BS EN 12547:2014

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Centrifuges — Common safety requirements

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National foreword

This British Standard is the UK implementation of EN 12547:2014. It supersedes BS EN 12547:1999+A1:2009 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/19, Centrifuges.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Centrifugeuses - Prescriptions communes de sécurité

Zentrifugen - Allgemeine Sicherheitsanforderungen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (EN 12547:2014) has been prepared by Technical Committee CEN/TC 313 “Centrifuges - Safety requirements”, the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2015 and conflicting national standards shall be withdrawn at the latest by April 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12547:1999+A1:2009.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

The major changes are as follows:

The references in the standard have been updated, thermal hazards have been included, text regarding integrity of the safety related parts of the control system has been further elaborated, the order of the annexes has been changed and the list of hazards has been moved to the main body of the standard.

Annex B of this European Standard is normative, whereas Annex A, Annex C, Annex D and Annex ZA are informative.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document is a type C standard as stated in EN ISO 12100:2010.

The machinery concerned and the extent to which hazards, hazardous situations and hazardous events are covered are indicated in the scope of this document.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of this type C standard.

The extent to which significant hazards are covered is indicated in Clause 1. It is indicated in greater detail in Clause 4.

Manufacturers are required to collect, retain and make available sufficient information, to enable centrifuges to be installed, commissioned, used, maintained and disposed of safely, i.e. that information is made available to users of centrifuges.

Different applications and particular centrifuge designs exist. Annex A includes more details of both of these ranges.

1 Scope

1.1 This European Standard applies to centrifuges for the separation or change in concentration of mixtures of liquids and solids.

It gives requirements to minimize the risks caused by the significant hazards arising during the operation of centrifuges as specified in 1.2.

1.2 This European Standard gives requirements for minimizing the risks caused by the following hazards:

— mechanical hazards common to all types of centrifuges, except those specified in 1.3;

— ergonomical hazards;

— thermal hazards;

— electrical hazards;

— noise.

1.3 Types of centrifuges and hazards excluded

1.3.1 Types of centrifuges excluded:

— centrifuges with a kinetic energy of rotation less than 200 J;

— centrifuges for household use;

— centrifuges for laboratory use according to EN 61010-2-020;

— centrifuges for forming, i.e. centrifugal hot metal casting machines.

1.3.2 Hazards excluded

This European Standard does not deal explicitly with the hazards listed below.

NOTE 1 In cases, where such hazards might occur and could become relevant for the construction of the centrifuge, use specific standards for this hazard or make a risk assessment.

— hazards caused by overpressure or negative pressure inside the centrifuge housing;

— hazards specific to processing radioactive products;

— hazards specific to microbiological processing - including viral and parasitic hazards;

— hazards from processing corrosive and/or erosive materials;

— hazards from processes involving flammable or explosive substances;

— hazards caused by leakage of hazardous substances;

— hazards caused by unsuitable hygienic design for applications involving food products;

— inherent chemical hazards of process materials and/or service media and their biological effects on exposed persons;

NOTE 2 Inherently hazardous substances include toxic, carcinogenic and flammable substances for example. Other substances may be hazardous because of their condition in the centrifuge, i.e. temperature, velocity and vapour pressure.

— hazards due to construction materials;

Materials used in the construction of centrifuges should not be hazardous in the condition in which they are used.

— centrifuges subject to application specific standards (e.g. EN 12505).

NOTE 3 The design of centrifuges covered by EN 12547 varies to the extent that additional hazards may exist that are not covered by the requirements of this standard and is not excluded above. The manufacturer is responsible for providing suitable measures to deal with these hazards as part of a general risk assessment for the machine. Such measures are outside the scope of this standard and the direct responsibility of the manufacturer.

1.3.3 This European Standard gives guidance on the selection of performance levels according to EN ISO 13849-1:2008, but does not identify performance levels for specific applications.

1.4 This European Standard is not applicable to centrifuges which are manufactured before the date of its publication as EN.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 349, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

EN 894-2:1997+A1:2008, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 2: Displays*

EN 894-3:2000+A1:2008, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 3: Control actuators*

EN 953:1997+A1:2009, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

EN 1005-2:2003+A1:2008, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

EN 1037:1995+A1:2008, *Safety of machinery — Prevention of unexpected start-up*

EN 60204-1:2006, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements (IEC 60204-1:2005, modified)*

EN 60529:1991, *Degrees of protection provided by enclosures (IP Code) (IEC 60529:1989)*

EN 61000-6-2, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments (IEC 61000-6-2)*

EN 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments (IEC 61000-6-4)*

EN 61310-1:2008, *Safety of machinery — Indication, marking and actuation — Part 1: Requirements for visual, acoustic and tactile signals (IEC 61310-1:2007)*

EN 62061, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems (IEC 62061)*

EN ISO 780, *Packaging — Pictorial marking for handling of goods (ISO 780)*

EN ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards (ISO 3740)*

EN ISO 3834-2:2005, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements (ISO 3834-2:2005)*

EN ISO 3834-3:2005, *Quality requirements for fusion welding of metallic materials — Part 3: Standard quality requirements (ISO 3834-3:2005)*

EN ISO 4871:2009, *Acoustics — Declaration and verification of noise emission values of machinery and equipment (ISO 4871:1996)*

EN ISO 5817:2014, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections (ISO 5817:2014)*

EN ISO 9614-1:2009, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points (ISO 9614-1:1993)*

EN ISO 9614-2:1996, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning (ISO 9614-2:1996)*

EN ISO 9614-3:2009, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 3: Precision method for measurement by scanning (ISO 9614-3:2002)*

EN ISO 11688-1:2009, *Acoustics — Recommended practice for the design of low-noise machinery and equipment — Part 1: Planning (ISO/TR 11688-1:1995)*

EN ISO 11688-2:2000, *Acoustics — Recommended practice for the design of low-noise machinery and equipment — Part 2: Introduction to the physics of low-noise design (ISO/TR 11688-2:1998)*

EN ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction (ISO 12100:2010)*

EN ISO 13732-1:2008, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces (ISO 13732-1:2006)*

EN ISO 13849-1:2008, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design (ISO 13849-1:2006)*

EN ISO 13850:2008, *Safety of machinery — Emergency stop — Principles for design (ISO 13850:2006)*

EN ISO 13857:2008, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs (ISO 13857:2008)*

EN ISO 14119:2013, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection (ISO 14119:2013)*

3 Terms and definitions

For the purposes of this document, the terms and definition given in EN ISO 12100:2010 and the following apply. Further definitions, giving the preferred terminology for all major parts of centrifuges and being a non-exhaustive list of types of centrifuges, not necessary for the understanding of this standard, are given in Annex A.

3.1 General terms

3.1.1
centrifuge
separation device with a chamber that – when in operation – rotates around its symmetry axis and thus subjects the process material to a centrifugal force

3.1.2
particular centrifuge design
family of centrifuges which may have minor variations in the basic dimensions or speed, but with basically similar specifications and properties of materials of construction

3.1.3
relevant hazard
hazard which is identified as being present at, or associated with, the machine

[SOURCE: EN ISO 12100:2010, 3.7]

Note 1 to entry: A relevant hazard is identified as the result of one step of the process described in EN ISO 12100:2010, Clause 5.

3.1.4
significant hazard
hazard which has been identified as relevant and which requires specific action by the designer to eliminate or to reduce the risk according to the risk assessment

[SOURCE: EN ISO 12100:2010, 3.8]

3.2 Parts of a centrifuge

3.2.1
drum
chamber which holds the process material, and is arranged to rotate about its symmetrical axis

3.2.2
hoop
ring secured to the outer periphery of a drum to give extra strength

3.2.3
basket
drum used for filtration purposes

3.2.4
bowl
drum used for the separation of immiscible liquids and/or the sedimentation of solids

3.2.5
rotor
assembled part of the centrifuge which rotates, comprising drum and shaft together with their attachments

3.2.6
casing
housing
enclosure in which at least the drum rotates and which may constrain process materials and the separated phases leaving the drum to particular paths

Note 1 to entry: The casing may consist of several components.

3.2.7
casing cover
lid
part fixed to the casing to provide access, for example for inspection, operation or maintenance

3.2.8
discharge device
device to induce discharge of liquids and/or solids from the centrifuge rotor

Note 1 to entry: A discharge device can for example be a paring tube which discharges a liquid from a rotating rotor by dipping a fixed tube into the liquid.

3.2.9
scraper
plough
peeler
device for the removal of centrifuged solids from the rotating drum

3.2.10
critical component
part of a centrifuge that cause significant hazardous situations to develop when it fails or ruptures

3.2.11
special lifting accessory
device tailored to the lifting and other handling requirements of a centrifuge or specific component of the centrifuge

3.3 Operational terms

3.3.1
process material
substances fed to a centrifuge for separation and other purposes, for example washing, purging or drying the load

3.3.2
filling mass
total mass of process material in the drum at any instant

3.3.3
maximum filling mass
filling mass determined by the limiting features of the centrifuge, for example either drum strength or linear dimensions

3.3.4
cleaning in place
CIP
cleaning of equipment by impingement or circulation of flowing chemical solutions and water rinses into, onto and over surfaces in equipment or systems without dismantling, using equipment designed and installed for that purpose

3.3.5
kinetic energy of total rotating system
total kinetic energy of the rotor together with the filling mass at operating speed

3.3.6
maximum temperature
maximum allowable temperature of the process material declared by the manufacturer

3.3.7
minimum temperature
minimum allowable temperature of the process material declared by the manufacturer

3.3.8
normal operation
operating condition of the centrifuge, determined by specification and design, considering feed and wash rates, load, vibration, rotational speeds, etc.

Note 1 to entry: Normal operation includes start up and shut-down procedures.

3.3.9
operating speed
<centrifuge> rotational speed measured in revolutions per unit time at which the rotor revolves either at constant speed during continuous operation or intermittently with different rotational speeds when operating in several steps during a multispeed programme

3.3.10
purging
removal of unwanted material from a centrifuge by means of a flushing media

3.3.11
throughput
⟨centrifuge with continuous process material flow⟩ actual feed rate

3.3.12
throughput
⟨centrifuge using a batch or non-continuous process⟩ charge mass per cycle and cycle time

3.3.13
out of balance
unbalance
unequal distribution of filling mass and/or rotor mass which produces oscillating forces during rotation

3.3.14
service media
liquids, gases etc. used for operating the centrifuge

3.3.15
critical speed
characteristic speed or rotating frequency of the centrifuge at which resonance of the centrifuge system is excited

3.3.16
run down time
period between the time at which the stop command is initiated and the time at which the rotor has stopped completely

3.3.17
maximum run down time
run down time that is required by the centrifuge after having been switched off or e.g. after an electrical power outage to come to a complete standstill without any deceleration device

3.3.18
dangerous run down time
run down time which is longer than the time needed for a skilled person to remove a guard and to reach dangerous moving parts of the machine

4 List of significant hazards

Table 1 is a list of significant hazards associated with the use of a centrifuge. The table is the result of a risk assessment carried out in accordance with EN ISO 12100:2010, Clause 5, for all centrifuges covered by the scope of this standard.

The technical measures in Clause 5 and information for use in Clause 7 are based on that risk assessment, and deal with the identified hazards by either eliminating them or reducing the effects of the risks they generate.

The designer should determine which of the hazards in Table 1 are applicable to their centrifuge design, paying particular attention to the intended use of the centrifuge including maintenance and cleaning, and of its reasonably foreseeable misuse. The designer should also consider other hazards related to the design of the centrifuge.

Table 1 — List of significant hazards

Hazards (see EN ISO 12100:2010, Annex B**)**	**Clause/subclause in this European Standard**
Hazards, hazardous situations and hazardous events	
Mechanical hazards	
Ejection of parts	5.2.1
Ejection of high kinetic energy process material or service media	5.2.2
Dangerous movement	5.2.3
Access to moving parts	5.2.6
Electrical hazards due to:	
Contact of persons with live parts (direct contact)	5.3
Contact of persons with parts which have become live under faulty conditions (indirect contact)	5.3
Noise hazards	
Noise	5.7, Annex B
Ergonomic hazards	
Unhealthy postures or excessive effort	5.2.4, 5.2.5, 5.4
Design, location or identification of control devices	5.4
Thermal hazards	5.5
Unexpected start-up, unexpected overrun/overspeed (or any similar malfunction)	
Restoration of energy supply after an interruption	5.6

5 Safety requirements and/or protective measures

5.1 General

Machinery shall comply with the safety requirements and/or protective measures of this clause. In addition, the machine shall be designed according to the principles of EN ISO 12100:2010 for relevant but not significant hazards, which are not dealt with by this document.

Centrifuges shall be so designed and manufactured as to withstand the loads associated with the specified and reasonably foreseeable operating and maintenance conditions without endangering the safety and health of exposed persons.

All hazards shall where possible be avoided by design (EN ISO 12100:2010, 6.2). Where this is not possible one or several protective measures shall be taken. Any residual hazards shall be indicated by warning labels positioned adjacent to the hazard and included in the instructions for use. Where personnel protective equipment is required this shall be stated in the instructions for use.

When applicable, requirements/measures already contained in other standards, specifically in EN ISO 12100:2010 or in type B-standards, reference is made to them.

The following parameters shall be taken into account, if applicable, for the purpose of designing, provision of information for use (instruction manuals, etc.), testing, inspection, operating and servicing centrifuges.

— allowed speed range;

— maximum filling mass;

— maximum and minimum through-put;

— starting, stopping, feeding and discharging sequences (cyclic loading);

— allowable ambient temperature range;

— excluded use (for example related to corrosive, erosive, explosive/flammable and toxic properties of the material to be processed by the centrifuge);

— allowable process material temperature range;

— minimum and maximum casing pressure;

— out of balance or vibration limits (dangerous movement);

— maximum power input;

— requirements and limitations regarding installation and connections (for example foundation, piping, ducting loading);

— corrosion and wear allowance on critical components;

— allowable dimensions on critical components;

— inspection/replacement intervals for safety related parts (see example in 5.6);

— inspection/replacement intervals for critical components.

A risk assessment carried out by the manufacturer should identify which of the hazards in Table 1 that are applicable to the centrifuge being produced taking into account intended use, maintenance, cleaning and reasonable foreseeable misuse. This risk assessment should also identify any additional hazards for the specific application. The manufacturer is responsible, outside the scope of this standard, for the provision of suitable protective measures to deal with the risks associated with additional hazards.

5.2 Mechanical hazards

5.2.1 Ejection of parts

5.2.1.1 Rotor rupture

5.2.1.1.1 General

The centrifuge shall be so designed and manufactured that:

a) there is no risk of a rotor rupture;

and/or;

b) the casing is capable of containing a ruptured rotor, for example a casing constructed of steel withstanding and containing the energy of the ruptured rotor.

To comply with 5.2.1.1.2 centrifuge rotors shall be manufactured from suitable materials with verified properties taking into account the operating environment (e.g. temperature, corrosion and erosion) and steady and/or cyclic loading.

5.2.1.1.2 Steady loading

The rotor shall be designed, manufactured and tested so that rotor rupture cannot occur under normal operating conditions. The manufacturer shall ensure a safety margin against general yielding and rupture, taking into account the steady loading due to the rotation of the rotor mass and the maximum filling mass.

The strength of cylindrical baskets or bowls may be determined using the simple method of analysis specified in Annex C provided that the loading, geometry and material of construction satisfy the requirements stated in that annex.

For stress analysis of more complex geometry's an elastic-plastic FEM (Finite Element Method) calculation is considered to be the most suitable.

NOTE The 120 % overspeed in 6.2 does not reflect the safety margin required for the rotor.

If a drive mechanism is employed which could drive the centrifuge at a speed higher than its maximum permissible speed, such as a frequency converter and a hydraulic drive, a speed control and an overspeed prevention device to prevent the rotor from exceeding the maximum permitted speed shall be provided, see 5.6.

5.2.1.1.3 Cyclic loading

The rotor shall be designed with a safety margin against fatigue failure.

Stresses which shall be considered in a fatigue evaluation are:

— bending stresses in horizontal rotors caused by the weight of the rotor;

— bending stresses in rotors caused by external forces such as loads from belt drives etc.;

— stresses caused by cyclic loading of the centrifuge (for example related to intermittent loading and discharging of process materials);

— stresses caused by unbalanced forces of rotors, in particular in the case of dual rotor systems.

All other foreseeable cyclic loads acting on the rotor shall be taken into account.

The operating load acting on a rotor as a result of the start/stop cycle of a centrifuge shall be considered as a cyclic load. The load and expected number of cycles shall be assessed to determine if this will lead to fatigue failure during the foreseeable life of the centrifuge.

Stress raisers such as sharp edges, perforations, rough surfaces (scores, grinding cracks etc.) and bores shall be avoided in regions subjected to high cyclic stresses.

All peak stresses at perforations or discontinuities shall be considered in the evaluation of the safety margin against fatigue failure.

The welding of all seams important to the integrity of a rotor shall be carried out in accordance with the requirements in EN ISO 3834-2:2005 or EN ISO 3834-3:2005.

The reduction of fatigue strength for structures with welded seams subject to cyclic loading shall be taken into account.

All welded seams on parts subjected to cyclic loads shall be machined to remove end craters, weld undercuts and arc strikes.

NOTE The 120 % overspeed in 6.2 does not reflect the safety margin required for the rotor.

5.2.1.2 Ejection of rotor parts

The risk of any rotor parts coming loose and being ejected (and the possible consequential discharge of high kinetic energy process material; see also 5.2.2) from the centrifuge shall be dealt with by:

a) ensuring that connections between rotor parts and connections of parts attached to the rotor can withstand all foreseeable loads on the connections considering the operating environment of the connection;

and/or

b) by having a casing capable of containing loosened or broken rotor parts, for example a casing manufactured of steel withstanding and containing the energy of the parts and deforming of the parts and/or the casing.

Connections and attached parts subjected to cyclic loading shall have a fatigue life that exceeds the foreseeable service life. All steady and cyclic loads on mechanical connections between rotor parts, as mentioned in 5.2.1.1, shall be considered.

When screwed and/or bolted connections are used for connecting rotor parts subjected to pressure loading from the filling mass, the screws shall be able to carry the sum of the pressure load and other loads on the connection related to the operation of the centrifuge, with a safety margin against rupture of the screws.

All thread type joints subjected to vibration and cyclic loads shall be secured against coming loose by pretensioning. The tightening torque for all critical joints requiring pretensioning shall be specified by the manufacturer.

The design for screwed and/or bolted joints requiring pretensioning shall be such that there is no risk of loss of pretensioning due to settling in the joint and indentation below screw heads and nuts.

The design of screwed and/or bolted connections should follow approved standards.

If it is not possible to secure screwed and bolted joints by specified pre-tensioning, it shall be secured against coming loose by a safe positive locking device, or by a method with an equal safety margin.

Mechanical connections shall be designed so that risk for erosion and corrosion is minimized.

The manufacturer shall specify precautions and inspection/replacement criteria for the parts of the connections between rotor parts subjected to corrosion and/or erosion.

5.2.1.3 Ejection of stationary parts

The risk of stationary parts or debris of such parts being ejected from the centrifuge as a consequence of heavy out of balance or vibration, ejection of rotor parts or a rotor rupture, or as a consequence of those stationary parts failing and/or loosening and being accelerated by the rotor and ejected (and the possible consequential discharge of high kinetic energy process material; see also 5.2.2) shall be dealt with by:

a) having a casing capable of containing loosened and accelerated stationary parts, for example a casing manufactured of steel withstanding and containing the energy of those parts and reducing the energy by friction between those parts and the casing or by deforming of those parts and/or the casing;

and/or by

b) employing specified and well controllable methods for fastening critical stationary components and ensuring that any critical part and its attachments subjected to high or low frequency cyclic loading have a fatigue life exceeding the specified or foreseeable service life with a sufficient margin.

For centrifuges without fixed vibration sensor the manufacturer shall specify reference points and directions for vibration measurement in the information for use (7.2.3).

For a centrifuge with a fixed vibration sensor it is the signal from this sensor that shall be used.

In both cases the manufacturer shall specify the maximum allowable vibration level for continuous operation and the maximum allowable vibration level for immediate stop.

Centrifuges shall be designed and manufactured in such a way as to safely withstand for a short duration of time start-up, operation (tested for 6 h) and run-down at the out of balance or vibration level for immediate stop.

If a particular centrifuge design cannot be operated safely with a reasonable excess out of balance or vibration level at the maximum allowable levels, then means for detecting and preventing these conditions shall be provided. The manufacturer shall carry out a risk analysis and ensure that the means provided for preventing these conditions have the appropriate safety level.

The manufacturer shall also specify how the centrifuge shall be accelerated or decelerated through any critical speed.

When it is necessary to keep the bowl filled, and/or maintain a flow, during the stopping period of a centrifuge, in order to avoid hazards due to vibration or unbalance conditions, this shall be specified in the information for use (7.2.3).

Centrifuges charged manually and/or operated with frequent starts and stops and centrifuges which can be affected dangerously by out of balance forces shall be equipped with a decelerating device. The decelerating device shall be so designed that the time taken to pass through any critical speed will be so short that the vibration energy will not develop hazardous movement. Examples of such decelerating devices are mechanical brakes, water brakes, hydraulic brakes, pneumatic brakes, electrical motor brakes and magnetic brakes.

5.2.2 Ejection of high kinetic energy process material or service media

Centrifuges shall be so designed and installed that neither solids, liquids, gases nor fumes can escape under normal and predictable circumstances if such an escape can cause impact hazards.

An example where the risk of such impact hazard has to be considered is for the solids outlet at centrifuges where the solids leave the drum at the periphery. Depending on the design of the drum the solids may leave the outlet at a velocity close to the peripheral velocity of the drum. There are several ways to dissipate the kinetic energy. One way is to use a cyclone where the solids can rotate until their velocity is reduced. Another way is to design the drum casing in such a way that the velocity is reduced in a similar way by rotation inside the casing. A third way is to use a closed receiving system having sufficient strength to handle the high velocity.

If a centrifuge is equipped with covers or hatches that need to be removed for cleaning or service when the centrifuge is at a standstill, but can cause a hazard by escape of material if they are removed when the centrifuge is running or have not been replaced, then those covers or hatches shall be designed according to the requirements in 5.2.6. Examples of such openings are for cleaning and inspection at the top of a solids outlet cyclone and openings in the bowl cover for cleaning and inspection of the nozzles of a nozzle centrifuge.

A hazard caused by escape of process or service media can occur if a connection between the centrifuge and equipment connected to the centrifuge is damaged. These connections shall be designed to withstand the forces to which they can be exposed. If for example the centrifuge is designed to be mounted on vibration isolators the connections shall be designed in such a way that the forces which are transmitted to the connections when the centrifuge moves, will not cause fracture.

All connections between the centrifuge and the fixed pipe work should be flexible to be able to withstand the movements of the centrifuge during all modes of operation.

Centrifuges which have a discharge device that can give a high pressure in predictable circumstances (for example a paring tube working against a closed valve), shall have connections designed for this pressure or means shall be provided to prevent the occurrence of this pressure.

5.2.3 Dangerous movement and vibration

5.2.3.1 General

Requirements for flexible connections shall be specified in the information for use (process media, service media and electrical connections). The electrical aspects of dangerous movement and vibration are covered in 5.3.3.

Means of protection, e.g. prevention of access, minimum gaps according to EN 349, shall be provided if crushing hazards exists at the centrifuge, or parts of it, and its surrounding area.

5.2.3.2 Fixing of centrifuges to foundation

The manufacturer shall specify the principles for fixing centrifuges that are to be fixed to a foundation to ensure that the centrifuge and foundation can withstand the occurring forces.

5.2.4 Transportation

Centrifuge crates shall be marked with the weight of the crate, the location of the centre of gravity, the location of securing positions (if applicable) and the location of lifting position if the transportation weight exceeds 25 kg (see Figure 1).

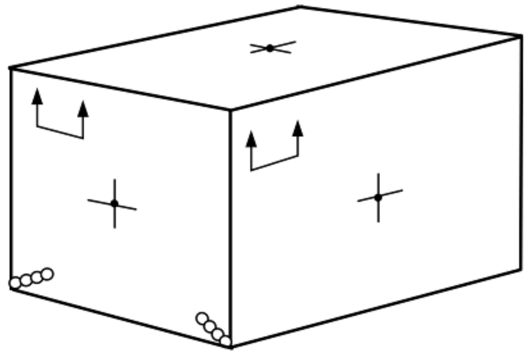


Figure 1 — Example of indication on crates

The graphical symbols used shall correspond to EN ISO 780.

5.2.5 Lifting

Instructions for lifting the centrifuge out of a centrifuge crate shall be included with each centrifuge in an easily accessible position in the crate, and that position shall be indicated on the crate.

Instructions for lifting the complete centrifuge, the rotating assembly and other major sub-assemblies, with a total weight of 15 kg or more respectively, shall be provided in the instruction manual. See also EN 1005-2:2003+A1:2008 and EN ISO 780.

If the centrifuge requires special lifting accessory these shall be referred to in the instruction manual.

The design of special lifting accessories should be consistent with existing standards for similar lifting accessories.

5.2.6 Access to moving parts

It shall be ensured that covers, fixed or removable, are not opened or removed while parts are turning.

NOTE It can take a considerable time to come to a complete stop after the power has been cut or a shutdown has been initiated.

The instructions for operation shall specify the use of a power supply disconnecting device according to EN 1037:1995+A1:2008, 5.1, for access associated with maintenance or repair.

Centrifuges shall be so designed that moving parts are not accessible accidentally with easy means during operation. Openings in guards shall be designed according to EN ISO 13857:2008. Guards shall be selected according to the criteria in Table 2. Principles for the design of interlocking guards and interlocking guards with guard locking shall be according to EN ISO 14119:2013, EN 953:1997+A1:2009, and EN ISO 13849-1:2008.

The manufacturer shall indicate the maximum run down time of the centrifuge, if necessary in various predictable circumstances, as the run down time of a centrifuge is longer than for most rotating machines of similar size.

The guard requirements of different types of openings shall be according to Table 2.

Table 2 — Selection of guards

Purpose of opening	Dangerous run down time[b]	Guard requirement
Access during normal operation e.g. to feed or remove product at stop (EN ISO 12100:2010, 6.3.2.3)	Yes	Guard, requiring tool for opening, with interlocking device_(the time for opening shall be greater than the run down time), or: interlocking guard with guard locking if frequent access is needed[d] .
	No	Interlocking guard
Maintenance or repair, not during normal operation[a] (of EN ISO 12100:2010, 6.3.2.2 and 6.3.2.4)	No	Fixed guard [c]

[a] Provided that these openings are clearly defined in the instructions for use, and that warnings are applied.

[b] See definition in 3.3.15.

[c] Fixed guards in compliance with EN 953:1997+A1:2009. The fixing element shall remain attached to the guard or machine when the guard is removed.

[d] Frequent access in this sense means once a day or more often.

5.3 Electrical hazards

5.3.1 Common hazards

Electrical equipment shall be designed and constructed in accordance with EN 60204-1:2006. The selection of control and indicating equipment shall take into account the environment in which the equipment will operate. The protection class of the equipment shall be according to the requirements in EN 60529:1991.

The following choices for centrifuges as permitted by EN 60204-1:2006 shall be followed (see also 5.4 and 5.6):

Control gear in the vicinity of the centrifuge shall be protected to a minimum of IP54 of EN 60529:1991.

Control devices at the centrifuge shall be protected to a minimum of IP55 of EN 60529:1991. All safety related control devices installed in locations, which are flushed with water or subjected to water and/or other liquids during operation of the centrifuge shall be protected to a minimum of IP56 of EN 60529:1991.

Centrifuges shall have sufficient immunity from electromagnetic disturbances to enable them to operate safely as intended and not fail to danger when exposed to the levels and types of disturbances intended by the manufacturer, see EN 61000-6-4 and EN 61000-6-2. The manufacturer of the machines shall design, install and wire the equipment and sub-assemblies taking into account the instructions of the suppliers of these sub-assemblies.

5.3.2 Specific hazards

Access to electrical equipment associated with the drive motor shall be prevented or prohibited until the rotor is known to be stopped.

5.3.3 Movement and vibration

A centrifuge or centrifuge part may move relative to the foundation due to out of balance. Centrifuges which are rigidly mounted, and centrifuges which are set-up on vibration isolators, are subject to relative movements.

This relative movement shall be taken into account when electrical cables are fitted to:

— sensors and actuators;

— electric drives;

— other electrical equipment.

Cables shall be selected and installed so that they can withstand predictable movement and/or vibration. See EN 60204-1:2006, 13.4.3, for connection and EN 60204-1:2006, Table D.4 for classification of conductors.

5.4 Ergonomical hazards

The manufacturer shall provide the centrifuge with additional equipment to avoid personal manual lifting of heavy or awkward loads (see 5.2.5), or if this cannot be avoided, the manufacturer shall provide instructions for use (see Clause 7) which will enable all the essential actions to be performed safely.

The manufacturer shall also provide:

— procedures associated with maintenance operations;

— information on control setting and how to investigate maloperation if the motion of any part is necessary during maintenance operations;

— information on the necessity of having only trained and suitably experienced personnel when determining extent or manner of malfunctions on machines with moving parts during maintenance operations;

— data relating to the position of machine controls which are non-machine mounted.

Machine controls shall be positioned so that persons operating the machinery are able to remain in a safe position whenever the need to operate the controls arises. In particular, stop controls shall be close to the centrifuge in a position clearly discernible from any foreseeable operating position.

In designing and marking centrifuge displays and control actuators EN 894-2:1997+A1:2008, EN 894-3:2000+A1:2008, EN 61310-1:2008 and EN 61310-2:2008 shall be used as appropriate. The colour of push-buttons shall comply with EN 60204-1:2006, 10.2.1 and indicator lights and displays with EN 60204-1:2006, 10.3.2.

5.5 Thermal hazards

If during the intended use of the centrifuge there could occur thermal hazards, these have to be taken into account – as far as appropriate – in accordance with EN ISO 13732-1.

5.6 Integrity of the safety related parts of control systems

5.6.1 Integrity of safety-related parts of control systems

Parts of machinery control systems assigned to provide safety functions are called safety related parts of control systems. The safety functions shall be designed in accordance with EN ISO 13849-1:2008 or EN 62061. An example on how to determine the performance level by using the risk assessment in EN ISO 13849-1:2008 is presented in Annex D. The actual PL_r or SIL for a specific application can vary and be significantly different from that given by the example.

NOTE 1 There are two different standards that handles safety related parts or functions, namely EN 62061 that handles only electrical part or functions and EN ISO 13849-1 that handles all types of parts or function such as electrical, mechanical, hydraulic and pneumatic. In many cases the safety related functions are only electrical and then both standards are applicable. A risk assessment based on EN 62061 will give the result as a SIL (= Safety Integrity Level) and a risk assessment based on EN ISO 13849–1 will give the result as a required performance level PL_r. The validation of chosen solutions to realize the safety function of safety related parts of a control system can be managed in accordance with EN ISO 13849-2. The approximate relationship between performance level and safety integrity level is given in EN ISO 13849-1:2008, Table 4.

NOTE 2 The requirements for PL_r or SIL is the responsibility of the centrifuge manufacturer. The verification of PL_r or SIL is the responsibility of the supplier of the control system. The requirements and verification is handled in EN ISO 13849-1:2008, EN ISO 13849-2:2012 or EN 62061. Dealing with this matter can require an input from component manufacturers or users.

Examples of safety related parts are:

— interlocking guards;

— interlocking guards with guard locking;

— monitoring and control systems with safety related functions.

Other parts, that might have a safety related function, are, e.g.

— vibration monitoring;

— speed control.

A vibration monitoring system used to allow a centrifuge to operate safely shall be defined as a safety related part of a control system, see 5.2.1.3.

A speed monitoring system which is used as a part of an over speed protection system (see 5.2.1.1) or to determine if the rotor has stopped (see 5.2.6) shall be defined as a safety related part of a control system.

After a stop, the centrifuge shall start only on an intentional start command (see EN 1037:1995+A1:2008). It shall not start unexpectedly, e.g. by

— a start command which is the result of a failure in safety related parts of the control system;

— a start command generated by a sensor initiated by dangerous movement or other event;

— restoration of the power supply after an interruption etc.

5.6.2 Emergency stop systems

Emergency stop equipment, if applicable, shall comply with and be selected according to the requirements in EN ISO 13850:2008.

5.7 Noise

The information and technical measures to control noise at source given in EN ISO 11688-1:2009 shall be taken into account when designing a centrifuge. Additional or alternative measures giving an identical or higher reduction may be used. See Annex B.

NOTE 1 EN ISO 11688-2 gives useful information about noise-generating mechanisms.

NOTE 2 The following is a non-exhaustive list of noise sources that can be present:

— airborne noise sources: turbulence created by rotating parts;

— liquid-borne noise sources: turbulence and cavitation;

— structure-borne noise sources: tooth meshing, rolling and magnetic fields.

6 Verification of the safety requirements and/or protective measures

6.1 General

The verification procedures according to this clause to shall be carried out for each type of centrifuge to demonstrate compliance with the requirements in Clause 5.

Table 3 indicates the method by which the conformity with the requirements in Clause 5 shall be verified. The table has the following columns:

— **Visual inspection** of the components will be used to verify the features necessary for the requirement;

— **Performance check/test** will verify that the features provided perform their function in such a way that the requirement is met;

— **Measuring by instrument** will verify by the use of instruments that requirements are met;

— **Calculations/drawings** will verify that the design characteristics of the components provided will meet the requirements;

— **Verification according to** indicates references for further information.

Table 3 — Methods of verifying the conformity with the safety requirements and/or measures

Clause		Verification method				Related standards[a]
		Visual inspection	Performance check/test	Measuring by instrument	Checking drawings/ calculation	
5.2.1.1 a	Ejection of parts by rotor rupture Rotor rupture prevented by design.	X	6.2		e.g. Annex C	EN ISO 3834-2 EN ISO 3834-3 EN ISO 5817
5.2.1.1 b	Ejection of parts by rotor rupture. Contained by casing	X	6.2			EN ISO 3834-2 EN ISO 3834-3 EN ISO 5817
5.2.1.2	Ejection of rotor parts	X	6.2			
5.2.1.3	Ejection of stationary parts	X	6.2			
5.2.2	Ejection of high kinetic energy process material or service media	X			X	
5.2.3	Dangerous movement	X	6.2	X		
5.2.4	Transportation	X			X	EN ISO 780
5.2.5	Lifting	X			X	EN ISO 780 EN 1005–2
5.2.6	Access to moving parts	X			X	EN 953 EN 1037 EN ISO 14119 EN ISO 13849-1 EN ISO 13857
5.3.1	Electrical hazards Common hazards	X		X	X	EN 60204–1 EN 60529 EN 61000–6-4 EN 61000–6-2
5.3.3	Movement	X		X	X	EN 60204–1
5.4	Ergonomical hazards	X		X		EN 894–2 EN 894–3 EN 60204–1 EN 61310–1
5.5	Thermal hazards			X	X	EN ISO 13732-1

Clause		Verification method				Related standards[a]
		Visual inspection	Performance check/test	Measuring by instrument	Checking drawings/ calculation	
5.6	Control systems	X			X	EN 1037:1995+A 1:2008
5.6.2	Emergency stops		X		X	EN ISO 13850
5.7	Noise			X	Annex B	EN ISO 3740 EN ISO 4871 EN ISO 9614-1 EN ISO 9614-2 EN ISO 9614-3 EN ISO 11203 EN ISO 11688-1 EN ISO 11688-2

[a] For year of issue of the listed standards, see Clause 2.

6.2 Verification of the integrity of centrifuges

6.2.1 Verification of the mechanical integrity of centrifuges against rotor failure

The verification of design against rotor failure depends on the selected design methodology:

a) if designed and manufactured with methodology based on 5.2.1.1 a), verification testing is performed by running the centrifuge at a speed sufficient to produce a stress level in the basket or bowl equal to or greater than 120 % of the stress at the maximum allowed conditions (design stress). The duration of the test shall be not less than 30 min.

A test result is satisfactory if the centrifuge remain in a condition which allows it to be used safely.

If it is impossible to arrange such a test the manufacturer shall demonstrate by verified calculations, using verifiable methods that the critical components of the centrifuge can safely withstand the overload conditions specified above.

NOTE 1 Calculations can be verified by comparison with results obtained from corresponding verification tests for previous similar designs.

or

b) if designed and manufactured with methodology based on 5.2.1.1 b), verification testing is performed by carrying out a rotor burst test to prove the adequacy of the protective casing to retain the ruptured rotor.

No parts or fragments shall be ejected from the centrifuge during the test. The rotor shall be subjected to the worst possible specified conditions, taking into account all parameters in 5.1. The test shall be carried out at normal operating speed until the rotor bursts.

NOTE 2 The rotor under test is first appropriately weakened to induce it to fail by rupture during the test of the protective casing.

NOTE 3 One of the fragments of a rotor more difficult to contain after a fracture, is an approximate half rotor. Experience over the years has shown that many designs of rotor can fracture to give such a size of fragment.

6.2.2 Verification that the centrifuge can withstand vibrations

This test shall be carried out to prove the ability of the centrifuge to withstand the excessive vibration level specified in 7.2.3 by testing in order to demonstrate:

— sufficient stability;

— no unintentional touching between rotating and stationary parts;

— no attached parts coming loose.

The test for a particular centrifuge design shall include normal start up, running at maximum operating speed for at least 6 h and normal shut down. The test shall be carried out with an unbalance which will result in a vibration level same or above the maximum allowed vibration level for immediate stop.

a) If the separator has been equipped with means to detect and prevent excessive vibration or unbalance according to 5.2.1.3 it shall be tested that the required safety is fulfilled. The manufacturer shall state the run-down procedure used for the test.

or

b) if the centrifuge casing and other stationary parts such as guards are designed and manufactured to withstand the impact of the rotor, a test to demonstrate this shall be carried out. The centrifuge shall also fulfil the requirements in 5.2.1.3.

6.3 Verification of effectiveness of noise control measures

Measurement and declaration of noise emission values shall be made in accordance with Annex B.

7 Information for use

7.1 General

The manufacturer shall provide instruction handbook(s) in accordance with of EN ISO 12100:2010, 6.4.5.

The use of overall or general instructions is not adequate.

7.2 Data sheet

7.2.1 General

The machine data sheet shall unambiguously identify the centrifuge by its type and/or series and shall include the information given on the name plate (see 8.2), with the exception of the serial number.

7.2.2 Application and operation

The limits of the intended use of the centrifuge shall be given by reference to filling mass and/or volume, speed of rotation, operating temperature range etc. The expected range of process material shall be given.

In general a manufacturer cannot give any detailed information on the abrasive and corrosion resistance of the main strength parts of a centrifuge, unless he knows in advance all operating conditions at his future customer's premises.

Therefore it has to be differentiated between the two cases:

a) The properties of the process material are not (or only roughly) known to the manufacturer.

In this case the manufacturer has to specify the construction materials used. This allows the user to evaluate abrasive and corrosive resistance and identify risks of intercrystalline corrosion, stress corrosion cracking, etc., triggered by his process material.

b) The manufacturer has received exact operating conditions and information about the process material.

In this case the manufacturer shall provide information about the abrasive and corrosion resistance of the main strength parts of the centrifuge, as well as resistance of polymeric materials. If applicable this information shall cover the conditions that could trigger intercrystalline corrosion, stress corrosion cracking, etc.

7.2.3 Specific operating limits

Specific operating limits of the centrifuge shall be given with regard to:

— feed rate;

— reference points and directions for vibration measurement;

— maximum allowable operating out of balance or vibration level:

  — for continuous operation;

  — for immediate shutdown;

— discharge volume and rate;

— acceleration or deceleration through any critical speed;

— cleaning-in-place procedures;

— allowed operational speed range;

— minimum and maximum pressures produced by the centrifuge at its outlet connections;

— minimum and maximum pressures allowed at the inlet connections;

— minimum and maximum casing pressure allowed;

— temperature limits;

— environmental conditions during start-up, operation and run down.

7.2.4 Prohibited use

Advice should be given on predictable or otherwise foreseeable prohibited uses related to the proposed duty.

Due to the fact that there is a wide range of applications for which the certain centrifuge is not suitable, it is not possible to specify all of them in a list. Instead, it is recommendable to specify for which applications it is suitable.

7.3 Installation instructions

Information shall be provided as applicable for the following items:

— storage instructions;

— handling and lifting of the centrifuge and major subassemblies;

— special lifting accessory;

— foundation requirements;

— recommendations for layout of piping, ducting and feeding/receiving equipment for inlet and outlet of process material;

— allowable piping and ducting nozzle forces, and if applicable the movements necessary for flexible connections;

— safeguarding against moving machines or parts of the machine;

— power and other utility supply requirements;

— disconnecting devices to isolate the centrifuge;

— installation of non-machine mounted controls and auxiliary equipment;

— recommendations on installation for low-noise exposure, for instance to choose sufficiently large rooms, by placing the centrifuges correctly in the rooms, by using sufficient absorption material etc.;

— recommendations for safeguarding against moving machines and machine parts, process material, cleaning agents, hot/cold surfaces noise;

— recommendations for the extent of free space around the centrifuge for operation and maintenance;

— information needed to design and install an inert gas system if such a system is needed but not included in the centrifuge. Examples of such information are for example gas volume in centrifuge and pressure difference between different connections on the cover caused by the fan action of the rotor;

— maximum feed rate and allowed speed;

— maximum wash rate and allowed speed;

— allowed speed for solids removal;

— lifting accessories.

7.4 Instructions for operation and routine maintenance

Information, generally in the form of model instructions, shall be provided as applicable for the following items:

— first start-up;

— operational starting and stopping;

— recommendations on safe operator positions;

— instructions for manually operated batch type centrifuges;

— routine monitoring of operations;

— emergency controls, location and function;

— criteria for emergency stop;

— run down time;

— routine check and maintenance procedures including cleaning and lubrication;

— handling and lifting of the centrifuge and major subassemblies;

— special lifting accessory;

— simple fault finding guide;

— noise declaration according to Annex B, and recommendations on how to minimize the noise exposure by planning of the work operations, and by reducing the exposure time at high noise levels as well as recommendations for the use of hearing protection;

— location of excessive hot or cold surfaces;

— risks related to escape of process materials, cleaning agents and harmful gases, mist or fumes;

— recommendation that if any inspection reveals unusual corrosion attack or consequential dimensional changes, advice shall be sought from a person with sufficient experience and knowledge to be able to assess the condition of the equipment (original manufacturer or other expert body);

— inspection frequency;

— inspection scope;

— allowable dimensions for critical items;

— lubrication;

— verification of containment capability;

— use of a power supply disconnecting device according to EN 1037:1995+A1:2008, 5.1, for access associated with maintenance or repair.

7.5 Service and repair instructions

The service and repair instruction document shall cover the work which shall be performed by skilled service personnel. Routine maintenance may be performed by trained operators.

The instruction document shall include the following:

— instructions, drawings and diagrams necessary for the safe major overhaul and subsequent testing of the centrifuge;

— schedule of periodic inspection, checks and/or replacement of parts and consumables;

— instructions for fault rectification (repair or replacement);

— recommendation that only one safety function may be put out of service at any one time for the purpose of inspection, maintenance or repair;

— address of maintenance agent(s) approved by the manufacturer;

— list of all relevant parts and consumables used for service with an unambiguous identification;

— a warning on sourcing of particular safety critical spare parts, if applicable.

7.6 Training

Recommendations for training of operators and service personnel shall be provided.

7.7 Decommissioning

Information on safe decommissioning shall be provided, if applicable.

8 Markings, signs, written warnings

8.1 General

Markings, signs and written warnings shall be legible, visible and permanently attached.

8.2 Name plate

The following information shall be permanently marked on the name plate:

— business name and address of the machine manufacturer and, where applicable, of his authorized representative;

— designation of the machinery and designation of series or type;

— batch number, or serial number, if applicable;

— year of construction, that is the year in which the manufacturing process is completed;

— maximum allowable speed;

— maximum and minimum temperature of the process material;

— maximum filling mass or density of filling mass, whichever applicable;

— maximum and minimum casing pressure, if applicable;

— maximum and minimum throughput, if applicable;

— mandatory marking [1)].

8.3 Signs and warnings

If relevant, signs to recommend the use of hearing and eye protectors shall be displayed.

Suitable warning symbols shall be attached to the centrifuge for excess movement, for example.

A sign showing the rotational direction of the rotor shall be permanently fixed to the centrifuge, if needed.

1) Applicable European Directive(s), e.g. Machinery.

Annex A
(informative)

Additional terminology

A.1 Applications and types of centrifuges

NOTE Some applications and types of centrifuges are not covered by this European Standard (see Clause 1).

A.1.1 Centrifuge applications

A.1.1.1 Separation machines

Centrifuges are used to separate materials in several industries; such as textiles, laundry, chemicals, mineral oils, waste water, sewage, pharmaceuticals, brewing, dairy products, other foods, dyestuffs and plastics.

A.1.1.2 Forming machines

Centrifuges are used in fabric forming to produce such things as hats and in metal forming to produce such things as hollow bar. Machines of that type actually displace liquid in the case of a hat drying centrifuge and vapour or non-metallic sediment in the case of a centrifugal casting machine.

A.1.1.3 Other applications

Laboratory centrifuges (see EN 61010-2-020) are used for example in forensic, chemical or biological analysis.

Centrifuges are used in the separation of nuclear industry products and other radioactive materials.

Centrifuges are used in products for use in the home such as washing machines (clothes) spin dryers and lettuce dryers.

A.1.2 Types of centrifuges

Centrifuges are classified in a number of different ways:

A.1.2.1 All centrifuges use one or both of the following ways of effecting a separation

1) The machines act as filtration machines and have a perforate chamber or basket. The centrifugal force speeds up the process of filtration compared to that achievable under normal gravitational force. Liquids pass through the solids which build up on a filter medium or on the perforate drum. Liquids then pass to the casing. There are a number of different discharge devices by which solids may be removed from the drum.

2) The machines act as sedimentation machines and have an imperforate chamber or bowl. The more dense parts of the process material migrate to the wall of the bowl whereas the less dense parts remain closer to the axis of rotation. The higher centrifugal force away from the centre speeds up the sedimentation (or makes it possible in some cases). Discrete centrifuging of several process material samples is achieved in some types of centrifuge in which the samples are contained in tubes, flasks or bottles which are in turn supported by the centrifuge rotor.

   The separated products are removed by a variety of means.

This group includes hot metal centrifugal casting machines.

1) and 2) A few centrifuges, for example screen bowl decanters, have both types of action. In the case of a screen bowl machine the perforate section follows the imperforate section and a screw conveyor moves the solids from the feed point in the imperforate section past the perforate section to the solids discharge point. Most of the liquid overflows from the imperforate section. The other liquid and any wash liquid flows through the perforate section.

A.1.2.2 Centrifuges are classified according to the way in which they work i.e. continuously or discontinuously.

A.1.2.3 Centrifuges are classified by the position of the axis of rotation. Horizontal centrifuges have a horizontal axis of rotation. Vertical and inclined centrifuges exist also.

A.1.2.4 Centrifuges are classified by the manner of their operation i.e. fixed speed, two speed, multispeed, variable speed.

A.1.2.5 Centrifuges are known by a variety of names depending on their manufacturer, their function or the industry in which they are used. Such names as separator, classifier, decanter, fugal, settler, solid bowl, disc bowl, spin dryer and salad dryer are in common use.

A centrifuge may therefore have a description of the following form for example: continuous; sedimenting; fixed speed; vertical decanter.

A.2 Definitions

A.2.1

batch centrifuge

centrifuge that processes a discrete batch of feed material

Note 1 to entry: It may be automated to go through to a sequence of feeding, washing and spinning. Solids discharge may be either automatic, the solids being removed either at full speed, or low speed; or the centrifuge may be stopped for manual removal of the material.

A.2.2

continuous working centrifuge

centrifuge where the main process steps like feeding, separation and washing are processed continuously

A.2.3

discontinuous working centrifuge

centrifuge where the main process steps like feeding, separation and washing are processed in sequence

A.2.4

pusher centrifuge

continuous working filtering centrifuge with an oscillating pushing mechanism for discharge of solids

A.2.5

scraper centrifuge

ploughing centrifuge

peeler centrifuge

centrifuge in which the solids are removed by the action of a blade which moves into the solids collected, from a parked position, whilst the rotor is turning and so dislodges the material from the rotating parts

Note 1 to entry: The blade then returns to the parked position.

Note 2 to entry: The motor may have to slow down for this operation.

A.2.6

decanter

continuous working sedimentation centrifuge with an internal screw mechanism for the removal of settled solids from the bowl

A.2.7

screen bowl decanter

centrifuge which has an imperforate section followed by a perforate section in the direction of solid flows, so that solids are collected by sedimentation and then further drained by filtration

A.2.8

disc bowl centrifuge; separator

continuously fed sedimentation centrifuge provided with a number of discs

Note 1 to entry: Solids are removed from the bowl either manually or as a slurry via nozzles or by a bowl opening mechanism.

A.2.9

conical drum centrifuge

centrifuge with the discharge position at the larger end diameter

Note 1 to entry: In the centrifugal force field the dehumidified filling mass moves towards the larger diameter and thus to the discharge zone while the liquid is filtered through the drum.

A.2.10

chamber bowl centrifuge

centrifuge with concentric chambers, generally with a vertical axis

A.2.11

ultracentrifuge

centrifuge having a circumferential speed exceeding 300 m/s

A.2.12

laundry centrifuge

textile centrifuge

centrifuge designed specifically to handle textiles, furs or other fabrics in water with a cleaning agent, or in a suitable solvent

A.3 Other terms

A.3.1

filtration

separation occurring when a fluid passes through and/or drains from a porous mass of solid and the supporting porous membrane or filter medium due to the local gravitational force or pressure

A.3.2

sedimentation

separation occurring when the denser or densest part of a mixture in a container settles due to the local gravitational force to the lower part of that container (or outermost zone of a rotating part)

Note 1 to entry: Sedimentation is taken to include such terms as classification, clarification and purification.

A.4 Illustrations

A.4.1 Product flow symbols

The product flow is one of the features which characterizes the individual type of centrifuge.

The following symbols are used in this standard to describe the various product flows.


= process material

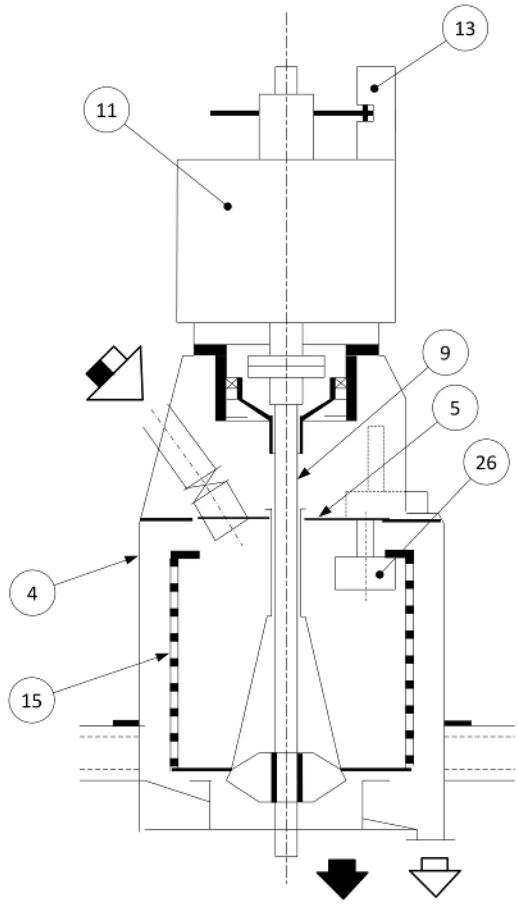

= discharge after sedimentation


= filtrate part of the loaded process material or phase with lower density after liquid-liquid separation


= solid part of the loaded process material or phase with higher density after liquid-liquid separation

= wash loaded on the centrifuge

A.4.2 Centrifuge components



Key

4 casing, housing

5 cover, lid

9 shaft

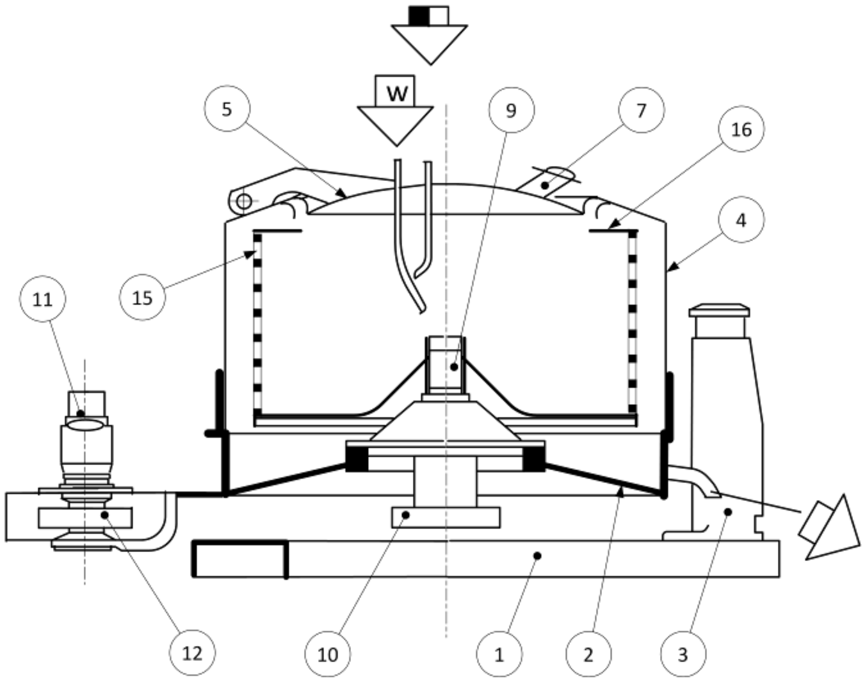
11 drive motor

13 brake

15 basket

26 plough

Figure A.1 — Pendulum centrifuge with automatic discharge, discontinuous working centrifuge, filtration machine



Key

1 baseplate, stand

2 frame

3 suspension column

4 casing, housing

5 cover, lid

7 sight glass

9 shaft

10 driven pulley

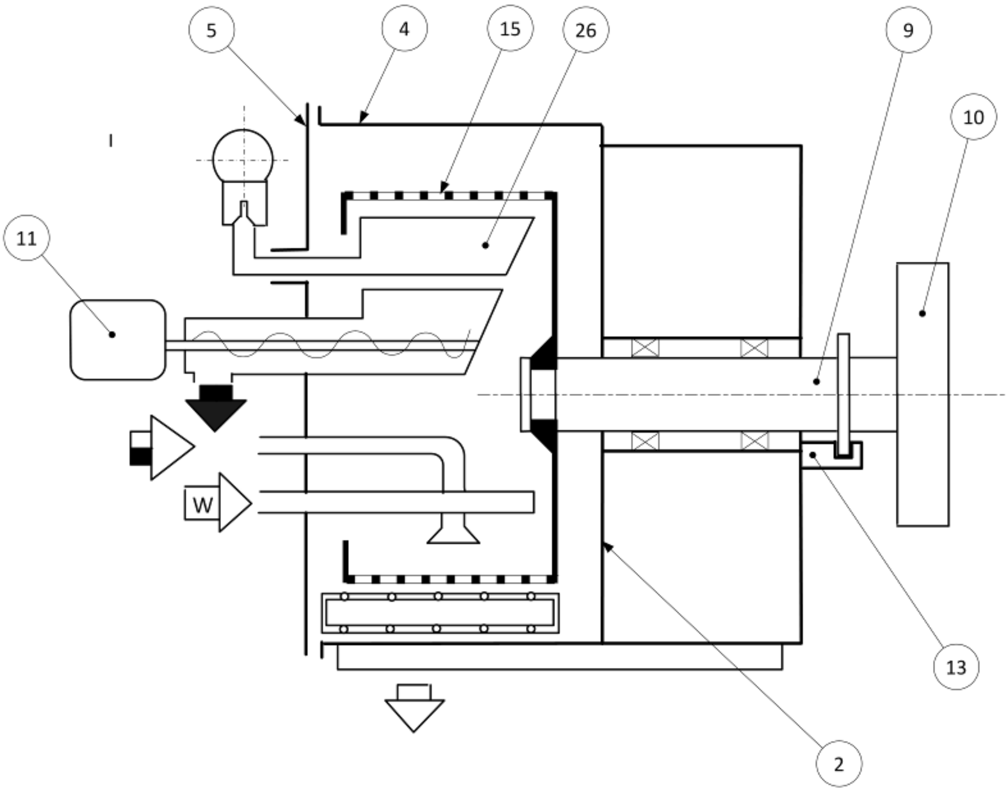
11 drive motor

12 driving pulley

15 basket

16 basket lip

Figure A.2 — Vertical centrifuge with manual discharge, discontinuous working centrifuge, filtration machine, sedimentation machine



Key

2 frame

4 casing, housing

5 cover, lid

9 shaft

10 driven pulley

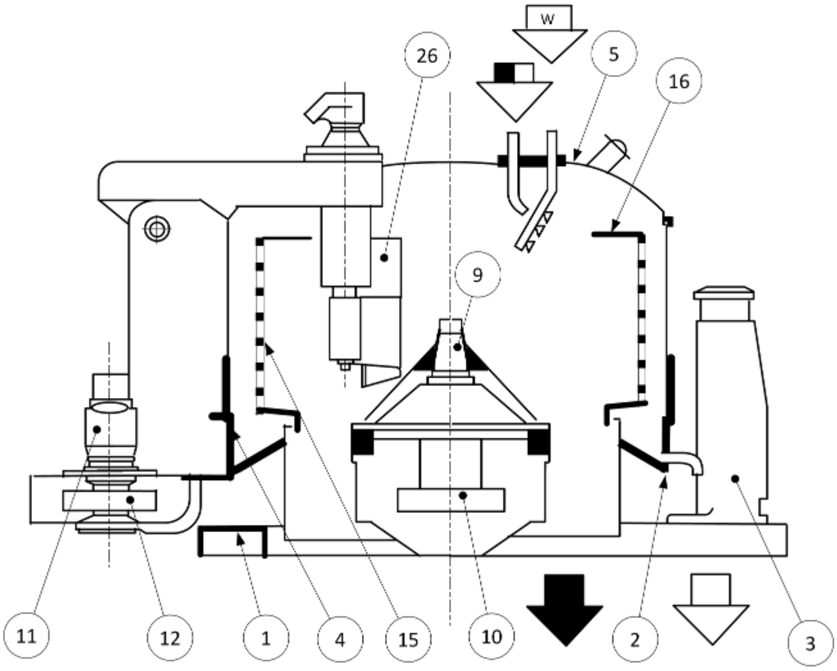
11 drive motor

13 brake

15 basket

26 plough

Figure A.3 — Horizontal peeler centrifuge with automatic discharge, discontinuous working centrifuge, filtration machine



Key

1 baseplate, stand

2 frame

3 suspension column

4 casing, housing

5 cover, lid

9 shaft

10 driven pulley

11 drive motor

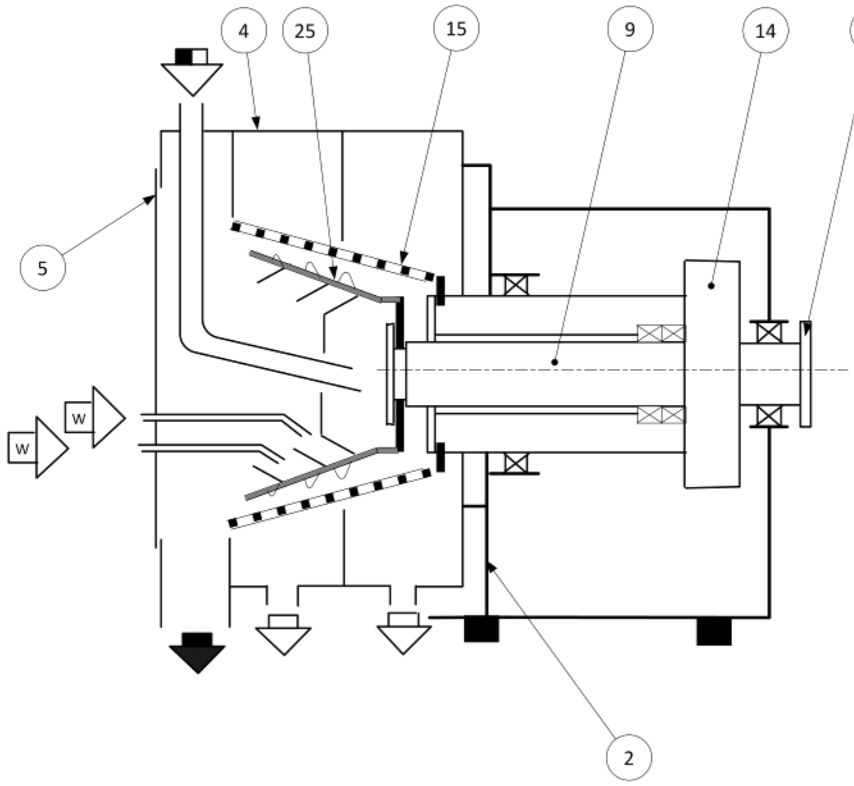
12 driving pulley

15 basket

16 basket lip

26 plough

Figure A.4 — Vertical centrifuge with automatic discharge, discontinuous working centrifuge, filtration machine



Key

2 frame

4 casing, housing

5 cover, lid

9 shaft

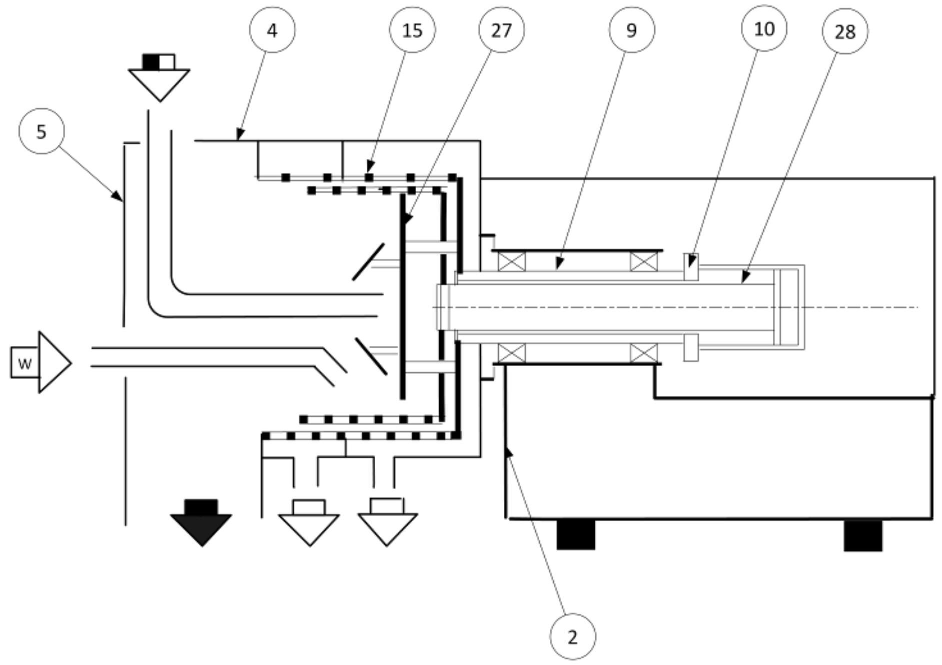
10 driven pulley

14 gearbox

15 basket

25 extract screw conveyor

Figure A.5 — Basket centrifuge, conical drum centrifuge, with screw conveyor, continuous working centrifuge, filtration machine



Key

2 frame

4 casing, housing

5 cover, lid

9 shaft

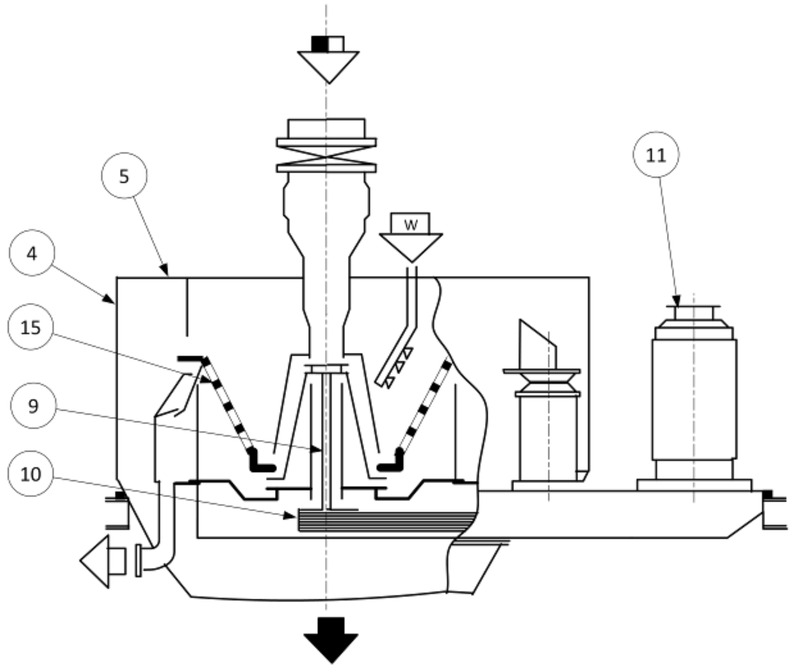
10 driven pulley

15 basket

27 pusher plat

28 pusher shaft

Figure A.6 — Pusher centrifuge, continuous working centrifuge, filtration machine



Key

4 casing, housing

5 cover, lid

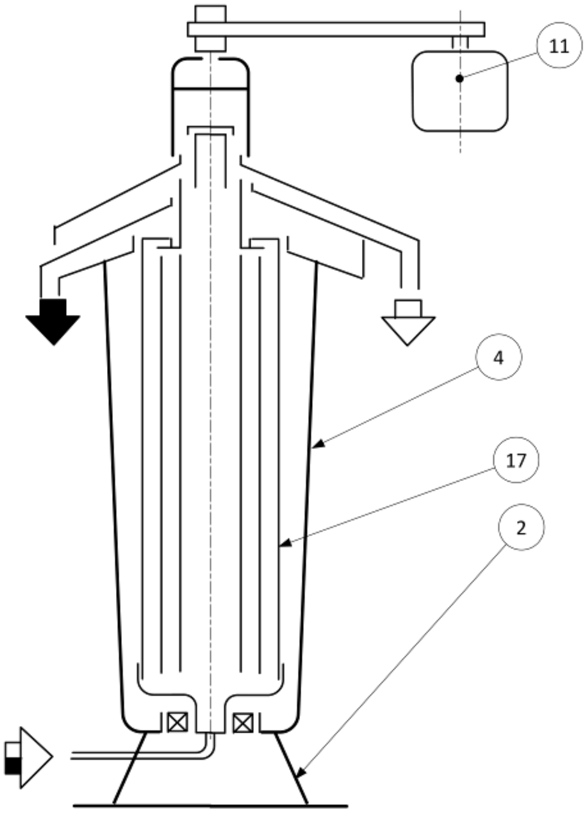
9 shaft

10 driven pulley

11 drive motor

15 basket

Figure A.7 — Vertical self discharge conical centrifuge, continuous working centrifuge, filtration machine



Key

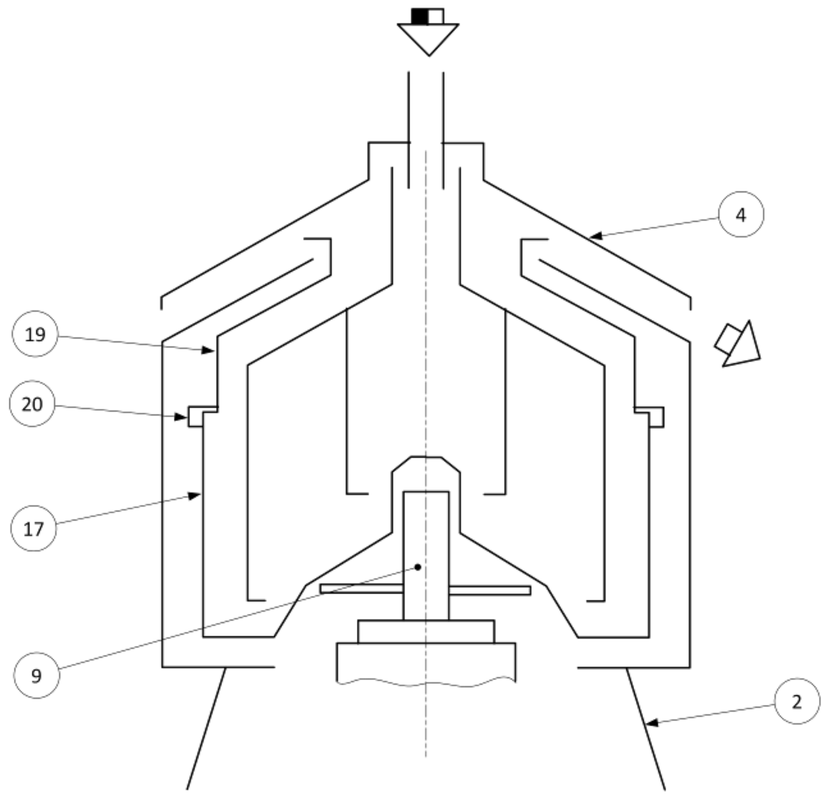
2 frame

4 casing, housing

11 drive motor

17 bowl

Figure A.8 — Tubular bowl continuous working centrifuge, sedimentation machine



Key

2 frame

4 casing, housing

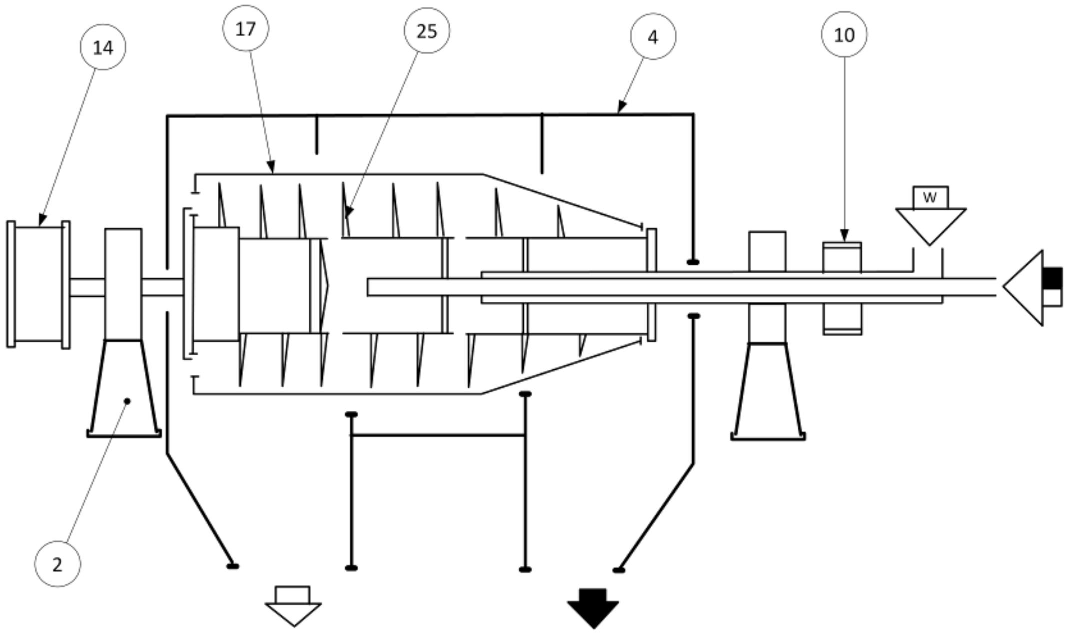
9 shaft

17 bowl

19 bowl hood

20 main lock ring

Figure A.9 — Solid wall chamber bowl centrifuge, continuous working centrifuge, sedimentation machine



Key

2 frame

4 casing, housing

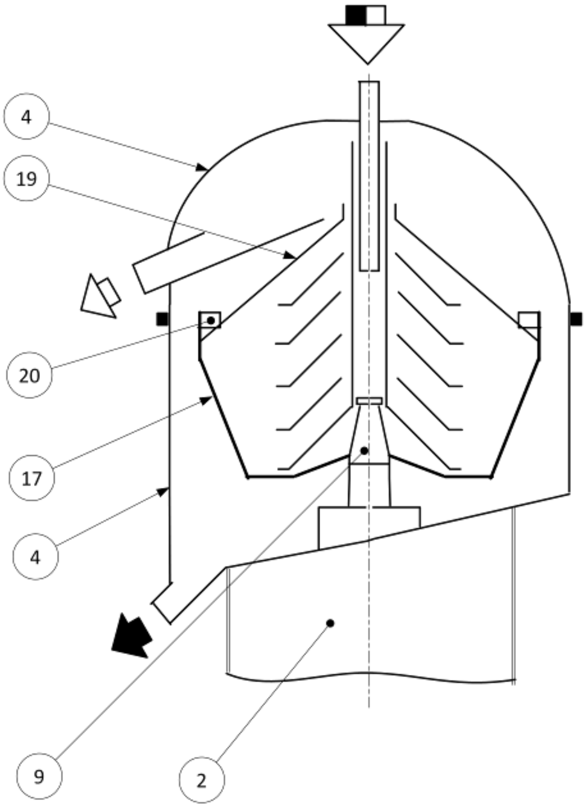
10 driven pulley

14 gearbox

17 bowl

25 extract screw conveyor

Figure A.10 — Solid bowl decanter, continuous working centrifuge, sedimentation machine



Key

2 frame

4 casing, housing

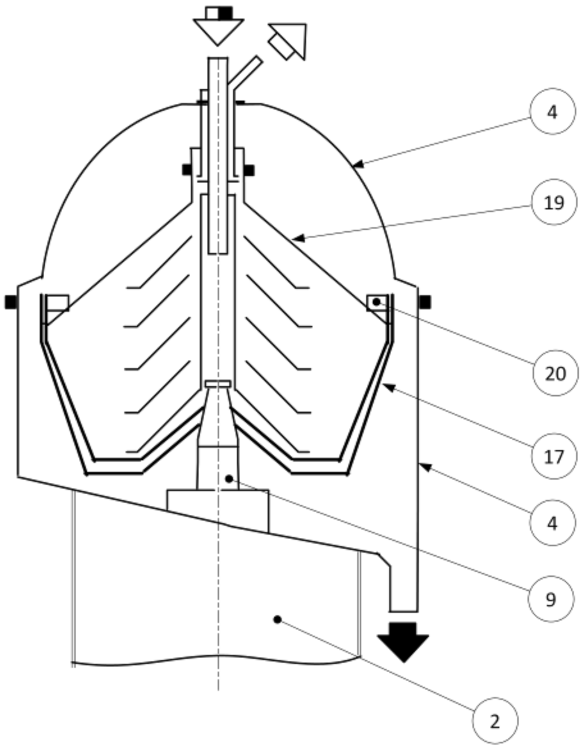
9 shaft

17 bowl

19 bowl hood

20 main lock ring

Figure A.11 — Nozzle discharge disc bowl centrifuge, continuous working centrifuge, sedimentation machine



Key

2 frame

4 casing, housing

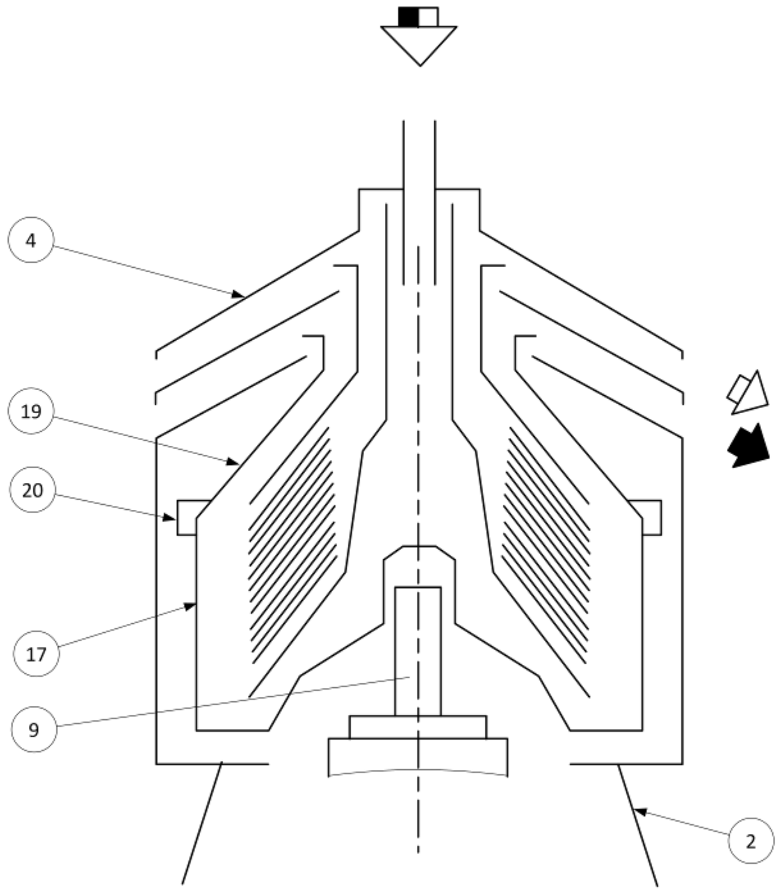
9 shaft

17 bowl

19 bowl hood

20 main lock ring

Figure A.12 — Automatic discharge bowl centrifuge, continuous working centrifuge, sedimentation machine



Key

2 frame

4 casing, housing

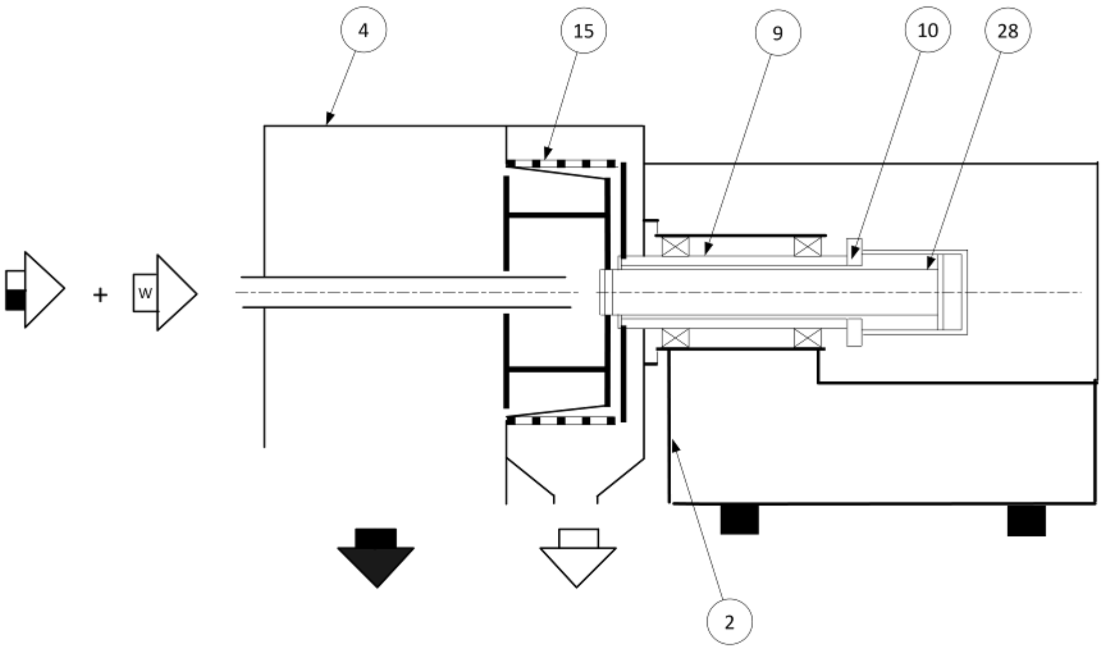
9 shaft

17 bowl

19 bowl hood

20 main lock ring

Figure A.13 — Solid wall disc bowl centrifuge, continuous working centrifuge, sedimentation machine



Key

2 frame

4 casing, housing

9 shaft

10 driven pulley

15 basket

28 pusher shaft

Figure A.14 — Inverting filter centrifuge, discontinuous working centrifuge, filtration machine

Annex B
(normative)

Noise test code for centrifuges

B.1 Scope

This noise test code specifies all the information necessary to carry out efficiently and under standardized conditions the determination, declaration and verification of the noise emission of centrifuges. It specifies noise measurement methods and operating and mounting conditions that shall be used for the test.

Noise emission characteristics include emission sound pressure levels at workstations and the sound power level. It is necessary to determine these parameters so that:

— manufacturers can declare the noise emitted;

— users can compare the noise emitted by different centrifuges on the market;

— designers can control noise at source at the design stage.

Using this noise test code ensures reproducibility when determining the noise emission characteristics within specified limits determined by the grade of accuracy of the basic airborne noise measurement method used.“

B.2 Sound emission determination

B.2.1 Sound power level

Sound power level determination shall be carried out using a method with an accuracy grade of 2 or 3. One of the following standards shall be applied; EN ISO 3744:2010, EN ISO 3746:2010, and EN ISO 9614-2:1996.

When using EN ISO 3744:2010 or EN ISO 3746:2010 the measurement surface shall be a parallelepiped and the measurement distance shall be 1 m. For disk stack separators and similar centrifuges rotating around a vertical axis a hemispherical measurement shape can be used. The noise declaration shall inform about the measurement shape used for the obtaining the declared sound power level.

For centrifuges with a length larger than 8 m, instead of determining the sound power level, the A-weighted emission sound pressure level shall be measured using one of the following standards: EN ISO 11201:2010, EN ISO 11202:2010 and EN ISO 11204:2010. The measurement shall be carried out at discrete measurement points on a contour at 1 m distance from the centrifuge and at a height of 1,6 m. The distance between two consecutive measuring points shall not exceed 2 m.

As far as possible a method of grade 2 accuracy shall be used. If a grade 3 method is used reasons for not using a grade 2 method shall be given.

B.2.2 Emission sound pressure level at workstations

Centrifuges are regarded as machines for which work stations are not defined.

If the sound power level has been determined (see B.2.1), the A-weighted emission sound pressure level at workstation shall be calculated from the A-weighted sound power level using EN ISO 11203:2009, method with Q_2, with a measurement surface 1,0 m from the reference box used for the determination of sound power. The measurement uncertainty will be that of the sound power standard used.

If the sound power level has not been determined, A-weighted emission sound pressure levels shall be measured, using one of the following standards: EN ISO 11201:2010, EN ISO 11202:2010 and EN ISO 11204:2010, at discrete points on a contour at 1 m distance from the centrifuge and at a height of 1,6 m. The distance between two consecutive measuring points shall not exceed 2 m. The maximum A-weighted emission sound pressure level measured shall be taken as the A-weighted emission sound pressure level at workstation.

For centrifuges with discontinuous discharge devices which will create impulsive noise, the peak C-weighted sound pressure level shall be measured. The measurement shall be carried out at discrete measurement points on a contour at 1 m distance from the centrifuge and at a height of 1,6 m. The distance between two consecutive measuring points shall not exceed 2 m. The highest value shall be declared if it exceeds 130 dB(C). The measuring time shall be sufficiently long to capture at least one representative impulsive noise event.

B.3 Mounting conditions

The centrifuge under test shall be installed according to the manufacturer's recommendations.

The mounting conditions shall be the same for the determination of both sound power levels and emission sound pressure levels at workstations, and for declaration purposes.

Care shall be taken to ensure that any electrical conduits, piping or air ducts which are connected to the machinery do not radiate significant amounts of sound energy.

Feed pumps, valves and other equipment which are needed for running the centrifuge, which do not belong to the centrifuge, shall be placed in a location away from the centrifuge under test or shall be sufficiently isolated so that the measurement will not be influenced by this equipment.

B.4 Operating conditions

The noise test shall be carried out in a condition as close as practically possible to the normal operating condition for the centrifuge.

The centrifuge shall always be tested at the speed, for which the noise emission is at maximum,

Openings, outlets and pipe connections, which are normally closed, shall be closed during the test. Openings, outlets and pipe connections, which are normally open, shall be open during the test.

The centrifuge shall if it is possible be tested with the process material for which it is intended. If this is not possible it shall be tested with water.

If the feed flow has a significant influence on the noise level of the centrifuge the noise test shall be carried out with the feed flow rate which gives the highest noise emission. The flow rate shall if possible be at least 50 % of the operating flow rate.

B.5 Information to be recorded

The information to be recorded by the person taking the measurements shall include all the data that the basic standards used require to be recorded i.e. precise identification of the centrifuge under test, mounting and operation conditions, acoustic environment, instrumentation and acoustical data.

B.6 Information to be reported

The information to be included in the test report is at least that which the manufacturer requires to prepare a noise declaration:

— reference to the basic noise emission standard(s) used (see B.2.1 and B.2.2);

— description of the mounting and operating conditions used (see B.3 and B.4);

— the noise emission values obtained (see B.2.1 and B.2.2);

— the related measurement uncertainty (see B.7).

It shall be confirmed that all requirements of this noise test code and basic standards used have been fulfilled, or, if this is not the case, any unfulfilled requirements shall be identified. The deviations from the requirements shall be stated and technical justification for the deviations shall be given.

B.7 Determination of measurement uncertainty

The total measurement uncertainty of the noise emission values determined according to this standard is depending on the standard deviation of reproducibility of the measurement:

$$\sigma_{R0}$$

given by the applied noise emission measurement method and the uncertainty associated with the instability of the operating and mounting conditions:

$$\sigma_{omc}$$

The resulting total standard deviation σ_{tot} is then calculated as:

$$\sigma_{tot}^2 = \sigma_{R0}^2 + \sigma_{omc}^2$$

The upper bound value of σ_{R0} is about 1,5 dB for the grade 2 measurement methods dealing with the determination of the emission sound pressure level or the sound power level.

For centrifuges σ_{omc} is normally small and can be ignored *so that* $\sigma_{tot} = \sigma_{R0}$.

The expanded measurement uncertainty U, in decibels, for a two-sided normal distribution at a confidence level of 95 %, is given by:

$$U = k \cdot \sigma_{tot} \qquad \text{with } k = 2$$

NOTE 1 The expanded measurement uncertainty depends on the desired confidence level. For the purpose of comparing the result with a limit value, it is appropriate to apply the coverage factor for a one-sided normal distribution. In that case, the coverage factor $k = 1{,}6$ corresponds to a 95 % confidence level. Further information is given in EN ISO 4871:2009. Note that the expanded measurement uncertainty U is denoted K in EN ISO 4871:2009.

NOTE 2 For more information on measurement uncertainty see EN ISO 11201:2010, Clause 11 and Annex C or EN ISO 3744:2010, Clause 9 and Annex H.

NOTE 3 The expanded measurement uncertainty as described in this standard does not include the standard deviation of production which is used in EN ISO 4871:2009 for the purpose of making a noise declaration for batches of machines.

B.8 Declaration and verification of noise emission values

Guidelines for noise declaration are given in EN ISO 4871:2009. The declared noise emission value shall be rounded to the nearest whole decibel. Additional noise emission quantities such as octave band levels may also be given in the noise emission values to be declared by the manufacturer are:

— The A-weighted sound power level in dB referred to 1 pW (see B.2.1) if the A-weighted emission sound pressure level at workstation exceeds 80 dB;

— For centrifuges with a length larger than 8 m, instead of the A-weighted sound power level, the A-weighted emission sound pressure levels at discrete points (see B.2.1) and a figure showing the measurement positions;

— The A-weighted emission sound pressure level at workstation in dB referred to 20 *μ*Pa, (see B.2.2). If determined by measurements, a figure showing the measurement positions and indicating the position where the maximum value was obtained shall be given.

C-weighted peak sound pressure level in dB referred to 20 *μ*Pa, if it exceeds 130 dB(C) (see B.2.2).

The uncertainty associated to each declared value shall be declared.

See an example of noise declaration in Table B.1.

Sales literature describing the performance characteristics of machinery shall contain the same information on noise emissions as is contained in the instructions.

The noise declaration shall be made in such a fashion that the values can be verified according to EN ISO 4871:2009.

Table B.1 — Example of noise declaration for a small centrifuge with no impulsive noise

Machine model number and identifying information:	
• **Values declared in accordance with** EN ISO 4871:2009	
• **A-weighted Sound Power Level** L_{WA}, referred to 1 *p*W (dB) Uncertainty, K_{WA} (dB)	**98** **3**
• **A-weighted Emission Sound Pressure Level** L_{pA}, referred to 20 *μ*Pa (dB) Uncertainty, K_{pA} (dB) These values have been determined from measurements using EN 12547:2014 and the basic standards EN ISO 9614-2:1996 and EN ISO 11203:2009 Measurement shape used for determination of declared sound power level: Operating conditions: • Speed: • Flow: • Closed outlets	**82** **3**
NOTE The sum of measured emission value and the stated uncertainty gives the upper limit for the values to be expected in measurements.	

Annex C
(informative)

Static stress analysis for cylindrical baskets or bowls

C.1 Validity

This stress analysis is applicable only for cylindrical basket or bowl shells of uniform thickness considered to be uniformly loaded in both the circumferential and the axial direction. The ratio of shell thickness to inner shell radius shall not exceed 0,15. The stress analysis can account for reinforcing hoops and round perforations. The material of construction shall satisfy the requirements in C.3.

C.2 Symbols and abbreviations

The following symbols are used, see also Figure C.1 and Figure C.2.

A_5	=	rupture elongation (L_0/D_0 = 5)
L_0	=	length of probe of test specimen (m)
D_0	=	diameter of probe of test specimen (m)
a	=	cross sectional area of reinforcing hoop (m^2)
b_1, b_2	=	centre distance between adjacent perforations (m)
c	=	pitch of reinforcing hoops (m)
d	=	diameter of perforations (m)
e	=	reinforcing hoop thickness (m)
l	=	longitudinal groove depth plus maximum allowable depth of corrosion at bottom of groove (m)
M	=	maximum filling mass (kg)
h	=	internal axial length of basket or bowl (m)
KV	=	impact strength (J)
k	=	lowest of coefficients k_1, k_2 and k_3
k_1	=	weld coefficient
k_2, k_3	=	stress coefficients due to perforations
k_4	=	stress coefficient due to the notch effect of perforations
p	=	total pressure on the shell wall (Pa)
p_{cm}	=	pressure on the shell wall due to the filling mass (Pa)
q	=	coefficient of reduction of the apparent density due to perforations
r_1	=	internal radius of shell (m)
r_2	=	arithmetic mean radius of shell (m)
r_3	=	internal radius of load (m)
s	=	shell thickness as new (m)
t_a	=	minimum hole pitch in axial direction (m)

t_c = minimum hole pitch in circumferential direction at radius = r_2 (m)

z = reinforcing hoop coefficient

α = angle between staggered perforations [= atan (t_c/t_a)] (rad)

ρ_1 = density of material of construction of shell (kg/m^3)

ρ_2 = density of saturated cake (or load) (kg/m^3)

σ_t = tangential stress acting on the shell (Pa)

R_m = ultimate tensile strength at the design temperature (P)

R_P = yield point stress for materials with marked yield point at the rotor design temperature,

or;

0,2 % proof stress at the rotor design temperature for materials without marked yield points,

or;

1 % proof stress at the rotor temperature for austenitic materials

(Pa)

ω = basket/bowl angular velocity (rad/s)

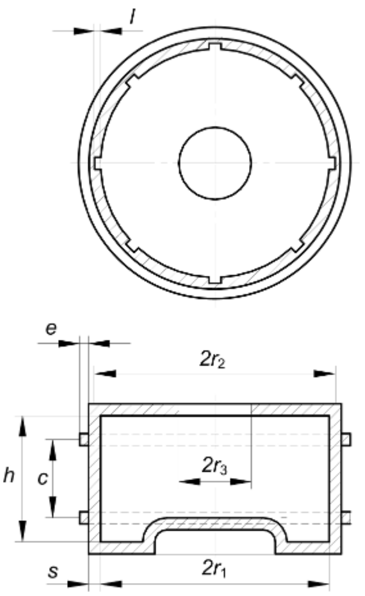
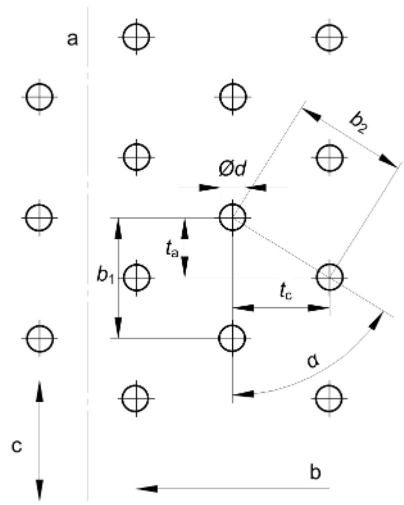


Figure C.1 — Schematic basket/bowl



Key

a axis
b axial direction
c circumferential direction

Figure C.2 — Pattern of perforations

C.3 Material of construction

The basket or bowl shall be manufactured from homogenous ductile metallic material having an elongation (A_5) of not less than 14 % and an impact strength (KV ISO V-test) of not less than 27 Joule at 20 °C. If the minimum process material temperature is less than 0 °C the impact strength requirement shall be met at the rotor design temperature.

If the basket or bowl shell is manufactured from a rolled and welded fabrication the procedure for welding shall be in accordance with EN ISO 3834-2:2005 and EN ISO 3834-3:2005. Full penetration welds shall be used. Arc-welded joints in steel shall comply with the requirements of EN ISO 5817:2014. There shall be 100 % NDT (Non Destructive Testing) after all heat treatment is completed.

The welded joint coefficient, k_1, for arc-welded joints in steel versus weld class and NDT method is given in C.4.4.

C.4 Method of analysis

C.4.1 General

The tangential stress in a rotating and uniformly loaded cylindrical shell is expressed as:

$$\sigma_t = \frac{1}{k} \times \left[\left(\frac{s}{s-l} \right) \times \left(q \times \rho_1 \times \omega^2 \times r_2^2 + \frac{p \times r_1}{s \times z} \right) \right]$$

k is the smallest of the welded joint coefficient, k_1 (see C.4.4) and/or the perforation coefficients, k_2 and k_3 (see C.4.5).

The coefficient q may be used to compensate for the lower average density in perforated shells (see C.4.5).

z is a hoop reinforcing coefficient (see C.4.3).

C.4.2 Pressure on the shell wall

The pressure on the shell wall is the summation of the pressures exerted by the filling mass (p_{cm}) and any liner, ribs or filter medium fitted on the inside of the shell.

For liquids or slurries the filling mass pressure is expressed as:

$$p_{cm} = \frac{1}{2} \times \rho_2 \times \omega^2 \times r_1^2 \times \left[1 - \left(\frac{r_3}{r_1} \right)^2 \right]$$

or in terms of the maximum filling mass:

$$p_{cm} = \frac{1}{2} \times \frac{M \times \omega^2}{\pi \times h}$$

For products with internal friction the pressure on the wall is expressed as:

$$p_{cm} = \frac{1}{3} \times \rho_2 \times \omega^2 \times r_1^2 \times \left[1 - \left(\frac{r_3}{r_1} \right)^3 \right]$$

or in terms of the maximum filling mass:

$$p_{cm} = \frac{1}{3} \times \frac{M \times \omega^2}{\pi \times h} \times \frac{1}{r_1} \times \frac{r_1^3 - r_3^3}{r_1^2 - r_3^2}$$

C.4.3 Reinforcing hoop coefficient

If hoops are used to reinforce the shell the effect is allowed for by using the coefficient:

$$z = 1 + \frac{a}{s \times c}$$

provided the following conditions are satisfied:

1) the hoop height, e (or thickness in radial direction) shall not be larger than $2s$;

2) the cross-sectional area of a hoop, a, shall not exceed: $2e^2$;

3) the pitch of reinforcing hoops, c, shall not exceed: $\sqrt{2 \times r_2 \times s}$

4) the material of construction of the hoops shall be the same as that used for the shell.

Without hoops z = 1.

C.4.4 Welded joint coefficient

The welded joint coefficient, k_1, depends on the welding class (quality) and the applied NDT method. For fusion-welded joints in steels Table C.1 applies. For other weld methods or other weldable metallic materials the manufacturer shall establish and verify the appropriate welded joint coefficient to be applied.

Table C.1 — Welded joint coefficient, k1 for arc-welded joints in steel

Welding quality requirements	**Quality level for imperfections** EN ISO 5817	**Welded joint coefficient, k_1**	
		100 % radiographic examination	**Other examination method**
EN ISO 3834-3	C	0,75	0,6
EN ISO 3834-3	B	0,9	0,75
EN ISO 3834-2	B	1	N/A
NOTE The welded joint coefficients in Table C.1 applies to steady loading only, cyclic loading and fatigue is not considered			

C.4.5 Perforation coefficients

In the case of uniformly distributed perforations the coefficients, k_2 and k_3 are determined as follows:

Determination of k_2:

$$k_2 = k_4 \left(1 - \frac{d}{b_1}\right)$$

or if a longitudinal weld crosses the holes:

$$k_2 = k_4 \times k_1 \left(1 - \frac{d}{b_1}\right)$$

Determination of k_3:

$$k_3 = k_4 \left(1 - \frac{d}{b_2}\right) \times v$$

or if a longitudinal weld crosses the holes:

$$k_3 = k_4 \times k_1 \left(1 - \frac{d}{b_2}\right) \times v$$

The coefficient k_4 considers the notch effect.

In the case of uniformly distributed perforation with round holes:

$k_4 = 0{,}75$

A perforation of the shell wall creates an increased stress at the edge of each hole by a factor of 2 to 3 compared to the average tangential stress in the rest of the material. By using materials in accordance with C.3 a single plastic elongation of the material due to the loading is permissible. This elongation of the material changes the static stress by a factor of approximately 1,33. Therefore the reduction coefficient k_4 of 0,75 should be used.

Determination of b_2:

$$b_2 = \frac{t_a}{\cos \alpha}$$

or

$$b_2 = \frac{t_c}{\sin \alpha}$$

$v = 1$ for a rectangular arrangement of holes

$v = 1$ for an offset arrangement where $\alpha \geq 45°$, and

$$v = \frac{1 + \tan^2 \alpha}{\sqrt{1 + 3 \tan^2 \alpha}}$$ for an offset hole arrangement, $0° < \alpha < 45°$

The coefficient, q, compensating for the reduction in the apparent density of perforate shells, is calculated as follows:

$$q = 1 - \frac{\frac{\pi}{4} \times d^2}{b_1 \times b_2 \sin \alpha}$$

or

$$q = 1 - \frac{\pi \times d^2}{4 \times b_1 \times t_c}$$

C.5 Design conditions

Load:	Maximum load which can occur during operation of the centrifuge, including the maximum specified load from process material
Geometry of rotor:	Minimum specified metal dimensions including any general corrosion and wear allowances
Rotor design temperature:	The higher of + 40 °C and the maximum allowed process material temperature, or the process material temperature if that temperature is below 0 °C.

C.6 Permissible stress

The permissible tangential stress is determined from Table C.2.

Use of the values in column B is allowed only if the quality of the material is controlled and certified according to EN 10204:2004, 3.1. The certification shall include checks on chemical composition, on heat treatment and of the relevant mechanical properties.

In all other cases the values in column A shall be used.

To determine the tensile strength at the rotor design temperature generally recognized data for strength reduction versus temperature for the particular rotor material may be used.

Table C.2 — Permissible tangential stress versus degree of verification of material properties

A	B
$\sigma_t \leq 0{,}50\ R_p$ and $\sigma_t \leq 0{,}33\ R_m$	$\sigma_t \leq 0{,}66\ R_p$ and $\sigma_t \leq 0{,}44\ R_m$

Annex D
(informative)

Example of the design of a safety related part of the control system in accordance with EN ISO 13849-1:2008

D.1 General

The following gives an example of an overspeed prevention device, mentioned in 5.2.1.1 and 5.6.1 of this document. The centrifuge in this case is equipped with a bowl drive system consisting of a frequency converter and a 3 phase motor.

D.2 Symbols and abbreviations

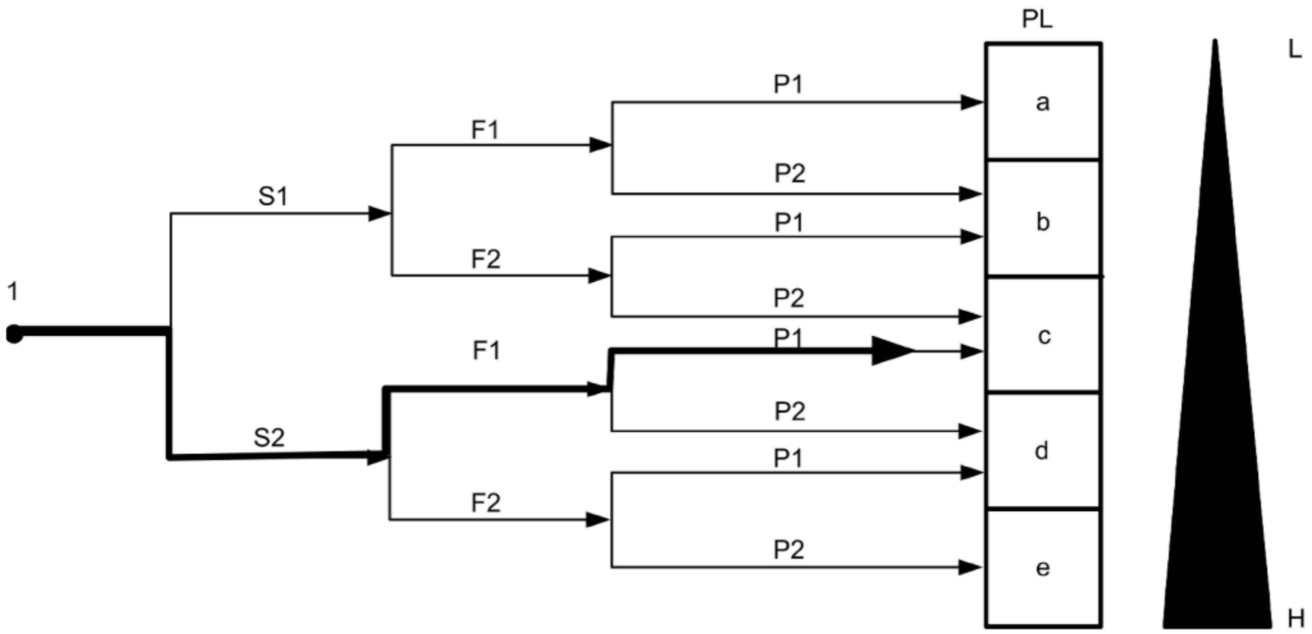
PL	Performance Level required
MTTF	Mean time to failure [a]
$MTTF_d$	Mean time to a dangerous failure for the whole channel
$MTTF_{di}$ $MTTF_{dj}$	$MTTF_d$ of each device, that has safety function in the channel
$MTTF_{com}$	Mean time to a dangerous failure completely (for all channels)
DC	Diagnostic coverage
DC_{avg}	Average diagnostic coverage
B_{10d}	Averaged number of cycles, until 10 % have a dangerous failure
n_{op}	Averaged number of cycles per year
PFH	Averaged probability of a dangerous failure per hour
PFH_{com}	Averaged probability of a dangerous failure per hour for whole system

D.3 Risk assessment

The following gives an example of a risk assessment for an overspeed prevention device. The risk assessment in accordance with EN ISO 13849-1:2008 results in this example PL “c”, see Figure D.1.

According to EN ISO 13849-1:2008, Table 3 the Performance Level “c” (PL = c) shall have an average probability of dangerous failures in the range of: ≥ 10-6 up to < 3 × 10-6 [1/h].

NOTE The risk assessment can lead to a different result depending on installation, application, centrifuge type, etc.



Key

1	starting point for evaluation of safety function's contribution to risk reduction
L	low contribution to risk reduction
H	high contribution to risk reduction
PL	required performance level

Risk parameters

S	severity of injury
S1	slight (normally reversible injury)
S2	high serious (normally irreversible injury or death)
F	frequent and/or exposure to hazard
F1	seldom-to-less-often and/or exposure time is short
F2	frequent-to-continuous and/or exposure time is long
P	possibility of avoiding hazard of limiting harm
P1	possible under specific conditions
P2	scarcely possible

Figure D.1 — Risk graph for determining required PLr for overspeed prevention device

D.4 Functional description

The function of the system is graphically described in Figure D.2.

A proximity switch (G1) is taking pulse signals from a sensor ring connected to the bowl spindle. The pulses are taken to a speed relay (A2) that calculates the speed.

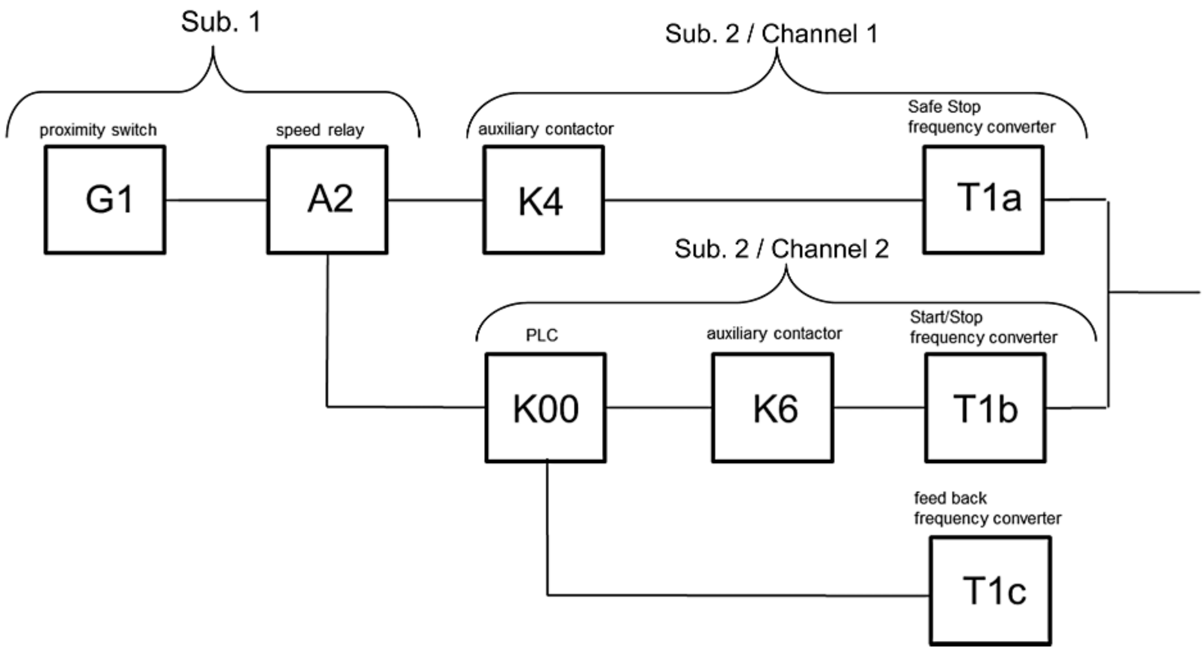
If the preset speed limit is exceeded, the speed relay (A2) initiates via the auxiliary contactor (K4) the safe stop of the frequency converter (T1a).

The speed relay (A2) monitors “wire break“ and “short circuit” of the cabling to the proximity switch (G1).

In redundancy to this shut down path the PLC (K00) gets the pulses from the proximity switch (G1) via the speed relay (A2) and calculates the speed as well. If the speed limit is exceeded, the PLC (K00) initiates via the auxiliary contactor (K6) the normal stop of the frequency converter (T1b).

The stop of the frequency converter (T1b) is been monitored by the PLC (K00) with the help of the feedback contact “operation” of the frequency converter (T1c). This also monitors the auxiliary contactor (K4).

If there is no speed signal while the motor is activated, the PLC (K00) stops the variable frequency drive, VFD, via the auxiliary contactor (K6) to the normal stop (T1b) (plausibility check).



Key

G1 proximity switch

A2 speed relay

K4 contactor

T1a safe stop (converter)

K00 PLC

K6 contactor

T1b start /stop (converter)

T1c relay

Figure D.2 — Block diagram

D.5 Calculation of the Performance Level, PL

D.5.1 Component data

The data for the components of this example can be found in the following list:

G1	$MTTF_d$ [a] = 1142	DC[%] = 90
A2	$MTTF_d$ [a] = 718	DC[%] = 60
K4	B10d [h] = 400.000	DC[%] = 99*
K00	$MTTF_d$ [a] = 51	DC[%] = 60*
K6	B10d [h] = 400.000	DC[%] = 99*
T1a	$MTTF_d$ [a] = 24816	DC[%] = 99
T1b	$MTTF_d$ [a] = 25	DC[%] = 60

T1c MTTF$_d$ [a] = 25 DC[%] = 60

* DC from EN ISO 13849-1, Annex E.

NOTE As a precondition for this calculation, it is essential to know the safety related key data of the electrical components in use. These data are provided by the manufacturers of the components or can be taken from the EN ISO 13849-1:2008, Annex C.

D.5.2 Mathematical basic functions

$$\frac{1}{MTTF_d} = \sum_{i=1}^{N} \frac{1}{MTTF_{di}} = \sum_{j=1}^{N} \frac{n_j}{MTTF_{dj}}$$

$$MTTF_d = \frac{B_{10\mathrm{d}}}{0{,}1 \cdot n_{0\mathrm{p}}}$$

D.5.3 Calculation

D.5.3.1 Calculation of K4 and K6

K4: B_{10d} = 400.000, 365 [switching operations per year]

K6: B_{10d} = 400.000, 1000 [switching operations per year]

$$MTTF_{d(\mathrm{K4})} = \frac{400.000}{0{,}1 \cdot 365 \cdot [a]}$$

$$MTTF_{d(\mathrm{K6})} = \frac{400.000}{0{,}1 \cdot 1000 \cdot [a]}$$

D.5.3.2 Calculation of DC

Sub.1

$$DC_{avg,Sub1} = not\ relevant$$

Sub.2

$$DC_{avg,Sub2} = \frac{\frac{DC_{K4}}{MTTF_d(K4)} + \frac{DC_{T1a}}{MTTF_d(T1a)} + \frac{DC_{K00}}{MTTF_d(K00)} + \frac{DC_{K6}}{MTTF_d(K6)} + \frac{DC_{T1b}}{MTTF_d(T1b)}}{\frac{1}{MTTF_d(K4)} + \frac{1}{MTTF_d(T1a)} + \frac{1}{MTTF_d(K00)} + \frac{1}{MTTF_d(K6)} + \frac{1}{MTTF_d(T1b)}}$$

$$DC_{avg,Sub2} = \frac{\frac{99\%}{10959[a]} + \frac{99\%}{24816[a]} + \frac{60\%}{51[a]} + \frac{99\%}{4000[a]} + \frac{60\%}{25[a]}}{\frac{1}{10959[a]} + \frac{1}{24816[a]} + \frac{1}{51[a]} + \frac{1}{4000[a]} + \frac{1}{25[a]}}$$

$$DC_{avg,Sub2} = 60,25\%$$

D.5.3.3 Calculation of PFH Sub 1

$$\frac{1}{MTTF_{d,Sub1}} = \frac{1}{MTTF_d(G1)} + \frac{1}{MTTF_d(A2)}$$

$$\frac{1}{MTTF_{d,Sub1}} = \frac{1}{1142[a]} + \frac{1}{718[a]}$$

$MTTF_{d,Sub1} = 440,8[a]$ (will be reduced to 100 [*a*])

According to EN ISO 13849-1:2008, Table K1, Category 1 (PL = c), DC = not relevant

$PFH_{Sub1} = 1,14 \cdot 10^{-6}$

D.5.3.4 Calculation of MTTFd Sub. 2 / Channel 1

$$\frac{1}{MTTF_{d,Sub2.1}} = \frac{1}{MTTF_d(K4)} + \frac{1}{MTTF_d(T1a)}$$

$$\frac{1}{MTTF_{d,Sub2.1}} = \frac{1}{10959[a]} + \frac{1}{24816[a]}$$

$MTTF_{d,Sub2.1} = 7601,9[a]$ (will be reduced to 100 [*a*])

D.5.3.5 Calculation of MTTFd Sub. 2 / Channel 2

$$\frac{1}{MTTF_{d,Sub2.2}} = \frac{1}{MTTF_d(K00)} + \frac{1}{MTTF_d(K6)} + \frac{1}{MTTF_d(T1b)}$$

$$\frac{1}{MTTF_{d,Sub2.2}} = \frac{1}{51[a]} + \frac{1}{4000[a]} + \frac{1}{25[a]}$$

$$MTTF_{d,Sub2.2} = 16,7\left[a\right]$$

D.5.3.6 Calculation of PFH Sub. 2 / Channel 1 and Channel 2

$$MTTF_{d,Sub2} = \frac{2}{3}\left[MTTF_{d,Sub2.1} + MTTF_{d,Sub2.2} - \frac{1}{\frac{1}{MTTF_{d,Sub2.1}} + \frac{1}{MTTF_{d,Sub2.2}}}\right]$$

$$MTTF_{d,Sub2} = \frac{2}{3}\left[100 + 16,7 - \frac{1}{\frac{1}{100} + \frac{1}{16,7}}\right]$$

$$MTTF_{d,Sub2} = 68,26\left[a\right]$$

According to EN ISO 13849-1:2008, Table K.1, Category 3 (PL = c), DC = 60,25 %

$$PFH_{Sub2} = 1,82 \cdot 10^{-7}$$

D.5.3.7 Calculation of PFH

$$PFH_{com} = PFH_{Sub1} + PFH_{Sub2}$$

$$PFH_{com} = 1,32 \cdot 10^{-6}$$

D.6 Result of the calculation

Consequently the performance level provided by this overspeed prevention device fulfills the requirement, that PFH_{com} = 1,32 × 10^{-6} meets the range of ≥ 10^{-6} to < 3 × 10^{-6} [1/h].

The Performance Level provided by this system can either be calculated with the help of the formulas given in the EN ISO 13849-1:2008 or by using available software tools.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC on machinery.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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