INTERNATIONAL STANDARD

ISO 7475

Second edition
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Mechanical vibration — Balancing machines — Enclosures and other protective measures for the measuring station

Vibrations mécaniques — Machines à équilibrer — Enceintes et autres mesures de protection pour le poste de mesurage

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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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7475 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 1, *Balancing, including balancing machines*.

This second edition cancels and replaces the first edition (ISO 7475:1984) and the technical corrigendum, of which it constitutes a technical revision.

Major chances to the previous edition are

— expanding the permissible particle velocity range,

— using the area-specific energy of a particle as criterion for the capability of the enclosure material to hold a particle which leaves the rotor,

— taking the absolute energy of a particle as criterion for the strength of the fastening of the whole enclosure or of its components,

— considering the impulse of a particle when it hits a free-standing enclosure, and

— adding other safety aspects that are intrinsic to balancing machines and are related to the integrity of the operator.

This International Standard follows the rules for drafting and presentation of a machinery-related safety standard as they are mandatory in European Standards, and gives verification procedures for the safety requirements.

Annex A constitutes a normative part of this International Standard. Annexes B and C are for information only.

Introduction

In designing and using 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 balancing machine 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. These potential hazards may theoretically increase with rotor size and balancing speed, but they are generally minimized by appropriate rotor design and balancing instructions.

Special-purpose balancing machines, for example those used in the mass production automotive industry, normally incorporate all necessary protective 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 multipurpose balancing machines, however, where the workpieces to be balanced are generally unknown to the machine manufacturer, and are thus beyond his control, basic protective measures are limited to obvious hazards, for example end-drive coupling and/or drive belt covers. Therefore the user of the balancing machine has to state the possible hazards originating in his rotors in order to allow the balancing machine manufacturer to supply equivalent protective measures, or the user has to provide adequate protective measures on his own.

When these rotors are not known in advance – e.g. in service and repair – a good estimation is needed. Table A.2 states typical values for different balancing machine sizes. But for each individual rotor to be balanced, the user should check if the protective measures cover all hazards.

Most local regulations require certain minimum protective 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 protective measures are so costly, or their use so time-consuming, that other protective 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 can 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 protective 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.

The significant hazards covered by this International Standard are those listed in clause 4. The safety requirements and/or protective measures to prevent or minimize those hazards identified in Table 1 and procedures for verification of these requirements or protective measures are found in clause 5.

Mechanical vibration — Balancing machines — Enclosures and other protective measures for the measuring station

1 Scope

This International Standard specifies requirements for enclosures and other protective measures used to minimize mechanical hazards produced by the rotor in the unbalance measuring station of centrifugal (rotational) balancing machines. The hazards are associated with the operation of balancing machines under a variety of rotor and balancing conditions. This International Standard defines different classes of protection that enclosures and other protective measures provide and describes the limits of applicability for each class of protection.

Devices for adjusting the mass distribution of a rotor and devices to transfer the rotor are not covered by this International Standard, even if they are combined with the measuring station.

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

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*

ISO 2041, *Vibration and shock — Vocabulary*

ISO 2806, *Industrial automation systems — Numerical control of machines — Vocabulary*

ISO 4849, *Personal eye-protectors — Specifications*

3 Terms and definitions

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

4 List of significant hazards

4.1 General

Significant hazards identified at measuring stations of centrifugal (rotational) balancing machines are listed in Table 1 together with examples of associated hazardous situations, activities and danger zones.

4.2 Risk assessment

The user of this International Standard (i.e. the user, designer, manufacturer or supplier) shall conduct a risk assessment. As part of the risk assessment, the user of this International Standard shall describe the intended use of the balancing machine including manual tool loading, workpiece set-up, maintenance, repair and cleaning, together with reasonably foreseeable misuse of the machine. As part of the risk assessment, the user of this

International Standard shall also verify whether the list of hazards in Table 1 is exhaustive and applicable to the balancing machine under consideration.

4.3 Access to balancing machine

The risk assessment shall assume foreseeable access to the balancing machine from all directions. Risks to both the operator(s) and other persons who may have access to the danger zones shall be identified, taking into account all hazards which may occur during the lifetime of the balancing machine. The assessment shall include an analysis of the effect of failure(s) of protective functions in the control system.

5 Safety requirements and/or protective measures

5.1 General requirements

5.1.1 General considerations

The balancing machine shall be securely attached to the foundation (or the floor) in such a way as to safely withstand all loads occurring from the rotor mass, the unbalance, particles or parts flying off the rotor, and the necessary movements of the enclosure whilst opening or closing.

During operation of a balancing machine, various potential hazards to the balancing machine operator or the surrounding workshop area can exist, for example,

— from personnel coming into contact with moving machine components or the rotor,

— from rotor components or unbalance correction masses detaching and flying off, and

— from the rotor lifting from the supports or disintegrating.

General safety requirements therefore have to cover two areas: protection against contacts with hazardous movements (mainly the rotating workpiece) and protection against particles or parts flying off the rotor.

5.1.2 Protection against contact

Many rotors represent a hazard during balancing due to the surface (e.g. bladed rotors) or due to the rotational energy stored. For that reason the work zone of a dynamic balancing machine shall be protected by guards (barriers, fences) to protect people from contacting the rotating workpiece and drive.

Such guards are not needed in special cases, provided that <u>all</u> of the following criteria apply.

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

b) The correction method shall be such that no particles can 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 Table 3 (item 1.3) 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.

e) The maximum drive torque shall be be low to ensure that the circumferential forces stay below 100 N at all relevant radii [for moments of inertia, see f)].

f) The kinetic energy of the rotor plus drive (if coupled without the ability to slip) shall be below 20 N·m at balancing speed. For rotors with large diameter (e.g. automotive wheels), higher values may be permitted if entanglement with operator’s clothes is not possible.

Table 1 — List of significant specific hazards and examples of hazard sources associated with the measuring station in balancing machines

Item	Specific hazard	Examples of hazard source	Associated activity	Related danger zone
1	**Mechanical**			
1.1	Crushing	workpiece moving	loading the workpiece	between rotor and pedestal
1.2	Shearing	workpiece rotating	check of belt drive	around drive shaft and rotor/guide rollers
		workpiece rotating	lubrication of rollers	between journal and roller
		workpiece moving in axial direction when rotating	during process control	between rotor and pedestal, access area around machine
		power operation of clamping device	loading of rotor	between rotor and clamping device
1.3	Impact of mass	ejection of rotor	protective bracket not closed, large unbalances, high balancing speed	area around machine and remote, depending on speed and energy of masses
		ejection of rotor parts	parts loose, excessive balancing speed	
		ejection of correction masses	masses insufficiently fixed	
1.4	Stabbing or puncture	end drive not coupled to rotor and drive actuated	start of drive	around end drive
		rotor with protruding parts rotating	checking set-up while rotor running	at rotor
1.5	Entanglement	belt drive running	check of belt drive	between belt and rotor/guide rollers
		rotor with protruding parts rotating	checking set-up while rotor running	at rotor
1.6	Slip, trip and fall	ejection of lubricant from sleeve bearing	during operation of machine	floor area around machine
2	**Electrical**			
2.1	High voltage	contact to live parts		
2.2	Drive power	automatic re-start after power loss	during set-up of rotor	around rotor and drive
		loss of speed control during indexing activity	indexing of rotor	between rotor and clamping device
3	**Excessive noise**	balancing bladed rotors, air-drive	balancing run	near machine
4	**Neglecting ergonomic principles**			
4.1	Unhealthy postures or excessive efforts (repetitive strain)	lifting and reaching while handling workpiece and machine parts	during loading/ unloading and maintenance	load/unload position; maintenance action points
4.2		inadequate consideration of human hand-arm or foot-leg anatomy	while operating the balancing machine	workplace
4.3	Inadequate local lighting	judgement and accuracy of manual actions during set-up and loading	during loading and set-up	at drive elements, pedestals and load/unload position
5	**Human errors**	inadvertent operation of controls, misuse of guard-controls	measuring unbalance during set-up	around rotor

NOTE This list should not be considered complete.

5.1.3 Protection against particles or parts

According to the mass and velocity of particles or parts flying off the rotor, different protective measures are needed, from personal eye-protectors (spectacles, goggles or face-shields), over-machine enclosures, to burst-proof protections. In general three different criteria shall be considered.

a) Area-specific energy

This criterion is based on the case that the kinetic energy of a particle or part is concentrated with its smallest possible area on the protection [see A.2.1 and equation (A.1)]. The particle or part shall not penetrate or escape from the protection.

b) Absolute energy

This criterion is based on the case that the kinetic energy of a particle or part is loading the structure of the protection [see A.3.1 and equation (A.6)]. The protection shall not disintegrate so that a particle or part cannot escape from the protection.

c) Impulse

This criterion is based on the case that the impulse of a particle or part is transmitted to the protection [see A.5.1 and equation (A.10)]. The protection shall not turn over and its displacement shall be reasonably limited.

5.1.4 System of protection classes

The system of protection classes on a balancing machine, as given in Table 2, can be described by two criteria:

— the area specific energy, absolute energy and impulse of a part which may fly off the rotor; and

— the need for a guard (e.g. barrier, fence) for the balancing machine (see Table 2).

In some cases it may be advisable to combine classes A and B, for example if a rotor is dangerous to contact and only small particles with limited energy can be ejected during balancing.

Table 2 — Protection classes, specified by the necessity for guards for the balancing machine and resistance against particles or parts

Necessity for guards (barriers, fences)		**No**		**Yes**		
Resistance to particles or parts	Area-specific energy	below the necessity for spectacles, goggles or face-shields	spectacles, goggles or face-shields needed	below the necessity for spectacles, goggles or face-shields	above class B, up to ≈ 340 mN·m/mm^2	above the values of class C
	Absolute energy				above class B, up to ≈ 2 000 N·m	
	Impulse				above class B, up to ≈ 200 kg·m/s	
Protection class		**0**	**A**	**B**	**C**	**D**

5.1.5 Mode of operation

If the machine is equipped with guards around the work zone, it shall have two modes of operation. These modes are as follows.

a) Mode 1: Normal (production) operation: Rotation of the workpiece under manual or numerical control to achieve sequential operation with the enclosure closed and/or protective devices active (e.g. guard lock, pressure-sensitive protection device, electro-sensitive protection equipment).

b) Mode 2: Setting mode of operation: Rotation of the workpiece under manual or numerical control to validate the set-up with work zone enclosure open and the interlocks suspended.

Mode 2 shall only be provided when details of the intended application and required skill level of operators are defined in the instructions for use. Reduced balancing speed is a significant factor in the risk reduction for this mode and the maximum speed permitted needs to be carefully considered and determined by risk assessment.

The selection of the mode shall be by either a key switch, access code or equally lockable means, and shall only be permitted from outside the work zone and shall not initiate start-up. For application of the modes, see Table 3.

The selected mode shall be clearly indicated.

5.1.6 Controls

The safety-related parts of control systems for interlocking, monitoring, reduced speed(s) and enabling device(s) shall be designed so that a single fault in the control shall not lead to loss of the protective function(s), and wherever reasonably practicable, the single fault shall be detected at or before the next demand upon the protective function.

Monitoring may be achieved by separate channels, automatic monitoring or other appropriate means.

An enabling device may be a two-position device in conjunction with an emergency stop device or a three-position device.

5.2 Specific requirements

Each machine shall be designed and safeguarded in accordance with the specific requirements and/or protective measures listed in Table 3.

6 Verification of safety requirements and/or protective measures

Safety requirements and/or protective measures implemented in accordance with clause 5 shall be verified using the recommended procedures given in Table 3, last column.

Table 3 — List of safety requirements and/or protective measures and their verification procedures

Item	Hazard sources	Safety requirements and/or protective measures	Verification
1	Mechanical		
1.1	Disengagement or failure of the end-drive coupling	An enclosure around the universal joint shaft shall prevent the whipping around of the shaft if not coupled to a rotor. Alternative interlocking devices shall prevent the start of the rotor if the shaft is not coupled.	By visual inspection
1.2	Axial rotor movement off the machine supports	On belt drive machines, axial thrust stops should prevent axial movement of the rotor. On end-drive machines, the drive shaft should be able to carry the axial load.	By visual inspection
1.3	Rotor lifting out of the machine's open bearings	The machine should be equipped with closed bearings or hold-down brackets (see also note).	By visual inspection and (if necessary) by calculation
1.4	Operator coming into contact with any part of the spinning rotor or rotor specific drive elements	Work zones shall be guarded using fixed and/or interlocked movable guards or fences designed to prevent access to the work zone by the operator. Guard interlocking shall incorporate redundancy and monitoring. Redundancy may be by two separate switches or by a guard-closed switch and detection of guard-lock position. Measures to minimize possible defeat of interlocking shall be taken. In some applications, only part of the rotor has to be protected, because other parts of the rotor fall into protection class 0. In such cases, it is sufficient to prevent contact only with the dangerous surface(s) of the rotor. (For example, low-speed wheel balancing machines where only the clamping mechanism shall be protected, or designed in such a way that entanglement of operator's clothes is not possible.)	By visual and practical checks
1.4.1		In mode 1 [see 5.1.5 a)], machine movements shall only be possible when the guards are closed and/or the protective devices are active. If in this mode, it is possible to open an interlocking movable guard, this shall cause the hazardous movements to cease and be inhibited. If opening of the interlocking guard gives access to hazards 1.1 to 1.6 of Table 1, guard locking shall be provided.	Examination of circuit diagrams and practical checks. Check to ensure that the hazardous moving parts are not accessible when the interlocking guard is opened.
1.4.2		In mode 2 [see 5.1.5 b)], powered machine movements shall be possible only when all of the following conditions are satisfied. a) Key or code access to this mode with program execution limited to a single block or fixed/canned cycle (see ISO 2806). b) Machine movements initiated by cycle start control in conjunction with an enabling device. c) The selection of mode 1 shall automatically reinstate all appropriate safeguarding (e.g. interlocking functions). d) Machine movements in the reinstated mode 1 shall not be possible until the cycle start control is operated.	Examination of circuit diagrams and practical checks
1.5	Ejection of very small particles	If the impact energy of the largest possible particle separating from the rotor is not negligible but does not exceed the limits set by ISO 4849 or local regulations, personal eye-protectors (spectacles, goggles or face- shields) shall be used to protect the operator.	By visual inspection and check of personal eye-protector specification

Item	Hazard sources	Safety requirements and/or protective measures	Verification
1.6	Ejection of particles	The rotor components, from which particles may separate, shall be completely enclosed. This requirement may also be met if a) the entire machine, including the rotor, is enclosed and entrance into the closed enclosure is prevented, or b) by vacating the dangerous area. After impact of a particle, 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 particles may escape. If perforated material is used for the enclosure, it shall be made sure that the smallest likely particle cannot penetrate it. The user shall evaluate the rotors, the balancing speeds, and the unbalance correction methods used to estimate the characteristics of the particles that might fly off the rotors during balancing. He shall take into account the area-specific energy, absolute energy and impulse for each particle to select an adequate enclosure. For further recommendations concerning general-purpose machines, see annex A.	By calculation of the criteria outlined in annex A, or equivalent means
1.7	Ejection of major parts (rotor burst)	The enclosure shall retain the fragments from a major rotor failure, where one quarter of the entire mass may impact the enclosure (see note). 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.	If the penetration potential of these high speed rotor fragments is such that the formulae given in annex A are no longer applicable, their penetration potential shall be calculated on the basis of armour piercing or similar technology.
1.8	Loss of stability	The machine shall be designed to maintain structural stability throughout the full range of functions and dynamic motions taking into account the maximum workpiece size and weight distribution (see also clause 7).	
1.9	Ejection of fluids	1) Containment of fluids: Where a fluid application system is provided, it shall be designed to minimize splash, spray, and mist. Fixed or movable guards of solid material shall be supplied to minimize splashing or mist dispersal during operation. “Information for use” shall draw attention to the importance of preventing spillage of fluid onto the surrounding area and thus creating a slipping hazard.	Visual examination and practical test involving the use of fluid
		2) Means of access: Means of access on machines (e.g. ladders, platforms, walkways) shall be designed to minimize the likelihood of slips, trips and falls by provision of adequate hand holds, foot holds, and where necessary by slip-resistant surfaces. Guard rails and toe boards shall be provided in accordance with local regulations.	Visual examination
2	Automatic restart after power loss	The electrical equipment shall comply with local regulations. An automatic restart after power loss shall be prevented.	By verifying compliance with the requirements in local regulations
3	Balancing bladed rotors; noise and windage	Depending on the type of rotor to be balanced, the machine shall be equipped so that risks resulting from the emission of airborne noise or windage are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at source. The equipment can be combined with enclosures or guards.	By measurement using suitable instruments

Item	Hazard sources	Safety requirements and/or protective measures	Verification
4	Neglect of ergonomic principles		
4.1	Lifting and reaching while handling workpiece and machine parts	Provision shall be made to enable components to be moved without excessive effort or adverse effects on health, by means of mechanical handling equipment, where repeated excessive efforts or unhealthy posture would otherwise be necessary. On machines with contiguous guards, provision shall be made to enable the work zone to be accessed with/by lifting equipment. Where components are manually loaded, fixtures, pockets, tool holders shall be located to minimize reaching into the machine	Practical test to check that weights, distances, and posture requirements are not excessive and are in accordance with the corresponding standards
4.2	Inadequate consideration of human anatomy	Means shall be provided to ensure safe operation by making controls, observations, and service points easily reached.	Check that distances involved in normal operation are in accordance with the corresponding standards
4.3	Reduced accuracy of manual actions by inadequate local lighting	Lighting within the work zone shall be provided in accordance with local regulations so that the movement of the rotor shall be visible through the vision panel, and be a minimum of 500 lux as measured at the rotor journals with the interlocked movable guards open. When lighting is made by fluorescent lamps, provisions shall be made that mains frequency modulation (creating a stroboscopic effect on the spinning rotor) is avoided.	By measurement and observation
4.4		Screen display information shall be clear and unambiguous, minimize reflections and glare. Input devices (e.g. keypads, buttons) shall be in accordance with local regulations.	Check legibility and visibility from operating position(s)
5	Failures of energy supplies, breakdown of machine parts, other functional disorders	The machine shall be designed and constructed such that a failure or interruption in any energy supply shall not result in any hazard.	Practical tests
6	Missing and/or incorrectly positioned safety-related measures/ means	Equipment and accessories for adjusting and maintaining of the machine which are not readily available to the user shall be provided [see also 7.2 e)].	By visual examination
NOTE When balancing cardan-shafts, one or all clamping devices may fail and the rotor as a whole has to be caught by protective catches. Fragments of the clamping devices may be caught by a protection of an appropriate protection class.			

7 Information for use

7.1 General requirements

Machine warning devices (e.g. audible and visual signals), markings (e.g. signs, symbols; see also ISO 3719), and instructional material (e.g. manuals for operation maintenance) shall be in accordance with local regulations.

7.2 Instruction handbook

In addition to the requirements of 7.1, each machine shall be accompanied by a printed handbook in at least one of the languages of the intended user country containing the following:

a) the name and address of the manufacturer/supplier;

b) a reference to this International Standard (protection class and resistance levels) and any other standards used in the design of the machine;

c) any necessary information for safe installation (e.g. floor conditions, services);

d) instructions for how the initial test and examination of the machine and its guarding system are to be carried out before first use and being placed into production;

e) instructions for periodic maintenance, test and examination of the machine, guards and other protective devices; periodic examinations shall be capable of being carried out with equipment or accessories which are generally available, or such accessories or equipment shall be provided with the machine;

f) instructions for any test or examination necessary after change of component parts or addition of optional equipment (both hardware and software) to the machine which can affect the protective functions;

g) instructions for safe use, setting, maintenance and cleaning, including avoidance of hazardous situations associated with the machine including those associated with fluids and other materials;

h) instructions on control systems, including circuit diagrams for electrical, hydraulic and pneumatic systems;

i) the specification for any fluid to be used in lubrication, braking or transmission systems;

j) guidance on the means for the emergency release of persons trapped in the machine.

The points e), f) and g) should be checklisted for periodic checking and signing, and should include drawings and diagrams.

Information for use shall include the following:

— safe working practices (e.g. operation, setting, maintenance, cleaning);

— warning of the hazards arising from sharp accessories/components and of the need to wear appropriate personal protective equipment, particularly protective goggles or face-shields;

— procedures to minimize the probability of errors of fitting, especially for the maintenance of safety-related functions;

— limits for the spatial envelope, maximum mass, position of the centre of gravity of the rotor and work holding fixture;

— information describing residual risks.

7.3 Marking

The designation of the balancing machine (or the protection) with the protection classes (see Table 2) and its resistance levels is mandatory. An example for class C is given in clause A.4.

This marking shall state the class (or combination of classes), the criteria and the limits for which the class qualifies. Criteria and limits shall be explained in an understandable manner to allow the operator to compare his actual task and hazards with the qualification of the protection.

Additionally, each machine shall be marked in a distinct and permanent manner withthe following:

a) manufacturer's name, address, model number and reference number, year of manufacture;

b) mass of machine;

c) supply data for electrical and, where applicable, hydraulic and pneumatic systems (e.g. minimum pneumatic pressure);

d) lifting points for transportation and installation purposes, where applicable;

e) speed range, where applicable;

f) load limits of major elements (e.g. maximum positive and negative load on pedestals, maximum load and speed of rollers, drive-shafts).

Guards, protective devices and other modules that are part of the machine but not fitted shall be marked with identification data and any other information needed for fitting.

Annex A
(normative)

Class C enclosure selection

A.1 General

For the selection of an adequate class C enclosure, three criteria shall be taken into account if a particle or part may fly off the rotor at its maximum balancing speed:

a) area-specific energy;

b) absolute energy;

c) impulse.

Concerning the area-specific energy, that particle with the largest value for the ratio between the absolute energy and smallest cross-section shall be taken into account. Concerning the absolute energy, that particle producing the highest kinetic energy shall be considered. The impulse can be of importance with very heavy parts at relatively low velocity.

The user of a balancing machine shall investigate the rotor spectrum and state the potential hazards on the basis of the above-mentioned criteria.

A.2 Consideration of area-specific energy, E_{spec}

A.2.1 General

The area-specific energy E_{spec} (see Figure A.1) is a measure of the penetration capability of a particle flying off the rotor.

The area-specific energy of a particle or part E_{spec} (mN·m/mm²) is given by

$$E_{spec} = \frac{E_{abs}}{A_p} = \frac{mv^2}{2A_p} \tag{A.1}$$

where

E_{abs} is the absolute energy of the particle [see A.3.1 and equation (A.6)], but here with the dimension mN·m to satisfy the designation convention according to A.4;

A_p is the smallest cross-section of the particle (mm²);

m is the mass of the particle (g);

v is the translational velocity of the particle (m/s).

The smallest cross-section of different body shapes is illustrated by Figure A.2 [the different body shapes and materials are taken into consideration by the definition of the penetration capability according to equation (A.2)].

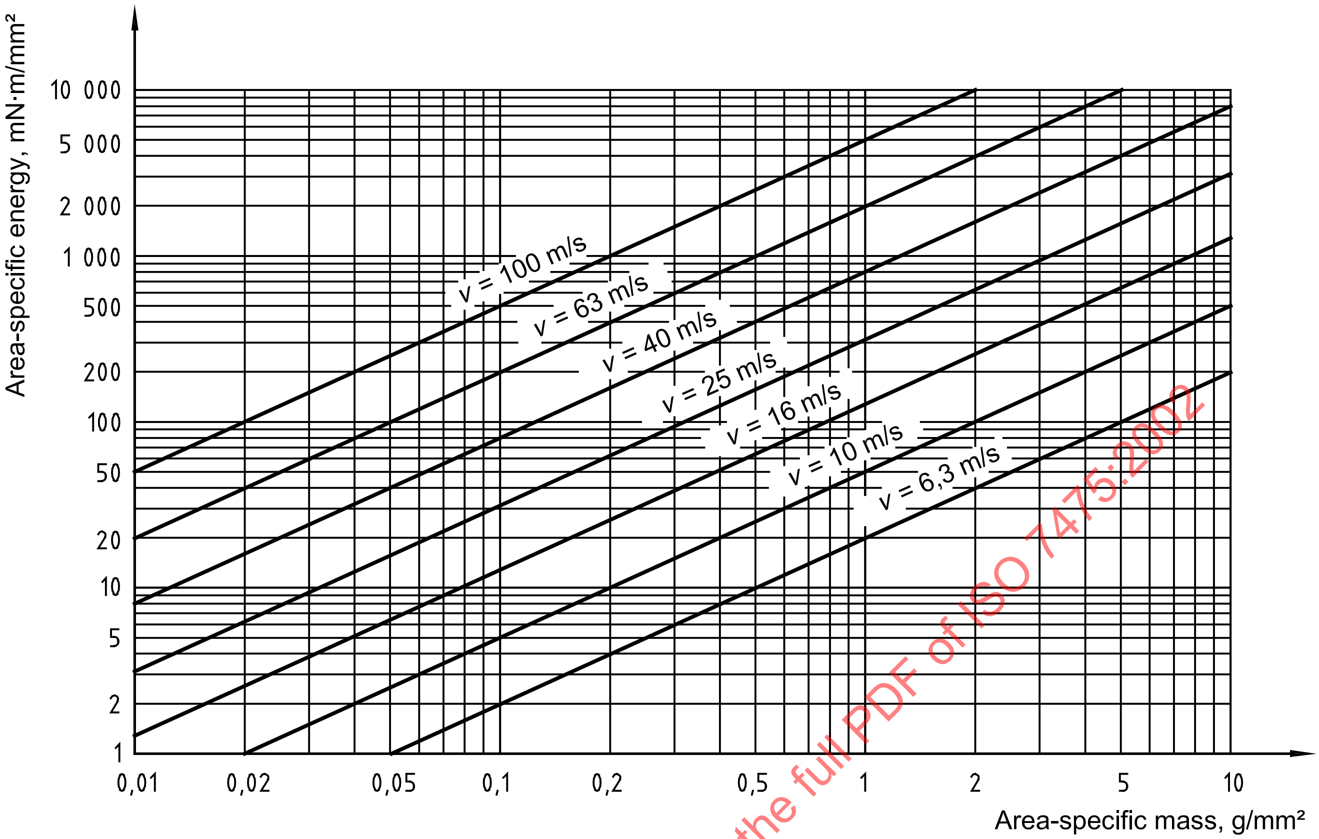

Figure A.1 — Area-specific energy, by area-specific mass and translational velocity

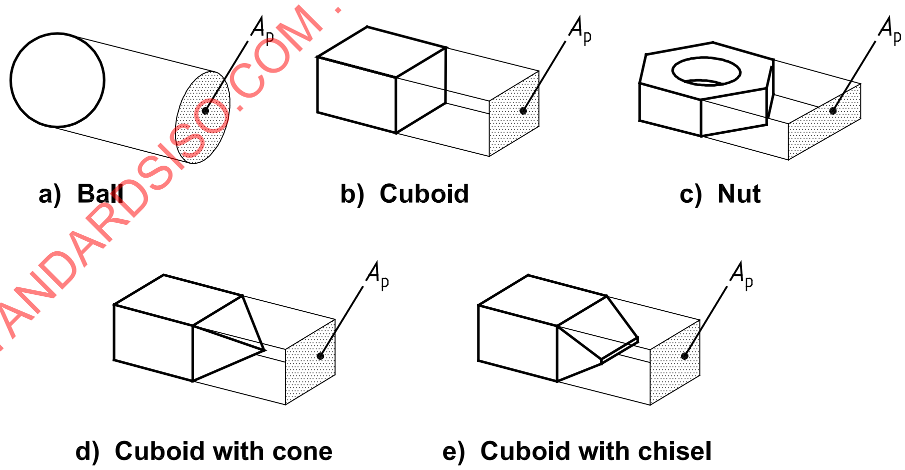

Figure A.2 — Smallest cross-section of different body shapes

The penetration capability P_{cap} of a particle (mN·m/mm²) in terms of that of a standard projectile (see Figure A.3 and Table A.1) with identical area-specific energy is given by

$$P_{cap} = f_{P,\,rel} \cdot E_{spec} \tag{A.2}$$

where

$f_{P,\,rel}$ is the particle penetration severity factor relative to the standard projectile, which reflects the influence of the material and form of a particle (dimensionless);

E_{spec} is the area-specific energy of a particle (mN·m/mm²).

For the standard projectile (see Figure A.3), $f_{P,\,rel}$ would be 1.

NOTE 1 This standard projectile is blunt and therefore differs from the projectile in the previous edition (ISO 7475:1984).

NOTE 2 It is advantageous to use the dimension mN·m/mm² since the values are more practical; see for example Figure A.1 and Table A.1.

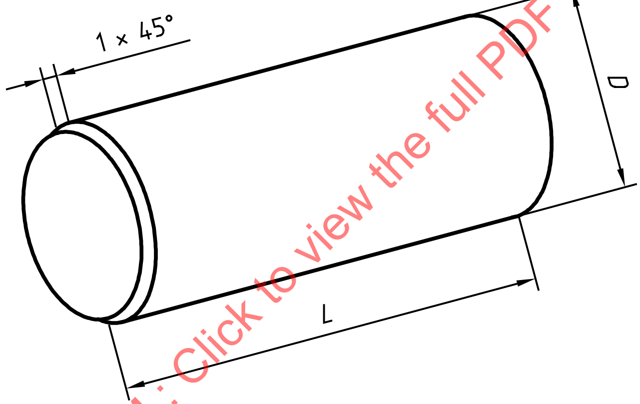

Figure A.3 — Blunt standard projectile (made out of steel with hardness 40 HRC to 50 HRC)

Table A.1 — Dimensions of blunt standard projectiles and their energies/impulses for a velocity of 20 m/s

Mass m kg	**Diameter** D mm	**Length** L mm	**Velocity** v m/s	**Area-specific energy** E_{spec} mN·m/mm²	**Absolute energy** E_{abs} N·m	**Impulse** I kg·m/s
0,01	8,6	22,1	20	34	2	0,2
0,03	12,5	31,3	20	50	6	0,6
0,1	18,6	47	20	70	20	2
0,3	26,8	67,8	20	110	60	6
1	40,1	100,9	20	160	200	20
3	57,8	145,7	20	230	600	60
10	86,4	217,3	20	340	2 000	200

As a result of penetration tests, the penetration resistance P_{res} of the material (mN·m/mm^2), which is the area-specific energy of the particle that can be absorbed when retaining it, can be approximated by

$$P_{res} = f_{m,\ std} \cdot R_m \cdot \varepsilon_B \cdot t \quad (A.3)$$

where

$f_{m,\ std}$ is the material resistance factor of the enclosure material (see A.2.2) for a standard projectile (dimensionless);

R_m is the tearing resistance of the enclosure material (N/mm^2);

ε_B is the breaking elongation of the enclosure material (dimensionless);

t is the thickness of the enclosure material (mm).

A.2.2 Verification

Verification of the penetration resistance can be carried out either by calculation or experiment.

To determine experimentally the penetration resistance of an enclosure within its weakest area, a projectile is used to impact a sample enclosure panel, point first and perpendicular to the surface. Depending on the velocity in the range up to 150 m/s, different test equipment (see annex B) may be used.

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

The projectile may pierce the enclosure material, but it shall be retained.

The penetration resistance of an enclosure (i.e. the factor $f_{m,\ std}$) shall be determined by using a standard projectile according to Figure A.3 and Table A.1.

The particle penetration severity factor $f_{P,\ rel}$ shall be determined by using a standard projectile modified to have a head section equal to the particle to be investigated.

A.2.3 Design by the manufacturer

An enclosure is qualified for an area-specific energy if for its penetration resistance $P_{res,\ qual}$ (mN·m/mm^2) the following holds true:

$$P_{res,\ qual} = \frac{P_{res}}{S_{F,\ spec}} \quad (A.4)$$

where

P_{res} is the area-specific energy which can be absorbed when retaining the particle (mN·m/mm^2);

$S_{F,\ spec}$ is the adequate safety factor concerning area-specific energy, e.g. 2 (dimensionless).

A.2.4 Selection by the user

For the user, a class C enclosure is qualified in terms of area-specific energy if the maximum penetration capability, $P_{cap,\,max}$ (mN·m/mm^2), of all particles which may fly off a rotor is less than or equal to the penetration resistance for which the enclosure is qualified:

$$P_{cap,\,max} \leqslant P_{res,\,qual} \quad (A.5)$$

where $P_{res,\,qual}$ is the penetration resistance in terms of area-specific energy for which the enclosure is qualified (mN·m/mm^2).

A.3 Consideration of absolute energy, E_{abs}

A.3.1 General

The absolute energy E_{abs} (N·m) is given by

$$E_{abs} = \frac{1}{2} m \cdot v^2 \quad (A.6)$$

where

m is the mass of the particle (kg);

v is the translational velocity of the particle (m/s).

Figure A.4 shows the absolute energy for masses between 0,01 kg and 10 kg and translational velocities between 6,3 m/s and 100 m/s. The absolute energy is a criterion for the strength of the fastening of the whole enclosure or of its components. Following a particle hit, no opening shall result through which the particle can escape from the inside of the enclosure.

This condition shall be fulfilled, especially by the joints within the enclosure and the window frames.

A.3.2 Verification

The resistance of the protective device against disintegration is checked experimentally by using a standard projectile (see Figure A.3 and Table A.1) within the velocity range of approximately 10 m/s to 30 m/s or more, if adequate.

Experimental testing can be carried out using a vertical pipe or a gun device explained in annex B. The bombardment can be made on the complete enclosure itself or on adequate components; which should be supported in a way similar to those in the actual enclosure. Concerning the direction of bombardment and the target area, the worst case should be assumed.

Experimental testing is done to determine the strength of the fastening of the whole enclosure or of its components; it is not used to determine the penetration resistance. Therefore if the standard projectile used penetrates the enclosure material during the test, a larger standard projectile shall be used with lower velocity but the same absolute energy.

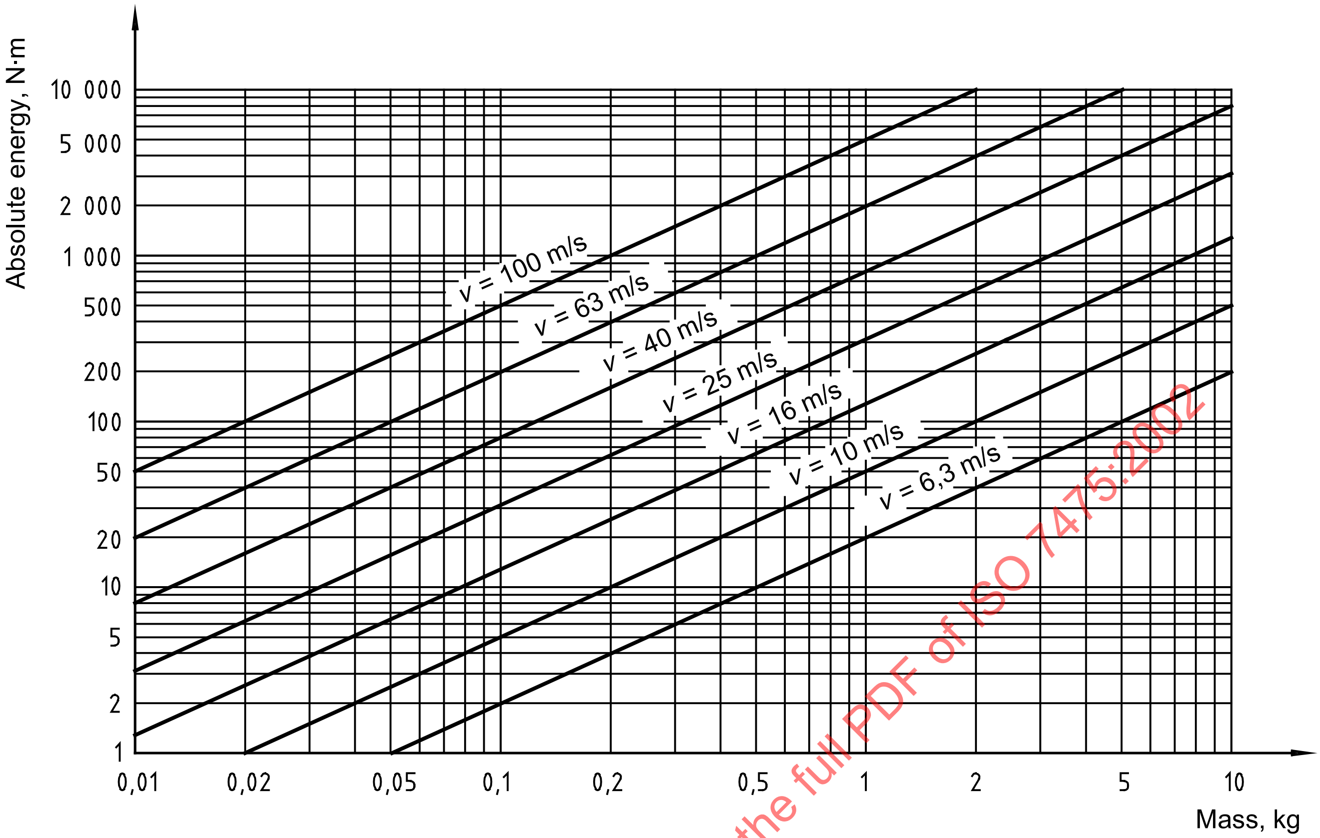

Figure A.4 — Absolute energy, by mass and translational velocity

A.3.3 Design by the manufacturer

An enclosure is qualified for an absolute energy $E_{\text{abs, qual}}$ (N·m) if the following holds true:

$$E_{\text{abs, qual}} = \frac{E_{\text{abs, adm}}}{S_{\text{F, abs}}} \tag{A.7}$$

where

$E_{\text{abs, adm}}$ is the absolute energy for which the enclosure did not suffer unacceptable damage during testing (N·m);

$S_{\text{F, abs}}$ is the adequate absolute energy safety factor, e.g. 2 (dimensionless).

A.3.4 Selection by the user

For the user, an enclosure is qualified in terms of absolute energy if the maximum energy $E_{\text{abs, max}}$ (N·m) of any of the particles which may fly off the rotor is less than or equal to the absolute energy for which the enclosure is qualified:

$$E_{\text{abs, max}} \leqslant E_{\text{abs, qual}} \tag{A.8}$$

where $E_{\text{abs, qual}}$ is the absolute energy for which the enclosure is qualified (N·m).

A.4 Designation of class C enclosures

The designation of class C enclosures is as follows:

C (value for $E_{abs, qual}$)/(value for $P_{res, qual}$) (A.9)

where

$E_{abs, qual}$ is the absolute energy for which the enclosure is qualified (N·m);

$P_{res, qual}$ is the penetration resistance in terms of area-specific energy for which the enclosure is qualified (mN·m/mm^2).

EXAMPLE C 600/230 means: maximum 600 N·m and maximum 230 mN·m/mm^2 for a class C enclosure.

NOTE The units have been chosen deliberately to be N·m and mN·m/mm^2 in order to avoid having numbers with magnitudes which are too different.

A.5 Consideration of impulse

A.5.1 General

The impulse I (kg·m/s) is given by

$$I = m \cdot v \quad \text{(A.10)}$$

where

m is the mass of the particle (kg);

v is the translational velocity of the particle (m/s).

When hit by a particle or part of the rotor due to impulse exchange, a free-standing enclosure may be displaced or may even be knocked over.

A.5.2 Verification

The resistance against impulse shall be checked by calculation. For the impulse exchange, the worst case (typically a large mass at relatively low velocity) shall be considered.

Knocking over of the enclosure shall be avoided. The possible displacement shall be reasonably limited, clearly stated and marked in the installation plan of the balancing machine/enclosure.

If necessary, the enclosure shall be anchored adequately in order to avoid it being knocked over or displaced by an unacceptable amount.

A.6 Higher particle velocity

If particle velocities higher than 150 m/s are expected, individual tests should be conducted at the expected maximum velocity.

A.7 Class C enclosures for general-purpose balancing machines

If the types of rotors are not known in advance (e.g. in service and repair) no hazards can be stated before the rotors have been defined. Some typical data for different machine sizes may help (see Table A.2) to decide on a suitable enclosure.

Table A.2 — General-purpose balancing machines — Suggested class C enclosures when possible hazards cannot be stated in advance

Balancing machine capacity, kg	1,5	8	50	250	1 500	8 000	50 000
Qualified absolute energy, $E_{abs, qual}$, N·m	2	6	20	60	200	600	2 000
Qualified area-specific energy, $E_{res, qual}$, mN·m/mm^2	30	50	70	110	160	230	340
Designation of enclosure	C 2/30	C 6/50	C 20/70	C 60/110	C 200/160	C 600/230	C 2 000/340

For each rotor to be balanced on this machine, a risk assessment shall be made. If all risks are within the stated capability of the enclosure, the balancing machine can be started. If not, either the risk shall be reduced to match the capability (e.g. by changing the speed, the balancing and/or correction method), or the enclosure shall be reinforced.