt covers over the motor and tensioning pulleys. More complete protection is offered by machine enclosures.

5.3 Axial rotor movement off the machine supports due to excessive axial thrust from skewed support rollers or windage

This hazard usually does not occur on machines with end-drive, provided the end-drive coupling prevents axial motion. On belt-drive machines, axial motion is prevented by axial thrust stops.

5.4 Rotor lifting out of the machine's open bearings (for example due to excessive initial unbalance, or shifting or separation of large masses during rotation)

This may be prevented by the use of closed bearings or, in the case of support rollers, by safety hold-downs.

5.5 Operator coming into contact with any part of the spinning rotor (for example blades or other protruding components)

This may be prevented by awareness barriers, fences or enclosures.

5.6 Small rotor particle, for example welding bead, bolt, key or correction mass separating from the rotor during rotation

Appropriate protection may be provided, in the case of very small rotors, by safety glasses or shields, or, in the case of larger rotors, by enclosures.

5.7 Rotor component, for example a blade, separating from the rotor during rotation

The precautions to be taken are similar to those described in 5.6 and 5.8.

5.8 Rotor or major components failing during high speed balancing or overspeed testing

Containment of this hazard generally requires burst-proof enclosures, such as pits or bunkers; under certain circumstances, other safety measures, such as vacating the surrounding workshop area, may be acceptable.

NOTE — If, for some reason, a burst-proof enclosure is not practicable, an appropriate means of protection should be devised, taking into account all relevant parameters of the rotor and special requirements with respect to manufacturing and material test procedures. During all test runs of such rotors (not only for balancing and overspeed testing), a series of precautionary measures should be taken.

6 Safety barriers and enclosures

The hazards described in 5.5 to 5.8 may be beyond the control of the balancing machine manufacturer since he has little or no influence over the type of rotor a user may put into the machine.

In the case of the hazard described in 5.5, standard safety measures, such as guard rails, fences, drive interlocks, etc., in accordance with local regulations, may be used.

In the case of the hazards described in 5.6 and 5.7, danger from a flying object depends essentially on three parameters, that is, its mass, velocity and impact area. If the mass and velocity are small, the particle that has separated from the rotor can be effectively stopped by safety glasses or a face shield. If the product of one-half of the mass and velocity squared ($1/2\ mv^2$) exceeds 0,56 N·m*, rotor or machine enclosures are required to stop a flying bolt, correction mass, blade or other rotor fragment.

In the case of the hazard described in 5.8, the mass and velocity of the separating fragments of the rotor are usually large. Burst-proof enclosures or other safety measures are then required.

Various types of rotor and machine enclosures are illustrated in figures 1 to 5.

7 Selection of protection classes

The user should evaluate his rotor, the balancing speed, and the intended unbalance correction method to determine appropriate safety measures. Five basic classes of protection are described in table 1, with, for each class, the limits of applicability.

* 0,56 N·m is equivalent to the requirement in ISO 4849 that oculars for protection against high-mass, low-velocity flying objects be designed to withstand the impact of a 22 mm diameter steel ball, of mass 44 g, dropped from a height of 1,3 m.

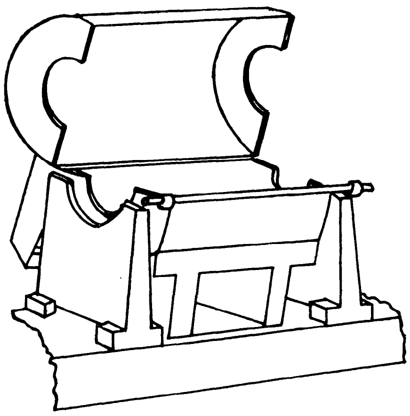

Figure 1 — Typical rotor enclosure on horizontal machine used for production balancing

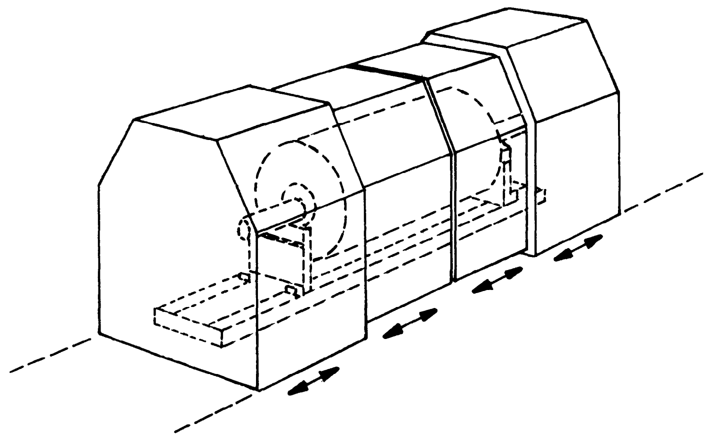

Figure 3 — Telescoping enclosure covering entire machine for general applications

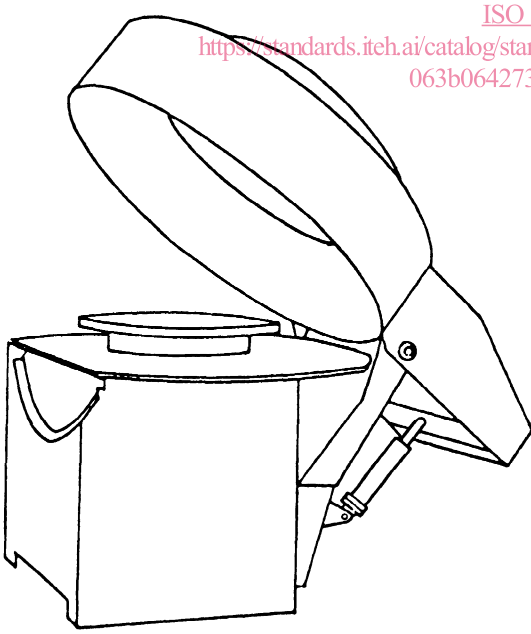

Figure 2 — Typical rotor enclosure on vertical machine used for production balancing

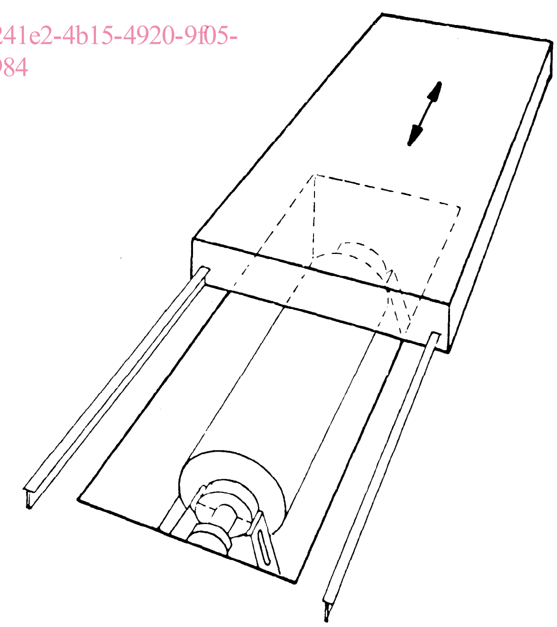

Figure 4 — Pit with burst-proof cover

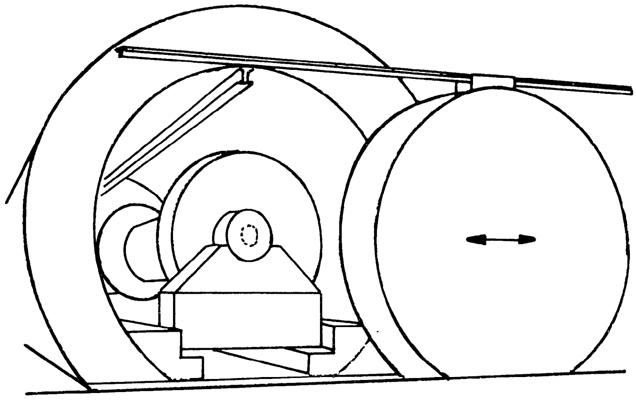

Figure 5 — Tunnel with burst-proof door
(Rail-mounted transporters move rotor and supports in and out of tunnel)

Table 1 — Protection classes

Protection class	Safety measure[1]	Hazard assessment
O	**None** No protection nor other provision necessary with respect to the workpiece. Safety guards on drive elements as required by national and local regulations.	No significant danger from rotor
A	**Safety glasses or face shield only** Safety guards on drive elements as required by national and local regulations. No protection around workpiece.	Maximum rotor speed such that major rotor failure is not expected; fragment severity factor x maximum fragment mass x velocity squared × 0,5 equals $\frac{Kmv^2}{2} \leqslant 0{,}56\ \text{N}\cdot\text{m}$
B	**Barrier protection and either safety glasses or face shield** Safety guards on drive elements as required by national and local regulations. A barrier or guard prevents contact with dangerous surfaces on the spinning workpiece.	Maximum rotor speed such that major rotor failure is not expected; rotor components (or unbalance correction masses) that might become detached with $\frac{Kmv^2}{2} \leqslant 0{,}56\ \text{N}\cdot\text{m}$
C[2]	**Fragment protection** Safety guards on drive elements as required by national and local regulations. Fragment-proof enclosure around that part of the workpiece from which fragments may become detached or around the entire machine to prevent penetration by the smallest fragment as well as fragment with greatest penetration potential that might separate from the rotor.	Maximum rotor speed such that major rotor failure is not expected; rotor components that might become detached with $\frac{Kmv^2}{2} > 0{,}56\ \text{N}\cdot\text{m}$
D[2]	**Burst protection** Safety guards on drive elements as required by national and local regulations. Burst-proof enclosure around workpiece or entire machine to prevent penetration of a major rotor portion in case of complete rotor failure.[3]	Maximum rotor speed such that major rotor failure cannot be excluded. Enclosure has to be designed for specific rotor parameters and fragment characteristics.

1) For additional information, see clauses 7 and 8.

2) Supplementary enclosure features :
a) noise reducing enclosure;
b) windage reducing enclosure;
c) vacuum enclosure.

3) Or other special safety measures, for example vacating the danger zone.

8 Requirements for protection classes
(see table 1)

8.1 Protection class O

To qualify as protection class O, all of the following requirements shall be met :

a) The surface of the rotor shall be so smooth that contact is not dangerous.

b) The correction method shall be such that no fragments might become detached (normally material removal).

c) The maximum rotor speed shall be such that major rotor failure is not expected.

d) The rotor shall be prevented from lifting out of the balancing machine bearings by provisions such as those mentioned in 5.4, or the rotational energy of the rotor at maximum balancing speed shall be so small that no damage is possible if the rotor lifts out of the machine.

8.2 Protection class A

For very small rotors, where the impact energy of fragments that might separate from the rotor is so small that safety glasses or safety shields are sufficient to protect the operator, no rotor enclosures are required.

Care shall be taken to ensure that the impact energy of the largest possible fragment does not exceed the limits set by national or local regulations for safety glasses (for example as specified in ISO 4849).

Furthermore, the requirements specified in 8.1d) shall apply and the hazards arising from contact with the rotating workpiece shall be negligible (for example, small gyros or small fractional horsepower armatures).

8.3 Protection class B

To qualify as protection class B, a rotor shall not have any component or unbalance correction masses larger than those permitted for protection class A that might separate during the balancing process. Unbalance correction by material removal will generally meet this requirement.

The only danger from the spinning rotor is assumed to be inadvertent contact by the operator. To prevent this, barrier type protection is usually sufficient, such as fences, rails, wire-mesh enclosures, etc. The barrier may be provided with an interlock to the machine drive so that the rotor cannot be spun unless the barrier is closed. In cases of extreme contact danger, such as exists with medium- and large-bladed rotors, a safety interlock may be required that prevents the barrier from being opened until the rotor has decelerated to near zero speed.

In some applications, only part of the rotor has to be protected, because other parts of the rotor fall into protection class O. In such cases, it is sufficient to prevent contact only with the dangerous surface(s) of the rotor.

If the barrier is large enough to permit an operator to work inside, appropriate safety precautions shall be taken to ensure his safety.

8.4 Protection class C

To qualify as protection class C, the rotor components, from which fragments may separate, shall be completely enclosed. The requirements of this class may also be met if the entire machine, including the rotor, is enclosed and entrance into the closed enclosure is prevented, or by vacating the dangerous area.

An enclosure should protect against the worst case, i.e. have a high probability of preventing penetration by fragments with the greatest penetration potential. After impact, the enclosure may be unusable until all or part of it has been repaired or replaced.

If the enclosure of the rotor is only partial (i.e. axially open) it should be taken into account that ricochetting fragments may escape. If perforated material is used for the enclosure, it shall be made sure that the smallest likely fragment cannot penetrate it.

Two factors need to be considered in the selection of an enclosure for fragment protection : the characteristics of fragments which might fly off the rotor and the protection ratings of various types of enclosures.

The user should evaluate his rotors, the balancing speeds, and the unbalance correction methods used to estimate the characteristics of the fragments that might fly off the rotors during balancing, and should calculate a worst-case penetration potential for each fragment and select an enclosure capable of withstanding an impact by the fragment with the greatest penetration potential. For recommendations concerning general purpose machines, see clause 9.

8.5 Protection class D

This protection class is intended for all rotors which are not sufficiently covered by protection classes O, A, B, and C, i.e. where major rotor failure cannot be excluded.

Enclosures in this class shall, therefore, contain the fragment from a major rotor failure, where one-third of the entire mass may impact the enclosure.

Burst-proof enclosures of this type shall be designed for the specific rotors to be balanced or tested, taking into account all relevant parameters of the rotors, and also manufacturing and handling procedures and requirements.

The penetration potential of these high speed rotor fragments is such that the impact energy formula used for the enclosure penetration resistance rating in clause 9 **is not** applicable. Their penetration potential shall be calculated on the basis of armour piercing or similar technology.

9 Class C enclosure selection for general-purpose machines

9.1 General

In many cases, the user may not be able to predict the size and type of rotors that will be balanced in his machine, much less the fragments that may separate from such rotors. In such cases, the following guidance is offered to assist in selecting an appropriate enclosure rating.

General-purpose machines are primarily used for low speed balancing and thus produce a typical rotor circumferential speed of 10 to 30 m/s.

9.2 Size of fragment

For the general type of rotors, it may be assumed that maximum initial unbalance, and therefore the maximum correction mass that might fly off, will not exceed

$$m_1 = 7{,}5\ m^{2/3}$$

where

m_1 is the correction mass, in grams;

m is the rotor mass, in kilograms.

9.3 Fragment shape and material

Since some assumption has to be made about the anticipated shape of the fragment, it is assumed to be equivalent to the shape of the "standard projectile", as shown in figure 6, and also that it will impact the enclosure wall point first.

The material of the standard fragment is assumed to be such (i.e. steel of 40 to 50 RC) that no significant deformation of the fragment itself occurs when it hits the enclosure.

9.4 Penetration potential of a fragment

The penetration potential is expressed in terms of

$$\frac{Kmv^2}{2}$$

where

m is the mass of the fragment, in kilograms;

v is the tangential velocity, in metres per second, i.e. the balancing speed, in revolutions per minute, multiplied by the radius, in metres, from which a particle might separate multiplied by $2\pi/60$;

K is the fragment severity factor, which the user should estimate, and which depends on the fragment material, hardness, shape, and impact area.

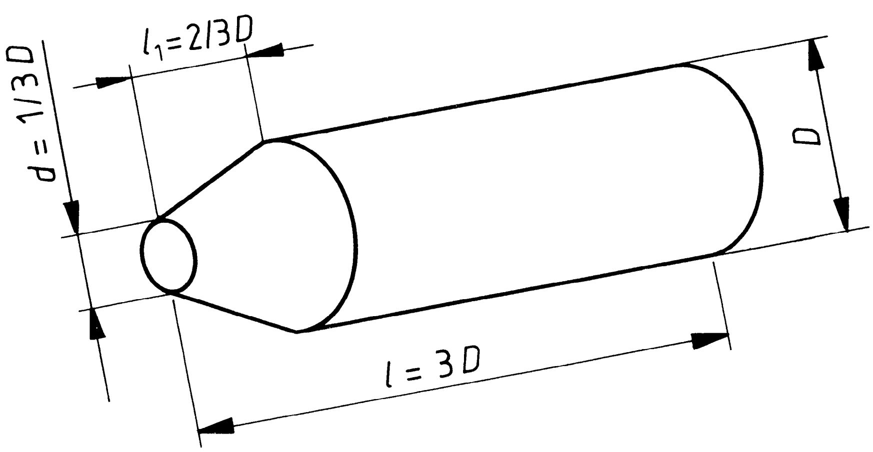

Figure 6 — Standard projectile for testing penetration resistance of safety enclosures

9.5 Selection of fragment severity factor

The appropriate fragment severity factor K should be estimated as follows.

9.5.1 Low fragment severity factor : $K = 0{,}3$

Fragments having low fragment severity factors may be spherical, of hardened steel or of any shape of soft material, such as untempered aluminium, soft copper, solder or plastic.

9.5.2 Standard fragment severity factor : $K = 1$

Fragments having standard fragment severity factors are considered to be equivalent to the standard projectile illustrated in figure 6, made of steel, hardened to 40 to 50 RC. Bolts, nuts and washers are typical fragments.

9.5.3 High fragment severity factor : $K = 10$

Fragments having high fragment severity factors have sharp corners which might apply large localized forces at the point of contact with the enclosure.

NOTE — A precise estimate of K may at times be difficult, in which case experimental determination is recommended.

9.6 Enclosure penetration resistance rating (PRR)

For typical fragment masses, and velocities of about 20 m/s, suitable enclosure classes are listed in table 2 together with appropriate general-purpose balancing machine capacities under the assumption that $K = 1$. Fragment velocity is assumed to be the same as rotor circumferential speed at the particular radius at which the fragment may detach.

If fragment masses or velocities or the value of K differ from those listed in the table, the following formula may be used to calculate the required penetration resistance rating (PRR) for the enclosure :

$$\text{PRR} = \frac{Kmv^2}{2}$$

provided that the fragment velocity v is in the range 10 to 30 m/s.

In this case, m is the maximum expected fragment mass, in kilograms; values of K as suggested in 9.5 may be used.

Figure 7 provides a graph from which the required penetration resistance rating and appropriate protection class may be determined from the fragment mass and velocity.

Example

m max. = 0,02 kg

v max. = 20 m/s

K = 10 (high severity factor)

From the graph, the required enclosure rating (40) necessitates an enclosure of protection class C 60.

NOTES

1 A fragment having a high severity factor for a mass of 0,02 kg is equivalent to a 0,2 kg standard fragment.

2 For unusual fragment shapes or velocities outside the 10 to 30 m/s range, experimental determination of the required enclosure penetration resistance may be necessary.

3 For balancing machines with variable speed, the maximum balancing speed (in revolutions per minute) should be limited by the formula

$$n\ \text{max.} = \frac{60\ v\ \text{max.}}{2\ \pi\ R\ \text{max.}}$$

where

v max. is in the range 10 to 30 m/s;

R max. is the maximum rotor radius, in metres, from which a fragment might separate.

9.7 Verification test for enclosures

To verify the penetration resistance of an enclosure with a given rating, the standard projectile for that particular enclosure class (see table 2) is used to impact, point first and perpendicular to the surface, a sample enclosure panel in its weakest area.

The sample panel shall be at least ten times as long and ten times as wide as the diameter of the standard projectile. Furthermore, the panel shall be supported under conditions which simulate those in the actual enclosure.

The enclosure may be judged to be suitable if the projectile travelling at 20 m/s does not fully penetrate the exit side of the enclosure wall.

If a fragment speed other than 20 m/s is used during the test, the formula in 9.6 shall be used to calculate the value of PRR. (The speed shall in any case be between 10 and 30 m/s.)