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English version

Cryogenic vessels

Pumps for cryogenic service

Récipients cryogéniques – Pompes pour service cryogénique

Kryo-Behälter – Pumpen für den Kryo-Betrieb

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CEN

European Committee for Standardization
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Europäisches Komitee für Normung

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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 268 "Cryogenic vessels", the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by November 2000, and conflicting national standards shall be withdrawn at the latest November 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This standard specifies the minimum requirements for the design, manufacture and testing of pumps for cryogenic service (i.e. for cryogenic fluids, see EN 1251-1).

This standard covers centrifugal pumps. However the principles may be applied to other types of pumps (e.g. reciprocating).

This standard also gives guidance on the design of installations (see annex A).

It does not specify requirements on operation or maintenance.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 809:1998, *Pumps and pump units for liquids – Common safety requirements.*

EN 1251-1:2000, *Cryogenic vessels - Transportable vacuum insulated of not more than 1000 litres volume – Part 1 : Fundamental requirements*

EN 1252-1:1998, *Cryogenic vessels - Materials - Part 1: Toughness requirements for temperatures below -80 °C.*

prEN 1252-2, *Cryogenic vessels - Materials - Part 2: Toughness requirements for temperatures between - 80 °C and - 20 °C.*

EN 1333:1996, *Pipework components - Definition and selection of PN.*

EN 1797:2000, *Cryogenic vessels - Gas/material compatibility.*

EN 12300:1998, *Cryogenic vessels - Cleanliness.*

EN ISO 5198:1998, *Centrifugal, mixed flow and axial pumps - Code for hydraulic performance test – Precision class (ISO 5198:1987).*

EN ISO 6708:1995, *Pipework components - Definition and selection of DN (nominal size) (ISO 6708:1995).*

EN ISO 9908:1997, *Technical specification for centrifugal pumps - Class III (ISO 9908:1993).*

ISO 5199:1986, *Technical specification for centrifugal pumps - Class II.*

ISO 9906:1999, *Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1 and 2.*

3 Terms and definitions

For the purposes of this European Standard, the following definitions apply :

3.1
nominal size (DN)
[EN ISO 6708:1995]

3.2
nominal pressure (PN)
[EN 1333:1996]

NOTE PN is equal to PS as defined in the directive 97/23/CE.

3.3
specified minimum temperature
the lowest temperature for which the pump is specified

3.4
duty point
a performance point defined by pressure or head and volume or mass flowrate

3.5
net positive suction head (NPSH)
[Table 1 in EN ISO 5198:1998 or ISO 9906:1999]

4 Requirements for pump

4.1 General

It is a requirement of this standard that a cryogenic pump shall first comply with appropriate EN standards e.g. EN 809. In the event of conflict, the requirements of this standard shall take priority over the general standards.

4.2 Materials

4.2.1 General

Materials of construction shall be selected taking into consideration that cryogenic pumps operate at low temperature, often in a damp environment, and at times with liquid oxygen, or with flammable fluids.

The minimum requirements given in 4.2.2, 4.2.3 and 4.2.4 shall apply.

4.2.2 Mechanical properties at low temperature

Metallic materials which are under stress at low temperature and which exhibit a ductile/brittle transition (such as ferritic steels) shall have minimum impact test values in accordance with EN 1252-1 or prEN 1252-2 as appropriate.

Metallic materials which can be shown to have no ductile/brittle transition do not require impact testing.

Non-metallic materials are generally used only for seal or heat barrier materials. If such materials are to be used for structural parts, stress levels and material impact values shall be shown to be acceptable for the intended use.

4.2.3 Corrosion resistance

Materials should be resistant to, or protected from, atmospheric corrosion. Where this is not achievable, a suitable corrosion allowance shall be considered.

4.2.4 Oxygen compatibility

If the specified minimum temperature is equal to or less than the boiling point of air or the pump is intended for oxygen service, the materials which are, or are likely to come, in contact with oxygen or oxygen enriched air, shall be oxygen compatible in accordance with EN 1797.

Consideration of the requirements for oxygen compatibility should be made when the pump is employed for oxidising cryogenic fluids , e.g. nitrous oxide.

Materials should be selected that minimise the potential of an ignition and inhibit sustained combustion.

These material properties are :

— high ignition temperature ;

— high thermal conductivity ;

— low heat of combustion.

A table of materials found through testing and operating experience to be particularly suitable for centrifugal cryogenic pumps in oxygen service, is included as annex B. Materials other than those identified in annex B may be used but their selection shall be justified by specific testing or long term experience in this application.

For (any) parts of the pump which are, or are likely to come, in contact with oxygen and which could be exposed to energy sources such as friction, aluminium or aluminium alloy shall not be used. The use of aluminium or aluminium alloy for any other parts shall only be adopted after careful consideration.

Stainless steel shall not be used for exposed thin components. Exceptions allowable are the seal bellows, trapped shims or gaskets and screw locking devices of stationary parts where knowledge of past satisfactory performance is available, however suitable alternative method e.g. Monel, Inconel should be considered.

NOTE Tin bronze has been found to be most suitable for the main "wetted" pump components. The most common aluminium bronzes, which contain typically between 6 % and 11 % aluminium have relatively high heats of combustion and if combustion occurs are practically impossible to extinguish in an oxygen environment.

4.3 Design

4.3.1 Pressure containing parts

The high pressure side of the pump shall be designed to withstand at least the nominal delivery pressure. The low pressure side shall be designed to withstand at least the nominal inlet pressure.

4.3.2 Performance

The pump design and installation shall meet the performance requirements specified on a data sheet (or similar document). An example of a data sheet can be found in ISO 5199 and ISO 9908.

4.3.3 Clearances

Clearances between moving and stationary parts within the pump shall be as large as practical, consistent with good hydraulic performance and sealing. Material selection for components should take into account the often large differences in expansion coefficients to ensure satisfactory clearances and interferences at the operating temperatures and during cooldown.

4.3.4 Rubbing prevention

The consequences of bearing failure or the consumption of wearing parts shall be considered, particularly in pumps designed for liquid oxygen duty.

4.3.5 Fastenings

All internal fasteners shall be secured to prevent them loosening in service. (e.g., friction nuts, tab washers).

Consideration shall be given to more adequately securing items which might normally be held in place by an interference fit only, (e.g. wear rings). These components can cool down more quickly than others and become temporarily loose.

4.3.6 Warm bearings

Rolling elements bearings designed to run warm, shall be located or protected such that freezing of the lubricating grease or oil is avoided. The effect of ice build up over a period shall be considered. This may result in overcooling of the bearing and may allow shaft seal leakage to be forced directly into the driver bearing. Motor bearing heaters may be considered for cold standby pumps.

4.3.7 Cold bearings

For bearings designed to run cold, lubricated by the cryogenic fluid, the use of materials and design arrangements that can safely withstand short term dry running shall be considered.

4.3.8 Bearing lubrication

For direct coupled cryogenic pumps, grease and oils shall be suitable for all oxidising and predictable offset conditions. The lubricants should typically be suitable down to – 40 °C.

Sealed bearings are preferred. Where bearing re-greasing in situ is required grease drain plugs should be provided to reduce the risk of accumulations of grease within the motor housing.

Liquid oxygen pumps shall be constructed so that possible oxygen leakage cannot contact any hydrocarbon lubricant. Where this cannot be prevented with certainty, the use of oxygen compatible lubricants meeting the requirement of EN 1797, shall be considered. It should be noted, however, that such oxygen compatible lubricants are less able to protect the bearing against corrosion, generally reduce the ability of the bearing to withstand load and speed, and may have some adverse reaction with some material combinations.

4.3.9 Shaft seals

Shaft seals will probably be either mechanical rubbing face or labyrinth type. Both have a high possibility of leakage.

The design of the mechanical seal shall prevent metal to metal rubbing between the seal carrier and the rotating seal ring when the soft face material wears out.

For pumps in oxygen service a protective sleeve shall be fitted between the bellows of any mechanical seal and the shaft.

Labyrinth shaft seals need to be treated as systems, engineered for the particular application. Injected gas may be an inert gas or oxygen.

Leakage detection devices should be considered, e.g. low temperature trip.

A slinger or other deflection device shall be used to prevent direct impingement of shaft seal leakage on the driver bearing.

4.3.10 Purging

A tapping for a dry inert gas purge may be used to :

a) prevent the ingress of moisture (and possibly ice build-up) within the seal area ;

b) prevent the ingress of moisture into areas using oxygen compatible lubricants ;

c) provide a barrier between oxygen compatible and non oxygen compatible parts of a pump (e.g. cold end and mechanical drive).

4.3.11 Particle prevention

Appropriate devices such as a filter shall be used if there is a risk of contamination in service.

4.3.12 Specific requirement for flammable fluids

The leak rate from the pump and its accessories shall not exceed 1 N.mm^3/s (10^{-3} mbar l/s) and its design should prevent the possibility of dangerous accumulations. Any higher leakage flows (from seal areas etc) shall be collected and vented to a safe location. If electric devices are used they shall be suitable for the hazard zone, in accordance with the relevant European Regulations. Pumps shall have sufficient electrical continuity to prevent build up of static electricity.

4.3.13 Protection against over pressurisation

The design of the pump should avoid the possibility of any trapped cryogenic liquid. Any area of the pump or its accessories that could become inadvertently pressurised beyond its design conditions shall be provided with a method of pressure relief. In particular any vacuum insulated space that could become pressurised by leakage through a defect.

4.3.14 Pump motors

Externally mounted electric motors shall be the totally enclosed fan cooled type (TEFC) for pumps where the specified minimum temperature is equal to or less than the boiling point of air or the pump is intended for oxygen service.

5 Testing

5.1 Prototype testing

5.1.1 General

At least one pump (representative of any new pump design) shall be subjected to the following tests.

These tests shall be repeated if any one of the following changes apply :

— manufacturer ;

— frame size ;

— material type ;

— increase in maximum pressure or speed.

5.1.2 Design evaluation

The prototype pump shall be inspected to ensure that the design satisfies the requirements detailed in clause 4.

5.1.3 Initial tests

The pump shall first be subjected to the tests normally applied as production test described in 5.2.

5.1.4 Cryogenic test

5.1.4.1 General test conditions

Pumps with a specified minimum temperature lower than, or equal to – 196 °C may be tested using liquid nitrogen. A deviation from – 196 °C of ± 10 % is allowed in temperature measurement.

Pumps with a specified minimum temperature higher than – 196 °C shall be tested at or below their specified minimum temperature ± 10 %.

Where the cryogenic fluid on test is different from that specified for final use, density corrections for power, etc.., are acceptable.

5.1.4.2 Mechanical integrity test

Centrifugal pumps shall be run at a minimum of five points. These shall include minimum, normal and maximum duty points. (This shall allow a head/flow pump characteristic curve to be generated). The run at the normal duty point shall be for at least one hour.

Where pump size and flowrate is large, a reduced test time is acceptable provided temperatures are reached.

As part of the test, the pump shall be stopped and started a minimum of ten times.

Throughout the test, the pump shall be seen to run normally with no visible leakage, excessive vibration or distress. For flammable fluids additional requirements for leakage apply that shall be demonstrated during type testing.

5.1.4.3 Net positive suction head (NPSH) test

The pump shall be tested to establish its NPSH requirement across its flowrate range.

Following the test, the pump shall be warmed up, disassembled onto its major component parts and examined. No significant touching, rubbing or indications of distress shall be present. (Marking on impeller labyrinth seal and bushings etc., is acceptable).

5.2 Production testing

5.2.1 General

Each pump shall satisfactorily pass the following production tests of the appropriate EN standards refer to in 4.1.

5.2.2 Hydrostatic pressure test

The pump pressure retaining envelope (casing flanges, etc.) shall be tested to 1,5 times the outlet and inlet PN. (Testing will normally be to 1,5 times the outlet PN unless special provision for separately testing the high and low pressure sections has been incorporated at the design stage).

The pressure test shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when held for five minutes and no gross plastic deformation, leaks or seepage (through the casing or casing joint) is observed.

5.2.3 Mechanical running and performance test

The pump shall be run for a minimum of five minutes at its quoted duty point(s), with cryogenic fluid temperature conditions as stated in 5.1.4. Throughout the test, the pump shall be seen to run normally with no visible leakage, excessive vibrations or distress.

Where the cryogenic fluid used on test is different from that specified for final use, density, corrections for power, etc., are acceptable.

6 Cleanliness

The pumps shall be dispatched with a cleanliness level and packing integrity which satisfies EN 12300.

7 Marking

The pump body or identification plate shall be marked in accordance with the applicable pump standard, with the following modification :

— the fluids for which the pump is suitable.

Annex A
(informative)
Guidance on installation design

A.1 Pump for cryogenic service

A.1.1 The following recommendations are given for guidance only and represent good industrial practice.

Alternative methods may be used that provide equivalent safety.

A.1.2 Suction pipework should be as short and straight as possible with a minimum number of bends. Pipework should be sized, arranged and insulated (if necessary) to ensure that the Net Positive Suction Head (NPSH) requirement for the pump (or pumps) should be met at the lowest design tank level and highest flowrate. (NPSH is defined in 3.5 but can be regarded as the difference between the head as measured by a pressure gauge at the pump suction flange and the pressure at which the fluid at the pump suction flange will boil.)

A.1.3 Consideration shall be given to the likely behaviour of liquid and vapour during cooldown to avoid gas locking. Where gas is to be vented externally during cooldown, consideration shall be given to having vents and lines of sufficient size and to where those vents are to be safely directed.

A.1.4 Where more than one pump is installed, dead-legs should be avoided or minimised by the use of individual lines, isolation valves mounted close to branches or correct use of lutes.

A.1.5 Pumps should be installed using flexible hoses. These should be installed to ensure that high flange loadings are not transmitted on cooldown (e.g. in pre-compressed conditions).

A.1.6 Provision should be made for safe removal of pumps for maintenance. Consideration should be given to the provision of any lifting beams or strong points for lifting equipment, and the layout of pipework and cable trays etc to maximise access.

A.1.7 Good ventilation is required in the vicinity of cryogenic pumps to avoid excessive concentrations of gas in the event of seal leakage or air condensation.

A.1.8 Safety distances from boundaries, pits, drains etc. should be in accordance with the relevant operational standard for cryogenic vessels.

A.1.9 A non return valve should be installed in the pump outlet pipework.

A.2 Additional guidance on oxygen installation design

A.2.1 Oxygen pump installations offer a higher level of risk than inert gas pump installations due to the possibility of a violent oxygen fire which can result in flame products and hardware being violently ejected some distance.

Consideration shall be given to measures to reduce the likelihood of an incident and to measure to protect personnel in the event of an incident.

Pumps constructed of suitable materials with attention to the design of the seal and lubrication system have a low probability of ignition.

A.2.2 For fixed installation, a barrier should be considered on at least one side of pumps to protect personnel.

On sides where a barrier is not in place, a hazard zone of radius 5 metres should be considered to exist. This should be clearly marked and access to unauthorised personnel denied.

For installation on vehicle or transportable vessel, the pumps should be installed in a position safe for personnel.

A.2.3 Installation of a barrier should be considered between pumps when all pumps cannot be shut down when maintenance is required on one.

A.2.4 A barrier may be reinforced concrete or equivalent, low carbon steel plate or other suitable material. The barrier should be dimensioned to adequately protect personnel. Consideration shall be given to reducing the effect any barrier has on restricting airflow and concentrating any oxygen leakage. The ability to easily observe any pump malfunction such as a leaking seal will reduce the likelihood of an incident occurring.

A.2.5 Valves and controls that need to be manually operated while a pumps is running (or likely to run) should be located outside any barrier or have their valve stems protruding through the barrier.

A.2.6 A fail close Emergency Shut-Off Valve (ESOV) should be considered on the suction pipework of oxygen pumps to isolate flow of oxygen in the event of a fire. This valve may be tripped automatically or by an operator pressing a button.

A.2.7 Where pumps share a common suction pipe, and the shutdown of all pumps can be tolerated, the installation of one ESOV is acceptable.

A.2.8 Where oxygen pumps are kept permanently cold but are not run, the avoidance of high hydrocarbon concentrations should be ensured.

A.2.9 It is recommended that the discharge non-return valve should be installed downstream of the first elbow in the delivery line to reduce the chance of it becoming inoperative due to fire or debris.

A.2.10 Asphalt, or other organic substances should not be used for ground surfaces. No combustible materials should be stored locally and the area should be kept free of debris at all times.

A.2.11 A suction filter of suitable material should be installed in the suction line. The open area should not be less than 150 % of the cross-sectional area of he pipe bore to ensure a low pressure drop. For this reason a conical filter design is preferred. The filter should be robustly constructed having a fine mesh filter material adequately supported by a perforated backing plate.

A.2.12 The design and layout of the piping and electrical cabling for oxygen installations should consider the possible consequences of an incident involving a fire.

A.2.13 A loss of prime detection system should be installed to stop the pump and prevent dry running. (e.g. low differential or discharge pressure, low current or high discharge liquid temperature).

Annex B
(informative)

Acceptable materials of construction for centrifugal liquid oxygen pumps

A list of acceptable materials particularly suitable for centrifugal cryogenic pumps for oxygen service is given in table B.1. Materials other than those identified in the table may be used but their selection should be justified by specific testing or long term experience in this applications. Examples of centrifugal pumps are given in Figures B.1 and B.2.

Table B.1 — Acceptable materials for centrifugal al liquid oxygen pumps

Component	Acceptable materials
1 Volute or pump body	Tin bronze or leaded bronze [a]
Backplates	--
2 Impellers	--
3 Inducers	--
4 Diffusers	--
5 Wear rings	--
6 Shafts	Austenitic stainless, martensitic stainless steel [c], monel
7 Shaft sleeve (as part of any interstage bearing)	Phosphor bronze, stainless steel, Monel, suitable copper alloy [b]. NB the phosphor bronze may be tungsten carbide or chrome plated. The stainless steel may be stellited
8 Interstage bushings or bearings	Copper alloy [b], monel (with or without PTFE coating). PTFE of carbon based materials that have passed oxygen compatibility test in EN 1797-1
9 Impeller bolts fasteners	Monel, austenitic stainless steel, beryllium copper or copper alloy [b]
10 Tab-lock-washers, shims	Monel, beryllium copper of copper alloy [b]
11.1 Mechanical seal	- Stainless steel, tungsten carbide, stellite or ceramic
Rotating ring	- Austenitic stainless steel or nickel alloys. (If a protective sleeve is used, this shall be copper alloy [b]
Bellows	- Non-metallic materials that have passed oxygen compatibility test in EN 1797-1
Wearing face	- Tin bronze, monel, inconel, stainless steel. Non-metallic material that have passed oxygen compatibility test in EN 1797-1
11.2 Labyrinth seal	(Note : Stainless steel may be used for one, but not for both surfaces)
12 Gaskets	Filled PTFE, flexitallic type (using monel or nickel)
13 O-Ring, atmospheric seal.	PTFE
14 Slinger or thrower	Material suitable for low temperature and corrosion resistant
15 External pump body screw, bolt	Material suitable for low temperature and corrosion resistant

"to be continued"

Table B.1 (*concluded*)

Component	Acceptable materials
16 Carrier frame	Austenitic stainless steel. Material suitable for low temperature operation see EN 1252-1
17 Thermal barrier	Materials suitable for use at low temperature and that have passed oxygen compatibility test in EN 1797-1
18 Filter/strainer	Monel or copper alloy [b] mesh screen, on a copper alloy [b] or monel or stainless steel support

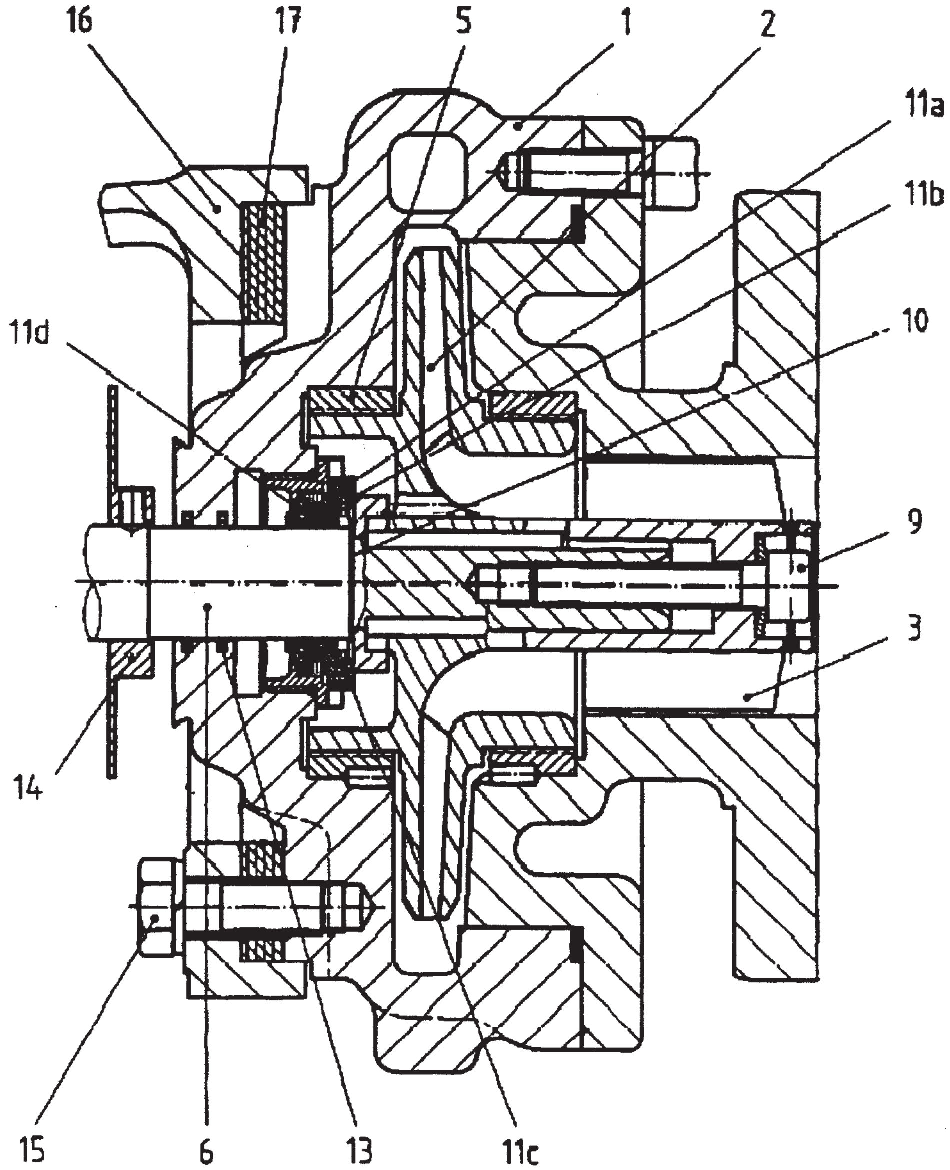
[a] In the table, the terms tin bronze and leaded bronze would be tvpically as follows :

- tin bronze : 10 % to 14 % Sn, remainder copper.
- Leaded bronze : 5 % to 7 % Sn ;
  5 % to 6 % Pb ;
  4 % to 5 % Zn.

[b] Copper alloy would typically be :

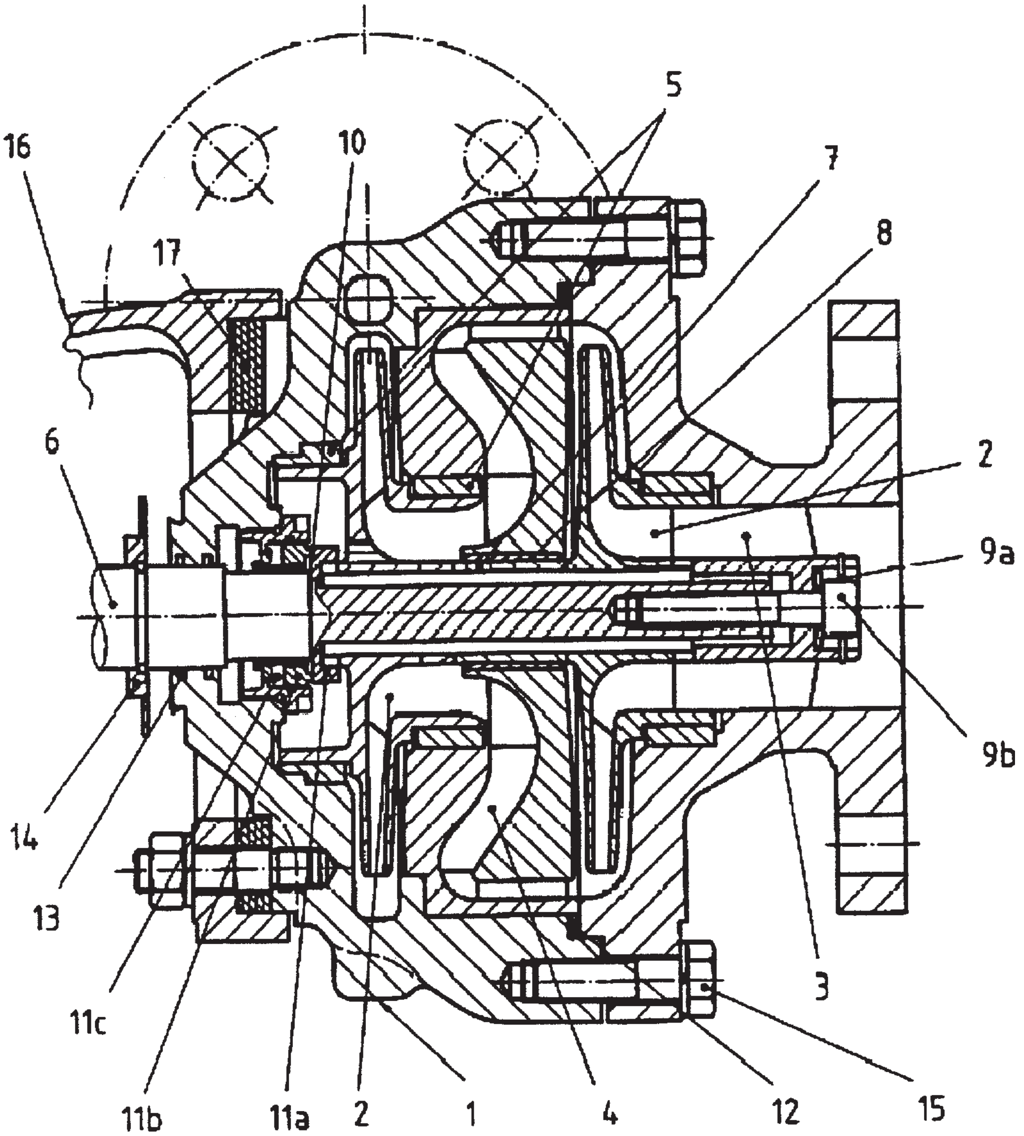
- eighty percent minimum copper alloy with a combined aluminium and iron of not more than 3 %.

[c] The use of martensitic stainless steels requires some special design considerations due to their low impact strength.



NOTE The numbers refer to table B.1.

Figure B.1 — Single stage centrifugal pump



NOTE The numbers refer to table B.1.

Figure B.2 — Two stage centrifugal pump