

CONFIRMED
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Specification for

Centrifuges of the basket and bowl type for use in industrial and commercial applications

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Foreword

The British Standard has been prepared under the direction of the Chemical and Petroleum Standards Committee. This standard for hydro-extractors which was originally issued in 1938, revised and modified in 1951, has been re-written and this edition supersedes BS 767:1951 which is withdrawn. The title has been altered and the scope has been extended to include all machines using centrifugal action to separate two or more substances, excepting only those laboratory machines which are covered by BS 4402 and high speed gas centrifuges used for the enrichment of fissile material. Centrifuges used in the processing of nuclear fuel should in general conform to this standard. There may be other specific requirements relating to the irradiation effect upon non-metals and lubricants, criticality and remote control. The method of calculating stresses is based on that produced by the European Committee of Chemical Plant Manufacturers (EUCHEMAP 1 November 1974).

The UK Health and Safety at Work etc. Act 1974 places a responsibility on manufacturers, suppliers and users of machinery, to ensure that, as far as is reasonably practicable, equipment is safe when used properly for the purpose for which it is designed. Information has therefore been included to give guidance on the best known practice at the time of preparing this revision, in particular safe access for product removal, cleaning, and maintenance of these machines. The UK Institution of Chemical Engineers "User guide for the safe operation of centrifuges", was used as a basis for many of the recommendations.

The aim of this standard is to specify the materials and methods of manufacture, operating procedures and accessories required for the safe operation of centrifuges and also to ensure sufficient information is made available from the manufacturer and user to enable an inspection authority to determine the degree of safety and hence the suitability of the equipment for the duty.

Materials of construction listed are those in current general use. The allowable stresses have been brought in to line with current practice.

The importance of noise, i.e. unwanted sound, has increased since 1951 and attention is drawn to the "Code of practice for reducing the exposure of employed persons to noise"¹⁾, which gives guidance on permissible levels and measurement techniques.

Figure 2 to Figure 6, Figure 8 and Figure 9 are reproduced from French standard NF E 40-010 August 1976, by kind permission of the Association Française de Normalisation (AFNOR).

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 30, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ Published by HMSO (ISBN 011 8803409).

1 Scope

This British Standard specifies design, materials, methods of construction, inspection and testing of centrifuges of the basket and bowl and vibrating types for use in industrial and commercial application. To assist manufacturers and users to fulfil their obligations under the Health and Safety at Work etc. Act 1974, information is included covering safe access and safe working. Additional provisions necessary for handling highly flammable and/or toxic substances are also included.

Tube and bottle type centrifuges as used in laboratories are covered in BS 4402 and are excluded from this standard. High speed gas centrifuges used for the enrichment of fissile material are also excluded. The handling of explosive or biologically hazardous materials and also the use of non-metallic material for stressed parts of rotating assemblies is outside the scope of this standard.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1

centrifuge

a machine in which extraction or separation of a liquid from a solid and/or separation of immiscible fluids is achieved by centrifugal action

NOTE Illustrations of some basic types of centrifuges are given in Appendix A.

2.2

batch centrifuge

a machine that processes a discrete batch of feed material. It may be automated to go through a sequence of feeding, washing and spinning. Solids discharge may be either automatic, the solids being removed either at full speed or at a low speed, or the machine may be stopped for manual removal of the material, solid waste or product

2.3

continuous centrifuge

a machine that takes a continuous feed of material, giving a continuous discharge of liquor. Solids are removed either continuously or intermittently

2.4

pusher centrifuge

a continuous filtering machine with an oscillating mechanism for discharge of solids

2.5

decanter centrifuge

a continuous sedimentation machine with an internal screw mechanism for removal of settled solids from a rotating bowl

2.6

disc bowl centrifuge

a continuously fed sedimentation machine provided with a number of equally spaced conical discs between which the feed passes

solids are removed from the bowl either manually, or as a slurry via nozzles or by a bowl opening mechanism

2.7

textile centrifuge

a machine used in dry cleaning, laundering and textile processes to extract liquid from textile materials or articles

2.8

basket

that part of a centrifuge, arranged to rotate about its axis, having a perforate shell in which the liquid is separated from the solid component

2.9

bowl

that part of a centrifuge arranged to rotate about its axis, having an imperforate shell for the separation of immiscible liquids and/or the sedimentation of solids

2.10

spindle

the shaft or shafts on which the basket or bowl is carried

2.11

rotor

the part of the centrifuge that rotates, comprising basket or bowl and spindle together with attachments

2.12

casing

the stationary casing surrounding the basket, or bowl, adapted to receive the separated products and having means for their discharge

2.13

plough

a device for the removal of centrifuged solids from the rotating basket or bowl

2.14**screw conveyor**

a helical screw device mounted either within the bowl or basket and rotating concentrically with it or statically mounted as part of the casing so as to feed or discharge solids

2.15**hoops**

rings secured to the outer periphery of a centrifuge basket to give extra strength

2.16**bumping ring**

a device to limit radial movement of the rotor. The bowl or shaft will normally run freely within the bumping ring

2.17**screen**

a medium, usually metallic, used as an alternative to a cloth within the rotating assembly for the purpose of solids retention or as a support for a filter cloth

2.18**cover or closure for baskets**

a detachable cover fitted in a centrifuge basket that holds the contents in position during rotation and is used to facilitate manual loading of the basket or lifting out of a filter bag

2.19**inspection cover or port**

an integral part of the centrifuge casing that is bolted, clamped or otherwise secured before the rotor is set in motion. It may be removed or opened for maintenance, inspection, lubrication or cleaning purposes.

2.20**cover (or lid)**

a plate or door forming part of the casing that, when closed or secured, prevents persons from coming into contact with moving parts, from becoming entangled with any material in motion within and from being splashed or affected by fumes from the machine

2.21**interlock**

a device using mechanical, electrical, pneumatic or hydraulic components, or any combination of these, that prevents an action or motion taking place until some specified safe or predetermined condition has been established. In addition it will normally continue to prevent an unsafe situation occurring

2.22**classification of hazardous areas**

an international system that recognizes three orders of probability of fire or explosion associated with the possible presence of flammable gases or vapours in a geographical area, namely Zone 0, Zone 1, and Zone 2 in decreasing order of severity (See BS 5345.)

2.23**combustion**

consumption by oxidation, with the production of heat, usually with incandescence or flame or both

2.24**flammable**

capable of burning in air with a flame

2.25**highly flammable**

any substance that, when tested in a manner specified in the Highly Flammable Regulations 1972, gives off a flammable vapour at a temperature of less than 32 °C and when tested in the specified way for combustibility, supports combustion

2.26**flash point**

the lowest temperature at which a liquid gives off sufficient flammable vapour in air to produce a flash on the application of a small flame

2.27**inert gas**

a gas that cannot support combustion (For practical purposes, usually nitrogen, but argon, flue gas or carbon dioxide are occasionally used when suitable and available.)

2.28**inert gas blanket**

a system where the oxygen content within an enclosure is reduced by the use of an inert gas to a concentration at which an explosive atmosphere cannot form

2.29**operating speed of a centrifuge**

the speed measured in revolution per unit time at which the rotor is expected to revolve either continuously or at each part of a multi-speed programme

2.30**permissible speed of a centrifuge**

the maximum allowable speed of the rotor determined from stress considerations allowing the appropriate factor of safety

2.31**frame**

the major stationary part that supports the rotor. The centrifuge casing is normally mounted on the frame

2.32**highly stressed parts**

those parts where the calculated stress is equal to or above 75 % of the maximum permitted stress

2.33**medium stressed parts**

those parts where the calculated stress is below 75 % and above 50 % of the maximum permitted stress

2.34**low stressed parts**

those parts where the calculated stress is equal to or below 50 % of the maximum permitted stress

3 Materials of construction

3.1 General. Materials shall conform to appropriate British Standards. The manufacturer and user shall agree a specification including chemical analysis and mechanical properties required when materials chosen are other than those specified in a British Standard.

They shall also agree the amount and type of testing needed to demonstrate that the agreed specifications are met.

NOTE Safety is dependent upon the integrity of the rotating assembly. No level of containment is specified.

3.2 Major parts

3.2.1 Rotating parts. Major parts of centrifuges subject to stress due to speed of rotation shall be manufactured from a ductile material having an elongation of not less than 12 % and an impact test value of not less than 25 J at 20 °C.

NOTE Preferred materials are those specified in BS 970-1, BS 970-2 and BS 970-4, BS 1449, BS 3072, BS 3100 and BS 4360.

Any heat treatment to which the unit has been subjected shall be recorded by the machine manufacturer and made available to the user on request.

3.2.2 Parts subject to corrosion, abrasion, erosion or low temperature conditions

3.2.2.1 Parts subject to corrosion, abrasion, erosion or low temperature conditions shall be manufactured from a material specified in a British Standard where available. If due to a customer's specific duty requirement a non-standard material has to be used, the manufacturer and customer shall agree the chemical and mechanical tests required and the manufacturer shall certify the part meets the requirements of the tests.

3.2.2.2 Materials for use at sub-zero temperatures shall meet the design requirements at the minimum operating temperature.

NOTE The manufacture of stressed parts of rotating assemblies in non-metallic materials is not covered by this standard.

3.2.3 Testing of materials. Tests shall be made on the materials for major items of construction to establish that the specified property requirements are fulfilled and that the materials comply with the relevant standard.

NOTE The values given in 3.2.1 refer to tests on separately cast or forged test pieces.

Calculations of the bowl/basket strength and the certificates of physical properties and chemical analysis shall be made available to the customer upon request. The request shall be made at the time of enquiry.

3.3 Protective lining materials and surface coverings

NOTE Lining materials and surface coverings are not specified but for guidance general requirements are listed in Appendix B.

3.3.1 Testing of lining. Inspection and test procedures specified in CP 3003 or BS 5624 shall be used, or in the case of a thick lined basket or bowl with non-conductive lining the procedure given in 3.3.2 shall be adopted.

3.3.2 Procedure. Partially submerge the basket, with its spindle in a horizontal position, in water containing less than 0.1 % of sulphuric acid, the spindle being above the level of the liquid. Apply a voltage of not less than 1 000 V a.c. between the spindle (which is electrically connected to the metal of which the basket is composed) and the liquid, and rotate the basket slowly through one revolution. No defect in the covering shall become visible during the test.

3.4 Materials for casings and other wetted components

Material for casings and other wetted components shall be chosen to suit the duty, e.g. abrasive, corrosive, erosive, high or low temperature.

NOTE Materials should preferably be chosen from those listed in 3.2.1.

4 Methods of construction

4.1 Casting, forging, rolling or welding. Basket and bowl cylindrical and conical sections shall be made from castings, forgings or rolled and welded fabrications.

4.2 Bolting and riveting. Where basket or bowl cylindrical and conical shells are joined to the ends by bolting or riveting, the manufacturer shall state the design stress to be applied to bolts or rivets during assembly.

NOTE The means by which this stress may be determined should be agreed between manufacturer and user.

4.3 Fabrication by welding

4.3.1 The procedures used for welding of highly stressed parts shall be in accordance with **5.2** of BS 5500:1982.

Welders shall be approval tested in accordance with **5.3** of BS 5500:1982. Welded joints shall comply with the requirements of **4.3** of BS 5500:1982 and if pre- or post-heat treatment is considered necessary it shall be in accordance with **4.4** of BS 5500:1982. There shall be 100 % NDT in accordance with **5.6** of BS 5500:1982 after all heat treatment is completed. Defects shall be assessed in accordance with **5.7** of BS 5500:1982.

4.3.2 Medium stressed parts shall be welded using either the above procedures or approval procedures given in BS 4870-1. Welders shall be approval tested as in **4.3.1** above or by procedures given in BS 4871-1. Any necessary heat treatment shall be completed using a written procedure.

On completion of heat treatment radiographic or ultrasonic examination shall be carried out, as given in either a) or b).

a) A minimum of 10 % of the weld length shall be subject to radiographic or ultrasonic examination; this examination shall be carried out at all welded joint intersections and on part of every seam. Where an opening occurs in any welded seam or within a distance equal to the metal thickness, radiographic or ultrasonic examination shall be carried out at each side of the opening over a length of approximately 100 mm.

b) A 100 % radiographic or ultrasonic examination shall be carried out on a random 10 % of any batch.

4.3.3 The welding of low stressed parts shall be in accordance with written procedures and shall be subject to visual inspection. The acceptance criteria for defects shall form part of or be appended to the written procedure.

4.3.4 Visual examination shall accompany all “non-destructive testing” and the examination result shall be recorded. A non-destructive testing specification shall be provided by the manufacturer for each centrifuge type.

4.4 Repair of defects. Where examination reveals unacceptable defects 100 % examination shall be made. The rectification of unacceptable defects shall be carried out using a written approved method and shall be subjected to the same examination as the original work using the same acceptance criteria.

5 Strength of baskets or bowls

5.1 Cylindrical baskets or bowls. The strength of cylindrical baskets or bowls shall be determined using the methods of stress analysis specified in Appendix C.

The shells shall be of uniform thickness and shall be either unperforated or have round perforations.

The ratio of shell thickness/basket radius shall be not greater than 0.1.

The maximum permitted stress (f_t) shall not exceed the smaller of the following two values:

$$f_t \leq 0.5 f_y$$

$$f_t \leq 0.33 f_R$$

where

f_R is the ultimate tensile strength (in N/mm²);

f_y is the yield point stress for steels with marked yield point (in N/mm²), or

0.2 % proof stress for steels without marked yield points (in N/mm²); or

1.0 % proof stress for austenitic steels (in N/mm²).

5.2 Other baskets or bowls. The criteria to be used in assessing calculated stresses shall be in accordance with Appendix A of BS 5500:1982.

NOTE 1 A finite element technique is considered to be the most suitable for stress analysis of a rotating basket or bowl.

NOTE 2 The purchaser and manufacturer should agree at the time of the order the fatigue design conditions, if any, to be evaluated having regard to the available service experience and experimental information. Appendix C of BS 5500:1982 refers to strain cyclic fatigue data for up to 5×10^6 cycles. It should be noted that the straight line may not be extrapolated.

The maximum permitted stress shall be determined from the equations given in **5.1**.

Each type of basket or bowl designed in accordance with this subclause shall be tested to demonstrate the integrity of the type and this test shall include a test at a speed and load sufficient to produce 125 % of the design stress for 30 min.

6 Design requirements

6.1 Casing. The casing, including doors, covers, lids and their fixings shall be secured either to the frame of the machine or the foundation and shall be sufficiently robust and of a suitable thickness to meet the duties specified and other predicted conditions. The thickness of any lining shall be in addition to the case thickness. A bumping ring shall be fitted to the casing of any centrifuge if the basket is liable to oscillate relative to the casing.

The casing shall provide adequate sealing against leakage of process fluid, gas or vapour.

6.2 Basket or bowl construction

6.2.1 Hoops. The basket or bowl shall be either unhooped or hooped. When hooped the spacing shall be symmetrical.

6.2.2 Joins in basket or bowl material. The manufacturer shall provide to the user evidence that the method of joining shell material is adequate for the proposed duty.

6.2.3 Perforations and holes. Perforations and holes shall be drilled or shall be produced by a method that induces stresses no higher than those caused by drilling.

NOTE if the calculated circumferential stress is below 60 N/mm² holes or perforations may be punched.

6.3 Spindle and couplings. The spindle and couplings shall be shown to be adequate for the maximum driving and braking torque and for the manufacturer's specified out-of-balance loads.

6.4 Drives. Electric motors for use on centrifuges shall be constructed in accordance with BS 4999.

For batch centrifuges, the duty cycle and rating of the machine shall be agreed between the centrifuge manufacturer, motor manufacturer and user in accordance with the designations of BS 4999-30.

6.5 Balancing and limits of vibration

6.5.1 Rotor balance. The centrifuge manufacturer shall state the balance quality of a rotor in accordance with BS 5265-1 in the new condition and, if different, the permissible value to which a used rotor should be balanced. The method of achieving balance shall be clearly visible on an assembled rotor and shall be recorded at the time it is applied. The manufacturer shall indicate zones where corrective balancing action may be applied and state his recommended method of achieving balance.

6.5.2 Vibration intensity. The limits of vibration intensity as specified in BS 4675-1 or, if appropriate, vibration amplitude at which the machine may be allowed to operate, shall be stated by the centrifuge manufacturer.

6.6 Locking and fatigue strength of bolted parts

6.6.1 Rotating parts. Bolted connections on all rotating parts shall be locked, e.g. by tab washers, spring washers, locking wire, or upsetting (peening). Double nuts shall not be used. All bolting on rotors shall be to an agreed fatigue resistant design. The manufacturer shall state the required torque loading or necessary bolt extension in the maintenance manual.

6.6.2 Stationary parts. Bolts fitted to stationary parts which, if they should loosen, could come into contact with the rotor, shall be to a fatigue resistant design and shall be locked.

6.7 Direction and speed of rotation

6.7.1 General. The direction of rotation, and the permissible speed shall be marked on the machine in a permanent manner (see clause 14).

6.7.2 Measurement. Suitable provision shall be made for the measurement of the speed of rotation.

6.8 Accessories. All accessories required for the safe operation of the centrifuge at the required duty shall be specified by the centrifuge manufacturer and shall include information on gearboxes, solids removal equipment, lubrication and sealing systems.

6.9 Screw threads. Screw threads shall be consistent throughout the machine and to BS/ISO metric dimensions.

6.10 Connections. The centrifuge manufacturer shall state the maximum force and movement to which connections may be subjected in compression, tension, bending and torque.

Centrifuges located on anti-vibrational mountings or vibration isolators require all connections to the machine to be sufficiently flexible to accommodate predicted movements.

6.11 Foundations. The machine manufacturer shall provide, on request by the user, recommendations in the form of drawings showing forces on foundations and the recommended methods of attaching machines to the foundations. In particular manufacturers shall give information on the forcing frequencies to which the foundation will be subjected.

6.12 Over-pressure protection. Where required by the user the maximum allowable operating pressure for the centrifuge casing shall be stated by the manufacturer. The design contractor and user shall ensure that the centrifuge casing is provided with an over-pressure protection device. Sources of possible over-pressure from associated equipment, for example feed systems, product discharge systems, dryers and wash supplies, shall be considered.

The manufacturer shall also provide over-pressure protection for any other pressurised system on the centrifuge such as an oil lubrication system where appropriate.

7 Guards, interlocks and safe working

NOTE 1 Particular attention is drawn to BS 5304 which is a code of practice indicating the principles to be used and the methods that may be applied in safeguarding machinery.

NOTE 2 A person may be injured at centrifuges as a result of, for example:

- a) coming into contact with, or being trapped by the machinery;
- b) being struck, trapped or entangled in or by any material in motion in the machinery;
- c) being struck by parts of the machinery ejected from it;
- d) being struck by material ejected from the machinery;
- e) being scalded, burned or splashed by liquids being fed to or ejected from the machine;
- f) being affected by gas or fumes from the machine.

7.1 Guards

7.1.1 All doors, inspection covers, lids and guards shall be secured by means which necessitate the use of a tool for removal unless interlocks are provided in accordance with 7.2.

7.1.2 When the process conditions allow and when it is necessary to wash down, feed or inspect whilst the machine is in motion, suitable guarding shall be fitted to prevent persons coming into contact with moving parts.

NOTE Fixed guards should be used whenever practicable.

7.2 Interlocks

7.2.1 interlocks shall be designed to ensure that the centrifuge remains in a safe condition if the interlock or its power supply fails.

7.2.2 Any centrifuge not protected as specified in 7.1.1, shall be equipped with devices designed to ensure that it cannot be started until doors, covers, lids and/or guards have been closed and secured and that access cannot subsequently be gained until linear and rotational motion have ceased.

Machines fitted with rotational sensing devices shall be considered stopped at speeds below 9 r/min.

7.2.3 If a drive mechanism is employed which is capable of driving the centrifuge at a speed higher than its permissible speed, a speed control and an overspeed prevention device shall be provided.

7.2.4 When a basket type centrifuge is fitted with a low speed plough discharge device, an interlock shall be fitted to avoid the possibility of the plough operating at a basket speed higher than that for which it was designed.

7.2.5 For a ploughing type centrifuge, interlocks shall be fitted which will:

- a) prevent the starting of the main drive of the centrifuge unless the plough unit is in the parked (i.e. withdrawn) position;
- b) prevent feed valves opening on the first or subsequent cycles until the basket is rotating at its normal feed speed, and the plough is in the parked position.

7.2.6 A centrifuge provided with an independent oil lubrication supply shall have an interlock to prevent the main drive starting until the lubrication system is functional. Failure of the lubrication system shall trip the centrifuge drive and stop the feeds.

7.3 Other safety features

7.3.1 Any centrifuge operating on a duty likely to give excessive out-of-balance forces shall be fitted with a vibration alarm and a high vibration trip which will initiate appropriate action to reduce the out-of-balance forces.

NOTE Consideration should be given to fitting vibration monitoring equipment to all centrifuges.

7.3.2 Centrifuge installations shall be effectively earthed and any non-conducting sections of pipework shall be bridged with an earth conductor.

NOTE Drive belts of anti-static material should be used.

7.3.3 A rigid mechanical back-up stop shall be provided for a ploughing type centrifuge to prevent the plough blade tearing into the cloth or basket unless the design of the plough geometry inherently prevents this occurrence.

7.3.4 Electrical heaters fitted in the centrifuge oil systems shall be rated at not more than 30 kW/m² and fitted with a high temperature trip device.

7.3.5 A centrifuge drive shall be so designed that in the event of a trip it can only be manually re-started.

7.3.6 The application of any brake shall automatically isolate the main drive mechanism unless the drive system is used as a break.

7.3.7 Centrifuges incorporating a lift-out basket and/or a lift-out basket lid arrangement shall have devices to prevent start-up until the basket and/or lid have been correctly located and locked into position.

NOTE Consideration should be given to the provision of adequately sized inspection windows, fixed light with internal wash or scraper facility and the provision of internal casing flush facilities to obviate the necessity of opening up the machine for process reasons.