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In Rest of World Contact:-

ILI, Index House, Ascot, Berks, SL5 7EU, UK

☎: +44 (0)1344 636400 Fax: +44 (0)1344 291194 E-mail: standards@ili.co.uk
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Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries

ANSI/API STANDARD 614
FIFTH EDITION, APRIL 2008

**ISO 10438:2008, (Modified) Petroleum, petrochemical
and natural gas industries—Lubrication, shaft-
sealing and oil-control systems and auxiliaries**



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

ISO 10438 was prepared by Technical Committee ISO/TC 67, *Materials equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

This second edition cancels and replaces the first edition (ISO 10438:2003), which has been technically revised.

ISO 10438 consists of the following parts, under the general title *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries*:

- Part 1: *General requirements*
- Part 2: *Special-purpose oil systems*
- Part 3: *General-purpose oil systems*
- Part 4: *Self-acting gas seal support systems*

Introduction

This International Standard was developed jointly with API 614 5th edition. ISO 10438 is divided into four parts corresponding to the four chapters of API 614.

Users of ISO 10438 should be aware that further or differing requirements can be needed for individual applications. ISO 10438 is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from ISO 10438 and provide details.

ISO 10438 requires the purchaser to specify certain details and features.

A bullet (•) at the beginning of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the datasheet(s); otherwise it should be stated in the quotation request or in the order.

In this International Standard, United States customary (USC) units are included in brackets for information.

Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and oil-control systems and auxiliaries —

Part 1: General requirements

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Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and oil-control systems and auxiliaries —

Part 1: General requirements

1 Scope

This part of ISO 10438 specifies general requirements for lubrication systems, oil-type shaft-sealing systems, dry-gas face-type shaft-sealing systems and control-oil systems for general- or special-purpose applications. General-purpose applications are limited to lubrication systems. These systems can serve equipment such as compressors, gears, pumps and drivers.

This part of ISO 10438 is intended to be used in conjunction with ISO 10438-2, ISO 10438-3 or ISO 10438-4, as appropriate.

2 Normative references

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

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 10434, *Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries*

ISO 13706, *Petroleum, petrochemical and natural gas industries — Air-cooled heat exchangers*

ISO 15649, *Petroleum and natural gas industries — Piping*

ISO 15761, *Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries*

ISO 16812, *Petroleum, petrochemical and natural gas industries — Shell-and-tube heat exchangers*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

ANSI/API RP 551, *Process Measurement Instrumentation*

API RP 520 (all parts), *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries*

API STD 526, *Flanged Steel Pressure Relief Valves*

API STD 611, *General-Purpose Steam Turbines for Petroleum, Chemical and Gas Industry Services*

API RP 686-96, *Machinery Installation and Installation Design*

ASME B1.1, *Unified Inch Screw Threads (UN and UNR Thread Form)*

ASME B16.5, *Pipe Flanges and Flanged Fittings: NPS 1/2 through 24*

ANSI/ASME B16.11, *Forged Fittings, Socket-Welding and Threaded*

ANSI/ASME Y14.2M, *Line Conventions and Lettering*

ASTM A193/A193M-07, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A194/A194M-07, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM E94, *Standard Guide for Radiographic Examination*

ASTM E709, *Standard Guide for Magnetic Particle Examination*

ANSI/AWS D1.1/D1.1M, *Structural Welding Code — Steel*

ISA 18.1, *Annunciator Sequences and Specifications*

NEMA 250, *Enclosures for Electrical Equipment (1 000 Volts Maximum)*

TEMA, *Standards of the Tubular Exchanger Manufacturers Association*, 8th ed.

3 Terms, abbreviated terms and definitions

For the purposes of this document, the following terms, definitions and abbreviated terms apply.

3.1 Terms and definitions

3.1.1

alarm point

preset value of a parameter at which an alarm warns of a condition requiring corrective action

3.1.2

block-in time

period required after the driver is tripped to isolate a piece of equipment, such as a compressor, from its system and to depressurize it

3.1.3

booster pump

oil pump that takes suction from the discharge of another pump to provide oil at a higher pressure

3.1.4

coast-down time

period required after the driver is tripped for the equipment to come to rest

3.1.5

components

machinery and hardware items, such as reservoirs, pumps, coolers, filters, valves, and instruments, that are part of the system

3.1.6

console

total system whose components and controls are packaged as a single unit on a continuous or joined baseplate

NOTE 1 With a console, the purchaser is required only to make external connections.

NOTE 2 Rundown tanks and seal-oil tanks that are separately mounted, as well as other items such as instrumentation mounted on the equipment, are not part of the console.

3.1.7

continuous-flow transfer valve

valve that can simultaneously divert both inlet and outlet flows from one component to its installed spare equipment without altering the continuity of full flow through the transfer valve to the equipment

3.1.8

control oil

oil required to operate such components as relays, servomotors and power pistons on the main equipment

3.1.9

cool-off time

period during which oil has to be circulated through the equipment to prevent heat damage after the driver is tripped

3.1.10

device position

3.1.10.1

normally open

de-energized position of a device (e.g. automatically controlled electric switch or valve) remaining in an open position during operation unless energized

NOTE During operation of the equipment, the positions of these devices are not necessarily the same as their on-the-shelf positions.

3.1.10.2

normally closed

de-energized position of a device (e.g. automatically controlled electric switch or valve) remaining in a closed position during operation unless energized

NOTE During operation of the equipment, the positions of these devices are not necessarily the same as their on-the-shelf positions.

3.1.11

double seal

seal arrangement that utilizes two seal faces in an opposed configuration, whereby sealing gas is injected between the seal faces

NOTE See tandem seal (3.1.49).

3.1.12

dry gas seal system

self-acting dry gas seal module and all other components necessary for operation of the self-acting dry gas seal

3.1.13

equipment

main machinery served by the oil or gas system

3.1.14

fail safe

system or component that causes the equipment to revert to a permanently safe condition (shutdown and/or depressurized) in the event of a component failure or failure of the energy supply to the system

3.1.15

gas-seal module

arrangement of piping, filters and instrumentation used to control and monitor the pressure or flow of seal, buffer or separation gas to the equipment shaft end seals

3.1.16

gauge board

unenclosed bracket or plate used to support and display gauges, switches and other instruments

NOTE A gauge board is not a panel. A panel is an enclosure. Refer to 3.1.31 for the definition of a panel.

3.1.17

general-purpose

usually spared or in non-critical service

3.1.18

local

mounted on or near the equipment or console

3.1.19

mission time

duration of the mission

NOTE Mission time begins when the equipment or system is 100 % operational, i.e. equipment or system capability has returned to engineered capability, and the equipment or system is ready for service. The mission time ends when the equipment or system can no longer meet the defined mission objectives. To meet the business plan, it is necessary that the actual mission time be equal to or greater than the planned mission time.

3.1.20

main oil pump

oil pump that is normally in operation

3.1.21

maximum allowable temperature

maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure

3.1.22

maximum allowable working pressure

maximum continuous pressure for which the manufacturer has designed the console or components when handling the specified fluid at the maximum allowable temperature

3.1.23

maximum discharge pressure

(centrifugal pump) maximum specified suction pressure plus the maximum differential pressure the pump with the finished impeller is able to develop when operating at rated speed with fluid of the specified normal relative density (specific gravity)

3.1.24

maximum sealing pressure

highest pressure expected at the seals during any specified static or operating conditions and during start-up and shutdown

NOTE Considerations should include both relief valve settings and relief-valve accumulation pressure.

3.1.25

multiple-package

total oil supply system whose components are separated into individually packaged units

NOTE With this arrangement, the purchaser is required only to install the interconnections between the packages and the external connections.

3.1.26

normal flow

total amount of fluid required by equipment components such as bearings, seals, couplings and steady-state controls excluding transient flow for controls or fluid bypassed directly back to the reservoir

3.1.27

normal operating point

point at which normal operation is expected and optimum efficiency is desired

NOTE This point is usually the point at which the vendor certifies that the performance is within the tolerances stated in the relevant standard.

3.1.28

observed

when the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled, whether or not the purchaser or his representative is present

3.1.29

owner

final recipient of the equipment, who may delegate another agent as the purchaser of the equipment

3.1.30

package

total system, or part of a system, whose components are mounted on a single baseplate

NOTE A package is complete in all respects, including controls and instrumentation.

3.1.31

panel

enclosure used to mount, display and protect gauges, switches and other instruments

NOTE Instruments in a panel may be open or enclosed by the panel. (See 3.1.16.)

3.1.32

pressure-limiting valve

PLV

automatic pressure-limiting device, which opens in proportion to the increase in pressure over the opening set pressure and automatically closes when the upstream pressure is reduced below the set pressure, and which is actuated by the static pressure upstream of the valve

NOTE 1 These devices are not necessarily tight shutoff when closed, i.e. they may have a small leakage flow when closed. These devices are designed for liquid service only and are normally used for limiting the discharge pressure of positive-displacement-type oil pumps and the downstream pressure of fail-open oil-pressure regulating valves when necessary.

NOTE 2 PLVs require a flowing test system in order to test. Normally, these valves are, therefore, tested in the system on which they are installed.

3.1.33

pressure safety valve relief valve PSV

automatic pressure-relieving device, which opens in proportion to the increase in pressure over the opening set pressure, has a rapid full opening or pop action characteristic and is actuated by the static pressure upstream of the valve

NOTE The device automatically closes when the upstream pressure is reduced below the set pressure. These devices are considered to be tight shutoff when closed and are normally used in gas, vapour or liquid service.

3.1.34

purchaser

agency that issues the order and specification to the vendor

NOTE The purchaser can be the owner of the plant in which the equipment is installed or the owner's appointed agent.

3.1.35

remote

located away from the equipment or the console, typically in a control house

3.1.36

seal buffer gas

clean gas supplied to the high-pressure side of a seal

NOTE 1 This term was originally used on oil seals and has been replaced with the term "seal gas supply" for clean gas that also serves as the sealing gas for a dry gas seal.

NOTE 2 See ISO 10438-4:2007, Figures D.1 to D.4.

3.1.37

seal gas

dry, filtered gas supplied to the high-pressure side of a self-acting gas seal

NOTE See ISO 10438-4:2007, Figures D.1 to D.4.

3.1.38

seal gas leakage

gas that flows from the high-pressure side of the seal to the low-pressure side of the seal

3.1.39

secondary seal-gas supply

clean purge gas supplied to the area between the seals of a tandem self-acting gas seal having an intermediate labyrinth

NOTE This gas is at a pressure lower than the process pressure.

3.1.40

self-contained regulator

regulating valve assembly that utilizes or internally senses the controlling pressure or temperature

3.1.41

separation gas

supply of inert gas or air fed into the region between the seal and the shaft bearing

3.1.42

settling-out pressure

maximum pressure the system can reach under static conditions

3.1.43

shaft-driven pump

oil pump driven by the shaft of one of the main machines served by the oil system

3.1.44

shutdown point

preset value of a parameter at which automatic or manual shutdown of the system is required

3.1.45

special-purpose application

application for which the equipment is designed for uninterrupted, continuous operation in critical service and for which there is usually no spare equipment

3.1.46

standby pump

oil pump that is capable, either automatically or manually, of being immediately brought up to operating speed, and that is capable of operating continuously

3.1.47

standby service

normally idle piece of equipment that is capable of immediate automatic or manual start-up and continuous operation

3.1.48

stilling tube

pipe extending into the reservoir from the connection to below pump suction-loss level to prevent splashing and provide free release of foam and gas

NOTE 1 A stilling tube is typically used for non-pressurized returns and has an open top or vent holes to equalize to reservoir pressure.

NOTE 2 See ISO 10438-2:2007, Figure B.24.

3.1.49

tandem seal

seal arrangement which utilizes two seal faces oriented in the same direction, whereby the outboard seal face acts as a backup seal to the inboard or primary seal face

NOTE 1 A special arrangement of this seal incorporates an intermediate labyrinth seal to allow an inert sealing gas to be injected between the seal faces. In this arrangement, the backup or outboard seal face seals against the inert sealing gas and is not exposed to the process gas.

NOTE 2 See double seal (3.1.11).

3.1.50

unit responsibility

responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order

NOTE Responsibility for such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping and testing of components is included.

3.1.51

vendor supplier

agency that manufactures, sells and provides service support for the equipment

NOTE The vendor may be the manufacturer of the equipment or the manufacturer's agent and normally is responsible for service support.

3.1.52

vent gas

seal gas leakage that is taken away by the vent system

3.1.53

vent system

arrangement of piping and valves used to take gas to a safe location

3.1.54

witnessed

inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or his representative is in attendance

3.2 Abbreviated terms

AS	air supply
BWG	Birmingham wire gauge
DN	nominal diameter
DP	differential pressure indicator
FAL	flow alarm low
FC	fail closed
FCV	flow control valve
FE	flow element
FG	flow glass
FI	flow indicator
FIC	flow indicator controller
FL	fail locked (when labelling a valve)
FO	fail open (when labelling a valve)
FRO	flow restriction orifice
FT	flow transmitter
FY	I/P (current to pneumatic) interposing relay
LC	level controller
LG	level gauge
LIC	level indicator controller
LSH	level switch high
LSHH	level switch high high
LSL	level switch low

LSSL	level switch low low
LT	level transmitter
LV	level valve
LY	level relay
NC	normally closed
NDT	non-destructive testing
NO	normally open
NPS	nominal pipe size
NPT	national pipe thread (tapered)
P&ID	process (piping) and instrument drawing
PCV	pressure control valve
PDCV	pressure differential control valve
PDI	pressure differential indicator
PDS	pressure differential switch
PDSH	pressure differential switch high
PDSL	pressure differential switch low
PDSLL	pressure differential switch low low
PDT	pressure differential transmitter
PI	pressure indicator
PLV	pressure-limiting valve
PN	nominal pressure
PSH	pressure switch high
PSHH	pressure switch high high
PSL	pressure switch low
PSLL	pressure switch low low
PSV	pressure safety (relief) valve
PT	pressure transmitter
TC	temperature controller
TCV	temperature control valve

TI	temperature indicator
TIC	temperature indicator controller
TS	temperature switch
TSH	temperature switch high
TSL	temperature switch low
UNC	unified national coarse thread
VDDR	vendor drawing and data requirements

4 General

4.1 Dimensions and units

- Drawings and maintenance dimensions shall be in SI units or United States customary (USC) units. Use of an SI datasheet indicates that SI units shall be used. Use of an USC datasheet indicates that USC units shall be used.

NOTE Dedicated datasheets for SI units and for USC units are provided in Annex A in each of the four parts of ISO 10438.

4.2 Design

The term “design” shall apply solely to parameters or features of the equipment supplied by the manufacturer. The term “design” should not be used in the purchaser's enquiry or specifications because it can create confusion in understanding the order.

EXAMPLES Design power, design pressure, design temperature, design speed.

4.3 System selection

- **4.3.1** Annexes in ISO 10438-2, ISO 10438-3 and ISO 10438-4 provide schemas and diagrams of typical complete lubrication, oil-type shaft-sealing, dry gas face-type shaft-sealing and control-oil systems. These schematics and diagrams illustrate the general philosophy and requirements of this part of ISO 10438 and are included to assist the purchaser in the selection of an appropriate system. Symbols shown on these schematics and diagrams are identified in Annex B of this part of ISO 10438. The purchaser and the vendor shall agree upon a mutually acceptable system before the order is released.
- **4.3.2** The purchaser shall define the scope of supply, the level of quality or the brand of components, the system type, the general arrangement (including plan and elevation views of the console orientation), the space available for the console, the service (special purpose or general purpose) and other requirements. Annexes C and D of this part of ISO 10438 are intended to assist in this definition.

4.4 Pressure design code

- The pressure design code shall be specified or agreed by the purchaser. Pressure components shall comply with the pressure design code and the supplementary requirements in this part of ISO 10438.

4.5 Basic design

- **4.5.1** Equipment shall be designed for installation in accordance with API 686.

- **4.5.2** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions.

4.5.3 The equipment, including all auxiliaries, shall be suitable for operation, using the utility stream conditions specified.

4.5.4 Spare and replacement parts shall meet all the criteria of the furnished system.

4.5.5 The vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.

4.5.6 Where drilled check valves are provided, they shall be labelled with stainless steel tags stamped indicating that they are drilled and the size of the drilled hole.

NOTE Drilled check valves are sometimes utilized with shaft-driven pumps or atmospheric rundown tanks.

4.5.7 The purchaser and the vendor shall mutually determine the measures that shall be taken to comply with any governmental codes, regulations, ordinances or rules that are applicable to the equipment.

It is recommended that this be done as early as possible and preferably in the inquiry stage.

4.6 Welding

4.6.1 Welding of piping and pressure-containing parts, as well as any dissimilar-metal welds and weld repairs, shall be performed and inspected by operators and procedures qualified in accordance with the pressure design code or the piping system design code as appropriate.

- **4.6.2** In addition to the requirements of 4.6.1 and the applicable piping code, the purchaser may specify that additional radiography, magnetic particle inspection or liquid-penetrant inspection of specific welds on equipment and/or piping is required.

NOTE 1 ISO 15649 already includes a level of NDT inspection for piping.

NOTE 2 ISO 10438-3 systems do not require radiography of piping (see ISO 10438-3:2007, 5.1.2).

4.6.3 All welding other than that covered by the pressure design code or the piping systems design code such as welding on baseplates, non-pressure ducting, lagging and control panels shall be in accordance with a structural welding standard such as AWS D1.1, unless otherwise specified.

4.7 Statutory requirements

The purchaser and the vendor shall mutually determine the measures to be taken to comply with any governmental codes, regulations, ordinances or rules that are applicable to the equipment, its packaging and any preservatives used.

4.8 Documentation requirements

The hierarchy of documents shall be specified.

NOTE Typical documents include company and industry specifications, meeting notes and modifications to these documents.

5 Piping

5.1 General

5.1.1 Piping design and joint fabrication examination and inspection shall comply with ISO 15649.

NOTE 1 ISO 15649 includes ASME B31.3 as a normative reference, and for the purposes of this part of ISO 10438, the provisions are identical. See also CEN/TR 14549.

NOTE 2 The alphanumeric designation of size used for reference purposes for components of a pipework system, when using the DN system, comprises the letters DN followed by a dimensionless whole number that is indirectly related to the nominal physical size in millimetres. The number following the letters DN does not represent a measurable value and it is not appropriate that they be used for calculation purposes except where specified in the relevant standard.

NOTE 3 The alphanumeric designation relating to pressure used for reference purposes for components of a pipework system, when using the PN system, comprises the letters PN followed by a convenient round, dimensionless number. For further information, see ISO 7268.

NOTE 4 It is intended that all equipment of the same nominal size (DN) designated by the same PN number have the same mating dimensions appropriate to the type of end connections.

The permissible working pressure depends upon the materials, design and working temperature and shall be selected from the pressure/temperature rating tables in corresponding standards.

5.1.2 Auxiliary systems are defined as piping systems that are in the following services:

a) Group I, Auxiliary process fluids (see Table 1):

- 1) sealing fluid,
- 2) gland and flushing fluid,
- 3) recirculation fluid,
- 4) balance gas,
- 5) buffer gas,
- 6) fuel gas or oil,
- 7) drains and vents associated with group I systems,
- 8) starting gas,
- 9) separation gas,
- 10) solvents injection;

b) Group II, Steam and air (see Table 2):

- 1) sealing steam,
- 2) steam injection,
- 3) water injection,
- 4) starting air,
- 5) instrument and control air,

- 6) drains and vents associated with group II systems;
- c) Group III, Cooling water (see Table 3):
 - 1) cooling water,
 - 2) liquid wash (water based),
 - 3) drains and vents associated with group III systems;
- d) Group IV, Lubricating, control and seal oil (see Table 4):
 - 1) lubricating oil,
 - 2) control oil,
 - 3) seal oil (see 5.4 for seal oil contaminated with process fluid),
 - 4) drains and vents associated with group IV systems.

Auxiliary systems shall comply with the requirements of Tables 1 through 6, except as modified in referencing standards, including references to Tables 1 through 6 in ISO 10438-2, ISO 10438-3 and ISO 10438-4.

NOTE Casing connections are covered in the associated equipment standards.

Table 1 — Minimum requirements for piping materials — Auxiliary process fluid

Pipe	Austenitic stainless steel, (e.g. ASTM A312 type 304 or 316 or the equivalent material designation located in Annex E). Seamless, except Schedule 10S and 40S may be electric fusion welded. Seamless carbon steel (e.g. ASTM A106-B, A53-B or the equivalent material designation located in Annex E)
Pipe fitting	Austenitic stainless steel, (e.g. ASTM A403 or the equivalent material designation located in Annex E, type 304 or 316 stainless steel). Seamless, except Schedule 10S and 40S may be electric fusion welded. Austenitic stainless steel, (e.g. ASTM A182 type 304 or 316 or the equivalent material designation located in Annex E), class 3000. Seamless carbon steel (e.g. ASTM A234 or the equivalent material designation located in Annex E). Carbon steel, (e.g. ASTM A105 or the equivalent material designation located in Annex E), class 3000
Flange	Austenitic stainless steel, (e.g. ASTM A182 type 304 or 316 or the equivalent code material designation located in Annex E) weld neck or slip-on. Carbon steel (e.g. ASTM A105) or the equivalent material designation located in Annex E, weld neck or slip-on
Tubing	Stainless steel, (ASTM A269 type 304 or 316 or the equivalent material designation located in Annex E)
Tube fittings	Austenitic stainless steel type 304 or 316 (vendor's standard with purchaser's approval)
Gaskets	For less than or equal to ANSI class 300: flat, non-asbestos type For greater than or equal to ANSI class 600: spiral wound with non-asbestos filler, 304 or 316 windings and external centring ring
Flange bolting	Refer to 5.1.28 and 5.1.29.
Valves	Refer to 5.1.22, 5.1.23 and 5.1.24.
NOTE Threaded joints require seal welding; however, seal welding is not permitted on instruments or where disassembly is required for maintenance.	

Table 2 — Minimum requirements for piping materials — Steam and air

Pipe	Seamless, carbon steel (e.g. ASTM A106-B, A53-B) or the equivalent material designation located in Annex E
Pipe fitting	Seamless, carbon steel (e.g. ASTM A234 or the equivalent material designation located in Annex E) Carbon steel (e.g. ASTM A105 class 3000 or the equivalent material designation located in Annex E)
Flange	Carbon steel (e.g. ASTM A105 or the equivalent material designation located in Annex E), weld neck or slip-on
Tubing	Stainless steel (e.g. ASTM A269 or the equivalent material designation located in Annex E), type 304 or 316
Tube fittings	Stainless steel type 304 or 316 (vendor's standard)
Gaskets	For less than or equal to ANSI class 300: flat, non-asbestos type For greater than or equal to ANSI class 600: spiral wound with non-asbestos filler, 304 or 316 windings and external centring ring
Flange bolting	Refer to 5.1.28 and 5.1.29.
Valves	Refer to 5.1.22, 5.1.23 and 5.1.24.

Table 3 — Minimum requirements for piping materials — Cooling water

Pipe	Carbon steel (e.g. ASTM A106-B & A53-B or the equivalent material designation located in Annex E), seamless
Pipe fitting	Carbon steel (e.g. ASTM A234 or the equivalent material designation located in Annex E), seamless Carbon steel (e.g. ASTM A105 or the material designation located in Annex E), class 3000
Flange	Carbon steel (e.g. ASTM A105 or the equivalent material designation located in Annex E), weld neck or slip-on
Tubing	Stainless steel (e.g. ASTM A269 or the equivalent material designation located in Annex E), type 304 or 316
Tube fittings	Stainless steel type 304 or 316 (vendor's standard)
Gaskets	Flat, non-asbestos type
Flange bolting	Refer to 5.1.28 and 5.1.29.
Valves	Refer to 5.1.22, 5.1.23 and 5.1.24.

Table 4 — Minimum requirements for piping materials — Lubricating, control and seal oil

Pipe	Stainless steel (e.g. ASTM A312 type 304 or 316 or the equivalent material designation located in Annex E). Seamless, except Schedule 10S and 40S may be electric fusion welded.
Pipe fitting	Stainless steel (e.g. ASTM A403 type 304 or 316 stainless steel or the equivalent material designation located in Annex E). Seamless, except Schedule 10S and 40S may be electric fusion welded. Stainless steel (e.g. ASTM A182 type 304 or 316 stainless steel or the equivalent material designation located in Annex E), class 3000. Socket weld fittings are prohibited.
Flange	Stainless steel (e.g. ASTM A181 type 304 or 316 stainless steel or the equivalent material designation located in Annex E), weld neck or slip-on. Socket weld flanges are prohibited. Carbon steel (e.g. ASTM A105 or the equivalent material designation located in Annex E), slip-on
Tubing	Stainless steel (e.g. ASTM A269 type 304 or 316 stainless steel or the equivalent material designation located in Annex E)
Tube fittings	Stainless steel type 304 or 316 (vendor's standard with purchasers approval)
Gaskets	For less than or equal to ANSI class 300: flat, non-asbestos type For greater than or equal to ANSI class 600: spiral wound with non-asbestos filler, 304 or 316 windings and external centring ring
Flange bolting	Refer to 5.1.28 and 5.1.29.
Valves	Refer to 5.1.22, 5.1.23 and 5.1.24.
NOTE Threaded joints require seal welding; however, seal welding is not permitted on instruments or where disassembly is required for maintenance.	

Table 5 — Minimum pipe wall thicknesses

Materials	Nominal pipe size minimum		
	DN	in	Schedule
Carbon steel	DN 40	($\frac{1}{2}$)	80
Carbon steel	DN 50 to 200	(2 to 8)	40
Carbon steel	DN 200	($\frac{7}{8}$)	20
Stainless steel	DN 25	($\frac{1}{4}$)	80S
Stainless steel	DN 40 to 75	($\frac{1}{2}$ to 3)	40S
Stainless steel	DN 100	($\frac{3}{4}$)	10S

Table 6 — Minimum tubing wall thicknesses

Nominal tubing size ^a		Minimum wall thickness	
mm	in	mm	in
6	($\frac{1}{4}$) ^b	1,0	0.035
10	($\frac{3}{8}$) ^b	1,0	0.035
12	($\frac{1}{2}$)	1,5	0.065
20	($\frac{3}{4}$)	2,0	0.095
25	(1)	2,6	0.109
^a The tubing size is the outside diameter.			
^b The sizes 6 mm ($\frac{1}{4}$ in) and 10 mm ($\frac{3}{8}$ in) are permitted for instrument and control air only.			

5.1.3 Piping systems shall include piping, isolating valves, control valves, relief valves, pressure reducers, orifices, temperature gauges and thermowells, pressure gauges, sight flow indicators and related vents and drains.

- **5.1.4** The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, any oil console base area or any auxiliary base area. The piping shall terminate with flanged connections at the edge of the base. When soleplates are specified for the equipment train, the extent of the piping system at the equipment train shall be defined by the purchaser. The purchaser shall furnish only interconnecting piping between equipment groupings and off-base facilities.

5.1.5 The design of piping systems shall achieve the following:

- a) proper support and protection to prevent damage from vibration or from shipment, operation and maintenance;
- b) proper flexibility and normal accessibility for operation, maintenance and thorough cleaning;
- c) installation in a neat and orderly arrangement adapted to the contour of the machine without obstructing access openings;
- d) elimination of air pockets by the use of valved vents or non-accumulating piping arrangements;
- e) complete drainage through low points without disassembly of piping.

5.1.6 Piping shall be fabricated by bending and welding to minimize the use of flanges and fittings where practical. Welded flanges are required at equipment connections, at the edge of any base and for ease of maintenance. Non-screwed pipe fittings are permitted to facilitate pipe layout in congested areas.

5.1.7 Pipe bushings shall be seal welded if used. Welded pipe bushings are acceptable only at the drain connections on pump suction strainers where the strainer cannot be rotated.

NOTE Y strainers have oversized drain connections. If a bushing is not allowed, it is necessary to elevate the entire pipe and system to include a drain valve.

5.1.8 Pipe threads shall be taper threads in accordance with ISO 7-1.

NOTE For the purposes of this provision, ANSI/ASME B1.20.1 is equivalent to ISO 7-1.

5.1.9 Flanges shall be steel and in accordance with the pressure design code.

NOTE If ASME is specified, flanges are in accordance with ASME B16.5 (see 4.4).

5.1.10 For socket-welded construction, there shall be a 1,5 mm (1/16 in) gap between the pipe end and the bottom of the socket before welding.

NOTE See ASME B31.3-04, Figures 328.5.2B (3) and 328.5.2C.

5.1.11 Connections, piping, valves and fittings that are 30 mm (1 1/4 in), 65 mm (2 1/2 in), 90 mm (3 1/2 in), 125 mm (5 in), 175 mm (7 in) or 225 mm (9 in) in size shall not be used.

5.1.12 Where space does not permit the use of DN 15 (NPS 1/2), DN 20 (NPS 3/4) or DN 25 (NPS 1) pipe, seamless tubing may be furnished in accordance with Tables 1 to 4, as applicable.

5.1.13 Minimum connection shall be DN 15 (NPS 1/2). For instrument connections, refer to 5.3.2.

5.1.14 Piping systems furnished by the vendor shall be fabricated, installed in the shop and properly supported. Bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centreline of the equipment.

5.1.15 Tapped openings shall be plugged with solid, round-head, steel plugs furnished in accordance with ANSI/ASME B16.11. As a minimum, these plugs shall meet the material requirements of the piping system. Plugs that can require later removal shall be of corrosion-resistant material. Plastic plugs are not permitted.

NOTE This section refers to piping only. Plugs on instrument valves and equipment, such as filters, coolers, etc., are covered in their appropriate sections.

5.1.16 A process-compatible thread lubricant that meets the proper temperature specification shall be used on all non-seal-welded threaded connections. Tape shall not be used.

5.1.17 The root pass of all butt welds on stainless steel pipe shall be made by tungsten inert-gas arc welding. Filler passes may be made by tungsten inert-gas arc welding or by the shielded metal arc process. Gas metal arc welding may be used, when approved, for filler passes on DN 150 (6,0 in) and larger pipe.

- **5.1.18** Special requirements for piping, flanges, gaskets, instruments and o-rings, valves and other appurtenances in special and/or hazardous service shall be specified by the purchaser.

5.1.19 All components, such as flanges, valves, control valve bodies or heads and relief valves, that contain oil, special and/or hazardous fluids or steam over 500 kPa (75 psig) shall be made of steel.

5.1.20 Threaded joints for special and/or hazardous fluids or for steam pressures greater than 500 kPa (75 psig) shall be seal-welded; however, seal welding is not permitted on cast iron equipment, instruments or locations that require disassembly for maintenance. Seal-welded joints shall be made in accordance with the codes specified. Where no codes have been specified, seal-welded joints shall be in accordance with ISO 15649.

5.1.21 Hand-operated block and bypass valves shall have bolted bonnets and glands. For service ratings greater than or equal to ANSI class 900, block valves may be of bolted bonnet, welded bonnet or no-bonnet construction with a bolted gland; these valves shall be suitable for repacking under pressure.

5.1.22 Wafer check valves in accordance with ANSI/API 594 may be used in sizes DN 40 (NPS 1 1/2) and larger for services other than hazardous process gas and steam.

5.1.23 Unless otherwise specified, block valves shall be supplied with nominal 13Cr stainless steel trim.

NOTE Certain fluid applications can require alternate trim materials (i.e. H₂S service). See 5.1.18.

5.1.24 Instrument valves for oil and gas service located in sensing lines downstream of a primary service block valve may be bar-stock instrument valves, provided the instrument valves are protected against accidental disassembly. Valves shall be stainless steel or carbon steel with corrosion-resistant plating and stainless steel stems.

5.1.25 Plugs in instrument valves shall be the manufacturer's standard design of stainless steel material.

5.1.26 Bleed valves provided at instruments may be the manufacturer's standard bleed fitting. Where test valves are provided according to 5.1.27, bleed valves may be omitted.

- **5.1.27** If specified, test valves shall be supplied adjacent to all of the instruments. Test valves shall terminate with a plugged DN 15 (NPS 1/2) connection (5.1.25). If specified, test valves in oil lines shall be vented back to the reservoir. Test valves may be combined with instrument valves supplied in accordance with 5.1.24.

5.1.28 The bolting for pressure joints, valves and piping shall be in accordance with ISO 15649 or the appropriate specified code. As a minimum, according to the requirements of ASME B1.1 or the appropriate specified code, this bolting shall be ASTM A193/A193M-07, Grade B7, or the equivalent material and shall use ASTM A194/A194M-07, Grade 2H nuts or the equivalent material.

5.1.29 Unless otherwise specified, through studs shall be used.

- **5.1.30** If specified, each utility such as air and inert-gas supply, cooling water supply and return lines and others as specified shall be manifolded to a common connection.

5.1.31 The manifold shall be sized to handle the maximum flow through all components that can require the simultaneous use of the specified utility.

- **5.1.32** If specified, valves shall be in accordance with purchaser-specified standards in addition to the mandated requirements of this part of ISO 10438.
- **5.1.33** If specified, flanged gate valves shall be in accordance with ISO 10434 and ISO 15761 in addition to the mandated requirements of this part of ISO 10438.

NOTE 1 For the purposes of this provision, ANSI/API 600 is the equivalent of ISO 10434.

NOTE 2 For the purposes of this provision, API STD 602 is the equivalent of ISO 15761.

5.1.34 Piping and components between double block valves shall be suitable for the more severe line classification on either side of the double block valve.

5.2 Oil piping

5.2.1 Oil drains shall be sized to run no more than half full when flowing at normal drain operating temperature at maximum flow conditions and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Horizontal runs shall slope continuously, at least 40 mm/m (1/2 in/ft), toward the reservoir. If possible, laterals (not more than one in any transverse plane) should enter drain headers at 45° angles in the direction of the flow. The minimum size for most oil drains shall be DN 40 (NPS 1 1/2); however, the minimum size for inner seal-oil drains shall be DN 25 (NPS 1).

5.2.2 Non-consumable backup rings and sleeve-type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions that can accumulate dirt. (See Table 4.)

5.2.3 Unless otherwise specified, piping and tubing, including fittings (excluding slip-on flanges), shall be made of stainless steel. (See Table 4.)

5.2.4 Provision shall be made for bypassing the bearings (and seals if applicable) of equipment during oil system flushing operations.

5.3 Instrument piping and tubing

5.3.1 The vendor shall supply all necessary piping, valves and fittings for instruments and instrument panels. Panels shall be completely assembled, requiring only connection to the purchaser's external piping and wiring circuits.

5.3.2 Connections on equipment and piping for pressure instruments and test points shall conform to 5.1.5. A DN 20 (NPS 3/4) isolating valve shall be provided for all remote-mounted instrumentation. DN 15 (NPS 1/2) piping or tubing, valves and fittings may be used after the isolating valve. Where convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Separate secondary DN 15 (NPS 1/2) isolating valves are required for each instrument on a common connection. Where a pressure gauge is used for testing pressure alarm or shutdown devices, common connections are required for the pressure gauge and alarm or shutdown device.

5.3.3 Tubing valves shall be the manufacturer's standard tube-end or instrument valve and shall be stainless steel, as approved by the purchaser.

5.4 Process piping

- **5.4.1** The extent of, and requirements for, process piping to be supplied by the vendor shall be specified.

- **5.4.2** If specified, the vendor shall review all piping, appurtenances (pulsation suppression devices, intercoolers, aftercoolers, separators, knockout drums, air intake filters, expansion joints) and supports immediately upstream and downstream of the equipment and supports. The purchaser and the vendor shall mutually agree on the scope of this review.

5.5 Intercoolers and aftercoolers

- **5.5.1** If specified, the vendor shall furnish an intercooler between each compression stage.
- **5.5.2** Intercoolers shall be air-cooled or water-cooled as specified.
- **5.5.3** The purchaser shall specify whether aftercoolers shall be furnished by the vendor.
- **5.5.4** Intercoolers and aftercoolers shall be furnished in accordance with the pressure design code.
- **5.5.5** Water-cooled, shell-and-tube intercoolers and aftercoolers shall be designed and constructed in accordance with TEMA Class C or R, as specified. When TEMA Class R is specified, the heat exchanger shall be in accordance with ISO 16812 as specified.

NOTE 1 It is necessary to exercise caution regarding the susceptibility of heat exchangers and their supporting structures to pulsation-induced vibration.

NOTE 2 For the purposes of this provision, ANSI/API 660 is equivalent to ISO 16812.

5.5.6 Unless otherwise approved by the purchaser, intercoolers and aftercoolers shall be constructed and arranged to allow removal of tube bundles without dismantling piping or compressor components. Water shall be on the tube side.

5.5.7 Fixed tube-sheet exchangers shall have inspection openings into their gas passages. Rupture disks on the shell side (to protect the shell in case of tube failures) shall be used only when specifically approved by the purchaser.

5.5.8 When air coolers are specified, they shall be in accordance with ISO 13706.

NOTE For the purposes of this provision, ANSI/API 661 is the equivalent of ISO 13706.

5.5.9 Unless otherwise specified, air-cooled heat exchangers used for intercoolers shall have automatic temperature control. This control may be accomplished by means of louvers, variable-speed fans, variable-pitch fans, bypass valves or any combination of these. Proposed control systems are approved by the purchaser.

- **5.5.10** If specified, water-cooled double-pipe intercoolers and aftercoolers shall be furnished. A finned double-pipe design may be furnished only when specifically approved by the purchaser.
- **5.5.11** Intercoolers shall be either integrally mounted on a skid or separately mounted, as specified.
- **5.5.12** Materials of construction shall be those specified.

5.5.13 When condensate separation and collection facilities are furnished by the vendor, they shall include the following:

- a) automatic drain trap with a manual bypass;
- b) armoured gauge glass with isolation valves and blowdown valves on the collection pot;
- c) separate connections and level switches for high-level alarm and trip on the collection pot;
- d) collection pots sized to provide an agreed-upon holding capacity and a 5 min interval between high-level alarm and trip, based on the expected normal liquid condensate rate;
- e) separate connections and level switches for the high-level alarm and trip on the collection pot.

- **5.5.14** If specified, the vendor shall furnish the fabricated piping between the compressor stages (or the nozzles of centrifugal compressor bodies) and the intercoolers and aftercoolers. Interstage piping shall conform to the piping design code (e.g. ISO 15649).

6 Instrumentation, control and electrical systems

6.1 General

6.1.1 Systems shall be instrumented and controlled for orderly start-up, stable operation, warning of abnormal conditions and shutdown of the main equipment in the event of impending damage.

6.1.2 Instrumentation and installation shall conform to the purchaser's specifications and, unless otherwise specified, shall conform to the requirements of this part of ISO 10438.

6.1.3 Unless otherwise specified, controls and instrumentation shall be designed for outdoor installation and shall meet the requirements of IP65 as detailed in IEC 60529 and NEMA 250, Type 4.

6.1.4 Unless otherwise specified, instrument and control terminal boxes shall be IP66 as detailed in IEC 60529 and NEMA 250, Type 4X.

6.1.5 Where applicable, controls and instrumentation shall conform to ANSI/API RP 551.

6.1.6 All controls and instruments shall be located and arranged to permit easy visibility for the operators, as well as accessibility for tests, adjustments and maintenance.

6.1.7 Unless otherwise specified, all wetted metallic parts of all instruments shall be made of an austenitic Type 300 stainless steel.

NOTE Certain fluid applications can require alternate trim materials (i.e. H₂S service). See 5.1.18.

6.2 Alarm, shutdown and control systems

6.2.1 General

6.2.1.1 Unless otherwise specified, the necessary valving, switches, bridging links (jumpers) or other approved protocol shall be provided to enable all instruments and other components except shutdown-sensing devices to be replaced with the equipment in operation.

- **6.2.1.2** If specified, shutdown-sensing devices shall be provided with valving, bridging links or other approved protocol to allow replacement with the equipment in operation. Isolation valves for shutdown-sensing devices shall be provided with a means of locking the valves in the open position.

- **6.2.1.3** If specified, a hand-auto (HA) or hand-off-auto (HOA) starting switch for the pump motor(s) shall be provided. The HA switch shall contain manual-on and automatic-start positions only, with a separate manual reset button. When an HOA switch is provided, there shall be a separate set of contacts to indicate or alarm that it is in the off position.

NOTE The manual reset button of the HA control allows the standby pump to be manually shut down while the switch is in the automatic-start position only if the primary pump is providing sufficient pressure (that is, if the pressure-rising limit relay of the low-pressure switch [PSL] has been satisfied).

A separate electrical disconnect switch with a lockable off position should be provided at a remote location and should be used only for pump maintenance or during the time the equipment is shut down. This is normally accomplished in the motor control center.

6.2.2 Alarm and shutdown systems

6.2.2.1 An alarm/shutdown system shall be provided which initiates an alarm if any one of the specified parameters reaches an alarm point and initiates shutdown of the equipment if any one of the specified parameters reaches the shutdown point.

- **6.2.2.2** The purchaser shall specify the alarms and shutdowns required which, as a minimum, should include those listed in ISO 10438-2:2007, Table 1; ISO 10438-3:2007, Table 3; ISO 10438-4:2007, Table 1.

NOTE Guidance for the use of various specified arrangements can be found in IEC 61511 (all parts).

6.2.2.3 The vendor shall advise the purchaser of any additional alarms and/or shutdowns considered essential to safeguard the equipment.

- **6.2.2.4** The purchaser shall specify the extent to which alarm/shutdown systems are supplied and installed by the equipment vendor.

6.2.2.5 Unless otherwise specified, the alarm/shutdown system shall comply with the following requirements.

- a) For every shutdown parameter, an alarm shall be provided with the alarm point set at a lesser deviation from the normal condition than the associated shutdown point.
- b) Any alarm parameter, reaching the alarm point, shall initiate an audible warning or flashing light or both, as specified. It shall be possible to determine which parameter initiated the alarm.
- c) Any shutdown parameter, reaching the shutdown point, shall cause the equipment to shutdown and shall initiate an audible warning or a flashing light or both, as specified, which shall be distinguishable from those associated with an alarm. It shall be possible to determine which parameter initiated the shutdown.
- d) When any component of the alarm/shutdown system malfunctions, an alarm shall be initiated and shall be distinguishable from alarms resulting from malfunction of the equipment.

NOTE To accomplish this, redundant sensors can be required.

- e) When any malfunction of a component of the shutdown system results in the system being unable to recognize a shutdown condition, the equipment shall automatically shutdown and an alarm shall be initiated. This alarm shall be distinguishable from shutdowns resulting from malfunction of the equipment (fail-safe system).
- f) When a non-fail-safe system is specified, a failure that results in the system being unable to recognize an alarm condition shall also result in all other alarms and shutdowns remaining functional.
- g) It shall be possible to test every component of every alarm function while the equipment is in operation. Such testing shall not require the disarming of any shutdown function.
- h) With the exception of the final shutdown device (circuit breaker, steam trip and throttle valve, fuel valve, etc.), it shall be possible to test every component of every shutdown function while the equipment is in operation. The testing of components associated with a shutdown function shall not require disarming of any other shutdown function nor any alarm function.

NOTE This allows all alarms to be bypassed during testing of switches.

6.2.2.6 When shutdown bypass functions are furnished in a vendor-supplied panel, the vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in a test bypass mode. Unless otherwise specified, shutdown systems shall be provided with key lock switches or another suitable means to permit testing without shutting down the unit.

6.2.3 Alarm and shutdown arrangements

- Alarm and shutdown arrangements shall be one of the following as specified.

6.2.3.1 Arrangement 1

Both shutdown and alarm switches shall be connected through normally energized, fail-safe circuits. The shutdown circuit wiring shall be completely independent from the alarm circuit wiring and shall be mechanically protected.

6.2.3.2 Arrangement 2

6.2.3.2.1 Shutdown functions shall be initiated by local, direct-acting switches connected in a normally de-energized circuit.

6.2.3.2.2 Alarm functions shall be comprised of locally mounted transmitters (electronic or pneumatic, as specified) connected to either separate, panel-mounted switches or to a multi-point, scanning-type monitor.

6.2.3.2.3 Where multi-point, scanning-type monitors are used, the alarm setting for each function shall be separately and independently adjustable.

6.2.3.3 Arrangement 3

6.2.3.3.1 Each function for which both an alarm and a shutdown have been specified shall be provided with three separate and independent transmitters (electronic unless agreed to otherwise). The detail arrangement should be jointly developed between the purchaser and the vendor or vendors of the system and the served equipment.

6.2.3.3.2 Each transmitter shall be independently connected to one of three independent, multi-point, electronic, scanning-type monitors for each transmitter input.

6.2.3.3.3 The shutdown and alarm function outputs from the three instruments shall be connected through "two-out-of-three" voting logic and shall allow the operation of any one alarm or shutdown function to initiate an alarm. Operation of two shutdown functions monitoring the same parameter initiates a separate alarm and shall cause the served equipment to shutdown. If any one transmitter is faulty, then the remaining two transmitters vote "one-out-of-two" for shutdown. If a second transmitter becomes faulty, then the system shuts down the served equipment.

6.2.3.3.4 Alarm functions not associated with a shutdown function shall be provided with one single transmitter. The detailed arrangement should be jointly developed by the purchaser and the vendor or vendors of the system and the served equipment.

NOTE This arrangement (Arrangement 3) has the following advantages.

- a) Any shutdown or alarm function can be tested at any time with the equipment in service without the need to disarm any part of the system.
- b) Failure of any one component initiates an alarm but does not result in equipment shutdown.
- c) The use of modern, digital instrument technology is facilitated.

6.2.4 Annunciators

- **6.2.4.1** If specified, the vendor shall provide a console-gauge-board-mounted and/or a control-panel-mounted annunciator.

- **6.2.4.2** The vendor shall furnish a first-out annunciator when an annunciator system is specified. The annunciator shall contain a minimum of 25 % spare points and, if specified, shall be arranged for purging. A summary (or common) output circuit shall be provided, as a minimum, for actuation of a remote signal when any function alarms or trips. The sequence of operation shall be as specified below.
 - a) The first parameter to reach alarm or shutdown shall cause the flashing of a light and the sounding of an audible device.
 - b) The alarm or shutdown condition shall be acknowledged by operating an alarm silencing button, common to all alarms and shutdowns.
 - c) When the alarm or shutdown is acknowledged, the audible device shall be silenced but the light shall remain steadily lit as long as that alarm or shutdown condition exists.
 - d) If another parameter reaches an alarm or shutdown level the light shall return to the flashing condition and the audible device shall sound, even if the previous alarm/shutdown condition has been acknowledged but still exists.
- **6.2.4.3** If specified, the annunciator sequence shall be selected from ISA 18.1 by the purchaser.
- **6.2.4.4** If specified, a separate first-out indication shall be provided.

6.3 Instrumentation

6.3.1 Instrument installation and gauge boards

- **6.3.1.1** Instruments for the console, gas seal module and equipment may be local or gauge-board mounted as specified.
- 6.3.1.2** The gauge boards shall have individually labelled instruments and be located as mutually agreed on by the purchaser and the vendor.
- **6.3.1.3** If specified, a common panel shall be provided and shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The panel shall be freestanding, located on the base of the package or machine baseplate or in another location, as specified. The instruments on the panel shall be clearly visible to the operator from the driver control location. A lamp test push button shall be provided if the panel contains indication lamps. The instruments mounted on the panel shall be specified. Wiring inside of the panel shall be neatly run in wire ducting.
- **6.3.1.4** Unless otherwise specified, panel fronts shall be made of steel plate at least 3 mm (1/8 in) thick, reinforced, self-supporting and closed on the top and sides. Tops and sides shall be a minimum of 12 gauge. If specified, panels shall be totally enclosed to minimize electrical hazards, to prevent tampering or to allow purging for safety or corrosion protection. All instruments shall be mounted flush on the front of the panel and all separate fasteners shall be of corrosion-resistant metal. All interior and exterior surfaces of carbon steel panels shall be suitably prepared and coated with an industrial grade painting system.
- **6.3.1.5** Panel-mounted and console-gauge-board-mounted instruments shall be specified by the purchaser. (See datasheets for an equipment instrumentation list.)
- 6.3.1.6** Gauge boards and panels shall be completely assembled, piped and wired, requiring only connection to the purchaser's external piping and wiring circuits.
- 6.3.1.7** When more than one wiring point is required on a unit for control or instrumentation, the wiring to each electrical control device or instrument shall be provided from common terminal boxes with terminal posts. Unless otherwise specified, multiple terminal boxes are required for segregation of different AC and DC electrical signals.

- **6.3.1.8** If specified, signal-segregation requirements in addition to the requirements defined in 6.3.1.7 shall be provided.

6.3.1.9 Unless otherwise specified, each terminal box shall be mounted on the package or baseplate.

NOTE Some soleplate-mounted equipment can result in maintenance access problems, which can be addressed by shipping terminal boxes loose for field wiring to a nearby location.

- **6.3.1.10** All wiring shall be installed in metal conduits, cable trays or enclosures, as specified.

6.3.1.11 All leads and posts on terminal strips, switches and instruments shall be tagged for identification. If specified, purchaser's tagging shall be applied in addition to or in place of the vendor's standard tagging.

6.3.1.12 Except for instrument air service, bleed valves are required between instruments and their isolation valves. Combination isolation/bleed valves may be used.

6.3.1.13 Low-pressure alarms and shutdowns, which are activated by falling pressure, shall be equipped with a valved bleed or vent connection to allow controlled depressurizing so that the operator can note the alarm set pressure on the associated pressure gauge. High-pressure alarms and shutdowns, which are activated by rising pressure, shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure.

6.3.2 Switches

6.3.2.1 Where alarm and/or shutdown functions are initiated by locally mounted switches, such switches shall comply with 6.3.2.2 through 6.3.2.7.

6.3.2.2 Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance.

6.3.2.3 Switches shall be hermetically sealed, single-pole, double-throw type with a minimum capacity of 5 A at 120 V AC and 0,5 A at 120 V DC. Mercury switches shall not be used.

- **6.3.2.4** The purchaser shall specify whether switches shall be connected to either open (de-energize) or close (energize) to initiate alarms and shutdowns.

6.3.2.5 Alarm and shutdown switches shall not be adjustable from outside the housing.

- **6.3.2.6** If specified or approved, multi-point instruments may be used, except that alarms and shutdowns shall be connected to separate instruments, and separate alarm or shutdown contacts (switches) shall be provided. Each alarm and shutdown level shall be separately adjustable.

6.3.2.7 Alarm and shutdown switches shall be arranged to permit testing of the control circuit, including, when possible, the actuating element, without interfering with normal equipment operation.

6.3.3 Transmitters

- **6.3.3.1** If specified transmitters shall be provided.

- **6.3.3.2** The purchaser shall specify output signal type, indicating or non-indicating (blind) type, housing type and power supply requirements.

- **6.3.3.3** Transmitters shall be of analogue or digital type, as specified.

- **6.3.3.4** The purchaser shall specify transmitters that are non-hazardous, non-incendive, explosion-proof or intrinsically safe (IS), as required by the electrical area classification.

NOTE Transmitters for normally hazardous electrical area classifications can be satisfied by more than one transmitter configuration, i.e. intrinsically safe or explosion proof.

6.3.3.5 Unless otherwise specified, transmitters shall be analogue, two-wire type and have an output of 4 mA to 20 mA.

6.3.3.6 Each transmitter shall be located to facilitate inspection and maintenance.

6.3.3.7 Each indicating transmitter shall be located to facilitate unobstructed viewing. Readout units shall be specified.

6.3.3.8 Each transmitter shall be arranged to permit testing of the control circuit, including, when possible, the actuating element, without interfering with normal equipment operation.

6.3.3.9 For transmitters that provide alarm/trip signals, transmitters with the shortest response time of those available shall be purchased.

6.3.4 Temperature indicators

6.3.4.1 Temperature-sensing elements shall be configured to extend adequately into the measured fluid.

It should be noted that this is particularly important for lines that can run partially full, such as drain lines.

6.3.4.2 Temperature-sensing elements may be located in oil-flow sight glasses.

6.3.4.3 Dial-type temperature indicators shall be heavy-duty and corrosion-resistant. They should be at least 125 mm (5 in) in diameter and bimetallic-type or fluid-filled. Black printing on a white background is standard for gauges. Temperature indicators shall be located per the datasheets.

6.3.5 Thermowells

Temperature indicators or sensing elements that are in contact with process fluids or are located in pressurized or flooded liquid lines shall be furnished with DN 20 (NPS 3/4), series 300 stainless steel, separable, solid-bar thermowells. Thermowells in flammable or toxic gas service shall use flanged connections. When considering pipe size, it should be noted that larger pipe sizes can be required to compensate for the restriction of flow by the thermowells.

6.3.6 Thermocouples and resistance temperature detectors

6.3.6.1 Where practical, the design and location of thermocouples and resistance temperature detectors shall permit replacement while the unit is operating. The lead wires of the thermocouples or resistance temperature detectors shall terminate in the thermocouple or resistance detector conduit head. The vendor shall install wiring from the temperature detector conduit head to an on-base terminal box.

6.3.6.2 If temperature element heads are exposed to temperatures above 60 °C (140 °F), a 20 mm (3/4 NPT) bronze hose with four-wall interlocking construction and joints with packed-on (heatproof) couplings shall be used.

6.3.7 Level instruments

Direct-acting level instruments may be operated by displacers, floats, capacitance, ultrasonic, transmitter, guided wave radar or other means as approved. Unless otherwise specified, sensing elements shall be made of austenitic stainless steel. See Annex F for explanation of reservoir levels.

6.3.8 Pressure indicators

- **6.3.8.1** Pressure indicators shall be located per the datasheets.

NOTE This refers to local indication of pressure and can be accomplished by indicators and/or pressure indicating transmitters.

6.3.8.2 Pressure indicators (not including built-in instrument-air indicators) shall be furnished with AISI standard type 316 stainless steel bourdon tubes and stainless steel movements, 110 mm (4 1/2 in) dials and 15 mm (1/2 NPT) male stainless steel connections. Black printing on a white background is standard for gauges. Pressure-sensing elements shall be made of AISI standard type 300 stainless steel.

NOTE Special sensing element materials can be required for some caustic process fluid applications (e.g. H₂S service).

- **6.3.8.3** If specified, liquid-filled gauges or dampened movement gauges shall be furnished in locations subject to vibration.

6.3.8.4 Pressure indicator ranges shall preferably be selected so that the normal operating pressure is in the middle of their range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 %.

6.3.8.5 Each pressure indicator shall be provided with a device, such as a disk insert or blowout back, designed to relieve excess case pressure.

- **6.3.8.6** The vendor shall supply all pressure indicators and transmitters as defined on the datasheets.

6.3.8.7 Local differential pressure indication shall be provided at the filter.

NOTE This can be by local gauge or indicator or by indicating transmitters.

6.3.8.8 Differential pressure indicators shall be furnished with carbon or stainless steel pressure-containing housings and stainless steel movements. Differential pressure indicators shall be designed to prevent damage by over-ranging. Dial size shall be 110 mm (4 1/2 in) minimum with black printing on a white background.

NOTE Direct pressure-sensing, non-magnetic-drive differential pressure indicators can be damaged by over-ranging. Precautions can be required to prevent damage if they are selected for systems with operating pressures higher than their differential range.

6.3.9 Oil sight flow indicators

6.3.9.1 Flow indicators shall be furnished in the atmospheric oil-drain return line from each bearing, gear and oil seal, and, unless otherwise specified, in the outlet piping of each continuously lubricated coupling. Flow indicators shall not be installed in pressurized lines except as indicated in 6.3.9.5.

NOTE Oil-drain indicators might not be practical for units where the oil reservoir or sump is part of the equipment or part of a compact package.

- **6.3.9.2** If specified, flow indicators shall also be installed in the drain lines of totally enclosed, dry coupling guards.

NOTE Flow indicators in dry coupling drain lines can be used to detect excessive oil leakage into the dry coupling guard.

6.3.9.3 Unless otherwise specified, the flow indicator shall

- a) be flanged,
- b) be of the bulls-eye type with glass on both sides,
- c) have a steel body construction,
- d) have a diameter of not less than one half the inside diameter of the oil pipe, and
- e) clearly show the minimum oil flow.

To facilitate viewing of the flow of oil through the line, each flow indicator should be installed with its bulls-eye glass in a vertical plane.

6.3.9.4 If flow indicators are provided for oil filter and cooler vent tubing, they may utilize screwed connections.

- **6.3.9.5** If specified, restrictive flow indicators shall be installed in the pressurized inlet line to each continuously lubricated coupling.

6.3.10 Solenoid valves

6.3.10.1 Direct solenoid-operated valves shall be used only in clean, dry instrument-air or control-oil service, shall have Class F insulation or better and a continuous service rating. When required for other services, the solenoid shall act as a pilot valve to pneumatic valves, hydraulic valves and the like.

6.3.10.2 Single-coil solenoid valves shall not be used in continuous services that can affect normal operations; they may be used in intermittent instrument services.

- **6.3.10.3** When continuously energized solenoids are specified for trip circuits, the vendor shall provide the purchaser with the coil rating and estimated service life of each solenoid coil based on continuously energized operation. Dual-coil solenoids may be specified for any trip function. Each coil shall be capable of keeping the solenoid in its energized condition. Separate circuits shall energize each coil.

6.3.11 Pressure-limiting valves and pressure safety relief valves

6.3.11.1 The vendor shall furnish the pressure-limiting valves and pressure safety valves that are installed on components or in piping that is supplied by the vendor. Other pressure safety valves are furnished by the purchaser. Only pressure safety valves for gas or steam service are required to meet the pressure-limiting requirements defined in API RP 520 (all parts), and in API STD 526.

6.3.11.2 The vendor shall determine the size and set pressure of all pressure-limiting valves and pressure safety valves associated with the system components. Pressure-limiting settings, including accumulation, shall take into consideration all possible types of equipment and component failures and the protection of oil-system or gas-seal-module components and piping.

6.3.11.3 Pressure safety valves shall not have an accumulation exceeding 10 % of set pressure.

6.3.11.4 Pressure-limiting valves shall not have an accumulation exceeding 10 % of the system design pressure.

- **6.3.11.5** If specified, thermal relief valves shall be provided for components that can be blocked in by isolation valves.

6.3.12 Control valves and regulators

6.3.12.1 Control valve(s) and self-contained regulators shall be installed to maintain system pressure, reduce pressure, regulate flow, maintain a differential pressure or regulate temperature.

6.3.12.2 Control valve(s) and self-contained regulators shall have steel bodies with stainless steel trim. All air supply or pressure-sensing tubing shall be made of stainless steel. The pressure rating of the body and head shall not be less than the maximum pressure to which the component can be exposed in its failed position.

6.3.12.3 Unless otherwise specified on the schematics, failure modes for control valves and self-contained regulators are the following:

- a) back-pressure fail closed;
- b) pressure reducing fail open;
- c) temperature control valves fail mode to divert all flow through the coolers.

6.3.12.4 Direct-acting control valves and self-contained regulators shall be sized to limit proportional offset to 10 % based on steady state and 25 % for maximum transients.

6.3.12.5 Control valve(s) may be either direct-acting or pneumatically operated with the following characteristics.

- a) Pneumatic-control valves shall be sized to be no less than 10 % open with the minimum flow through the valve and no more than 90 % open with the maximum flow expected through the valve.
- b) Pneumatic-control valve(s) actuator and spring shall be sized to open or close against the maximum pressure (relief valve plus accumulation) expected in the system.
- c) Direct-acting control valves shall have an external sensing line.
- d) Control valves shall have visual valve stem position indication.

6.3.12.6 When a failure or a malfunction of a pressure control valve can create a hazard or result in damage to equipment or components, an additional pressure-limiting valve discharging to the reservoir or drain header shall be furnished. (See ISO 10438-2:2007, Figures B.10 and B.11, for typical arrangements.) The design criteria for sizing this additional pressure-limiting valve depends only on the sizing of the pressure control valve in a fail-open mode; fail-open modes include oil starvation, overpressure and flooding of bearing housings. Other methods for limiting pressure may be employed, e.g. short-stroke valve with a mechanical stop.

6.4 Electrical systems

6.4.1 Motors, electrical instrumentation, components and electrical installations shall be suitable for the area classification (class, group and division or zone) specified by the purchaser and shall meet the requirements of the applicable parts of IEC 60079 (NFPA 70:2007, Articles 500, 501, 502 and 504) as well as any local codes specified and furnished on request by the purchaser.

- **6.4.2** The characteristics of electrical power supplies for motors, heaters and instrumentation shall be specified.

6.4.3 A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. The pilot lights shall be installed on the control panel.

6.4.4 Power, control and instrument wiring within the confines of the baseplate or module shall be flame retardant and resistant to oil, heat, moisture and abrasion.

6.4.5 Stranded conductors shall be used within the confines of the baseplate and in other areas subject to vibration.

- **6.4.6** If specified, instrument and control wiring may be solid conductors in areas not subject to vibration.

6.4.7 Where rubber insulation is used, a neoprene rubber or high-temperature thermoplastic sheath shall be provided for insulation protection.

6.4.8 Wiring shall be suitable for environmental temperatures.

6.4.9 Unless otherwise specified, all leads on terminal strips and electrical components shall be permanently tagged for identification. All terminal boards in terminal boxes and control panels shall have at least 20 % spare terminal points.

6.4.10 To facilitate maintenance, adequate clearances shall be provided for all energized parts (such as terminal blocks and relays) on all components. The clearances required for 600 V service shall also be provided for lower voltages. Enclosures shall be provided for all energized parts to guard against accidental contact.

- **6.4.11** Electrical materials, including insulation, shall be corrosion resistant and non-hygroscopic insofar as is possible. If specified for tropical location, materials shall be given the treatments specified as follows.

a) Parts (such as coils and windings) shall be protected from fungus attack.

b) Unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

6.4.12 Circuits for AC and DC shall be clearly labelled, connected to separate terminal blocks and isolated from each other.

- **6.4.13** Control, instrumentation and power wiring (including temperature element leads) within the limits of the baseplate shall be installed in rigid metallic conduits, cable trays or enclosures, as specified, properly bracketed to minimize vibration and isolated or shielded to prevent interference between voltage levels.

6.4.14 Conduits shall be arranged to permit removal of elements without conduit removal. Conduits may terminate with a flexible metallic conduit, suitable for the electrical class and long enough to permit access to the unit for maintenance without removal of the conduit.

6.4.15 For Division 2 locations, flexible metallic conduits shall have a liquid-tight thermosetting or thermoplastic outer jacket and approved fittings.

6.4.16 All conduits shall be grouped and mounted above the baseplate to prevent the formation of a dam, which can limit the free drainage of fluids. The conduit shall not be located in a maintenance access area.

6.4.17 Conduit drains shall be installed in all conduit low points for outdoor installations.

- **6.4.18** If specified, conduit drains shall be provided in all conduit low points for indoor installations.

7 Inspection testing, and preparation for shipment

7.1 General

- **7.1.1** The purchaser shall specify the extent of participation in the inspection and testing.
- **7.1.2** If specified, the purchaser's representative, the vendor's representative or both shall indicate compliance in accordance with the inspector's checklist in the applicable chapter by initialling, dating and submitting the completed checklist to the purchaser before shipment.

7.1.3 After advance notification to the vendor, the purchaser's representative shall have entry to all vendor and subvendor plants where manufacturing, testing or inspection of the equipment is in progress.

7.1.4 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

- **7.1.5** The purchaser shall specify the amount of advanced notification required for a witnessed or observed inspection.

7.1.6 When shop inspection has been specified, the purchaser and the vendor shall coordinate manufacturing hold points and inspectors' visits.

7.1.7 A witnessed mechanical running or performance test requires confirmation of the successful completion of a preliminary test.

7.1.8 Equipment, materials and utilities for the specified inspections and tests shall be provided by the vendor.

7.1.9 The purchaser's representative shall have access to the vendor's quality programme for review.

7.2 Inspection

7.2.1 General

7.2.1.1 The vendor shall keep the following data available for at least 20 years:

- a) necessary or specified certification of materials, such as mill test reports;
- b) test data and results to verify that the requirements of the specification have been met;
- c) fully identified records of all heat treatment, whether performed in the normal course of manufacture or as part of a repair procedure;
- d) results of quality control tests and inspections;
- e) details of all repairs;
- f) other data specified by the purchaser or required by applicable codes and regulations;
- g) purchase specifications for all items on bills of material;
- h) results of documented tests and inspections, including fully identified records of all heat treatment and radiography.

7.2.1.2 Pressure-containing parts shall not be painted until the specified inspection and testing of the parts is complete.

NOTE This refers to individual pressure-containing equipment. The assembled system pressure test can be performed with painted components.

- **7.2.1.3** In addition to the requirements of the governing piping, pressure vessel and welding code or standard, the purchaser may specify the following:
 - a) that parts shall be subjected to surface and subsurface examination;
 - b) the type of examination required, such as magnetic particle, liquid penetrant, radiographic and ultrasonic examination.

7.2.2 Material inspection of pressure vessels and piping systems

7.2.2.1 General

When radiographic, ultrasonic, magnetic particle or liquid penetrant inspection of welds or materials is required or specified, the criteria in 7.2.2.2 to 7.2.2.5 shall apply unless other criteria are specified by the purchaser. Welds, cast steel and wrought material may be inspected in accordance with 7.2.2.2 to 7.2.2.5.

7.2.2.2 Radiography

7.2.2.2.1 Radiography shall be in accordance with ASTM E94.

7.2.2.2.2 The acceptance standard used for welded fabrications shall in accordance with the pressure design code. The acceptance standard used for castings shall be in accordance with the pressure design code.

7.2.2.3 Ultrasonic inspection

7.2.2.3.1 Ultrasonic inspection shall be in accordance with the pressure design code.

7.2.2.3.2 The acceptance standard used for welded fabrications shall be in accordance with the pressure design code.

7.2.2.4 Magnetic particle inspection

7.2.2.4.1 Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709.

7.2.2.4.2 The acceptance standard used for welded fabrications shall be in accordance with the pressure design code.

7.2.2.5 Liquid penetrant inspection

7.2.2.5.1 Liquid penetrant inspection shall be in accordance with the pressure design code.

7.2.2.5.2 The acceptance standard used for welded fabrications shall be in accordance with the pressure design code.

7.2.2.6 Positive material identification (PMI)

NOTE Additional information on PMI testing can be found in API RP 578.

- **7.2.2.6.1** If specified, the following alloy items shall be subject to PMI testing:
 - a) overhead seal tank;
 - b) rundown oil tank.
- **7.2.2.6.2** In addition to the components outlined in 7.2.2.6.1, other materials, welds, fabrications and piping shall be PMI tested as specified and fully defined, including any sampling requirements.

7.2.2.6.3 When PMI testing has been specified for a pressurized fabrication, the components comprising the fabrication, including welds, shall be checked after the fabrication is complete. Testing may be performed prior to any heat treatment.

NOTE Pressurized fabrications in the context of this International Standard are overhead seal-oil tanks and certain pressurized rundown tanks. Other components are covered by 7.2.2.6.2, for which it is necessary to specify the extent of testing.

7.2.2.6.4 When PMI is specified, techniques providing quantitative results shall be used.

7.2.2.6.5 Mill test reports, material composite certificates, visual stamps or markings shall not be considered as substitutes for PMI testing.

7.2.2.6.6 PMI results shall be within ASTM governing standard limits with allowance for the accuracy of the PMI device as specified by the device manufacturer.

7.2.3 Mechanical inspection

7.2.3.1 During assembly of the system and before testing, each component and all piping and appurtenances shall be inspected to ensure they have been cleaned and are free of foreign materials, corrosion products and mill scale.

- **7.2.3.2** If specified, the purchaser may inspect the equipment and all piping and appurtenances for cleanliness before heads are welded onto vessels, openings in vessels or exchangers are closed or piping is finally assembled.
- **7.2.3.3** If specified, the hardness of parts, welds and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

7.3 Testing

7.3.1 General

7.3.1.1 At least six weeks prior to the first scheduled test, the vendor shall submit to the purchaser, for review and comment, detailed procedures for all running tests, including acceptance criteria for all monitored parameters.

7.3.1.2 Notification requirements are covered in 7.1.5; however, hydrotest and running test requirements shall not be less than five working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than five working days before the revised test date.

7.3.2 Hydrostatic test

7.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1,5 times the maximum allowable working pressure (MAWP) unless limited by the hydrotest pressure of a component in the system that has been hydrotested to 1,3 times its MAWP. In this case, hydrotest shall be a minimum of 1,3 times the MAWP. Minimum hydrotest pressure shall not be less than 150 kPa (1,5 bar; 20 psi). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested. See ASTM E1003.

NOTE 1 The nil-ductility temperature is the highest temperature at which a material experiences complete brittle fracture without appreciable plastic deformation.

NOTE 2 The ASME pressure vessel code and other pressure vessel codes allow hydrotesting to 1,3 times MAWP.

7.3.2.2 The assembled piping system, in each package, shall be hydrostatically tested as per 7.3.2.1. Alternately, by prior agreement, the piping spools may be tested individually instead of an assembled hydro test.

Removal of spools, screens or the loosening of flanges does not void the original hydro test.

7.3.2.3 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at the testing temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at the testing temperature by that at the rated operating temperature. The stress values used shall conform to those given in the piping system design code for piping or in the pressure design code for vessels. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The datasheets shall list actual hydrostatic test pressures.

It is advisable to verify the applicability of this requirement to the material being tested before hydrotest, as the properties of many grades of steel do not change appreciably at temperatures up to 200 °C (400 °F).

7.3.2.4 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 µg/g (50 ppm). To prevent deposition of chlorides on austenitic stainless steel as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

NOTE Chloride content is limited in order to prevent stress corrosion cracking.

7.3.2.5 Tests 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 neither leaks nor seepage through the pressure-containing parts or joints is observed for a minimum of 30 min.

7.4 Preparation for shipment

7.4.1 Equipment shall be suitably prepared for the type of shipment specified. The preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, it is necessary that the purchaser consult with the vendor regarding the recommended procedures.

7.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up, as described in API RP 686-96, Chapter 3.

7.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include that specified as follows.

- a) Except for machined surfaces, all exterior surfaces that can corrode during shipment, storage or in service shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates.

NOTE Austenitic stainless steels are typically not painted.

- b) Exterior machined surfaces except for corrosion-resistant material shall be coated with a suitable rust preventive.
- c) The interior of the equipment shall be clean; free from scale, welding spatter and foreign objects; and sprayed or flushed with a rust preventive that can be removed with solvent.
- d) Internal surfaces of bearing housings and carbon steel oil systems' components shall be coated with an oil-soluble rust preventive that is compatible with the lubricating oil.
- e) Flanged openings shall be provided with metal closures at least 5 mm (3/16 in) thick with elastomer gaskets and at least four full-diameter bolts. For studded openings, all nuts required for the intended service shall be used to secure closures. Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.
- f) Threaded openings shall be provided with steel caps or round-head steel plugs in accordance with ANSI/ASME B16.11. The caps or plugs shall be of material equal to or better than that of the pressure casing. In no case shall non-metallic (such as plastic) caps or plugs be used.
- g) Openings that have been bevelled for welding shall be provided with closures designed to prevent entrance of foreign material and damage to the bevel.
- h) Lifting points and lifting lugs shall be clearly identified on the equipment package. The recommended lifting arrangement shall be as described in the installation manual.
- i) The equipment shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

- j) The base and all components and piping of a package or an assembled oil system or dry gas seal module shall be shipped as a single assembly and shall be temporarily braced as necessary to prevent damage during shipment. To minimize the entrance of contaminants, no component shall be disassembled for shipment except as required for protection against vibration or other damage during handling and shipment.
- k) Pumps and drivers shall be uncoupled and exposed shafts and shaft couplings shall be wrapped with waterproof, mouldable waxed cloth or volatile corrosion inhibitor paper. The seams shall be sealed with oil-proof adhesive tape.
- l) Each filter shall be shipped with clean elements installed and shall carry outside a securely affixed all-weather tag stating "SHIPPED WITH CLEAN ELEMENTS INSTALLED".

7.4.4 Turbine drivers shall be dried thoroughly and prepared for shipment in accordance with API STD 611.

7.4.5 Auxiliary piping connections furnished for the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

7.4.6 Assemblies and components shall be fully protected from entry of moisture and dirt. If vapour-phase inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags shall be attached in an accessible area for ease of removal. When applicable, bags shall be installed in wire cages attached to flanged covers and bag locations shall be indicated in corrosion-resistant tags attached with stainless steel wire.

- **7.4.7** If specified, one copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

7.4.8 Connections on auxiliary piping removed for shipment shall be match-marked for ease of assembly.

7.4.9 Loose components shall be dipped in wax or placed in plastic bags and contained by cardboard boxes. Loose boxes are to be securely blocked in the shipping container.

8 Vendor's data

8.1 General

8.1.1 The information that the vendors furnish is specified in 8.2 and 8.3. The vendor shall complete and forward the vendor drawing and data requirements form (see Annex C) to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

8.1.2 The data shall be identified on transmittal (cover) letters, in title blocks and title pages or other prominent position on drawings, with the following information:

- a) purchaser's/owner's corporate name;
- b) job/project number;
- c) equipment item number and service name;
- d) inquiry or purchase order number;
- e) any other identification specified in the inquiry or purchase order;
- f) vendor's identifying proposal number, shop order number, serial number or other reference required to completely identify return correspondence.

8.1.3 A coordination meeting shall be held, preferably at the vendor's plant, within four to six weeks after order commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting, which, as a minimum, shall include a review of the following items:

- a) purchase order, scope of supply, unit responsibility, subvendor items and lines of communication;
- b) datasheets;
- c) applicable specifications and previously agreed exceptions;
- d) schedules for transmittal of data, production and testing;
- e) quality assurance programme and procedures;
- f) inspection, expediting and testing;
- g) schematics and bills of materials;
- h) physical orientation of the equipment and piping, including access for operation and maintenance;
- i) other technical items.

8.2 Proposals

8.2.1 General

8.2.1.1 The vendor shall forward the original proposal, with the specified number of copies, to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 8.2.2 and 8.2.3, as well as a specific statement that the system and all its components are in strict accordance with this part of ISO 10438. If the system and components are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 8.1.2.

8.2.1.2 The materials of construction of all major components shall be clearly stated in the vendor's proposal. Materials shall be identified by reference to applicable International Standards, including the material grade. When no such designation is available, the vendor's material specification, giving physical properties and chemical composition, and test requirements shall be included in the proposal. Where International Standards are not available, internationally recognized national or other standards may be used.

8.2.2 Drawings

8.2.2.1 The drawings indicated on the vendor drawing and data requirements form (see Annex C) shall be included in the proposal. As a minimum, the following shall be included:

- a) general arrangement or outline drawing for skid-mounted package, showing overall dimensions, maintenance clearance dimensions, overall masses, erection masses and the largest maintenance mass for each item, as well as the size and location of major purchaser connections;
- b) cross-sectional drawings showing the details of the proposed equipment;
- c) schematics of all auxiliary systems, including the fuel, lube-oil, control and electrical systems, as well as bills of material;
- d) sketches that show methods of lifting the assembled machine or machines and major components and auxiliaries. [This information may be included on the drawings specified in item a) above.]

8.2.2.2 If "typical" drawings, schematics and bills of material are used, they shall be marked up to show the correct mass and dimension data and to reflect the actual equipment and scope proposed.

8.2.3 Technical data

8.2.3.1 The following data shall be included in the proposal:

- purchaser's datasheets, with complete vendor's information entered thereon and literature to fully describe details of the offering;
 - predicted noise data (6.1.5);
 - VDDR form (see Annex C), indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract;
 - schedule for shipment of the equipment, in weeks after receipt of the order;
 - list of spare parts recommended for start-up and normal maintenance purposes;
 - list of the special tools furnished for maintenance;
 - description of any special weather protection and winterization required for start-up, operation and periods of idleness under the site conditions specified on the datasheets (the list shall clearly indicate the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply);
 - complete tabulation of utility requirements, e.g. steam, water, electricity, air, gas, lube oil (including the quantity and supply pressure of the oil required and the heat load to be removed by the oil), and the nameplate power rating and operating power requirements of auxiliary drivers (approximate data shall be defined and clearly identified as such);
 - description of any special requirements specified in the purchaser's inquiry;
 - any start-up, shutdown or operating restrictions required to protect the integrity of the equipment;
 - list of components that can be construed as being of alternative design, hence requiring the purchaser's acceptance.
- **8.2.3.2** If specified by the purchaser, procurement of components shall not proceed without the purchaser's review and acceptance of the components selected. If specified by the purchaser, the manufacture of the console shall not proceed without the purchaser's review of the layout of components and piping.

8.2.4 Optional tests

The vendor shall furnish an outline of the procedures used for each of the special or optional tests that have been specified by the purchaser or proposed by the vendor.

8.3 Contract data

8.3.1 General

8.3.1.1 The contract data shall be furnished by the vendor in accordance with the agreed VDDR form. Each drawing shall have a title block in its lower right-hand corner with the date of certification, identification data specified in 8.1.2, the revision number and date, and the title. Similar information shall be provided on all other documents including subvendor items.

8.3.1.2 The purchaser will promptly review the vendor's data when received; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data have been reviewed and accepted, the vendor shall furnish certified copies in the quantity specified.

8.3.1.3 A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers and a schedule for transmission of each item listed. This list shall cross-reference data with respect to the VDDR form in Annex C.

8.3.2 Drawings

The drawings furnished shall contain sufficient information so that, with the drawings and the manuals specified in 8.3.6, the purchaser can properly install, operate and maintain the ordered equipment. Drawings shall be clearly legible (8-point minimum font size even if reduced from a larger-size drawing), shall be identified in accordance with 8.3.1.1 and shall be in accordance with ANSI/ASME Y14.2M. As a minimum, each drawing shall include the details for that drawing listed in Annex C.

8.3.3 Technical data

8.3.3.1 The data shall be submitted in accordance with Annex C and identified in accordance with 8.3.1.1. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notations shall result in the purchaser's issue of completed, corrected datasheets as part of the order specifications.

- **8.3.3.2** If specified, the vendor shall submit certified copies of the test data to the purchaser before shipment.

8.3.4 Progress reports

- If specified, the vendor shall submit progress reports to the purchaser at the intervals specified.

NOTE Refer to the description of item m) in Annex C for the content of these reports.

8.3.5 Parts lists and recommended spares

8.3.5.1 The vendor shall submit complete parts lists for all equipment and accessories supplied. These lists shall include part names, manufacturer's unique part numbers and materials of construction (identified by applicable International Standards). Each part shall be completely identified and shown on appropriate cross-sectional, assembly-type cutaway or exploded-view isometric drawings. Interchangeable parts shall be identified as such. Parts that have been modified from standard dimensions or finish to satisfy specific performance requirements shall be uniquely identified by part number. Standard purchased items shall be identified by the original manufacturer's name and part number.

8.3.5.2 The vendor shall indicate on each of these complete parts lists all those parts that are recommended as start-up or maintenance spares, and the recommended stocking quantities of each. These should include spare parts recommendations of sub-suppliers that were not available for inclusion in the vendor's original proposal. The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified in 8.1.3.

8.3.6 Installation, operation, maintenance and technical data manuals

8.3.6.1 General

The vendor shall provide sufficient written instructions and all necessary drawings to enable the purchaser to install, operate and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in 8.1.3, an index sheet and a complete list of the enclosed drawings by title and drawing number. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. "Typical" manuals are unacceptable.

8.3.6.2 Installation manual

All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of final certified drawings. For this reason, it may be separate from the operating and maintenance instructions. This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centres of mass, rigging provisions and procedures and all other installation data. All drawings and data specified in 8.2.2 and 8.2.3 that are pertinent to proper installation shall be included as part of this manual.

8.3.6.3 Operation and maintenance manual

A manual containing all required operating and maintenance instructions shall be supplied after all specified tests have been successfully completed. In addition to covering operation at all specified process conditions, this manual shall also contain separate sections covering operation under any specified extreme environmental conditions. Manuals shall be furnished within a reasonable time after shipment, as mutually agreed.

NOTE VDDR allows for input of required document dates.

8.3.6.4 Technical data manual

- If specified, the vendor shall provide the purchaser with a technical data manual within 30 days of completion of shop testing.

Annex A (informative)

Datasheets






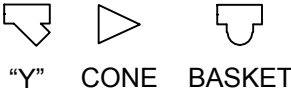























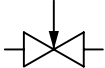

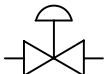


This annex contains a link to datasheets in both SI and USC units, together with an explanatory note. To access the appropriate datasheet, click on "[Datasheet](#)", then the page tab for the corresponding figure (Figure A.1 — Scope and attachments; Figure A.2 — Instrument suppliers; Figure A.3 — Local instruments and panel). Select the appropriate set of units from the menu available on the first page for Figure A.1.




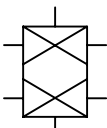
The options for units are as follows:

- USC units;
- SI units (MPa);
- SI units (kPa);
- metric (kg/cm²);
- hybrid.

Annex B (informative)

Symbols

	Actuator, diaphragm		Line, hydraulic
	Actuator, diaphragm, with hand jack		Line, pneumatic
	Actuator, differential pressure diaphragm		Line strainer
	Actuator solenoid		Manual reset feature
	Connections by purchaser		Orifice, flow restriction
	Control switch, manual, with hand/off/automatic positions		Piping, oil and gas
	Coupling, continuously lubricated		Line reduction
	Device, purging		Spectacle blind
	Flange, blind, or plug		Trap
	Flow indicator, rotameter type		Tubing, capillary (filled systems)
	Instrument, combined arrangement		Valve, atmospheric breather
	Instrument, externally connected		Valve, check
	Instrument, locally mounted		Valve, gate or valve, two-way actuator-mounted
	Instrument, pad mounted (flush)		Valve, globe
	Instrument, panel mounted		Valve, needle
	Instrument, single, with two functions		Valve, pressure-control
	Line, electrical		Valve, pressure-limiting, PLV or-PSV

FC	Ports failing closed	NC	Normally closed
FI	Ports failing indeterminately		Valve, ball
FL	Ports failing locked in position		Valve, three-port manual
FO	Ports failing open		Valve, three-port, for actuator
NO	Normally open		Valve, six-port continuous-flow transfer, manually operated

Annex C

(informative)

Vendor drawing and data requirements (VDDR)

Table C.1 — VDDR for general- and special-purpose oil-system applications (see text for details of the Description)

Vendor drawing and data requirements for general- and special-purpose oil-system applications		Job No.	Item No.
		Purchase order No.	Date
		Requisition No.	Date
		Inquiry No.	Date
		Revision by	Console manufacturer
		For	Unit
		Site	Service ^e

Minimum requirements for general-purpose systems indicated by "Req'd". ^d				Distribution record				
Description (see following text)				Review due from vendor b, c	Review received from vendor	Review returned to vendor	Final due from vendor c	Final received from vendor
Req'd	/	/	/	a)	Certified dimensional outline drawing and list of connection			
	/	/	/	b)	Component drawings and bills of materials			
N/A	/	/	/	c)	System schematic and bill of materials, including component sizing criteria			
N/A	/	/	/	d)	Component datasheets			
Req'd	/	/	/	e)	Electrical and instrumentation wiring diagram and bill of materials			
	/	/	/	f)	Electrical and instrumentation terminal box layout and list of connections			
	/	/	/	g)	Console test procedure			
N/A	/	/	/	h)	Weld procedures			
	/	/	/	i)	Hydrostatic test logs			
	/	/	/	j)	Operational test logs			
N/A	/	/	/	k)	As-built datasheets			
Req'd	/	/	/	l)	Installation, operating and maintenance manuals			
N/A	/	/	/	m)	Progress reports			
	/	/	/	n)	Spare parts recommendation and price list			
	/	/	/	o)	Pressure vessel certification data			
^a Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.								
^b Purchaser may indicate in the column the desired time frame for submission of data.								
^c Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.								
^d N/A signifies an item is generally not applicable to general-purpose systems.								
^e Service may be GP lube (GPL), SP lube (SPL), SP seal (SPS), SP combined lube and seal (SPLS), or self-acting gas seal module (GM).								

Details of each numbered item of the description list given in Table C.1 are as follows:

- a) certified dimensional outline drawing and list of connections for oil or dry-gas support system, including the following:
 - size, rating and location of all customer connections;
 - approximate overall handling mass;
 - overall dimensions, maintenance clearances and dismantling clearances;
 - dimensions of baseplates from a fixed control point complete with diameter, number and locations of bolt holes; thickness of the metal through which it is necessary that the bolts pass and recommended clearance; centres of gravity; and details for foundation design;
- b) component drawings and bills of materials for oil or dry-gas support system, including the following:
 - filter outline drawings;
 - cooler outline drawings (oil systems);
 - rundown tank and/or overhead seal tank outline drawings (oil systems);
 - instrumentation cut sheets with dimensions;
 - oil-pump outline drawings (oil systems);
 - oil-pump coupling drawings (oil systems);
- c) system schematic and bill of materials, including component-sizing criteria for oil or dry-gas support system, which includes the following:
 - steady-state and transient flows and pressures at each use point;
 - control, alarm and trip settings (pressures, temperatures and flows as applicable);
 - supply temperatures and heat loads at each point at maximum load;
 - utility requirements, including electricity, steam, water and air;
 - pipe and valve sizes;
 - instrumentation, safety devices and control schemes;
- d) individual component datasheets as applicable on the following:
 - pump datasheets;
 - filter datasheets;
 - cooler datasheets;
- e) electrical and instrumentation wiring diagram and bill of materials; the schematics shall show all alarm and shutdown limits (set points);
- f) electrical and instrumentation arrangement drawings, including terminal box layout and list of connections;

- g) console test procedures, including any special or optional tests to be performed;
- h) welding procedures for fabrication and repair;
- i) certified hydrostatic test logs;
- j) operational test logs;
- k) as-built datasheets;
- l) installation, operating and maintenance manuals describing the following:
 - start-up;
 - normal shutdown;
 - emergency shutdown;
 - operating limits [see item e)];
 - oil recommendations and specifications;
 - routine operational procedures;
 - instructions for maintenance of purchased mechanical components such as pump, pump seals, etc.;
 - performance data, including flows, pressures, temperatures and heat loads;
 - as-built data, including datasheets [see item k)] and test logs.
- m) progress reports and delivery schedule, including vendor buyouts and milestones; the reports shall include engineering, purchasing, manufacturing and testing schedules for all major components; planned and actual dates and the percentage completed shall be indicated for each milestone in the schedule;
- n) spare parts list with stocking level recommendations;
- o) pressure vessel certification data, including pressure vessel calculations, hydrotest reports and material mill test reports for filters, coolers and rundown tanks in the system.

Annex D

(informative)

Oil or gas filter performance and oil-system cleanliness testing

D.1 General considerations

This annex is intended to provide users of ISO 10438 (all parts) with information relative to oil or gas filter performance and oil-system cleanliness testing.

D.2 Filter specifications

D.2.1 General characteristics

The primary requirement of filtration is to reliably remove contaminants in a different phase from a liquid or gas stream. ISO 10438-2 describes filters necessary to remove from the oil particles that can be detrimental to special-purpose machine bearings, gears or oil seals over an extended operating period. ISO 10438-3 describes filters that are intended to remove sufficient solid particles from lubricating oil to provide an economical measure of protection for general-purpose equipment bearings and gears. ISO 10438-4 describes filters necessary to remove from the seal gas liquid-phase contaminants and particles that can be detrimental to a dry gas seal.

D.2.2 Filter element reliability

The filters shall be reliable, not fail or plug off during normal operation of the system and be able to retain contaminants during extreme upsets and even pulsating pressures. For this reason, it is necessary that filter elements for ISO 10438 systems be able to withstand high differentials without collapse or release of trapped particles. (See the other parts of ISO 10438 for specific allowable collapse pressures.)

D.2.3 Water contamination

A requirement has been added to ISO 10438-2 and ISO 10438-3 that the filters be water resistant up to a water content of 5 % at elevated temperatures to further assure filter element integrity. Water contamination of the oil can initiate the deterioration of some elements due to the incompatibility of the filter media with water at operating temperatures.

Elements can also absorb water and experience high differential pressures caused by the swelling of the filter medium. An optional requirement has been added for non-hygroscopic media that, over an extended exposure period, clean elements do not double their pressure drop. Users of oil systems for which water contamination can be a problem should consider non-hygroscopic filters. The user should keep in mind that water contamination should not persist on a routine basis. If water contamination is experienced, the source of the water should be determined and corrected. When correction is not feasible, a separate water-removal system or a slip stream filter/coalescer should be considered to keep the water contamination under control.

Water contamination can be a problem for an oil system serving a steam turbine. Other systems commonly exposed to water contamination include the following:

- oil systems where make-up oil is provided from bulk storage or storage drums that are inadequately protected;
- oil systems where the water pressure in the cooler(s) can exceed the oil pressure;

- oil systems located at humid sites, especially if the equipment served is in intermittent service and can also experience problems with water contamination.

D.2.4 Beta ratio

Of primary importance in the selection of filters for ISO 10438 (all parts) systems is the filter element micron size rating. In earlier standards, the requirement was 10 µm *nominal* rating. In a clarification note (see the third edition of API 614), *nominal* was implied to be 90 % efficient for 10 µm spherical particles and *absolute* was presumed for 15 µm particles for a 10 µm *nominal* rated element. The words “nominal” and “absolute” are not applied uniformly by vendors and there can be significant performance differences from one filter to another with 10 µm *nominal* filters.

It is more precise to rate filter elements by the beta ratio of the element for a given size particle and larger. The beta ratio expressed as $\beta_x \geq y$, where x is the filter element rating, expressed in micrometres, and y is the ratio of particles x µm or larger entering a filter; divided by the number of particles x µm or larger exiting a filter.

EXAMPLE 1 Display a beta ratio of equal to or greater than 10 for a 10 µm rated filter: $x = 10$ µm; $y \geq 10$.

$$\beta_{10} \geq 10$$

EXAMPLE 2 Display a beta ratio of equal to or greater than 200 for a 25 µm rated filter: $x = 25$ µm; $y \geq 200$.

$$\beta_{25} \geq 200$$

In order to determine the particle-removal efficiency, E_{PR} , expressed in percent, for a filter with a known beta ratio, use Equation (D.1):

$$E_{PR} = \left[1 - \left(1/y \right) \right] \times 100 \quad (D.1)$$

For Example 1, where $\beta_{10} \geq 10$ and $y \geq 10$ for particles 10 µm and larger, the minimum E_{PR} is calculated as

$$E_{PR}(10 \mu\text{m}) = \left[1 - \left(1/10 \right) \right] \times 100$$

$$E_{PR}(10 \mu\text{m}) = 90 \%$$

For Example 2, where $\beta_{25} \geq 200$ and $y \geq 200$ for particles 25 µm and larger, the minimum E_{PR} is calculated as

$$E_{PR}(25 \mu\text{m}) = \left[1 - \left(1/200 \right) \right] \times 100$$

$$E_{PR}(25 \mu\text{m}) = 99,5 \%$$

For every type of filter element, a curve of the beta ratio plotted against the micron size can be developed. The position and shape of this curve is significantly affected by the construction features of the filter element. Some filter elements can have a very wide band of performance and others can have a narrow band. An example of a filter element, A, with a wide performance band can have a series of ratios $\beta_2 \geq 2$, $\beta_{10} \geq 10$; $\beta_{15} \geq 200$ and a $\beta_{25} \geq 1\,000$. Another filter element, B, with a narrower band can have a series of ratios $\beta_5 \geq 2$; $\beta_{10} \geq 10$; and a $\beta_{15} \geq 1\,000$.

In both examples A and B, the filter element is acceptable for special-purpose systems. The main issue is that the manufacturer of both A and B may give a different nominal rating. It is not until the beta ratio for a given micron size is greater than or equal to the specified beta ratio that the filter is acceptable.

There are many factors in determining the performance of a filter on a range of particles. Factors such as pressure, flow differential pressure, particle size, particle shape, fluid and degree of loading can result in different beta ratios for the same type of element. There is a widely used standard hydraulic filter test that is relatively similar to the conditions encountered in API STD 614 lube and seal systems. For the purpose of ISO 10438-2 and ISO 10438-3, ISO 16889 or equal multi-pass-method type testing is required for passing the filter rating. A more detailed description of ISO 16889 testing is outlined in D.2.8.2. Filter vendors who supply type-tested elements have and can make available the test data for the elements being considered by ISO 10438-2 and ISO 10438-3.

D.2.5 Relative size of particles

In order to provide protection for equipment, it is necessary that the filter be able to remove particles that are in the range of the clearance of the component. For some insight into film thickness and particle sizes, see Tables D.1 and D.2. For the majority of systems covered by ISO 10438-2, ISO 10438-3 and ISO 10438-4, the filter ratings provide sufficient removal of the particles of concern as well as a reasonable installed life.

Based on the data presented in Tables D.1 and D.2, it can be tempting to use a finer filtration specification; but this can be inappropriate in many cases. Over-specification of the filter requirements can result in costly filter systems and frequent and expensive element changes.

Users of ISO 10438 filter specifications should be aware that filters remove particles smaller than the specified size. The filtration efficiency, E_{PR} , or beta ratio, for 1 μm to 10 μm particles can be low, but some are captured by the element. It only takes more passes through the filter before the levels reach an equilibrium state where the filter removes the same number as ingress into the system. How small a particle below the specified size that be captured effectively is a function of the filter construction.

There are some exceptions where fine filtration can be necessary. These include, but are not limited to, control-oil systems with electrical-hydraulic pilot valves that have very close internal clearances and the oil-supply systems for high-speed gear-type couplings. In these applications, it can be appropriate to install separate duplex filter(s) in the branch stream(s) just ahead of the sensitive component(s). The E_{PR} for these filters should be mutually agreed based on the requirements of the component.

Table D.1 — Relative size comparison of particles of some common materials

Particle size μm	Comparison
159	100 mesh screen opening
100	Table salt
74	200 mesh screen opening
60	Pollen
40	Lower limit of human vision
2	Bacteria

Table D.2 — Typical dynamic film thickness for equipment

Component	Thickness μm
Roller bearings	0,4 to 1
Ball bearings	0,1 to 0,7
Journal bearings	0,5 to 25
Gears	0,1 to 1
Seals	0,05 to 0,5
Servo valves: — orifice	130 to 450
— flapper to wall	18 to 63
— spool to sleeve	1 to 4
Hydraulic actuators	25 to 250

D.2.6 Dry gas seal filtration

In most cases, it is necessary that the seal gas filtration system for a compressor dry gas seal performs two functions. The first is to remove debris and small particles that can cause excessive wear of the seal faces and silt up the seal cartridge. The second is to prevent liquids from entering the seal and causing sudden failure of the seal.

The gas filtration for dry gas seals cannot be effective unless the characteristics of the gas supply are provided to the vendor for all conditions. Seal-gas supplies can vary from dry, inert gas with dew points below 100 °C (212 °F) to a complex hydrocarbon mixture at the dew point with droplets or aerosols of hydrocarbon liquid in equilibrium. The characteristics of the seal gas can vary considerably with the operating conditions of the compressor.

For the vendor to supply appropriate seal-gas filters/separators, it is necessary for the vendor to have a complete description of the characteristics and gas composition of the supply at all operating conditions from start-up to settle-out. When the seal-gas supply is taken from the compressor discharge, the gas composition may be identified from the API 617 compressor datasheet number 2 of 6. It is necessary that the purchaser, vendor, dry gas seal supplier and dry gas seal console supplier work together to identify the applicable condition, such as testing, off-design operation, start-up and settle-out, where the presence of liquids is possible. For all possible conditions, special attention should be paid to the gas-supply dew point, pressure, supply temperature and ambient temperature. Special attention is also required to assure that the seal gas is compatible with the filters, filter elements and elastomers over the range of possible operating conditions.

On most dry gas seal systems, there are two sets of gas filters; one for the separation gas and one for the seal gas. The separation gas is generally an inert, dry gas, such as nitrogen. Unless there are special circumstances identified to the vendor, the filters for separation gas do not require coalescing capability.

If the seal gas has a dew point too close to operating temperature (including any Joules/Thompson effect at the control valve) downstream of the controlling device, a seal gas filter/separator should be supplied with elements that are a combined filter/coalescer or with two separate elements, one for filtering and one for coalescing (see ISO 10438-4:2007, 4.2.7).

Because the seal-gas and separation-gas filters are not part of a recycling system, the filter beta ratings or particle-removal efficiency should be identified on a one-time-through basis at conditions similar to the seal support operating conditions. The multi-pass test method, ISO 16889, is not applicable to gas filters.

The two factors for dry gas seal systems that it is necessary to address are the coalescing capacity and the dirt-holding capacity of the filter/separator. Dry gas seals require fine filtration ($\beta_4 \geq 85$) along with the ability to remove liquid aerosols with droplets as fine as 1 μm. This, combined with the single-pass nature of the service filter/separator elements in the presence of significant liquid, can quickly overload a filter. If the liquid rate to the filter/separator can exceed 50 % of the vendor's published capacity for a filter, a mechanical centrifugal separator

ahead of the filter/separator is necessary to handle the liquid. The vendor's published separator capacity is based on steady-state liquid flow and new, clean elements. Excess capacity is necessary both to prevent overload of the separator as the element's time in service increases and to handle small, intermittent liquid slugs that can develop in horizontal pipe runs.

It is critical in services where the seal-gas dew points are close to the seal-gas flowing temperatures to trap any low points or slope all piping to a location where the liquids can be removed. This applies to both on- and off-skid seal gas piping.

The fine filter/separator elements can quickly plug off if the gas stream is contaminated with solid particles or sediment. If dirty gas is a problem, a guard filter with a large holding capacity can be necessary to obtain an acceptable filter/separator element life. Where practical, the element's dirt-holding capacity for a dry gas seal filter or filter/separator should be on the order of six months. For some "dirty" systems, the vendor and purchaser should review and agree on an acceptable filter-holding-capacity requirement based on what change-out frequency is possible and cost effective.

D.2.7 Filter-holding capacity

In most systems covered by ISO 10438-2 and ISO 10438-3, the ingress of contamination is not significant after the system is initially flushed. In general, filters that have sufficient flow capability to meet the requirements of ISO 10438-2:2007, 4.6.7, or ISO 10438-3:2007, 4.7.7 o), have an acceptable service life. The service life of filter elements in a system after flushing should be more than six months unless there is some problem external to the filters that is causing a significant degree of contamination.

D.2.8 Standards

D.2.8.1 General

A brief description of applicable filtration standards is outlined in D.2.8.2 to D.2.8.5 to provide the users of this part of ISO 10438 with some background on the basis for use of these standards. For more information, the actual standard should be reviewed.

D.2.8.2 ISO 16889

ISO 16889 specifies a rigorous method of type testing of filter elements in a recirculating loop with the injection of a standard test dust into the upstream side of the loop. Reporting of the results of the tests is in a standard format and the beta ratio for each of several micron sizes is averaged over the range from clean to maximum element differential pressure. This averaging is done over ten equal time increments. Typically, test data are taken for five particle-size ranges. The test is valid for 4 μm to at least 30 μm ratings and at flow rates in the test loop from 4 l/min to 600 l/min (1 gal/min to 160 gal/min). In addition to the filter-element average beta rating for five or more particle sizes, a contaminant loading capability for a filter element is established.

The following items are controlled during the test of a filter to assure consistent results.

- a) The type of oil shall meet a given specification.
- b) The temperature of the test fluid is controlled within a specific range.
- c) The test contaminate is restricted to a known particle distribution and is standardized (ISO medium test dust).
- d) An automatic particle counter is used and calibrated to a standard.
- e) The automatic particle counter is used on-line and is validated to be correct in the system by means of a validation procedure.
- f) A system volume-to-flow ratio is established.

- g) Testing condition variations are limited to flow, upstream contamination level on a mass basis, viscosity, temperature and system volume.
- h) Instrument accuracy is established for the test circuit.
- i) The injection system is validated to assure constant rates of contaminate injection.

The ISO 16889 test procedure provides a method to type test filter elements for lube-oil, control-oil and seal-oil systems in a loop that simulates as closely as possible conditions the element encounters in service. Filters used in ISO 10438-2 and ISO 10438-3 should have elements that have been type-tested to ISO 16889 or equivalent. The ISO 16889 test differential pressure should also be within the range of the expected operational differential pressure, since some types of elements can have significantly different beta ratios depending on the differential pressure range selected.

D.2.8.3 ISO 4406

ISO 4406 provides a means of defining the quantity of solid particle contaminants in oil or hydraulic fluid. The code is comprised of two scale numbers or grades based on the number of particles greater than or equal to 5 μm and 15 μm per millilitre of fluid. In recent years, many groups have expanded on the standard system to cover a third range for counts of particles 2 μm or larger. Particle counts are made using a microscope or by means of automatic particle counters. The results are reported as two or three grade numbers (see Table D.3 for a partial list of grade numbers) separated by a slash, "/". The number for the smallest size range is presented first.

EXAMPLE 1 For a 1 ml sample with the following particle concentrations and grade numbers:

- 58 000 particles $\geq 2 \mu\text{m}$: 23,
- 4 100 particles $\leq 5 \mu\text{m}$: 19,
- 210 particles $\leq 15 \mu\text{m}$: 15,

the grade for the sample is designated as ISO grade 23/19/15.

EXAMPLE 2 For a 10 ml sample with the following concentrations:

- 4 100 particles $\geq 5 \mu\text{m}$,
- 210 particles $\geq 15 \mu\text{m}$,

the grades numbers are determined as

- $4\ 100/1 = 410$: 16,
- $210/10 = 21$: 12,

and the grade for the sample is designated as ISO grade 16/12.

Table D.3 — ISO 4406 grade numbers

Number of particles per millilitre n	Grade number
$80\,000 < n \leq 160\,000$	24
$40\,000 < n \leq 80\,000$	23
$20\,000 < n \leq 40\,000$	22
$10\,000 < n \leq 20\,000$	21
$5\,000 < n \leq 10\,000$	20
$2\,500 < n \leq 5\,000$	19
$1\,300 < n \leq 2\,500$	18
$640 < n \leq 1\,300$	17
$320 < n \leq 640$	16
$160 < n \leq 320$	15
$80 < n \leq 160$	14
$40 < n \leq 80$	13
$20 < n \leq 40$	12
$10 < n \leq 20$	11
$5 < n \leq 10$	10
$2,5 < n \leq 5$	9
$1,3 < n \leq 2,5$	8
$0,64 < n \leq 1,3$	7
$0,32 < n \leq 0,64$	6
$0,16 < n \leq 0,32$	5
$0,08 < n \leq 0,16$	4
$0,04 < n \leq 0,08$	3
$0,02 < n \leq 0,04$	2
$0,01 < n \leq 0,02$	1

D.2.8.4 SAE AS 4059E

SAE Aerospace Standard 4059E (which replaces NAS 1638) is another frequently used standard for assigning cleanliness. SAE AS 4059E defines 14 different cleanliness classes. The particle count basis is 100 ml of fluid. Each class specifies a given number of particles in each of five size groups: 5 µm to 15 µm, 15 µm to 25 µm, 25 µm to 50 µm, 50 µm to 100 µm and > 100 µm. Table D.4 is provided for reference.

Of the SAE AS 4059E and ISO 4406 standards, ISO 4406 is more frequently used. The reason the SAE class is referenced is that it can be estimated by filtering a measured sample of fluid through filter disc in a standard apparatus and making a comparison to standard comparator discs. This can be much more applicable in a field situation.

Table D.4 — SAE AS 4059E classification

Class	Number of particles/100 ml for selected particle-size ranges μm				
	5 to 15	15 to 25	25 to 50	50 to 100	> 100
00	125	22	4	1	0
0	250	44	8	2	0
1	500	89	16	3	1
2	1 000	178	32	6	1
3	2 000	356	63	11	2
4	4 000	712	126	22	4
5	8 000	1 425	253	45	8
6	16 000	2 850	506	90	16
7	32 000	5 700	1 012	180	32
8	64 000	11 400	2 025	360	64
9	128 000	22 800	4 050	720	128
10	256 000	45 600	8 100	1 440	256
11	512 000	91 200	16 200	2 880	512
12	1 024 000	182 400	32 400	5 760	1 024

D.2.8.5 Comparison of SAE AS 4059E and ISO 4406

Table D.5 provides the approximate ISO grades for each SAE class. It is not possible to provide an equivalent three-number ISO grade because the SAE does not count particles smaller than 5 μm . Conversion from ISO grade to SAE class can only be approximated (see Table D.5) and can indicate a better grade quality than if the actual particle count is taken.

Table D.5 — SAE AS 4059E to ISO grade approximation

SAE AS 4059E class	Number of particles per millilitre for selected particle sizes		ISO 4406 grade
	> 5 μm	> 15 μm	
00	1,52	0,27	8/5
0	3,0	0,54	9/6
1	6,1	1,1	10/7
2	12,2	2,2	11/8
3	24,3	4,3	12/9
4	48,6	8,6	13/10
5	97,3	17,3	14/11
6	195	35	15/12
7	389	69	16/13
8	779	139	17/14
9	1 551	277	18/15
10	3 114	554	19/16
11	6 228	1 108	20/17
12	12 456	2 216	21/18

D.3 System cleanliness testing

D.3.1 General

The intent of the 100 mesh screen test for special-purpose lube and seal system consoles is to confirm that, when shipped, there is no debris remaining in the console or vendor-supplied piping or components that can contaminate the remainder of the system and extend system flushing time at the site. When applied by other standards to vendor testing of equipment or by users at machinery installation, it is intended to confirm there is no debris remaining in the system downstream of the filters that can be immediately detrimental to the machinery components served by the system(s).

D.3.2 Special-purpose systems

The method for determining when a special-purpose oil or seal-oil system is clean enough to deliver or when a vendor oil system is clean enough for factory-run testing of special-purpose machinery is covered by ISO 10438-2:2007, 7.3.3.9. This requirement may also be extended to a site evaluation of installed oil and seal-oil systems.

To comply with ISO 10438-2:2007, 7.3.3.9, systems that have been circulated for 1 h through the 100 mesh test screens shall have no more than the maximum particle counts shown in Table D.6.

Table D.6 — Maximum number of particles

DN	NPS in	Schedule 40 or less	Schedule 80	Schedule 160	Double extra-strong
25	< 1	6	5	4	—
25 to 40	1 to 1,5	15	10	10	5
50	2	20	20	15	10
75	3	45	40	35	25
100	4	80	70	60	50
150	6	180	160	130	115

The use of test screens has been a reliable indicator of when an oil system with an adequate filter system can support start-up and/or testing of special-purpose machinery. The advantage of this testing is that a large representative volume of fluid is circulated through the test screens and the harmful debris that is introduced during fabrication and assembly of a special-purpose system is removed. When this test is done to an appropriate procedure and the test screens are located where there is downward flow through the screens in supply lines, the system will be free of damaging debris downstream of the screens.

There is some concern that 100 mesh screens do not pick up the small particles that can have undesirable long-term effects on the equipment serviced by the lube- and seal-oil system. The test specified in ISO 10438-2:2007, 7.3.3.9, is not intended to define how well a system performs in the long term. Long-term reliability of components served by a special-purpose system is more a function of the system design than filter specification. Other factors, such as control of the ingress of damaging size particles and the type of particle contamination, are important factors contributing to long-term reliability of machinery.

Some users of ISO 10438 have started to add a criterion from ISO 4406 or SAE AS 4059E to make sure the system is clean enough for long-term operation. The ISO 4406 grade specification often used is 20/15/12, (15/12 when only 5 µm and larger particles are counted). The approximate equivalent SAE requirement is Class 6. For some very critical or sensitive special-purpose machines, the ISO criterion may be as stringent as 18/14/11 (14/11 when particles smaller than 5 µm are not counted) downstream of the filters. This is approximately equivalent to SAE class 5. (See Table D.5.)

In the context of factory testing large consoles with a large residence capacity, the use of a low particle count requirement, such as ISO grade 14/11, can result in extensive circulation through the filters before a sufficient

number of passes through the filters have been completed to remove enough particles in the 5 μm to 10 μm range. This testing can be valid only after the screens have shown that the system is free of damaging debris at the equipment-supply connections. It is highly likely that the act of inspection of a console for debris of the console in accordance with ISO 10438-2:2007, 7.3.3.9, introduces enough dust to exceed the particle-count criteria. If not, the particle-count criteria will almost certainly be exceeded, due to even minor contamination that is inevitable in the course of special-purpose console and system preservation, shipping, storage and construction.

Caution should be used if only a particle-count criterion is specified for special-purpose systems/consoles in any context (console vendor, machinery test floor, at site operation). Because small volumes are sampled, the use of only particle-count criteria can easily miss damaging debris that can be released intermittently from piping and components.

Particle-count criteria can be useful in the course of flushing an entire system at the installation site when used in conjunction with testing the supply lines with 100 mesh screens. An ISO grade 15/12 criteria (SAE class 6) is acceptable for the start-up of most special-purpose equipment and even an ISO grade 16/13 criterion should not be a problem for start-up so long as particle counts are trending downward. In general, unless there is an equipment malfunction or a deficiency in the system filters, the system should be able to reach an ISO grade 14/11 (SAE class 5) level or better within a week or two of continuous service.

In general, users of special-purpose lube-oil and seal-oil systems who have tracked their systems by means of qualitative testing (e.g. using ISO 4406 or SAE AS 4059E) from installation through operation have noted at least one grade or class improvement from start-up of the system until a steady state particle level is reached.

D.3.3 General purpose

ISO 10438-3:2007, 7.3.3.8 b), requires 100 mesh screen testing of general-purpose oil consoles. This test is justified for relatively large general-purpose systems. The percent of the cost added for 100 mesh screen testing of large general-purpose systems is not large.

The alternate test specifies an ISO 4406 grade 17/14 or SAE class 8 be obtained as a method to verify whether the oil console is clean enough. It is necessary to select a circulation time to assure that there is mixing to suspend any sediments. Prior to taking a sample, it is suggested that the minimum circulation time be five times the reservoir capacity divided by the pump normal flow.

Some larger debris in the general-purpose oil console can be missed by checking only the particle count. If the oil is clean enough to pass ISO 4406 17/14 grade, then the quantity of debris left in the system should not require additional flushing effort at the site. At the site, prior to placing the system in service, it is still recommended that the entire system be flushed. A 100 mesh screen evaluation based on Table D.5 at the equipment oil-supply header should be done prior to commissioning the general-purpose equipment.

D.3.4 Dry gas seal console testing

Dry gas seal console cleanliness testing is covered by ISO 10438-4:2007, 7.3.3.3. This test is also based on inspection of a 100 mesh screen after the console is blown for a set period of time with 680 kPa (6,8 bar; 100 psig) dry and filtered air. The particle counting methods of SAE AS 4059E and ISO 4406 are not applicable to seal gas module testing because they are hydraulic tests. The use of a particle-count criterion is very difficult to set up in the context of a 10 min flow or blow test and is not normally required.

The cleanliness test procedure should be reviewed with the console fabricator. Whenever possible, the test screen should be located so that the gas flows down through the screen. The flow path through the console of the gas should be reviewed and it can be necessary to remove flow restrictions, such as orifice plates and control valve trim, for the test.

The console filter/separator elements shall be removed if there is any possibility of reaching the collapse differential for the element or if the element can present a significant restriction to the flow of air. Removal of the console filter/separator elements should be done only after the upstream console piping and components are confirmed as being clean.

The location of the air source pressure gauge [680 kPa (6,8 bar; 100 psig) minimum] should be reviewed and it should always be downstream of the air supply filter. An agreement should be made with the vendor concerning whether or not the pressure can drop under flowing conditions and, if so, how large a drop is acceptable. It is also suggested that only one supply connection be checked at a time.

In the context of ISO 10438-4, this test is applicable to factory tests of consoles. With agreement of all parties, the use of this test can be expanded to include vendor test stand dry gas seal support consoles and the testing of the assembled dry gas seal support system in the field to determine if the system is clean enough to allow factory testing or field start-up.

Annex E (informative)

International materials specifications

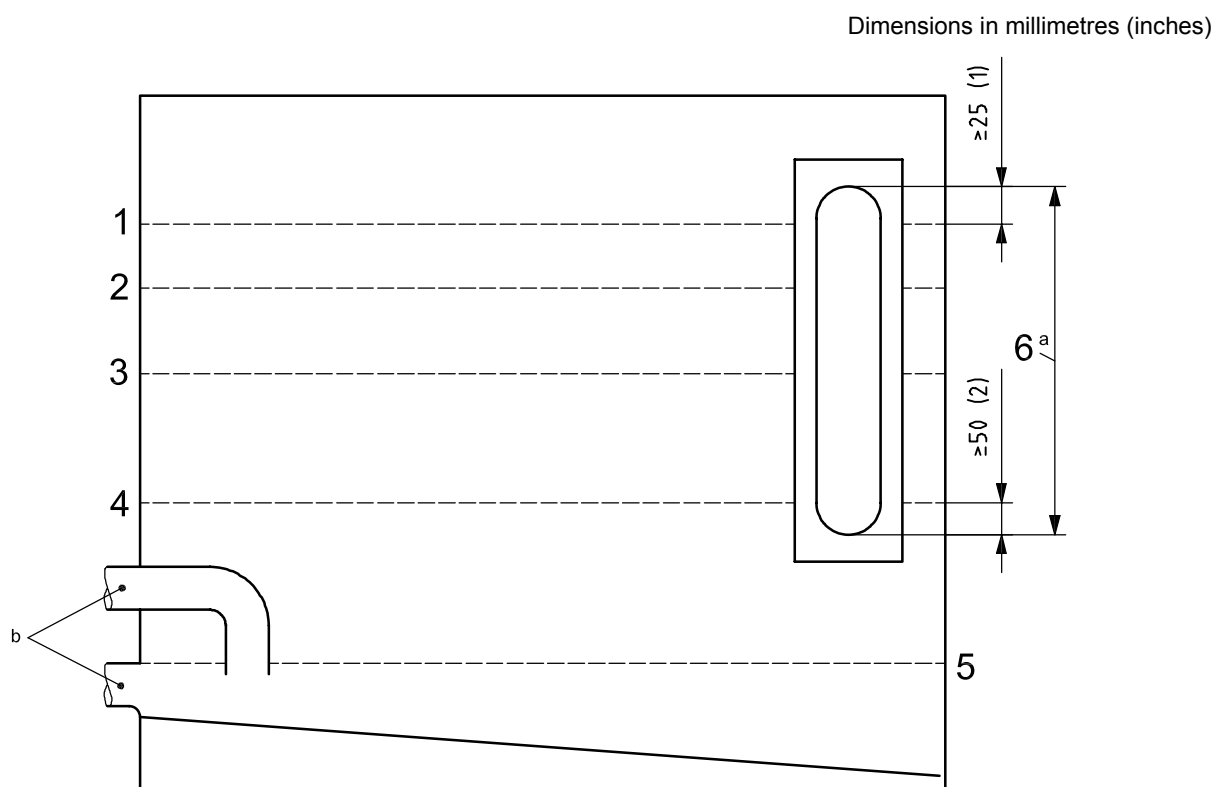
Table E.1 — International material specifications

Material Class	Applications	USA		International	Europe		Japan	
		ASTM	UNS	ISO	EN	Grade	Material No.	JIS
Carbon steel	Bolts and studs	A193 Gr B7	G 41 400	2604-2-F31	EN 10269	42 Cr Mo 4	1.7225	JIS G4107 CI SNB7
	Nuts	A194 Gr 2H	K 04 002	683-1-C35e	EN 10269	C 35 E	1.1181	JIS G4051 CI S45C
Stainless steel	Reservoirs (lube oil)	A240 Type 304	S30400	—	—	—	—	JIS G4304 SUS304
Stainless steel	Pipe 300 series	A312 TP 304	S30400	—	—	—	—	JIS G345 SUS304TP
		A358 Grade 304	S30400	—	—	—	—	JIS G3468 SUS304TPY
		A312 TP 316	S31600	—	—	—	—	JIS G3459 SUS316TP
		A358 Grade 316	S31600	—	—	—	—	JIS G3468 SUS316TPY
	Pipe fitting	A403 CR 304	S30400	—	—	—	—	JIS G3459 SUS304TP
		A105		—	—	—	—	JIS G4051 S25C
		A182		—	—	—	—	JIS G3201
		A234		—	—	—	—	—
	Flange	A181	—	—	—	—	—	JIS G3214
	Admiralty metal seamless heat-exchanger tubing materials	B111 C44300	C44300	—	EN 12451 CW706R	—	—	JIS H3300 C4430 T

Annex F **(informative)**

Explanation of reservoir levels

- F.1** The rundown level (key item 1 in Figure F.1) is the highest level that oil in the reservoir can reach when the entire system is shut down.
- F.2** The maximum operating level (key item 2 in Figure F.1) is the highest level that oil can reach during normal operation of the equipment.
- F.3** The minimum operating level (key item 3 in Figure F.1) is the lowest level that oil can reach during normal operation of the equipment.
- F.4** The suction-loss level (key item 4 in Figure F.1) is the level above the pump suction level (key item 5 in Figure F.1) at which the pump begins to lose prime. The pump suction level is defined by the pump suction vortex and net positive suction head requirements.
- F.5** The charge capacity is the total volume below the rundown level.
- F.6** The normal operating range is any level between the maximum and minimum operating levels.
- F.7** The retention capacity is the total volume below the minimum operating level.
- F.8** Retention time is the time allowed for disengagement of entrained air or gas.
- F.9** The rundown capacity is the volume between the rundown level and the maximum operating level.
- F.10** The working capacity is the volume between the minimum operating level and the suction-loss level.



Key

- 1 rundown level
- 2 maximum operating level
- 3 minimum operating level
- 4 suction-loss level
- 5 pump suction level
- 6 manufacturer's standard glass length

^a A manufacturer's standard gauge glass may be used in this arrangement with the bottom of the gauge no less than 50 mm below the minimum operating level and with any excess length being above maximum operating level.

^b Alternative pump suction arrangements.

Figure F.1 — Reservoir levels and oil level glass details

Bibliography

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- [3] ISO 7268, *Pipe components — Definition of nominal pressure*
- [4] ISO 10438-2:2007, *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 2: Special-purpose oil systems*
- [5] ISO 10438-3:2007, *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 3: General-purpose oil systems*
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Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and oil-control systems and auxiliaries —

Part 2: Special-purpose oil systems

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Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and oil-control systems and auxiliaries —

Part 2: Special-purpose oil systems

1 Scope

This part of ISO 10438, in conjunction with of ISO 10438-1, specifies requirements for oil systems for special-purpose applications. These oil systems can provide lubrication oil, seal oil or both. These systems can serve equipment such as compressors, gears, pumps and drivers.

NOTE The term “special-purpose application” is defined in ISO 10438-1.

2 Normative references

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

ISO 10438-1:2007, *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 1: General requirements*

ISO 13706:2005, *Petroleum, petrochemical and natural gas industries — Air-cooled heat exchangers*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

ISO 4572, *Hydraulic fluid power — Filters — Multipass method for evaluating filtration performance*

API STD 611, *General- Purpose Steam Turbines for Petroleum, Chemical and Gas Industry Services*

API RP 686-96, *Machinery RP Installation and Installation Design*

ASTM A240/A240M, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

3 Terms, abbreviated terms and definitions

For the purposes of this document, the terms, abbreviated terms and definitions given in ISO 10438-1 apply.

4 General requirements

4.1 General

4.1.1 The equipment (including auxiliaries) covered by this part of ISO 10438 shall be designed and constructed for a minimum service life of 20 years and at least 5 years of uninterrupted operation.

NOTE It is recognized that this is a design criterion.

4.1.2 The oil system shall be suitable for special-purpose applications as defined in ISO 10438-1. The system shall be designed as a separate console, or, if approved by the purchaser, it may be designed to be integral with the baseplate of the equipment it serves. The design shall allow for transfer between and shutdown of the main and spare components of the system for maintenance without interrupting the operation of the system or the equipment the system serves.

4.1.3 Unless otherwise specified, one oil system per equipment train shall be supplied.

NOTE If equipment trains share a common oil system, damage due to cross-contamination can affect all equipment served. Block valves can be needed in supply lines that, for maintenance reasons, have the potential to be accidentally closed. Equipment location can require unacceptably long runs of piping, equipment transients and other potentially detrimental factors that it is necessary to consider.

- **4.1.4** The purchaser shall specify the equipment's normal operating point and alternate operating points including transients.

NOTE Data sheets that can be used for specifying are included in Annex A.

- **4.1.5** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor having unit responsibility. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified. In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for the equipment.
- **4.1.6** The purchaser shall specify whether the seal-oil and lube-oil systems are to be separate or combined.

NOTE Annex B contains piping and instrument diagrams (P&IDs) for typical arrangements.

- **4.1.7** Where oil is supplied from a common system to two or more machines (such as a compressor, a gear and a motor), the oil's characteristics shall be specified by the owner on the basis of mutual agreement with all vendors supplying equipment served by the common oil system.

NOTE Site conditions with extreme variations, such as desert or arctic applications, can also require special oil grade viscosity and increased oil supply temperatures.

- **4.1.8** The system shall be designed to supply oil to all equipment specified.

4.1.9 The recycled oil shall originate upstream of the filters.

NOTE This is to minimize the potential for generation of static electricity (or a static charge) that can result when filtered oil bypasses the equipment and is recycled directly to the reservoir. This is very important, especially if explosive gas can also be present in the reservoir.

- **4.1.10** The seal-oil system shall be designed to serve the full range of equipment operating conditions specified. These conditions may include but are not limited to the following:
 - a) settling-out pressures;
 - b) process relief-valve settings;
 - c) shop test and field run-ins;
 - d) start-up conditions.

4.1.11 In addition to the above requirements, seal-oil systems shall be designed to operate safely prior to process start-up or any other idling condition specified, with the system in total automatic control and with the shaft end seal at atmospheric pressure.

4.1.12 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

- **4.1.13** If applicable, the purchaser shall specify minimum requirements for clearance around and access to components (especially clearance around and access to coolers, filters and hand valves).

4.1.14 Pumps, filters, strainers, coolers, traps, valves and all other components that retain oil under pressure and are external to the reservoir shall be made of steel.

4.1.15 Valved vents, drains and piping shall be furnished to permit draining, cleaning and refilling of idle components while the equipment is in operation.

- **4.1.16** The purchaser shall specify when and where double block and bleed valves are required for isolating a component and how they are arranged.
- **4.1.17** Coolers, filters, overhead oil tanks, drain traps, accumulators and other pressure vessels shall be in accordance with the specified pressure design code (Refer to ISO 10438-1:2007, 4.4). If specified by the purchaser, vessels shall be code stamped.

NOTE 1 Code stamping might not be applicable for pressure design codes other than ASME.

NOTE 2 Refer to ISO 10438-1:2007, 4.5.7. Local jurisdictions can require a code stamp and conformity assessment markings.

4.1.18 The console shall perform on the test stand and on its permanent foundation within the specified acceptance criteria. After installation, the performance of the oil system, including piping, console and associated auxiliaries, shall be the joint responsibility of the purchaser and the vendor who has unit responsibility for the equipment train served.

NOTE Certain auxiliaries, such as overhead seal-oil tanks, rundown tanks, interconnecting piping, etc., might not be installed on test.

- **4.1.19** The vendor shall advise the purchaser of, and both parties shall mutually agree upon, any special provisions that are necessary to ensure that an adequate supply of backup lube or seal oil or both is maintained in the event of complete failure of the primary lube- or seal-oil supply system. These provisions may include emergency pumps, accumulators, rundown tanks and special arrangements for equipment safety and protection when the equipment decelerates. Provisions shall be adequate for coast-down time, cool-off time and block-in time as applicable; the purchaser shall specify the required block-in time. The purchaser and the vendor shall mutually agree upon the system and its components.

4.1.20 Block valves that interrupt the oil flow to the equipment shall not be installed in oil supply lines downstream of the filters unless the block valves are part of a component block and bypass arrangement.

4.2 Baseplates

- **4.2.1** The system shall be designed as a single console, in multiple packages or in any other arrangement as specified. Each package shall have a structural steel baseplate with all system components and related valves and manifolds mounted on the baseplate. The major component supports (pumps, filters, coolers, reservoir, etc.) shall be mounted directly on structural steel.

4.2.2 Unless otherwise specified, package baseplates shall be of the drain-gutter type with one or more drain connections at least DN 40 (NPS 1 1/2) in size. Baseplates, mounted components and decking shall be arranged and installed to ensure drainage and to avoid the retention of liquid by sloping of the decking and gutters.

- **4.2.3** If specified, flat decking may be furnished.

NOTE Minor puddling of fluid can occur.

4.2.4 The baseplate shall be provided with lifting lugs for at least a four-point lift. The baseplate shall be designed so that after the components and all piping mounted on it are drained of oil, the package can be lifted without permanently distorting or otherwise damaging either the baseplate or any component mounted on it.

NOTE Spreader bars can be required.

4.2.5 Unless otherwise specified, non-skid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

NOTE Examples of other options are grating or phenolic material to reduce mass for off-shore applications, or deletion of decking and a grout poured to create a walking surface.

4.2.6 Baseplates shall be suitable for installation in accordance with API RP 686. Unless otherwise specified, all baseplates shall be provided with at least one opening or hole in each bulkhead section through which grout can be poured and vented. Each opening shall have a clear area of no less than 125 cm² (20 in²) and no dimension less than 100 mm (4 in), and each shall permit filling and venting of the entire cavity with grout under the baseplate without creating air pockets. Each hole into which the grout is poured shall be accessible: no component or piping shall be disturbed and no tripping hazards in the walk and work areas shall be created. Vent holes at least 13 mm (1/2 in) in diameter shall be provided for each bulkhead compartment. Each grout hole shall also be provided with steel curbing 13 mm (1/2 in) high to prevent accumulated oil or water from entering the grout. Vent holes shall be provided without curbing.

NOTE The 13 mm (1/2 in) curb required for grout holes is not considered a tripping hazard.

- **4.2.7** When epoxy grout is specified, the vendor shall pre-coat all the grouting surfaces of the mounting plates with a catalyzed epoxy primer applied to degreased white metal. The epoxy primer shall be compatible with epoxy grout. The vendor shall submit instructions for field preparation of the epoxy primer to the purchaser.

4.2.8 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, accessibility for grouting under all load-carrying structural members shall be provided.

- **4.2.9** If specified, the baseplate shall be designed for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon between the purchaser and the vendor.

4.2.10 Levelling screws shall be provided in the proximity of each hold-down bolt.

4.3 Oil reservoirs

4.3.1 General

Unless otherwise specified, reservoirs shall be separate from the baseplate for the equipment train served by the oil console and shall be rigid enough to prevent sagging and vibration. Components bolted to the reservoir shall be mounted on pads; no bolt holes shall extend into the reservoir. If reinforcing ribs are required, they shall be installed externally to avoid deposit accumulation.

NOTE For special features, see 4.3.12.

4.3.2 Protection from dirt and water

4.3.2.1 Reservoirs shall be sealed to prevent dirt and water from entering. Top-surface openings shall be raised at least 25 mm (1 in) and shall have a gasket.

4.3.2.2 Unless otherwise approved, pumps, coolers or filters shall not be mounted on top of the reservoir.

NOTE It is possible that this can be a user consideration for offshore or other installations where available space is limited.

4.3.2.3 The tops of reservoirs shall slope at least 10 mm/m (1/8 in/ft).

NOTE It might not be possible to implement this requirement for reservoirs integrated with the main equipment baseplate.

4.3.3 Oil connections and internal piping

4.3.3.1 All oil return flow streams shall be hydraulically located as far away from the pump suction connections as possible.

NOTE The use of the term "hydraulically located as far away" is intended to convey the concept that it is possible to direct return flow streams by internal piping or baffling to avoid disturbing the oil flow at pump inlets. This internal piping or baffling can be used in lieu of external connections physically located such a distance from the pump suction connections that they avoid disturbing the oil flow at the pump inlets.

4.3.3.2 All atmospheric oil return connections (including fill connections) shall be located above the maximum operating level and shall transport oil (via open-top stilling tubes or degassing trays) as shown in Figure B.24. Stilling tubes shall have bottom baffles.

4.3.3.3 Control back-pressure valve and return stream-control valve connections shall be separate and shall discharge oil via internal piping below the pump suction-loss level as shown in Figure B.24. Pressurized oil shall not be returned to vented stilling tubes or degassing trays. Internal piping shall have bottom baffles.

4.3.3.4 Pump suction connections shall be located near the high end of the sloped reservoir bottom and at least 50 mm (2 in) above it.

4.3.3.5 Except as specified in 4.3.9, reservoir pipe connections shall be flanged.

4.3.4 Manways and drains

To ensure complete drainage, the bottom of each reservoir shall slope continuously, at least 1:50 (1/4 in/ft), to a low point. A flanged drain connection (with a valve and a blind flange) at least 50 mm (2 in) in diameter shall be provided. The manway openings provided shall permit unobstructed entry for inspection and cleaning of all interior compartments. Manways, where entry is required for cleaning, unless otherwise specified, shall be located on top of the reservoir and each manway shall be at least 600 mm × 600 mm or 450 mm in diameter (24 in × 24 in or 18 in in diameter). Internal manways are not acceptable.

4.3.5 Features and appendages

4.3.5.1 The oil reservoir shall have the following features and appendages:

- a) capacity to settle moisture and foreign matter adequately and to provide allowance for rundown from the entire system;
- b) provisions to eliminate air and minimize migration of foreign matter to each pump suction;
- c) a reflex-type, welding-pad oil level glass (with stainless steel weld pad and carbon steel cover) arranged to cover the span from at least 25 mm (1 in) above the rundown level to 50 mm (2 in) below the pump suction-loss level. The oil level glass shall be located as far away as possible from the oil return lines and be visible from the perimeter of the unit (see 4.3.3.1). The maximum and minimum operating levels, rundown level and suction-loss level shall be indicated on the level glass. If more than one level glass is provided, they shall be offset;

- d) unless otherwise specified, a fill opening at least 50 mm (2 in) in diameter, which automatically closes (normally held shut by a spring) and is equipped with a stainless steel fine-mesh strainer basket that has an open area equal to 200 % of the internal pipe area;

NOTE Some users pipe up fill connections using the connections provided in 4.3.9. If manual fill is used, the connection described above is required.

- e) blind-flanged vent connection at least 50 mm (2 in) in diameter;
- f) for lube-oil reservoirs, a weatherproof, corrosion-resistant filter-breather cap at least 50 mm (2 in) in diameter with filtration rating of 10 μ m beta 10 or better. (For reservoirs containing seal oil, see 4.3.5.2.);
- g) internal baffles that do not trap gas;
- h) if the driver of the train is lubricated by the same system as the compressor and the oil reservoir contains the seal oil, a separate connection shall be provided on the reservoir for the compressor seal-oil return line.

NOTE 1 This line prevents pressurization of the drivers lube-oil drain header if the compressor seals fail.

NOTE 2 If this option is incorporated, it requires separate bearing and seal-oil drains from the compressor.

4.3.5.2 On reservoirs containing seal oil, a flanged vent sized to handle the total flow of gas coming from the failed seal(s) through the oil drain lines shall be furnished. The vendor shall provide the purchaser with the vent size and the sizing criteria.

4.3.6 Capacity and configurations

4.3.6.1 A low-level alarm shall actuate at the minimum operating level.

4.3.6.2 The criteria for sizing a reservoir are given in 4.3.6.3 through 4.3.6.8.

NOTE All level references refer to ISO 10438-1:2007, Figure F.1.

4.3.6.3 The working capacity between 3 and 4 in ISO 10438-1:2007, Figure F.1 shall be sufficient for at least 5 min of normal flow.

4.3.6.4 The minimum retention capacity shall be calculated based on 8 min of normal oil flow.

4.3.6.5 The rundown capacity shall allow for all of the oil contained in all of the components, such as bearings and seal housings, overhead seal tanks, rundown tanks, accumulators, control elements and vendor-furnished piping that drain back to the reservoir. The rundown capacity shall also allow for at least an additional 10 % of these volumes for the purchaser's interconnecting piping.

NOTE Rundown can cause some backup in the drain lines entering the reservoir.

4.3.6.6 The capacity between the minimum and maximum operating levels shall be at least 50 mm (2 in) of reservoir height, and, based on the manufacturer's estimated seal-oil usage rate when the seals have worn to two times their maximum design clearance, the capacity shall be sufficient to permit at least 3 days of operation without requiring that oil be added to the reservoir.

The usage rate shall be provided by the seal manufacturer. This is of special concern when the sour oil is not returned to the reservoir.

4.3.6.7 In a lube-oil system, the capacity between the minimum and maximum operating levels shall be at least 50 mm (2 in) of reservoir height.

4.3.6.8 The free surface of the oil in the reservoir shall be a minimum of 60 cm² for each litre per minute (0.25 ft² for each gallon per minute) of normal flow.

4.3.7 Heating

4.3.7.1 Heaters shall be provided if the minimum site temperature on the data sheet is less than the minimum oil start-up temperature.

Users may elect to use tempered water in the lube-oil cooler for the cooler to operate as a lube-oil heater prior to start-up. Details of this alternate operation shall be discussed and mutually agreed upon (see 4.5.1.15).

NOTE There are many factors to consider when heating the lube oil to minimum starting temperature, including lube pump start-up minimum oil temperature, equipment minimum oil temperature, circulating heat loss, etc. Many of these factors are the responsibility of the installing contractor in coordination with the console designer. Insulation, location and heat tracing requirements are considerations of the installation.

- **4.3.7.2** Purchaser shall specify whether the heaters are steam or electric.

4.3.7.3 Unless otherwise specified, the reservoir heat loss during heating shall be determined based on an uninsulated reservoir, the minimum site ambient temperature and a 16 km/h (10 mi/h) wind. The vendor shall provide data to support this.

4.3.7.4 When a steam heater is specified, a removable element external to the oil reservoir shall be provided for heating the charge capacity of oil before start-up in cold weather. The device shall have the capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the minimum oil start-up temperature required by the equipment being served within 12 h while circulating oil through the system. If minimum site temperatures are lower than 10 °C (50 °F), it is necessary that the oil in the reservoir be heated to 10 °C (50 °F) before starting the pump.

NOTE Lube-oil pumps and drivers are sized for 10 °C (50 °F) oil.

4.3.7.5 When an electric heater is specified, a thermostatically controlled removable electric immersion heating element shall be provided for heating the charge capacity of oil before start-up in cold weather. The device shall have the capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start-up temperature within 12 h while circulating oil through the system. If minimum site temperatures are lower than 10 °C (50 °F), it is necessary that the oil in the reservoir be heated to 10 °C (50 °F) before starting the pump. It shall have a maximum watt density of 2 W/cm² (15 W/in²). Heater elements shall be sheathed in austenitic stainless steel or Incoloy¹⁾; copper or copper-bearing materials shall not contact the oil.

Electric immersion heaters shall be interlocked by the purchaser to be de-energized when the oil level drops below the minimum operating level.

NOTE Lube-oil pumps and drivers are sized for 10 °C (50 °F) oil.

4.3.7.6 Electric immersion heaters shall be installed in a manner that allows the heaters to be removed during operation. Top or angle-mounted direct immersion elements are preferred. If oil-filled tubes with vented expansion chambers are used, the oil inside the tubes shall be the same as in the reservoir and its temperature maintained at a minimum of 10 K (18 °R) below its flash point. If dry tube heating elements are used, the cold section of the element shall extend at least 30,5 cm (12 in) beyond the reservoir wall, and the thermostat shall be located external to the dry well. The hot section of the heater element shall be located a minimum of 50 mm (2 in) below the reservoir minimum operating level.

- **4.3.7.7** If specified, the vendor having train responsibility shall conduct an analysis of the complete system, including lube-oil console, interconnecting piping, rundown tanks, equipment heat loss and other system components, to verify that the complete system heats up to the minimum equipment starting temperature in 12 h when ambient temperature is at the minimum specified value.

1) Incoloy is an example of a suitable product available commercially. This information is given for the convenience of users of this part of ISO 10438 and does not constitute an endorsement by ISO of this product. This term is used as an example only, and does not constitute an endorsement of this product by API.

This requires that the installing contractor provide details of the interconnecting piping arrangements and can result in the need for additional heating.

Consideration of a lighter-viscosity oil compatible with the entire train can allow the permissive starting temperature to be lowered.

4.3.8 Provision for insulation

- If specified by the purchaser, reservoirs shall be fitted with insulation clips. The purchaser shall furnish and install the insulation.

4.3.9 Plugged connections

Above the rundown oil level, each reservoir shall be provided with two threaded and plugged connections that are at least 25 mm (1 in) in diameter. These two connections may be used for such services as purge gas, makeup oil supply and oil conditioner return. One connection shall be located to ensure an effective sweep of purge gas toward the vents.

4.3.10 Provision for oil conditioner

- **4.3.10.1** If specified, the vendor shall provide a 25 mm (1 in) flanged, valved and blinded connection (see Figure B.24, Footnote i), located below the minimum operating level for use as an oil supply connection for an oil conditioner.

4.3.10.2 The vendor shall also provide inside the reservoir a pipe loop with a siphon-breaker hole at the top which has a maximum diameter of 6 mm (1/4 in). This pipe loop shall prevent the oil level from falling more than 50 mm (2 in) below the minimum operating level due to the action of the conditioner recirculation.

4.3.11 Welds

Joints, pads and connections shall be both internally and externally welded to eliminate cavities, potential sources of corrosion and contamination. The reservoir's wall-to-top junctions may be welded from the outside if a full-penetration weld is used. All welds shall be continuous. Internal joints shall be made smooth by grinding or other suitable means as necessary to eliminate pockets and provide an unbroken finish.

4.3.12 Special features

4.3.12.1 Reservoir tops shall be provided with the following:

- a) if specified, an accessible ladder with extended handrails;
- b) if specified, handrails around the perimeter of the reservoir top;
- c) if specified, non-skid surfaces decking (checker or diamond plate or hot-dipped galvanized steel grating).

4.3.12.2 For equipment mounted on the reservoir, the reservoir shall provide sufficient structural stiffness to properly support the equipment (see 4.3.2.2).

4.3.12.3 If the reservoir top is to be used as a personnel access area, it shall be designed to withstand a live load of 1 100 N (250 lbf) without permanent distortion.

4.3.13 Materials

Unless otherwise specified, reservoirs and all appendages welded to reservoirs shall be fabricated from austenitic stainless steel in accordance with ASTM A240/A240M. Pipe connections shall be as specified in 5.1.

NOTE Carbon steel appendages, such as ladders and handrails, can be bolted to clips welded to the reservoir.

4.3.14 Grounding

Two grounding clips or pads diagonally opposed to each other (see Figure B.24) shall be welded to the reservoir. The pads shall accommodate a 13 mm (1/2 in UNC) bolt.

4.4 Pumps and pump drivers

- **4.4.1** The oil system shall include a main oil pump and a standby oil pump both suitable for continuous operation. For non shaft-driven pumps, the main and standby pumps shall be identical. The purchaser shall specify whether horizontal centrifugal or rotary pumps shall be used. Except as modified in this part of ISO 10438, pumps shall conform to ISO 13709.

NOTE For the purpose of this provision, API STD 610 is equivalent to ISO 13709.

4.4.2 Unless otherwise specified, pumps shall be external to the reservoir.

- **4.4.3** If specified by the purchaser, an emergency oil pump shall be furnished to allow safe shutdown without damage to the equipment in the event that both the main and standby pumps fail. The purchaser and driven-equipment suppliers shall define the requirements for safe shutdown.

NOTE A lube-oil rundown tank can provide bearing oil for rundown. Sometimes an emergency oil pump with separate power source is supplied in order to allow cool-down oil after coast-down or seal oil.

4.4.4 Unless otherwise specified, oil pumps not submerged inside the reservoir shall be equipped with mechanical seals that have carbon rings with mating tungsten or silicon carbide rings; Buna or Viton gaskets²⁾ and O-rings; and end plates with throttle bushings as outlined in ISO 13709.

NOTE For the purpose of this provision, API STD 610 is equivalent to ISO 13709.

- **4.4.5** Purchaser shall specify if the main oil pump shall be turbine or motor driven. Standby pumps shall be motor driven.

NOTE 1 Standby pumps are motor driven due to relatively long start-up times for turbine driven pumps.

NOTE 2 Typically, installations for two motor driven pumps have electric feeds from independent sources.

4.4.6 Each pump shall be driven separately.

4.4.7 A shaft-driven pump may be provided when approved by the purchaser. The pump shall be positive-displacement type.

NOTE 1 If the shaft-driven pump fails, on-line maintenance of the pump is not possible and requires an outage for maintenance of the pump.

NOTE 2 When a shaft-driven pump is provided, consideration for a lube-oil rundown tank might not be required.

4.4.8 When a shaft-driven pump is provided, the following pump design considerations shall be taken into consideration as a minimum:

- a) NPSH;
- b) priming;
- c) maintenance accessibility;

2) Buna and Viton gaskets are examples of suitable products available commercially. This information is given for the convenience of users of this part of ISO 10438 and does not constitute an endorsement by ISO of this product. This term is used as an example only, and does not constitute an endorsement of this product by API.

- d) shaft coupling;
- e) drive shaft positioning due to thermal growth.

4.4.9 If required by area classification, motors shall comply with IEEE 841 or explosion proof NEMA MG-1.

4.4.10 Steam turbines shall conform to API STD 611.

4.4.11 The minimum criteria given in a) through e) shall be used when sizing pumps.

- a) In all cases, pumps shall be sized to deliver the required capacity when pumping lube oil at the highest temperature and the corresponding minimum viscosity.
- b) Each pump shall be capable of
 - 1) supplying the normal oil flow required by the equipment plus the greater of 20 % of the normal oil flow or 40 l/min (10 gal/min);
 - 2) transient oil requirements;
 - 3) equipment vendor's allowance for normal wear.
- c) Accumulators may be provided to meet transient control-oil requirements, if approved by the purchaser. Accumulators shall be sized according to 4.8.1. The equipment supplier shall define all transient conditions.
- d) In booster systems, the capacity of the main pump, as established in 4.4.11 a), shall be increased by the amount required to supply both the main and the standby booster oil pumps simultaneously.
- e) Rotary pumps shall be capable of passing the total flow, as established in 4.4.11 a) and 4.4.11 b), at the relief-valve set pressure while not exceeding 90 % of the pump manufacturer's maximum differential pressure rating at the minimum operating viscosity. The pump shall also be capable of operating continuously at the normal flow, pressure-relief-valve or pressure-limiting-valve set pressure and minimum operating viscosity.

NOTE This selection criterion is required to avoid pump rotor contact during operation under extreme conditions.

4.4.12 The normal operating capacity of the centrifugal pumps shall be within 50 % to 110 % of their best efficiency point. From their normal operating point to shutoff, centrifugal pumps shall have a continuous rise in head of at least 5 % and, with the installation of a new impeller, shall be capable of a future increase in head of at least 10 %.

4.4.13 Pump drivers shall be sized according to whichever of the following requires the larger driver:

- applicable pump standard; or
- conditions given in 4.4.13 a) and 4.4.13 b).

Motor drivers for centrifugal pumps shall have a power rating which covers the end-of-curve requirements of the supplied impeller with a minimum nameplate rating of 1,0 kW for kW-rated motors or 1,0 hp for horsepower rated motors.

- a) Centrifugal pumps shall deliver the specified system pressure over the pump's stable flow range when the temperature of the pumped oil is 10 °C (50 °F).
- b) Rotary pumps shall be capable of operating at the specified pump pressure limiting valve setting (including accumulation) when the temperature of the pumped oil is 10 °C (50 °F).
- c) Purchaser shall specify the minimum inlet steam temperature and pressure and the highest exhaust pressure under which the turbine is expected to operate.

4.4.14 Check valves shall be provided on each pump discharge to prevent the flow of oil backwards through a standby or idling pump.

4.4.15 Shaft-driven pumps, if provided, shall have check valves and bypasses arranged such that the shaft-driven pump continues to supply pressurized oil during periods of reverse rotation. The supplied pump shall be capable of supplying pressure while running backwards.

4.4.16 For rotary pump systems, the vendor shall furnish external oil-pressure limiting valves that shall be installed on the components or in the piping supplied by the vendor. Oil-pressure limiting valve settings, including an allowance for accumulation, shall be determined after all of the possible equipment and component failures are considered. The settings shall protect the oil system components and piping. Fully accumulated pressure shall not exceed 110 % of the system design pressure.

4.4.17 Oil-pressure limiting valves (PLV) shall be pressure-modulating devices (as opposed to snap-acting or pop-type safety relief valves) with a pressure increase proportional to flow above the valve cracking pressure (that is, the pressure at which the valve begins to open). These devices shall be mounted external to the reservoir and shall operate smoothly, without chattering and without causing a drop in supply pressure to the equipment. Pressure-limiting valve piping shall be sized for the full flow of each pump; the valves shall not chatter and the piping shall not vibrate. The minimum pressure-limiting valve cracking pressure shall be 10 % or 170 kPa (1,7 bar; 25 psi) higher than the highest required operating pressure, including operation at 10 °C (50 °F), whichever is greater. To avoid unnecessary delay in opening, pressure-limiting valve takeoff points shall be located as close to the oil pump discharge as possible and below the reservoir oil level. Pressure-limiting valves shall not be used for continuous pressure regulation. For high-pressure applications (typically above 5,5 MPa (55 bar; 800 psig), where pressure-modulating valves cannot be provided, provisions for venting or otherwise relieving the pumps is required.

4.4.18 The oil system shall be provided with pressure-regulating devices that prevent fluctuation of the oil pressure to the equipment when both the main and the standby pump are in operation or when either the main or the standby pump is in operation while the other pump is being started, brought up to operating speed or stopped. Each device shall have an adequate response time and shall operate smoothly in a stable manner, without chattering or producing pressure or flow transients that can cause the equipment to shut-down (see 7.3.3.8). These pressure-regulating devices shall be located so that an excessive rise in oil temperature resulting from a recirculation of uncooled oil is avoided (see, for example, Figure B.12, Footnote g).

4.4.19 Bypass pressure-regulating valves shall be sized to cover a range from the minimum usage of one pump to the maximum usage of two pumps.

4.4.20 All pumps (except shaft-driven and booster pumps) shall be installed with flooded suctions to ensure self-priming and shall be installed with suction-block valves and with discharge-block and check valves. Vertically mounted pumps shall be arranged to assure that the entire pump remains flooded. Suction piping shall be continuously vented or arranged to avoid pockets in which air can accumulate or become trapped. Each pump shall have a separate suction line from the reservoir. The pump suction lines shall be designed to avoid excessive piping loads on the pump casing flanges (see API RP 686-96, Chapter 6). Designs for suction piping, suction-block valves, pump casings and all other components (particularly those for booster-pump arrangements) shall avoid the possibility of overpressure caused by leaking discharge check valves.

NOTE Shaft-driven pumps are primed by starting the auxiliary pump prior to starting the unit.

4.4.21 For the protection of centrifugal pumps during flushing and for the initial operation of new oil systems, a removable strainer made from austenitic stainless steel and having a minimum open flow area equal to 150 % of the cross-sectional area of the suction pipe, shall be installed in the suction piping of each pump between the pump suction flange and the block valve. The temporary strainer shall be identified by a protruding tab and shall have a mesh size adequate to stop all objects that can damage the pump. The piping arrangement shall permit the removal of the strainer without disturbing the alignment of the pump. The maximum strainer hole size shall be 3 mm (1/8 in). Cone strainers shall be installed in spool pieces to minimize piping removed.

NOTE Strainer can be cone, basket or Y-type.

4.4.22 Unless otherwise specified, for rotary pumps, a permanent Y-type strainer with an austenitic stainless steel basket with a minimum open flow area equal to 150 % of the cross-sectional area of the suction pipe shall be installed in the suction piping of each pump. The strainer shall have a mesh size in accordance with the pump manufacturer's recommendation. A blowdown/drain valve shall be provided on strainers. Strainers can require the use of a bushing for blowdown connections due to space limitations. These bushings shall be rated at the pressure rating of the pipe as a minimum.

NOTE 1 Strainer bodies can require removal from the system for basket access.

NOTE 2 Elimination of these bushings can raise pump suction connections.

4.4.23 Strainers are not required for booster pumps that are located downstream of primary filters.

4.4.24 Unless otherwise specified, when a permanent strainer is being used, a compound-type pressure gauge shall be installed between it and the pump suction. The gauge shall be scaled properly to detect a fouled strainer.

4.4.25 In order to maintain satisfactory system operation when the main pump fails to meet system requirements, the vendor shall furnish the primary element for the purchaser's start-up control for the standby oil pump. The start-up control of the standby pump shall be actuated by devices that sense low supply pressure to the equipment or low oil levels in the overhead seal-oil tanks. Motor-control centres shall be provided by the purchaser. The control system shall have a manual reset. (See ISO 10438-1:2007, 6.2.1.1, for instrumentation that allows the operation of the standby-oil-pump controls to be checked while the main pump is in operation.)

4.4.26 For each system requiring booster pumps, the supply of low-pressure oil shall be sufficient for simultaneous operation of both the main and the standby high-pressure booster pumps. The vendor shall provide a device to alarm or to trip the booster pumps on low suction pressure (see Figure B.23).

4.4.27 Each coupling shall have a coupling guard which is removable without disturbing the coupled elements and shall meet the requirements of a) through c).

- a) Coupling guards shall enclose the coupling and the shafts to prevent personnel from contacting moving parts during operation of the equipment train. Allowable access dimensions shall comply with specified standards, such as ISO 14120 or ASME B15.1.
- b) Guards shall be constructed with sufficient rigidity to withstand a 900 N (200 lbf) static point load in any direction without the guard contacting moving parts.
- c) Guards shall be fabricated from solid sheet or plate with no openings. Guards fabricated from expanded metal or perforated sheets may be used if the size of the openings does not exceed 10 mm (0,375 in). Guards shall be constructed of steel, brass or non-metallic (polymer) materials. Guards of woven wire shall not be used. If specified, non-sparking guards of agreed material shall be supplied.

4.4.28 Unless otherwise specified, flexible-element couplings shall be used. Coupling hubs shall be made of steel. Metallic flexible-element types shall have elements of corrosion-resistant material. A spacer coupling shall be used unless otherwise specified. The spacer shall have a nominal length of at least 125 mm minimum (5 in minimum) or as required to remove coupling, bearings, seal and rotor as applicable, without disturbing the driver or the suction and discharge piping.

4.4.29 Couplings shall be keyed in place. Information on shafts, keyway dimensions and shaft end movements because of end play and thermal effects shall be furnished to the vendor supplying the coupling.

4.4.30 Couplings and coupling-to-shaft junctures shall be rated for at least the maximum driver power (including any motor service factor). Couplings shall have a minimum service factor of 1,5.

4.4.31 To assure that the connected machinery is accurately aligned, the total indicator reading of coupling registration and alignment surfaces shall be controlled within specific limits. For all pumps, the coupling surfaces normally used for checking alignment shall be concentric with the axis of coupling hub rotation within the following limits: 13 µm (0,000 5 in) total diameter, with a minimum applicable tolerance of 25 µm (0,001 in) total indicator reading and a maximum of 75 µm (0,003 in) total indicator reading. All other diameters not used for location, registration, or alignment shall be to the coupling manufacturer's standard, provided balance requirements are met.

4.4.32 Mounting plates shall be provided as specified below.

- a) Mounting pads shall be provided for each pump and its driver. Pads shall be at least 25 mm (1 in) larger than the feet of the mounted equipment to allow for levelling of the console or package baseplate without removal of the equipment. The pads shall be fully machined flat and parallel. Corresponding surfaces shall be in the same plane within 125 $\mu\text{m}/\text{m}$ (0,002 in/ft) of distance between the pads. To prevent distortion, machining of mounting pads shall be deferred until welding on the baseplate in close proximity to the mounting pads has been completed. This tolerance shall be met at the time of assembly at the vendor's shop between coupled rotating pieces of equipment. The coupled pieces shall be capable of being re-aligned in the field when the console is properly installed in accordance with API RP 686.

- b) Pumps and drivers shall be mounted on a machined surface. All pads for oil pumps and drivers shall be machined to allow for the installation of stainless steel shims; shim packs, at least 3 mm (1/8 in) thick, shall be placed under the feet of each component.

NOTE Due to mounting surface tolerances on purchased pumps and drivers, the installation of shims with different thicknesses under each foot can be necessary. Additionally, shims under the pump are required to allow future shimming of a replacement pump to the inlet pipe. [IEEE 841 motor and small PD pump tolerance 130 μm (0,005 in) from foot to foot, NEMA MG-1 motor and large PD pump 260 μm (0,010 in) from foot to foot.]

- c) To minimize misalignment of the pump and driver shafts due to piping load effects, the pump and its baseplate shall be constructed with sufficient structural stiffness to limit total misalignment to within acceptable limits.
- d) When the pump and driver are mounted on the console without a separate sub-base, the pump and driver shall be mounted to a structural member of the console base rather than merely being attached to deckplate or other non-structural components.
- e) Alignment between pump and driver shall be in accordance with API RP 686.
- f) Transverse and axial alignment positioning jackscrews shall be provided for all pump drivers. The lugs holding these positioning screws shall be attached to the baseplate so that the lugs do not interfere with the installation or removal of the component. Alignment positioning screws shall be at least the same size as the jackscrews furnished with each component.
- g) Supports and the design of jack screws and their attachments shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews.

4.5 Coolers

4.5.1 General

4.5.1.1 For liquid-cooled exchangers, twin coolers shall be provided and shall be piped in a parallel arrangement using a continuous-flow transfer valve (see 4.7).

4.5.1.2 Unless otherwise specified, coolers shall be shell-and-tube type and shall be in accordance with the requirements of 4.5.1.4.

- **4.5.1.3** If specified, multi-plate frame or air coolers in accordance with 4.5.3 or 4.5.4, respectively, shall be supplied. The vendor shall include in the proposal complete details of any proposed air-cooled or plate-frame cooler.
- **4.5.1.4** If specified, the vendor shall supply connections for installation of the purchaser's air-cooled oil cooler(s) off the oil console.

When the purchaser supplies the off-console cooler(s), the interconnecting piping pressure drop, elevation and runback volume shall be detailed to the console supplier in order to properly size pumps and reservoir.

- a) The vendor shall supply all relevant data such as heat load and oil flow.
- b) Pressure-drop criteria for the oil side shall be mutually agreed between the vendor and purchaser.

4.5.1.5 Unless otherwise specified for duplex cooler arrangements, the equalization/fill valve shall be locked or car sealed in the open position with the equalization/fill line orifice thermally sized by the vendor to provide thermal overprotection.

- **4.5.1.6** If specified, in lieu of the requirements of 4.5.1.5, for duplex cooler arrangements, the vendor shall provide thermal over-pressure protection of the oil side of the coolers by providing separate thermal relief valves on each cooler.

4.5.1.7 A cooling water system or systems shall be designed for the following conditions:

— Velocity over heat-exchange surfaces	1,5 m/s to 2,5 m/s	(5 ft/s to 8 ft/s)
— Maximum allowable working pressure, MAWP, (gauge)	≥ 690 kPa	(≥ 100 psig)
— Test pressure (gauge) ≥ 1,5 × MAWP	≥ 1,03 MPa	(≥ 150 psig)
— Maximum pressure drop	103 kPa	(15 psi)
— Maximum inlet temperature	30 °C	(90 °F)
— Maximum outlet temperature	50 °C	(120 °F)
— Maximum temperature rise	20 K	(30 °R)
— Minimum temperature rise	10 K	(20 °R)
— Fouling factor on water side	0,35 m ² K/kW	(0,002 h·ft ² °F/Btu)
— Carbon steel corrosion allowance	1,5 mm	(0,063 in)

4.5.1.8 Provision shall be made for complete venting and draining of the system or systems.

4.5.1.9 The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat-exchange surfaces result in a conflict. The criterion for velocity over heat-exchange surfaces is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. The purchaser shall approve the final selection.

4.5.1.10 Each oil cooler shall maintain the lube-oil supply temperature at or below 50 °C (120 °F).

NOTE Under certain ambient site conditions or with certain viscosities of oil, it can be necessary to operate with an oil-supply temperature greater than 50 °C (120 °F).

4.5.1.11 Each cooler shall be sized to accommodate the total cooling load.

4.5.1.12 Oil coolers shall not be located inside the reservoir.

4.5.1.13 Unless otherwise specified, an oil bypass line around the cooler with a temperature-control valve shall be included to regulate the oil-supply temperature. This includes oil systems where the purchaser supplies the cooler. In no case, however, shall oil bypass the filter. The control valve shall be in accordance with the following provisions a) to d).

NOTE When fouling or freezing of the water side of a cooler is a factor and oil temperature is regulated by adjusting water flow through the cooler, it is possible for the cooler water side to silt up or freeze and break at low water flow rates.

- a) Unless otherwise specified, the oil bypass valve shall be a flanged and pneumatically operated (air-to-open fail-close), two-port or three-port temperature-control valve. Failure of the control valve shall cause all the oil to pass through the cooler.

NOTE Three-port valves can direct the oil more advantageously due to system pressure drops and allow all of the oil to bypass the cooler; however, they can complicate bypass arrangements required for maintenance relative to those of a two-port valve.

- b) If specified, the temperature-control valve shall be an internal, thermostat-operated three-port valve.
- c) The temperature-control valve shall be provided with a manual override that permits operation independent of temperature conditions.
- d) The temperature-control valve and piping shall be sized to handle all oil flow passing through the cooler. For a three-way temperature control valve, the pressure drop should not exceed that through the cooler. For a two-way temperature control valve, pressure drop should not exceed 50 % of the pressure drop through the cooler.

4.5.1.14 The maximum allowable working pressure for coolers shall not be less than the maximum operating pressure of the system, less than the pressure limiting valve setting for the positive displacement pumps or less than the maximum discharge pressure (at the trip speed for the turbine drive) for the centrifugal pumps.

- **4.5.1.15** If specified, shell-and-tube or plate-frame coolers shall be suitable for use of a 150 °C (300 °F) heating medium.

Steam may be used for auxiliary heating on start-up by sparging it into the cooling water. Steam should not be introduced directly into the cooler.

4.5.1.16 Both the water side and the oil side of the cooler shall be provided with valved vent/drain connections.

- **4.5.1.17** If specified, the coolers shall be fabricated with flanged vent and drain nozzles. Screwed and seal-welded or socket-welded pipe and flange additions to coolers after cooler certification are not acceptable.
- **4.5.1.18** If specified, cooler oil drains shall be manifolded together with filter clean-side oil drains.
- **4.5.1.19** If specified, vents on the oil side shall be piped back to the reservoir through flow indicators.

NOTE These vent lines are normally tubed.

4.5.2 Shell-and-tube coolers

4.5.2.1 In addition to the requirements of the general cooler section, shell-and-tube coolers shall be in accordance with 4.5.2.2 through 4.5.2.7.

4.5.2.2 Shell-and-tube coolers shall have water on the tube side. Unless otherwise specified, a removable-bundle design is required for coolers with more than 0,5 m² (5 ft²) of heat-transfer area. Removable-bundle coolers shall be in accordance with TEMA class C or other code specified for heat-exchangers and shall be constructed with a removable channel cover. Nominal tube outside diameter shall be at least 16 mm (5/8 in) and nominal tube wall thickness shall be at least 18 BWG [1,245 mm (0,049 in)]. U-bend tubes may be supplied with purchaser's approval (see 4.5.2.6).

4.5.2.3 With purchaser's approval, alternative designs to 4.5.2.2 may be offered for high-pressure oil coolers [pressures greater than 3 MPa (30 bar; 500 psig)].

4.5.2.4 To prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure.

4.5.2.5 Cooler tubes shall be bare or of integrally finned (lofin) design.

- **4.5.2.6** U-bend tubes are permitted when approved by the purchaser.

4.5.2.7 Unless otherwise specified, cooler shells, channels and covers shall be of steel; tube sheets shall be of brass; and tubes shall be of a copper/zinc/tin non-ferrous material, such as UNS C44300 (ASTM B111) (inhibited admiralty).

Alternative materials should be considered for salt and brackish water services. Tube materials such as 90-10 copper-nickel may be an appropriate choice for such services.

NOTE High-pressure oil coolers can require steel tubes and tubesheets.

4.5.3 Multi-plate type coolers

4.5.3.1 If specified, and in addition to the requirements of the general cooler section, multi-plate type coolers shall be in accordance with 4.5.3.2 and 4.5.3.3.

4.5.3.2 Multi-plate coolers shall have plates of austenitic stainless steel for fresh-water cooling or titanium for brackish or salt water, or as specified by the purchaser.

4.5.3.3 To prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure.

4.5.4 Air cooled heat exchangers

4.5.4.1 General

Air coolers are infrequently required on these systems and, when provided, are commonly specified using purchaser's specifications. Guidance when a detailed specification is not available is given in 4.5.4.2 to 4.5.4.4.

4.5.4.2 Unless otherwise specified, air-cooled heat exchangers shall be provided in a single bank of tubes with 10 % extra tubes to allow for plugging tubes in the event of tube leaks.

- **4.5.4.3** The purchaser may specify sizing and configuration or connections only for purchaser's separate supply of air-cooled heat exchangers.

4.5.4.4 If specified, and in addition to the requirements of the general cooler section, air coolers shall be in accordance with the following provisions a) to g).

- a) The cooler shall be provided with two fans. Each fan shall be capable of 100 % of the duty requirement.
- b) If specified, the cooler tubes shall be austenitic stainless steel.
- c) If specified, the header boxes shall be made of hardened stainless steel plate. The header plug material shall be selected to prevent galling.
- d) Two separate headers shall be provided for each cooler.
- e) Electronic vibration switches shall be provided for each fan and shall alarm on high vibration.
- f) Refer to ISO 13706:2005, 7.2.8.2, for belt drive requirements.

NOTE For the purposes of this provision, API STD 661 is equivalent to ISO 13706.

- g) Turbulence promoters may only be used with purchaser approval. When supplied, turbulence promoters shall be austenitic stainless steel.

4.6 Filters

4.6.1 Duplex full-flow filters with replaceable elements or cartridges shall be provided. Filters shall provide a minimum particle removal efficiency, E_{PR} , of 90 % for 10 μm particles ($\beta_{10} \geq 10$) and a minimum E_{PR} of 99,5 % for 15 μm particles ($\beta_{15} \geq 200$), both in accordance with ISO 4572 when tested to a minimum terminal (end-of-test-run) differential pressure of 350 kPa (3,5 bar; 50 psi). Filter installations shall be in accordance with the following provisions a) to g).

NOTE 1 See ISO 10438-1:2007, Annex D, for additional information concerning filter ratings.

NOTE 2 This applies to all filters in the system, including booster-pump-discharge and control-oil filters if provided.

a) The filters shall be located downstream of the coolers.

NOTE Coolers can trap and release dirt and debris.

b) The filters shall be piped in a parallel arrangement using a continuous-flow transfer valve (see 4.7).

c) Filter cases and heads shall be suitable for operation at the maximum discharge pressure (at the trip speed for turbine drives) of centrifugal pumps or at a pressure not less than the pressure-limiting device setting of positive displacement pumps.

d) Filters that have covers weighing more than 15 kg (35 lb) shall have cover lifters.

e) The filters shall not be equipped with differential pressure-limiting valves or other valves that can cause bypass of unfiltered (dirty) oil around the filter elements.

f) The filters shall be equipped with valved vents and clean- and dirty-side valved drain connections. The dirty-side connections shall be located lower in the housing than the filter elements or cartridge support bases to allow complete drainage of the dirty side.

g) Unless otherwise specified, the equalization/fill valve shall be locked or car sealed in the open position with the equalization/fill line orifice thermally sized by the vendor.

NOTE This provides thermal over-protection of the standby filter in addition to the primary function of pressure equalization for filling and switching filters.

- **4.6.2** If specified for duplex filter arrangements where the filters are not in accordance with 4.6.1 g), the vendor shall provide thermal over-pressure protection of the offline filter.

- **4.6.3** If specified, duplex oil filter clean-side oil drains shall be manifolded together with duplex cooler drains.

- **4.6.4** If specified, the filter vents shall be routed back to the oil reservoir through flow indicators.

NOTE These filter vent lines are normally run with tubing.

4.6.5 Oil filter design shall be in accordance with the following provisions a) to h).

a) Oil shall flow from the outside inward toward the centre of the filter element.

b) Oil flow from the centre towards the outside of the filter element may be provided with purchaser's approval.

c) Adequate support of the filter elements shall be provided to prevent them from rupturing or to prevent unfiltered (dirty) oil from bypassing the elements and reaching the equipment.

d) Centre posts and other hardware in contact with filtered oil but not integral with the filter housing shall be made of austenitic stainless steel.

- e) The maximum number of filter cartridges permitted in one stack is two.
- f) If the cartridge-to-cartridge joint is not self-aligning, a collar shall be used between the stacked cartridges to ensure alignment.
- g) Filter stacks shall not exceed 1 m (3 ft).
- h) Stacked cartridges shall have adequate support and maintainable alignment.

4.6.6 Filter cartridge materials shall be water- and corrosion-resistant and in accordance with the following provisions a) to d).

- a) Water-resistant filter cartridges shall not deteriorate if water contamination in the oil reaches 5 % by volume and the operating temperature reaches as high as 70 °C (160 °F).
- b) If specified, filter-element media shall be non-hydroscopic. If water contamination in the oil reaches 5 % for extended periods of time (up to 3 months), clean filter cartridges shall not have a clean-filter pressure drop greater than 60 kPa (0,60 bar; 10 psi) at rated oil viscosity, flow and temperature.

NOTE This is a design requirement for filter elements and not for system operation.

- c) When a specific filter element or cartridge is required, the purchaser shall completely specify the make, the model number and the type of construction.
- d) Metal mesh or stainless metal filter elements are not acceptable.

4.6.7 The pressure drop for clean filter elements or cartridges shall not exceed 30 kPa (0,30 bar; 5 psi) at an operating temperature of 40 °C (100 °F) and normal flow.

Pressure drop across the total filter system may exceed these values by the amount of pressure drop across the transfer valve and other filter system components.

NOTE The 30 kPa (0,30 bar; 5 psi) is the difference between the drop across the filter housing with no elements installed and the drop across the filter housing with clean elements installed.

4.6.8 Elements or cartridges shall have a minimum collapsing differential pressure of 500 kPa (5,0 bar; 70 psi).

4.6.9 When the tops of filter housing covers are more than 1,2 m (4 ft) above the console base, the vendor shall provide a step to facilitate their maintenance.

4.6.10 Systems with booster pumps shall be provided with twin filters downstream of the pumps.

NOTE This is to protect the equipment from damage from particles resulting from pump wear.

- **4.6.11** When required, or if specified, more stringent requirements for control-oil filtration shall be provided.

Filtration requirements of serviced equipment, such as hydraulic servo-valves, should be utilized in determining filtration requirements.

4.7 Transfer valves

4.7.1 Unless otherwise specified, the vendor shall supply individual transfer valves independently serving each cooler set and each filter set (see Figure B.20).

4.7.2 Transfer valves shall be two-way, six-ported, continuous-flow valves. A single-body, six-port taper or a straight plug valve, with or without resilient seats, may be used or two three-way plug or ball valves permanently aligned and joined with a single operating lever may be used.

- a) Tapered plug-type valves shall have provisions for plug lifting.

- b) Valves shall be designed so that, if the internal valve mechanisms fail, both flow paths shall not be blocked.
- c) Valves and assemblies shall be designed to prevent incorrect assembly.
- d) Transfer valves with resilient seats shall be capable of transfer without sliding contact. Resilient seats shall be positively retained.

4.7.3 Transfer valves shall have steel bodies. Valve stems and valve plugs or balls shall be made of austenitic stainless steel.

- **4.7.4** Spectacle blinds shall be provided if specified to assure tight shutoff.

NOTE 1 Transfer valves are not intended for use as tight shutoff devices for the maintenance of filters and coolers [see 7.3.3.8 h)].

NOTE 2 Transfer valves with resilient seats provide tighter shutoff.

4.8 Accumulators

4.8.1 An accumulator shall be provided if it is needed to maintain the turbine control-oil pressure during servo control transients or to maintain lube- or seal-oil pressure while the standby pump accelerates from an idle condition to operating speed. The control pressure shall be maintained above the equipment manufacturer's minimum specified supply pressure for all operating conditions (including transients). Typically, this is within 10 % of the normal system pressure when a servomotor makes a full stroke in 1 s.

4.8.2 The system delivery pressure shall be maintained above the shutdown settings during standby pump acceleration or for at least 4 s for motor-driven pumps [see 7.3.3.8 e)].

4.8.3 Unless otherwise specified, accumulator vessels shall be made of austenitic stainless steel.

- **4.8.4** For direct-contact-type accumulators, a manual precharge valve or a constant-pressure regulating system shall be furnished as specified by the purchaser (see Figure B.19).

4.8.5 If a direct-contact-type accumulator is used, it shall be equipped with an armoured reflex-type gauge glass that extends from 25 mm (1 in) above the maximum operating level to not less than 25 mm (1 in) below the minimum operating level. The glass shall show the oil level when the vessel is precharged at the controlled normal operating pressure.

NOTE Purchaser might want to give consideration to a non-glass level indicating device.

4.8.6 A connection for a pressure gauge shall be provided for checking the precharge pressure in the accumulator.

4.8.7 The physical location and piping arrangement of the accumulator shall avoid pockets in which foreign materials or air could accumulate.

- **4.8.8** If specified, the accumulator shall be equipped to maintain the contained oil at the required system oil temperature. The purchaser shall provide the details of the required temperature-control system.

4.8.9 Unless otherwise specified, direct-contact-type accumulators provided with a constant-pressure regulating system for pump switchover or other purposes shall automatically vent and automatically reset.

- **4.8.10** If specified, bladder-type accumulators provided with a constant-pressure regulating system for pump switchover or other purposes shall automatically vent and automatically reset. Accumulators shall be provided with a gas-side anti-extrusion feature and adequately sized for the charge-gas regulator and piping.

4.8.11 Accumulator designs shall not allow precharge gas to be delivered with the oil to the equipment or to impair the flow of the oil to the equipment. Bladder-type accumulators shall be furnished with an oil-side anti-extrusion feature (see Figure B.18).

4.8.12 Accumulators shall be isolated (for example, by a check valve; see Figure B.12) from the standby oil pump start controls to eliminate delay in the actuation of the starting signal.

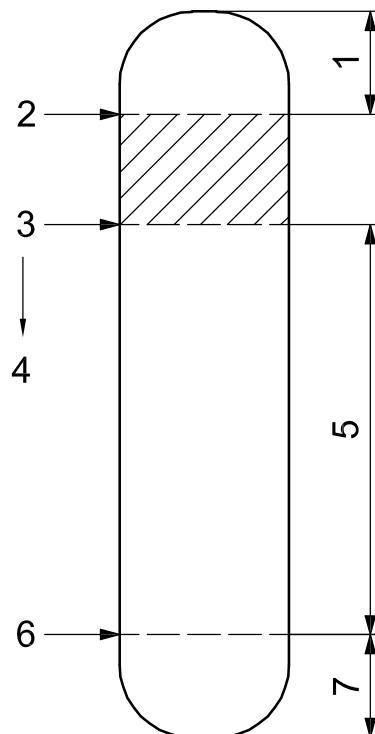
4.9 Overhead tanks

4.9.1 Seal-oil tanks

4.9.1.1 Separately mounted or equipment-mounted overhead tanks shall be provided when they are required by the designs of the seals and the seal-oil control systems. Unless otherwise specified, the tanks shall be made of austenitic stainless steel.

- **4.9.1.2** Each overhead seal-oil tank (see Figure 1) shall be sized so that the oil capacity above the low-level alarm setting is equal to a 2 min flow at normal seal-oil rates, and each tank shall have the capacity for a 10 min flow from low-level alarm to low-low-level shut-down plus sufficient time (as specified by the purchaser but not less than 3 min at normal flow rates after shut-down) for coast-down, block-in and depressurization of the equipment. Larger tanks can be required for special operating conditions, such as rapid depressurization of high-pressure equipment. The vapour column above the high-level alarm setting shall be no less than 1 min of normal flow.

The purchaser and the manufacturer together shall determine the required capacity after trip, based on the compressor block-in and blowdown and the seal-oil flow rate for various conditions.



Key

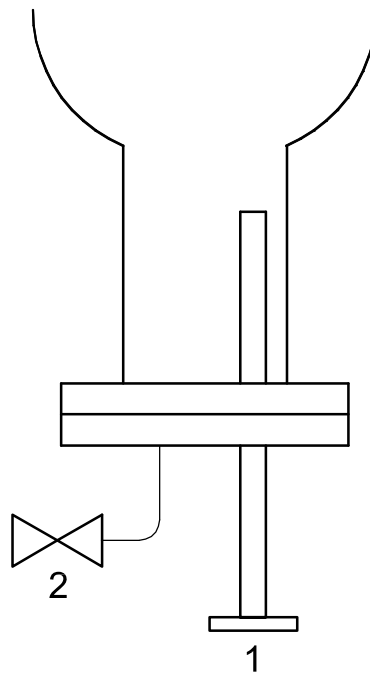
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| 1 vapour volume (equivalent to a 1 min supply) | 5 emergency operating range (10 min supply) |
| 2 high-level alarm | 6 low-level shutdown |
| 3 low-level alarm | 7 coast-down and block-in (minimum 3 min supply) |
| 4 auxiliary pump start | |

Figure 1 — Overhead seal-oil tank

- **4.9.1.3** Overhead seal-oil tanks shall be designed in accordance with the specified pressure design code and, if specified, shall be code stamped.

4.9.1.4 Overhead seal-oil tanks shall be provided with the following items a) to g):

- a) one bottom outlet nozzle, at least DN 150 (NPS 6) in size, which shall not extend inside the vessel; this nozzle shall be used for internal access and inspection;
- b) one reference gas connection at least DN 25 (NPS 1) in size;
- c) reference line that shall be routed to prevent traps that can accumulate liquid;
- d) full-length reflex-type level glass that extends from 25 mm (1 in) above the high-level alarm to 25 mm (1 in) below the low-level shutdown;
- e) one DN 150 × DN 50 (NPS 6 × NPS 2) flanged reducing spacer that is 450 mm (18 in) long and is fitted to the bottom outlet connection;
- f) if specified, e.g. for dirty, sludge-building gas service, the reducing spacer shall project into the bottom nozzle and a valved blowdown connection shall be provided (see Figure 2); the nozzle shall be at least 200 mm (8 in) long;
- g) level transmitter externally mounted to the tank and provided with isolation valves, a vent connection and a valved drain.



Key

- 1 blowdown connection
- 2 drain valve

Figure 2 — Blowdown connection

The presence of free water, dirt, and dissolved gases in lubrication, control, and seal oil can contribute to accelerated wear, corrosion, sludge formation and sticking of hydraulic controls. Dilution or contamination of compressor seal oil by hydrocarbons, hydrogen sulphide, and other contaminants also causes a reduction in

viscosity and flashpoint. Oil-condition maintenance procedures and equipment should be considered during project planning.

4.9.1.5 If specified, the reference gas shall be isolated from the seal oil by a bladder of material suitable for the service (see Figure B.17).

4.9.2 Lube-oil rundown tanks

- **4.9.2.1** If specified, a separately mounted emergency lube-oil rundown tank (either atmospheric or pressurized) shall provide oil for the coast-down period specified by the purchaser. This tank shall be sized for not less than 3 min of normal operating lube-oil flow (see Figures B.15 and B.16). Unless otherwise specified, the tank shall be made of austenitic stainless steel.

Coast-down time shall be provided by the purchaser (normally the supplier of the equipment served by the oil system).

NOTE The minimum sizing criteria results in more than 3 min of coast-down oil flow due to supply pressure decay.

4.9.2.2 A rundown tank shall be provided with a sight flow glass in the tank overflow line. The sight flow glass shall be located in an area that can be readily observed, such as the oil reservoir or equipment operating deck. A DN 150 (NPS 6) nozzle for accessing and inspecting the interior of the rundown tank shall be provided. Alternatively, for atmospheric rundown tanks, a bolted cover can be provided in lieu of the DN 150 (NPS 6) nozzle for access and inspection. The vendor shall specify the allowable minimum and maximum height of the bottom outlet nozzle above the machine centreline; the maximum static head shall be less than the lube-oil trip pressure but not less than 30 kPa (0,3 bar; 5 psig) at the beginning of coast-down.

4.9.2.3 When an atmospheric rundown tank is provided in accordance with Figure B.15, it shall be provided with low-level alarm and high-level permissive start functions. These functions may be served by a common device.

4.9.2.4 A pressurized tank (see Figure B.16) shall be designed in accordance with the specified pressure design code and, if specified, shall be code stamped.

NOTE Code stamping might not be applicable for pressure design codes other than ASME.

4.10 Seal-oil drain traps

4.10.1 One drain trap per seal shall be provided. An emergency line and isolating valves and valve to cross-connect trap inlets and permit trap maintenance shall be provided where seals operate at the same oil-sealing pressure (see Figure B.14).

- a) If specified, spectacle blinds shall be provided to isolate individual seal-oil drain traps during maintenance.
- b) Drainer bypass orifices shall be a minimum of 1 1/2 mm (1/16 in).
- c) Automatic seal traps are required. For gas pressures less than or equal to 5 MPa (50 bar; 725 psig), mechanical float-type traps are permitted. The float and trim shall be the single-lever, stainless steel design and arranged so that the gas flow does not impinge upon the float or float mechanisms.

Level transmitter control-type traps should be used when gas fouling can interfere with the operation of mechanical float-type traps.

- d) For pressures greater than 5 MPa (50 bar; 725 psig), snap-acting level transmitter/controllers and separate control valves shall be used.
- e) Drain traps shall be pre-piped and mounted in a package arrangement. All appurtenances shall be located within the confines of the package base. Manually operated drain valves shall be provided on each trap.

4.10.2 Traps shall be furnished with reflex-type gauge glasses. The inlet piping shall enter the seal traps above the oil level of the traps.

Special consideration should be given to the level device at higher-pressure applications.

4.10.3 Unless otherwise specified, seal-trap vents shall be equipped with mist eliminators (with appropriate connections) to agglomerate the residual oil before the vent gas is recycled to the compressor suction or vented to other disposal outlets. Mist eliminators shall be self-draining or provided with separate automatic drain traps.

- **4.10.4** The seal-gas vent piping arrangement shall be jointly developed by the purchaser and the vendor. Consideration should be given to avoid pocketing of liquids, system backpressure, motive flow available and other issues.

NOTE The arrangement of seal-gas vent piping is important to the proper function of the compressor shaft seals.

- **4.10.5** The drain line for each trap shall be piped to a proper disposal system, to the degassing drum or to the reservoir, as specified.
- **4.10.6** If specified, drain lines for each trap shall be piped separately.

NOTE Separate piping of the drain lines allows the leakage from each seal to be monitored.

4.10.7 A level-transmitter-controller-type drain trap shall be designed in accordance with the specified pressure-vessel design code and, if specified by the purchaser, shall be code stamped.

NOTE Code stamping might not be applicable for pressure design codes other than ASME.

4.11 Degassing drum

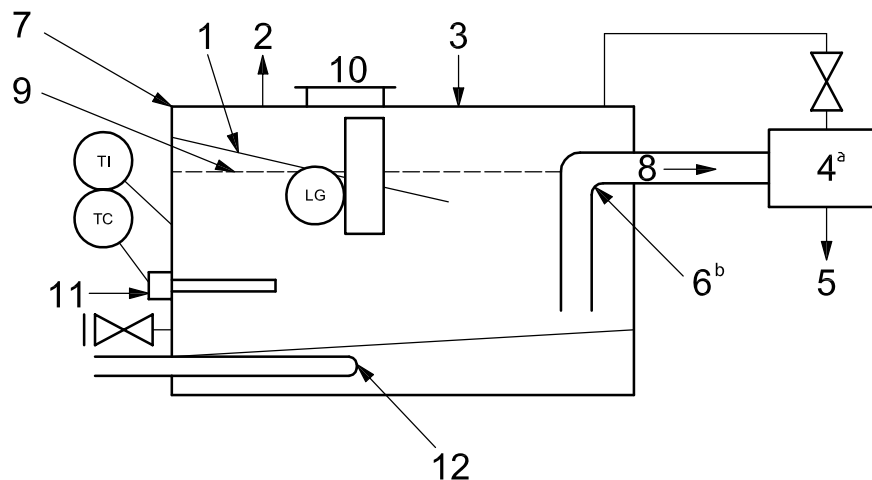
- **4.11.1** If specified, seal-oil degassing facilities shall be provided. Unless otherwise specified, the tank and internals shall be made of austenitic stainless steel.

4.11.2 The degassing drum shall be a single-chamber tank (see Figure 3) provided with the following features a) to g):

- a) sloped inlet tray, extending below the operating level, which ensures that the oil enters the tank in a thin layer;

NOTE Having the oil enter in a thin layer facilitates degassing.

- b) oversized gas-vent connection to handle the flow of gas from the seals through the oil drains; the size of the connection shall be at least DN 50 (NPS 2) and flanged; the purchaser shall pipe the vented gas to a safe location;
- c) purge connection with a minimum size of DN 25 (NPS 1);
- d) cleanout opening and a valved, low-point drain;
- e) weld-pad reflex level glass extending a minimum of 50 mm (2 in) above and 50 mm (2 in) below the operating level;
- f) temperature indicator with a thermowell;
- g) level device with high alarm.



Key

1 degassing tray	7 oil from traps
2 gas vent	8 outlet
3 inert gas purge	9 oil level
4 trap	10 manway
5 to reservoir	11 electric heater (optional)
6 3 mm (1/8 in) hole (vacuum break)	12 steam heater (optional)

^a Refer to 4.11 for design details.

^b Provide a 3 mm (1/8 in) hole inside the degassing tank. The trap prevents the gas from entering the reservoir via the hole.

Figure 3 — Typical degassing drum arrangement

- **4.11.3** If specified, an electric immersion heater, steam heater or some other method of heating shall be provided to assist in degassing the oil. If a steam heater is used, it shall be external to the drum and shall be removable. If an electric immersion heater is used, its heat flow (power) density shall not exceed 2 W/cm² (15 W/in²). Electric heater elements shall be sheathed in austenitic stainless steel; copper or copper-bearing materials shall not contact the oil. The vendor shall provide temperature element and controls for the heater as mutually agreed upon with the purchaser.

Electric immersion heaters should be interlocked by the purchaser to be de-energized when the oil level drops below the heater.

4.11.4 A level device shall be provided where electric immersion heaters are used.

4.11.5 The drum shall have a 4 h minimum retention time, based on the guaranteed total inner-seal-oil leakage rate or a minimum liquid volumetric capacity of 60 l (15 gal) per compressor body.

- **4.11.6** If specified, the degassing drum shall be designed and constructed for pressurized service in accordance with the specified code and, if specified by the purchaser, shall be code stamped. The degassing drum shall permit discharge of the gas to the compressor suction or to a disposal outlet.

5 Piping

5.1 General

All piping shall be in accordance with ISO 10438-1:2007, Clause 5, unless otherwise specified in 5.2 to 5.5 of this part of ISO 10438.

5.2 Oil piping

Piping shall be in accordance with ISO 10438-1:2007, Tables 4, 5 and 6.

5.3 Instrument piping

Piping shall be in accordance with ISO 10438-1:2007, Tables 4, 5 and 6.

5.4 Process piping

Piping shall be in accordance with ISO 10438-1:2007, Tables 1, 5 and 6.

5.5 Water piping

Piping shall be in accordance with ISO 10438-1:2007, Tables 3, 5 and 6.

6 Instrumentation, control and electrical systems

6.1 General

6.1.1 As a minimum, the vendor shall furnish and mount devices to facilitate the alarm and shutdown functions specified in Table 1. The alarm setting shall precede the shutdown setting.

6.1.2 Instrumentation shall be in accordance with ISO 10438-1:2007, Clause 6, except as modified in 6.2 to 6.4.

Table 1 — Conditions requiring alarms and shutdowns

Condition	Alarm	Shutdown
Low control oil pressure ^a	x	—
Low pressure to start standby oil pump	x	—
Low pressure at lubricated equipment	x	x
Pump running for each stand-by and emergency pump ^b	x	—
High oil temperature leaving cooler	x	—
Low level for oil reservoir	x	—
Low level for each seal-oil overhead tank or low seal-oil differential pressure for each seal-oil level ^a	x	x
High level for overhead seal tank ^a	x	—
High level for atmospheric lube-oil rundown tank (permissive) ^a	x	—
High differential pressure for each oil-filter set	x	—
^a If applicable.		
^b Not required if the purchaser's alarms are from the motor-control centre.		

6.2 Arrangement 1

- If specified, both shutdown and alarm switches shall be connected through normally energized, fail-safe circuits. The shutdown circuit's wiring shall be completely independent from the alarm circuit wiring and shall be mechanically protected.

6.3 Arrangement 2

6.3.1 Shutdown functions shall be initiated by local direct-acting switches connected in normally de-energized circuits.

6.3.2 Alarm functions shall be comprised of locally mounted transmitters (electronic or pneumatic, as specified) connected to separate panel-mounted switches, a multipointed scanning-type instrument, a PLC or plant DCS.

6.3.3 Where multipoint, scanning-type instruments are used, the alarm setting for each function shall be separately and independently adjustable.

6.4 Arrangement 3

6.4.1 Each function for which both an alarm and a shutdown have been specified shall be provided with three separate and independent transmitters (electronic unless specified otherwise).

6.4.2 Each transmitter shall be independently connected to one of three multipoint, electronic, scanning-type instruments for each transmitter's input.

6.4.3 Each multipoint instrument shall provide both alarm and shutdown settings, separately and independently adjustable, for each transmitted input.

6.4.4 The shutdown and alarm function outputs from the three multipoint instruments shall be connected through "two-out-of-three" voting logic. The arrangement shall allow operation of any one alarm or shut-down function that initiates an alarm; operation of two shutdown functions monitoring the same parameter shall initiate a separate alarm and shall cause the served equipment to shut down.

6.4.5 Alarm functions not associated with a shutdown function shall be provided with one single transmitter. These alarm transmitters may be connected to one of the three alarm/shutdown multipoint instruments or to a separate multipoint instrument. The detailed arrangement should be jointly developed between the purchaser and the vendor or vendors of the oil system and the served equipment.

NOTE Arrangement 3 has the following advantages:

- a) any shutdown or alarm function can be tested at any time with the equipment in service without the need to disarm any part of the system;
- b) failure of any one component initiates an alarm but does not result in equipment shutdown;
- c) use of modern, digital-instrument technology is facilitated.

If the circuit is normally energized, this shall be a fail-safe arrangement to avoid spurious trips (e.g., 2-out-of-3 voting, DC power supply, UPS).

6.5 Instrumentation

Instrumentation shall be in accordance with ISO 10438-1:2007, 6.3.

6.6 Electrical systems

Electrical systems shall be in accordance with ISO 10438-1:2007, 6.4.

7 Inspection, testing and preparation for shipment

7.1 General

Inspection, testing and preparation for shipment shall be in accordance with ISO 10438-1:2007, Clause 7, unless otherwise specified in this clause.

7.2 Inspection

The oil system furnished shall meet the inspection requirements of ISO 10438-1:2007, 7.2.

7.3 Testing

7.3.1 General

7.3.1.1 Equipment shall be tested in accordance with 7.3.2 and 7.3.3. Other tests may be specified and shall be jointly developed by the purchaser and the vendor.

- **7.3.1.2** The purchaser shall specify whether the purchased oil system shall be used during the shop testing of the equipment.
- **7.3.1.3** Complete-unit tests or other tests of the oil system and the equipment it serves shall be performed in place of or in addition to separate tests of the oil system as specified by the purchaser. Details of these tests shall be developed jointly by the purchaser and the vendor.

7.3.2 Hydrostatic test

The hydrostatic test shall be performed in accordance with ISO 10438-1:2007, 7.3.2.

7.3.3 Operational tests

7.3.3.1 The complete oil system shall be run in the vendor's shop to test its operation and cleanliness. The oil used shall be as mutually agreed upon and shall be compatible with the system oil (see 4.1.7).

7.3.3.2 System cleanliness shall be demonstrated by the vendor after the operational and sound-level tests.

7.3.3.3 The running tests shall be conducted under normal system operating conditions for at least 4 h. The operational tests may be done concurrently within the 4 h.

7.3.3.4 If console-mounted, the low-oil-pressure alarm, the standby-pump start and the shutdown devices purchased for the project shall be used for the operational tests. Otherwise, the vendor shall provide shop devices for the tests.

NOTE Some of these devices are normally mounted near the equipment rather than on the console.

7.3.3.5 All oil pressures, viscosities and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested.

7.3.3.6 All filter elements shall be installed prior to all operational tests.

7.3.3.7 Steam turbine pump drivers shall be mechanically tested. If the turbine has been previously tested, a test motor may be considered to replace the turbine during the console operational tests.

7.3.3.8 The operational testing of the oil system shall be conducted in the sequence given in a) through h) below.

- a) The oil system shall be thoroughly checked for leaks; all leaks shall be corrected prior to testing.

- b) The limiting pressures shall be determined so that the subsequent proper operation of each pressure limiting valve may be verified.
- c) A filter-cooler changeover shall be accomplished without the system delivery pressure dropping to the automatic-start setting of the standby pump.
- d) If applicable, it shall be demonstrated that the control valve or valves can handle a simulated governor-transient step change on the main equipment drive turbine without the pressure-limiting valves lifting and without the delivery pressure dropping to the automatic-start setting of the standby pump.
- e) It shall be demonstrated that, after a failure or trip of the main oil pump, the standby pump starts automatically and returns the system to normal operating pressure without the delivery pressure dropping as follows:
 - 1) in a single-level oil-pressure system, below the midpoint between the standby pump's automatic-start setting and the equipment's shutdown pressure;
 - 2) in a multilevel oil pressure system, below the midpoint between the equipment's normal operating and shutdown pressures.

Verification of this criteria requires test instrumentation, such as a switch or other device, with a response time adequate to record the transient pressures during pump switchover. (The response time of switches is typically under 25 ms.)

- f) It shall be demonstrated that the control valve(s) is/are capable of controlling the oil pressure when only one pump (either the main or the standby pump) is operating at minimum oil requirements and when both pumps are operating at minimum oil requirements, defined as the sum of the normal bearing and seal-oil requirements and the steady-state control-oil requirements. The test shall be considered satisfactory when no abnormal conditions occur during the operational test (see 4.4.18).

NOTE Some typical abnormal conditions encountered are system instability, an excessive drop in delivery pressure, alarm or shutdown signals or other conditions that require operator attention.

- g) All warning, protective and control devices shall be checked and adjustments shall be made as required.
- h) While the system is at maximum operating pressure, the internal side-to-side leakage around the plugs of continuous-flow transfer valves shall be demonstrated to be less than the drainage capability of the inactive filter housings. Leakage shall not exceed the expected or specified rates.

7.3.3.9 Conformity to the criteria for system cleanliness listed below in a) and b) shall be demonstrated.

- a) After 1 h of oil circulation at the design flow rate and a temperature of 66 °C to 71 °C (150 °F to 160 °F) or lower, as component design dictates, screens placed at all discharge terminations from the console or the packages and at other strategic points mutually agreed on by the purchaser and the vendor shall be within the particle-count limits listed in ISO 10438-1:2007, Table D.6. The screen mesh shall be No. 100 plain-weave, stainless steel wire with a diameter of 0,1 mm (0,004 in) and a 0,15 mm (0,006 in) opening. The greatest dimension of the particles shall not exceed 0,25 mm (0,010 in), and the particles shall be randomly distributed on the screen. Piping, coolers and valves shall be hammered frequently during the test.

NOTE Typically, screens are mounted such that the flow entering the screen is in a vertical downward direction to prevent debris from escaping the screen.

- b) To further verify cleanliness, the system shall be visually inspected at two to six points selected by the inspector. The system shall be considered clean when foreign matter, such as scale, rust, metal shavings and sand, are not visible to the eye and grittiness is not detectable to the touch. This verification shall not require a re-hydrotest nor necessitate the installation of screens.

7.3.3.10 If dismantling of the oil system is required to make modifications to improve operation, the initial running test shall not be conclusive and final tests shall be run only after corrections are made. In any event, the demonstration of cleanliness shall be conducted only after the final assembly.

- **7.3.3.11** If specified, the vendor, by unbolting and re-bolting pump inlet and discharge piping, shall demonstrate that the pump on its baseplate is in compliance with API RP 686 alignment requirements.

7.4 Preparation for shipment

The oil system shall be prepared for shipment in accordance with ISO 10438-1:2007, 7.4.

8 Vendor's data

8.1 General

A coordination meeting shall be held, preferably at the vendor's plant, within 4 weeks to 6 weeks after order commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting, which, as a minimum, shall include review of the following items a) to j):

- a) purchase order, scope of supply, unit responsibility, sub-vendor items and lines of communication;
- b) data sheets;
- c) applicable specifications and previously agreed upon exceptions;
- d) schedules for transmittal of data, production and testing;
- e) quality assurance program and procedures;
- f) inspection, expediting and testing;

NOTE Annex C contains an inspector's checklist to assist in defining inspection requirements.

- g) schemas and bills of material;
- h) physical orientation of the components and piping, including access for operation and maintenance;
- i) plot plan and equipment layout;
- j) other technical items.

NOTE For special-purpose oil systems, the coordination meeting is typically held in conjunction with the coordination meeting for the main equipment. This is typically held at the plant of the vendor having prime responsibility for the equipment.

8.2 Proposals

Proposals shall be prepared in accordance with ISO 10438-1:2007, 8.2.

Annex A **(informative)**

Datasheets

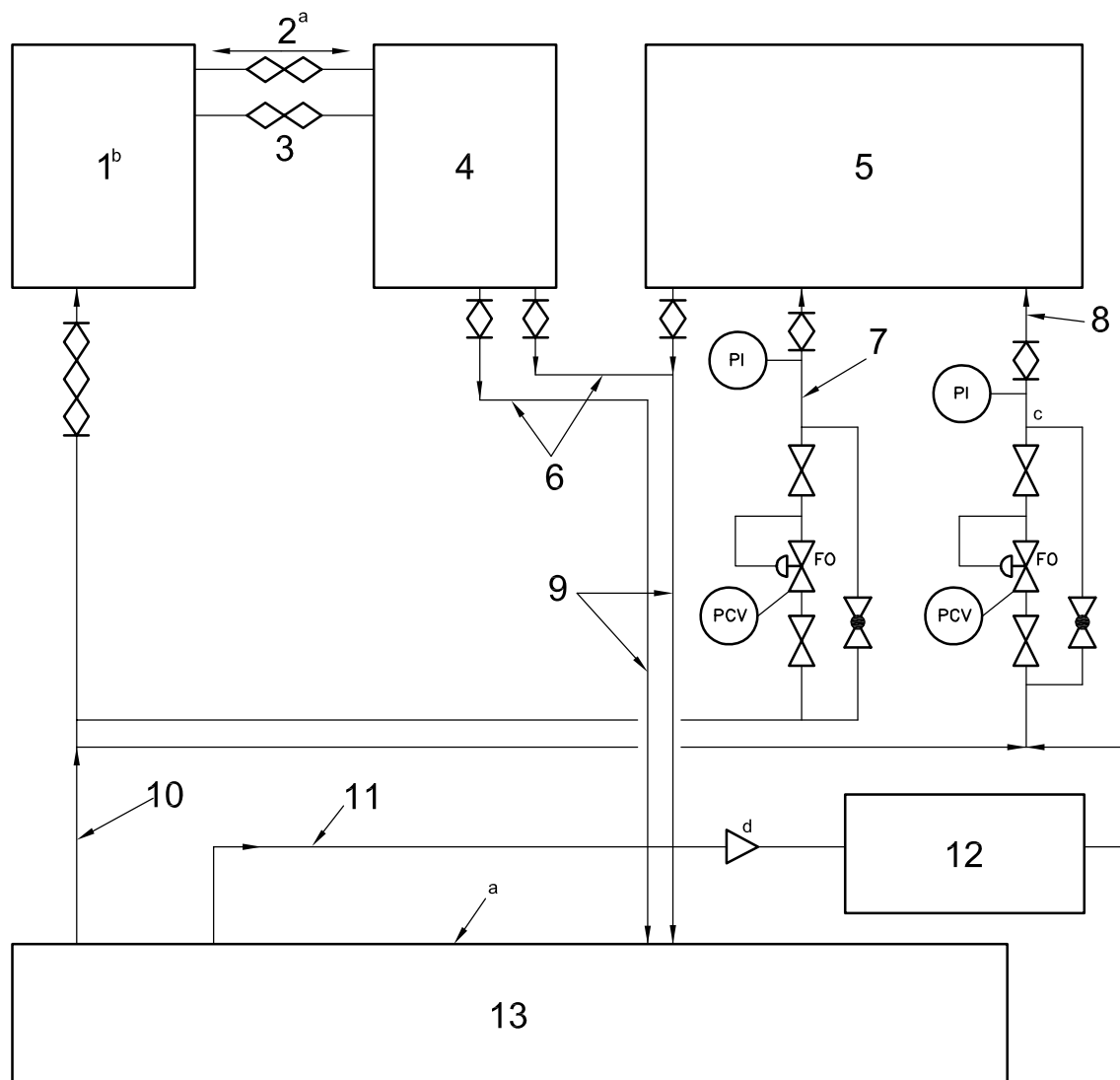
This annex contains a link to datasheets in both SI and USC units, together with an explanatory note. To access the appropriate datasheet, click on "[Datasheet](#)", then the first page tab for Figure A.1 — Scope and attachments. Select the appropriate set of units from the menu available.

The options for units are the following:

- USC units;
- SI units (MPa);
- SI units (kPa);
- metric (kg/cm²);
- hybrid.

Annex B (informative)

Piping and instrument diagrams



Key

- | | |
|---|---|
| 1 overhead-tank module | 8 control oil |
| 2 gas reference | 9 oil-return headers |
| 3 seal-oil supply | 10 oil-supply header |
| 4 seal-oil system module (Figure B.9) | 11 alternative control-oil flow |
| 5 main equipment lube- and control-oil module (Figure B.10) | 12 twin filter and cooler set (Figure B.20 or B.21) |
| 6 drain | 13 basic oil-supply module (Figure B.12) |
| 7 lube oil | |

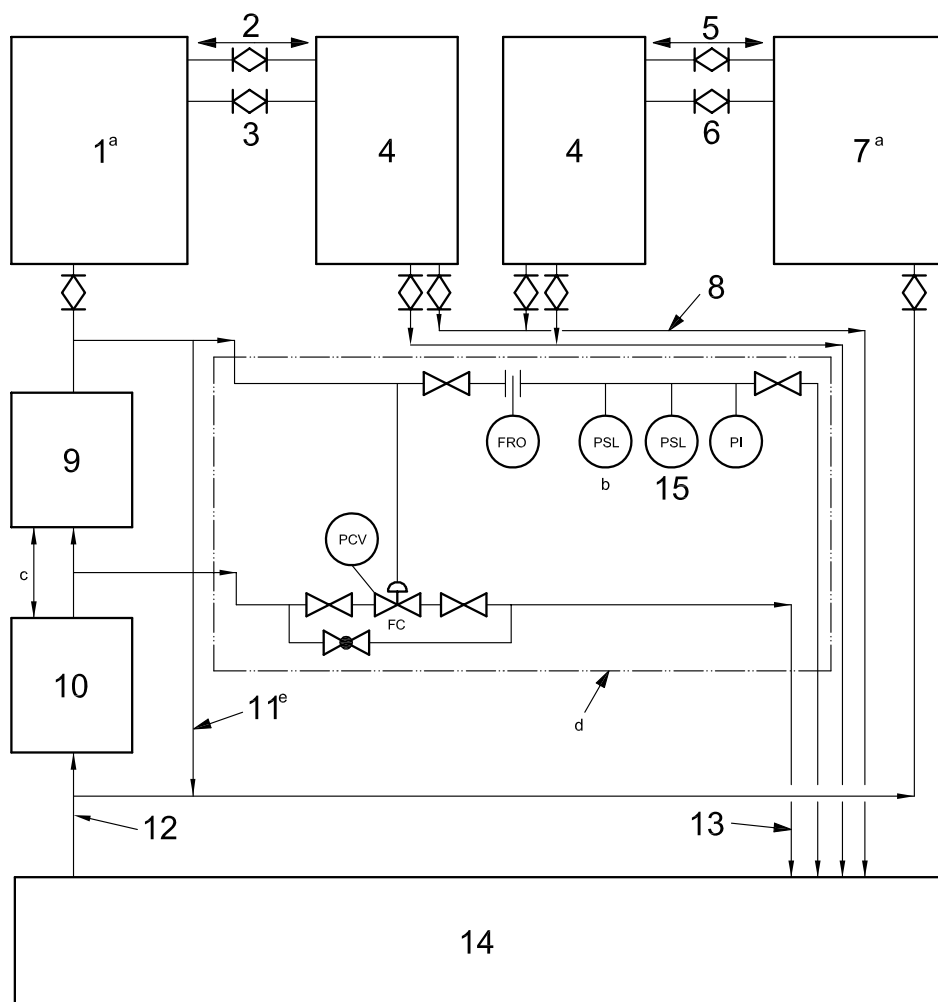
a Figure B.1, option A: For systems without overhead seal-oil tanks, the gas reference is connected to a direct-acting differential-pressure control valve. The alternative arrangement is shown in Figure B.12.

b The overhead-tank module may be either upstream (Figure B.4) or downstream (Figure B.5) of the seal-oil system module.

c This arrangement is valid only when the minimum seal-oil supply pressure is higher than the control-oil pressure.

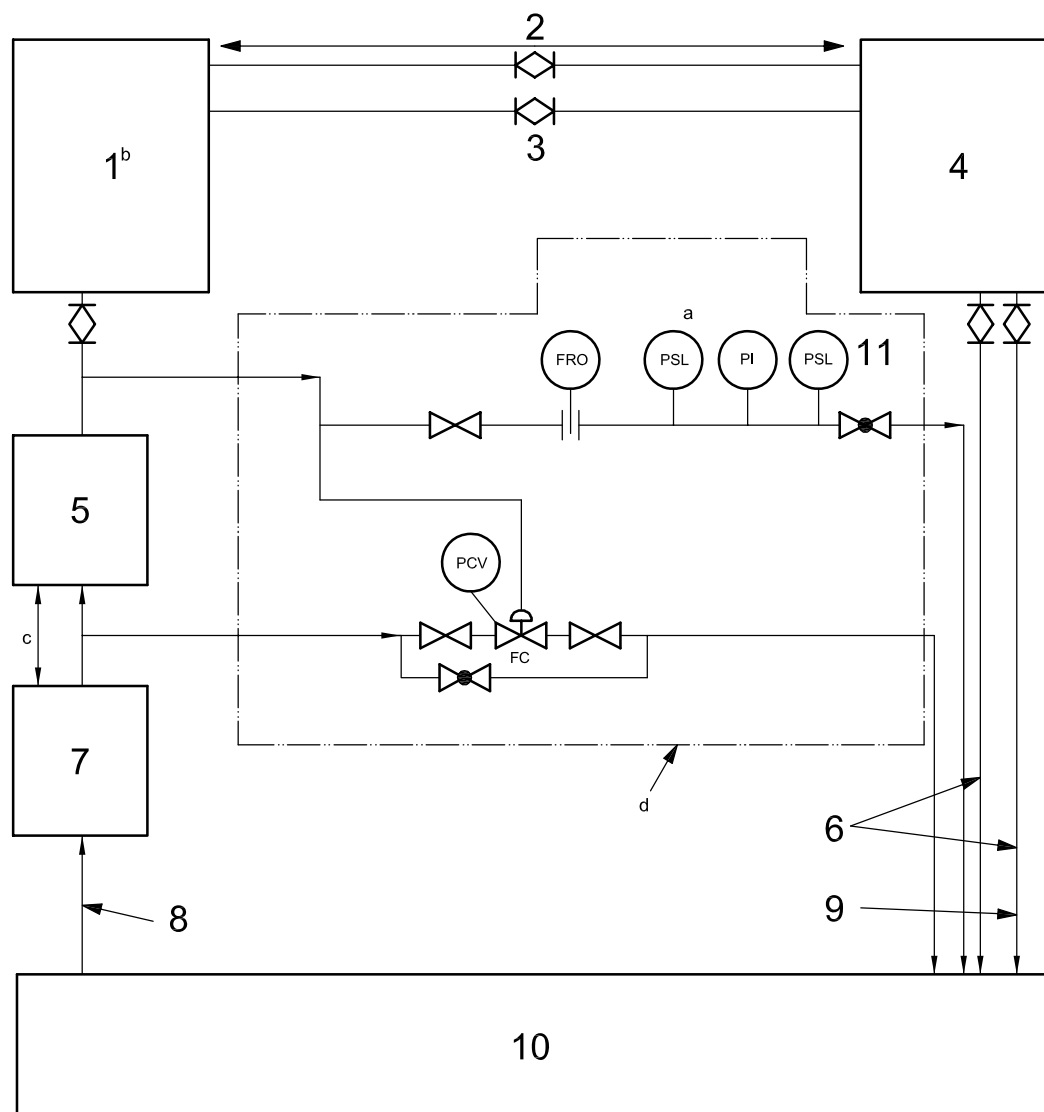
d The check valve is omitted if an accumulator is not used.

Figure B.1 — Combined seal-oil, lube-oil, and control-oil system



- Key**
- | | |
|--|---|
| 1 high-pressure overhead-tank module (Figure B.17) | 9 filter and cooler module (Figure B.20 or B.21) |
| 2 high-pressure gas reference | 10 booster pump (Figure B.23) |
| 3 high-pressure seal-oil supply | 11 alternative low-pressure seal-oil supply lines |
| 4 seal-oil module (Figure B.9) | 12 oil-supply header |
| 5 low-pressure gas reference | 13 oil-return headers to reservoir |
| 6 low-pressure seal-oil supply | 14 basic oil-supply module (Figure B.12) |
| 7 low-pressure overhead-tank module (Figure B.17) | 15 alarm |
| 8 drain | |
- ^a The overhead-tank module may be either upstream (see Figure B.4) or downstream (see Figure B.5) of the seal-oil system module.
- ^b Figure B.2, option A: A switch is included to start the standby booster pump.
- ^c Figure B.2, option B: The booster pump and filter are omitted if the basic oil-supply system is specified to provide the required pressure.
- ^d Figure B.2, option C: The pressure control valve and associated switches and pressure indicator may be deleted when the equipment has seals that take the total flow of oil from the pumps without the need for back-pressure regulation.
- ^e The source for low-pressure seal oil depends on the required pressure.

Figure B.2 — Seal-oil system only, with overhead tanks for equipment with more than one pressure level



Key

- | | |
|--|--|
| 1 overhead-tank module (Figure B.17) | 7 booster pump (Figure B.23) |
| 2 gas reference | 8 oil-supply header |
| 3 seal-oil supply | 9 oil-return headers to reservoir |
| 4 seal-oil module (Figure B.9) | 10 basic oil-supply module (Figure B.12) |
| 5 filter and cooler module (Figure B.20 or B.21) | 11 alarm |
| 6 drain | |

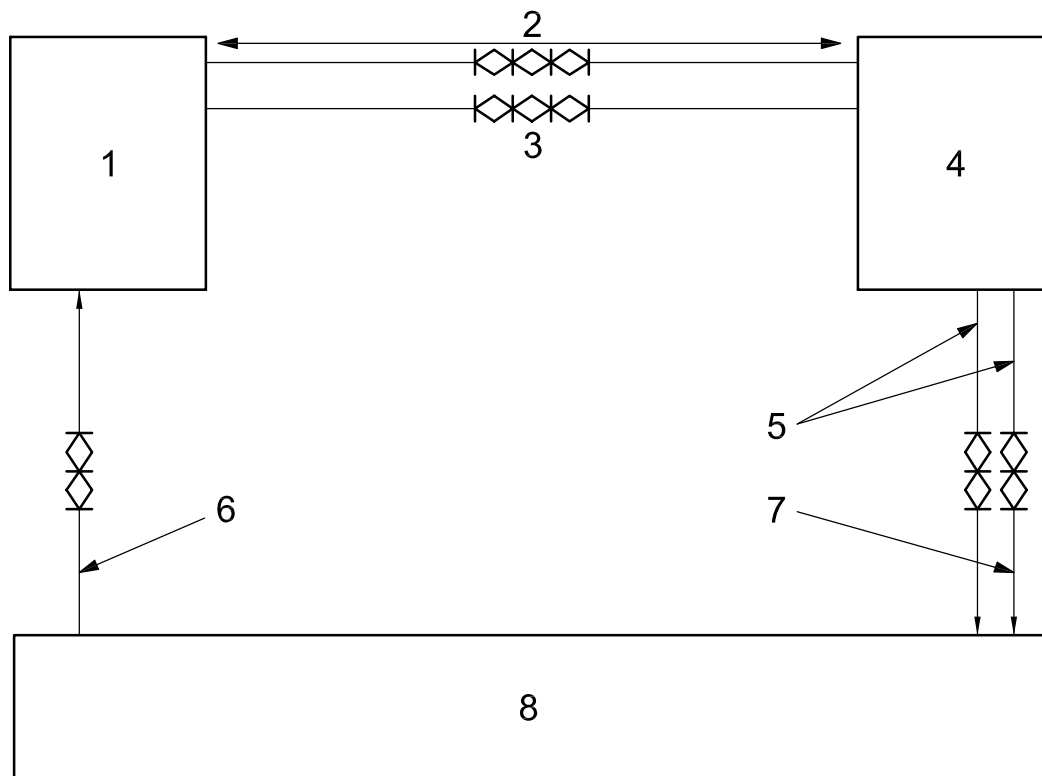
a Figure B.3, option A: A switch is included to start the standby booster pump.

b The overhead tank module may be either upstream (see Figure B.4) or downstream (see Figure B.5) of the seal-oil module.

c Figure B.3, option B: The booster pump and filter are omitted if the basic oil-supply system is specified to provide the required pressure.

d Figure B.3, option C: The pressure control valve and associated switches and pressure indicator may be deleted if the equipment seals utilize the total flow of oil from the pumps (e.g., for cooling purposes).

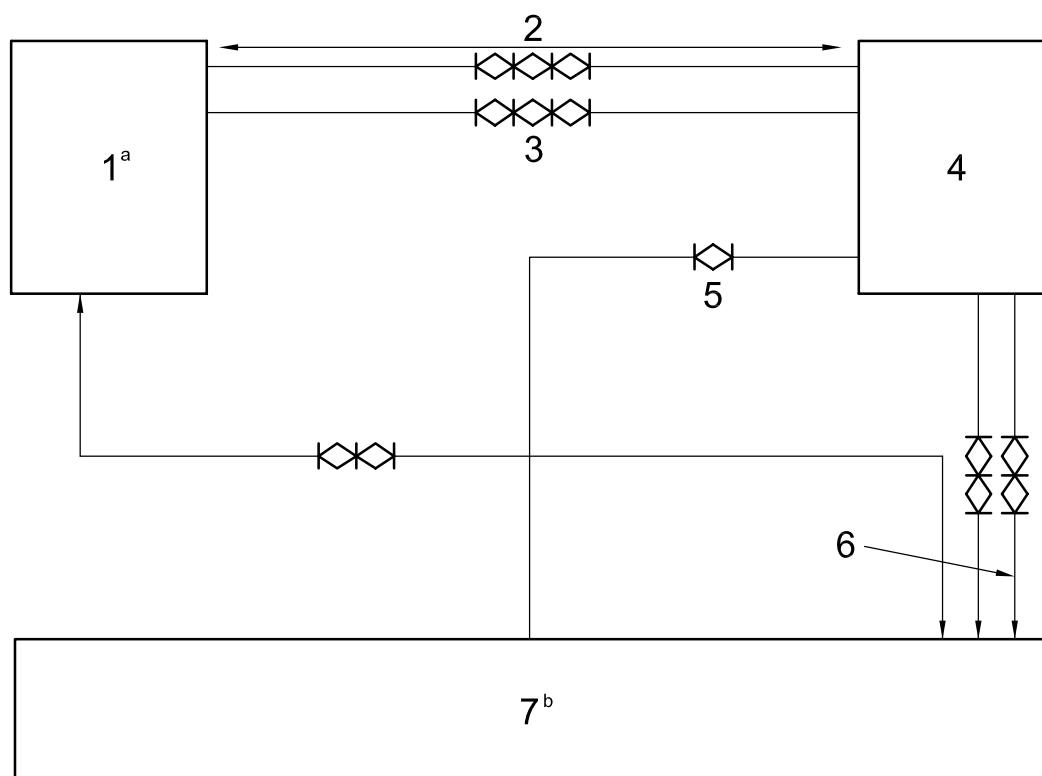
Figure B.3 — Seal-oil system only, with overhead tank for equipment with one pressure level



Key

- 1 overhead-tank module (Figure B.17)
- 2 gas reference
- 3 seal-oil supply
- 4 seal-oil module (Figure B.9)
- 5 oil-return headers to reservoir
- 6 oil-supply header
- 7 oil-return headers to reservoir
- 8 basic oil-supply module (Figure B.12)

**Figure B.4 — Seal-oil system only, for equipment with liquid film-type seals —
Overhead tank upstream of seals**



Key

- 1 overhead-tank module (Figure B.17)
- 2 gas reference
- 3 oil out
- 4 seal-oil module (Figure B.9)
- 5 seal-oil supply
- 6 oil-return headers to reservoir
- 7 basic oil-supply module (Figure B.12)

^a The check valve shown in Figure B.17 is omitted from the overhead-tank module.

^b The direct-acting pressure-control-valve circuit shown in Figure B.12 is omitted.

**Figure B.5 — Seal-oil system only, for equipment with liquid film-type seals —
Overhead tank downstream of seals**

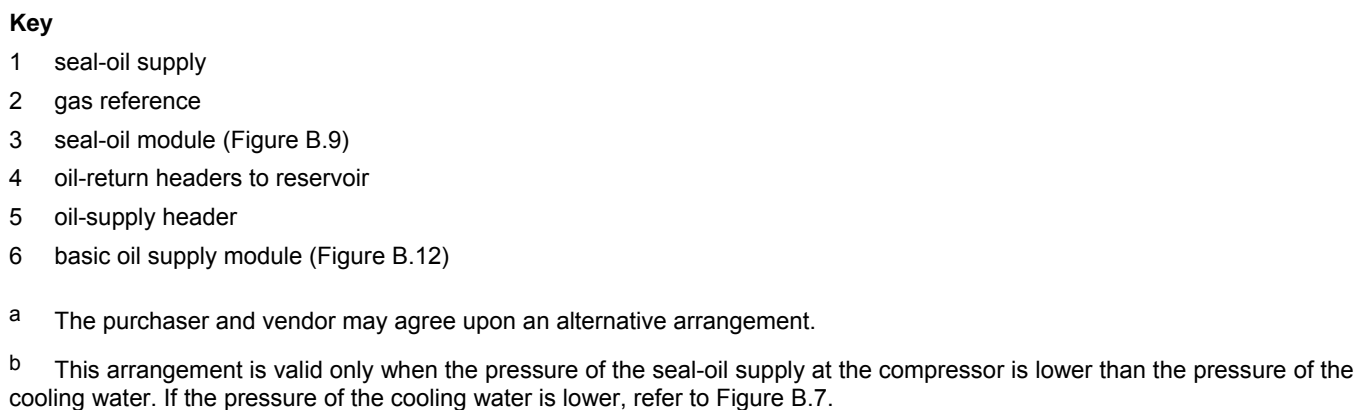
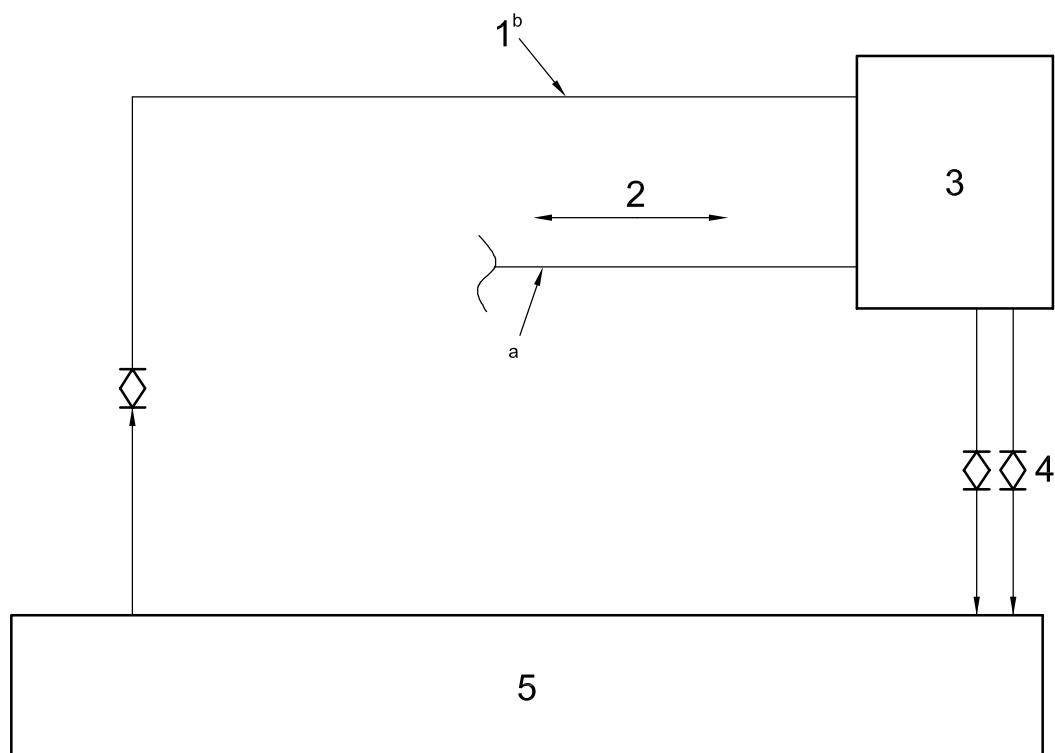


Figure B.6 — Seal-oil system with oil pressure lower than cooling water pressure

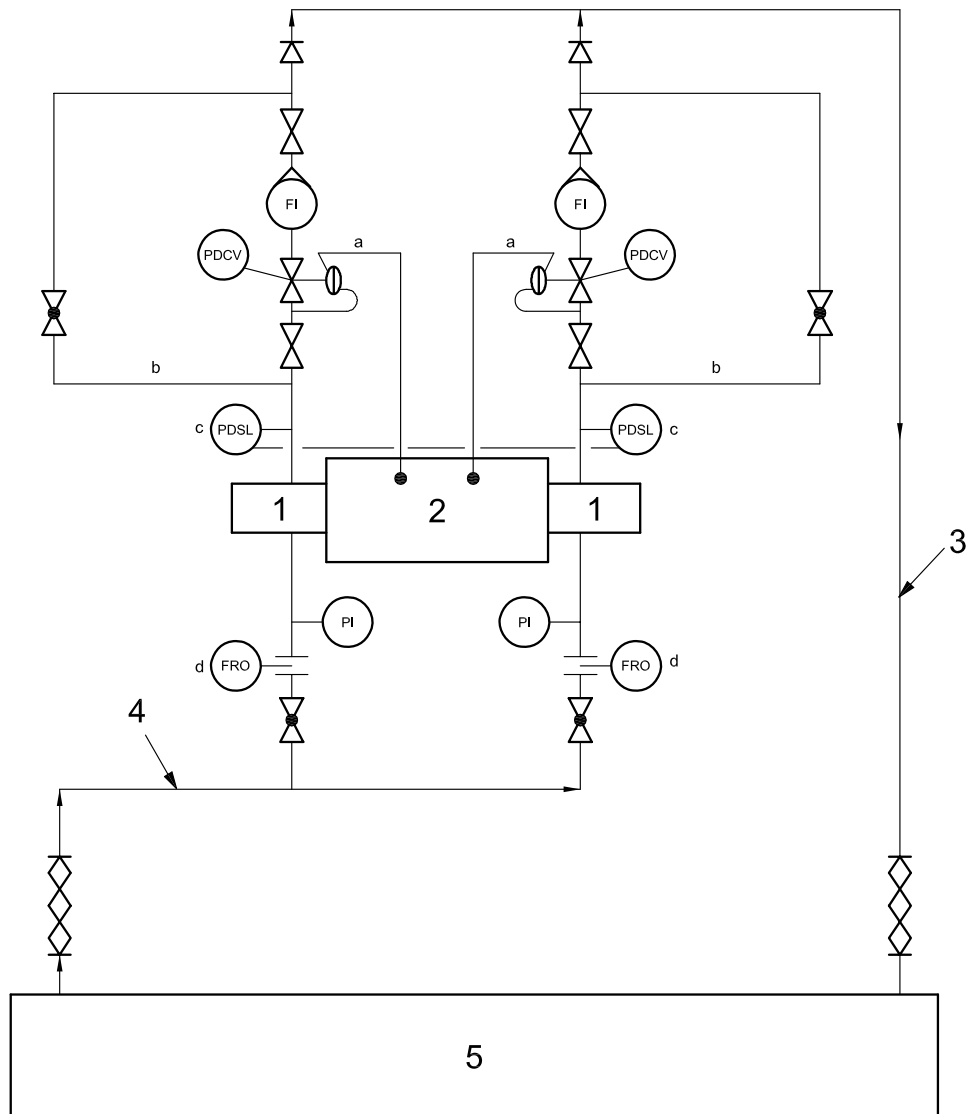


Key

- 1 seal-oil supply
- 2 gas reference
- 3 seal-oil module (Figure B.9)
- 4 oil-return headers to reservoir
- 5 basic oil-supply module (Figure B.12)

- ^a A direct-acting differential-pressure control valve is used according to the alternative arrangement shown in Figure B.12.
- ^b This arrangement is valid only when the pressure of the seal-oil supply is higher than the pressure of the cooling water. If the pressure of the cooling water is higher, refer to Figure B.6.

Figure B.7 — Seal-oil system with oil pressure higher than cooling water pressure

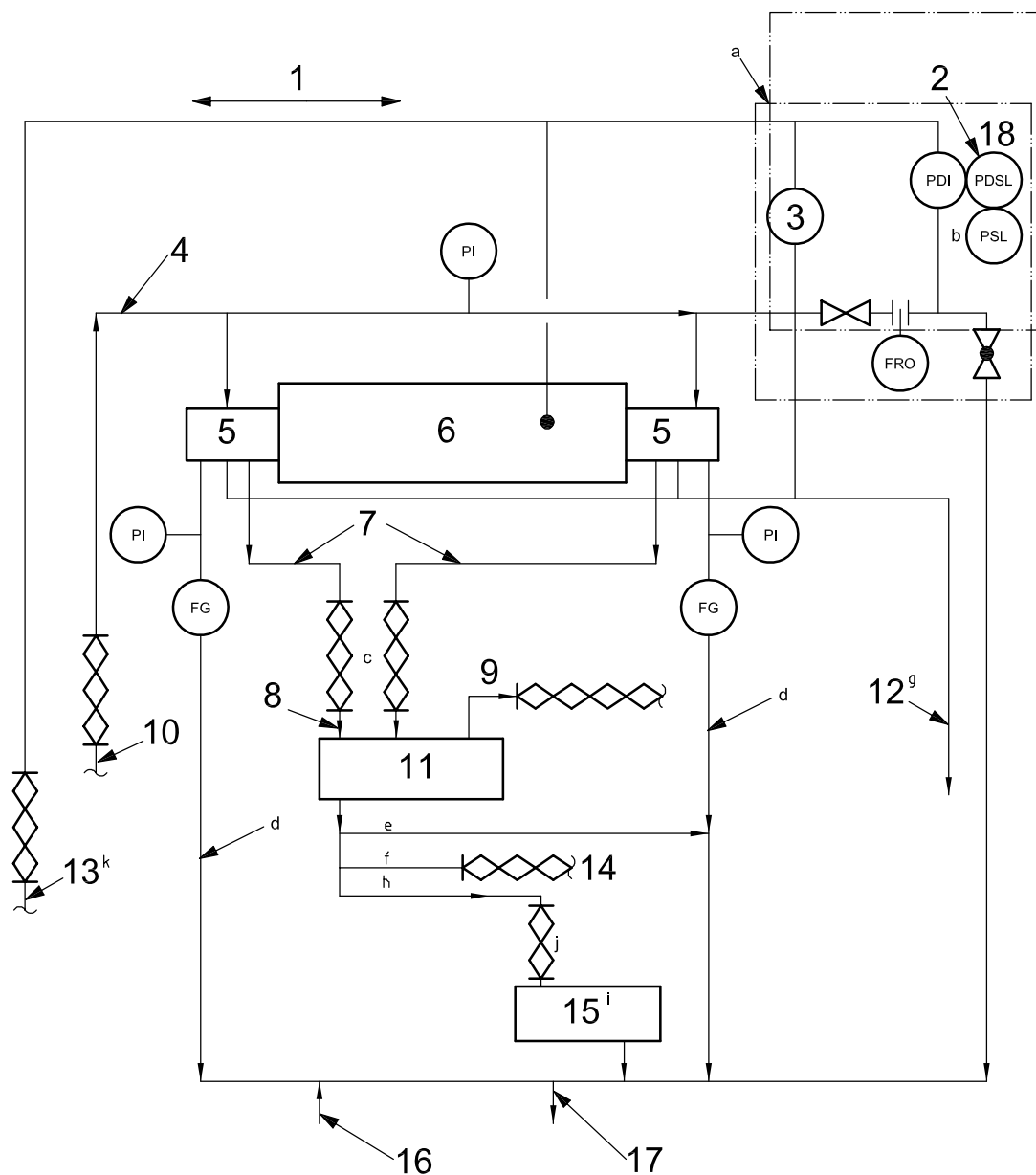


Key

- 1 seal
- 2 equipment
- 3 oil-return header to reservoir
- 4 oil-supply header
- 5 basic oil-supply module (Figure B.12)

- a Each direct-acting differential-pressure control valve shall be referenced to sense the working-fluid pressure acting at the corresponding mechanical seal.
- b Block, isolation, and vent-bleed valves can be omitted for all instruments in trip service with owner's approval.
- c Figure B.8, option A: A switch to alarm or trip or both is/are included.
- d Figure B.8, option B: A flow-restriction orifice is included.

Figure B.8 — Seal-oil circulation system for equipment with double mechanical seals or multiple sealing pressure levels



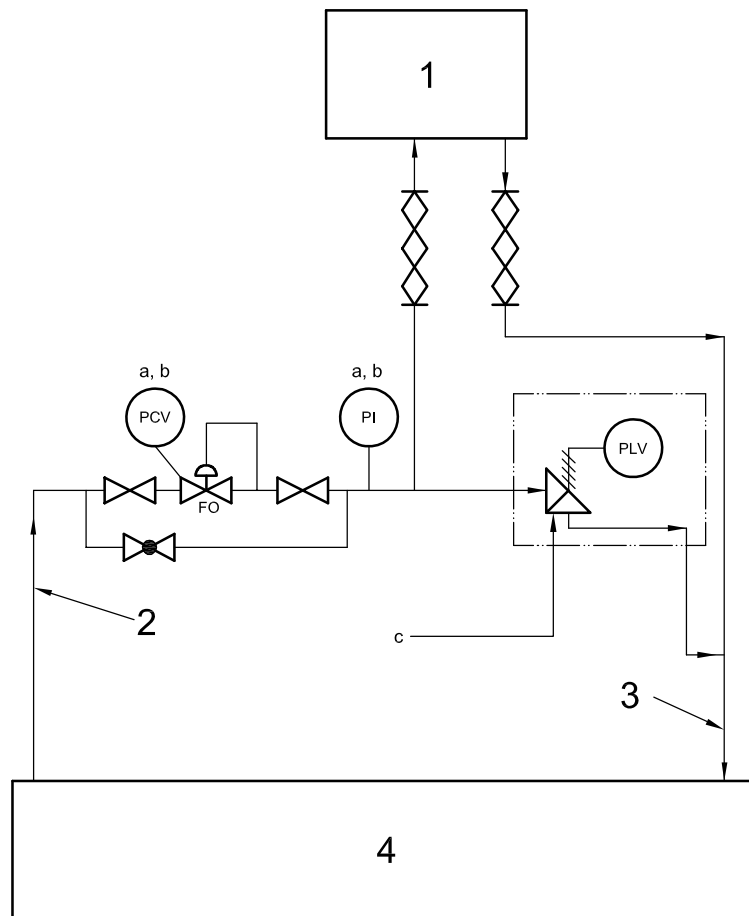
Key

- | | |
|-----------------------------|--|
| 1 gas reference | 10 seal-oil supply |
| 2 to start standby pump | 11 inner oil seal drain traps (Figure B.14) |
| 3 PDSLL to trip main driver | 12 seal-oil return header |
| 4 seal-oil supply header | 13 gas reference to differential control or overhead tank |
| 5 seal | 14 purchaser's drains |
| 6 equipment | 15 degasifier |
| 7 inner seal-oil drains | 16 drain header (lube drain for combined lube- and seal-oil systems) |
| 8 drain | 17 oil return(s) to reservoir |
| 9 vent | 18 alarm |

Figure B.9 — Seal-oil module at equipment

- a The indicated components are omitted if they are furnished separately on the overhead tank.
- b The low-pressure switch is not required if the module is supplied with a back-pressure regulator circuit (see Figure B.12).
- c This piping is furnished by the vendor when the drainers are mounted on a compressor baseplate.
- d On combined lube- and seal-oil systems, the outer seal drain may be combined with the lube-oil drain inside the compressor.
- e Figure B.9, option A: A drain to the reservoir is included.
- f Figure B.9, option B: A drain to the purchaser's drains is included.
- g Alternate seal-oil drain arrangement. For this arrangement, sensing instruments (key items 2 and 3) are referenced to a pressure-controlled header, either upstream or downstream of the seals, as agreed.
- h Figure B.9, option C: A drain to the degassing drum is included.
- i Figure B.9, option D: A degassing drum (see Figure 3) is included.
- j This piping is furnished by the vendor if the degassifier is mounted on a compressor baseplate supplied by the vendor.
- k Each direct-acting differential-pressure-control valve shall be referenced to sense the working-fluid pressure acting at the corresponding seal.

Figure B.9 — Seal-oil module at equipment (*continued*)



Key

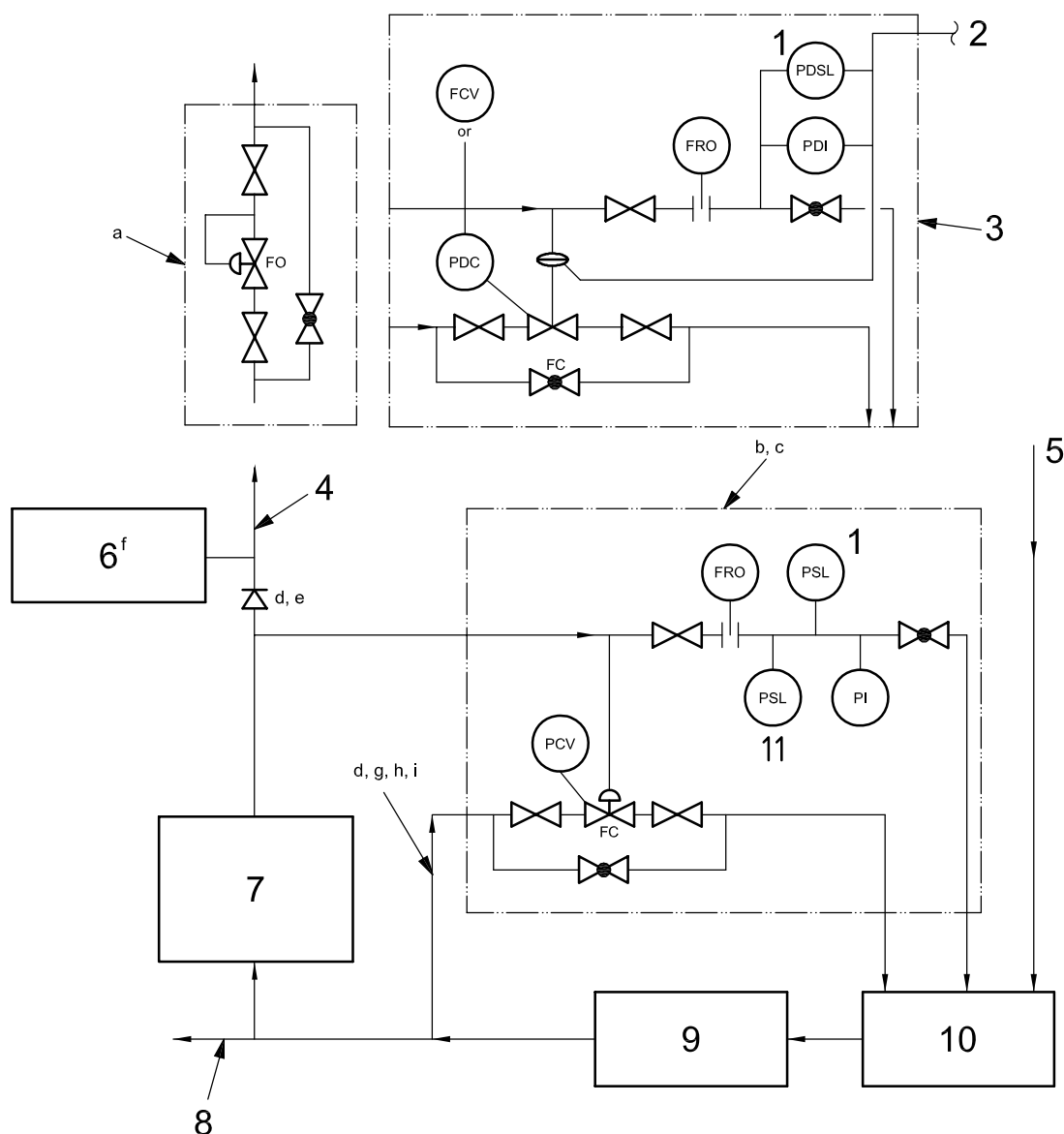
- 1 equipment lube-oil module (Figure B.13)
- 2 oil supply header to equipment
- 3 oil return header from equipment
- 4 basic oil-supply module (Figure B.12)

^a The direct-acting pressure-control valve and the pressure indicator are omitted when the pressure of the lube-oil supply is higher than the pressure of the cooling water.

^b A direct-acting pressure-control valve is required if centrifugal pumps are used.

^c This represents a typical arrangement that includes an additional pressure-limiting valve (PLV) for any system in which failure of a control valve can jeopardize or damage a low-pressure system.

Figure B.11 — Equipment lube-oil system only



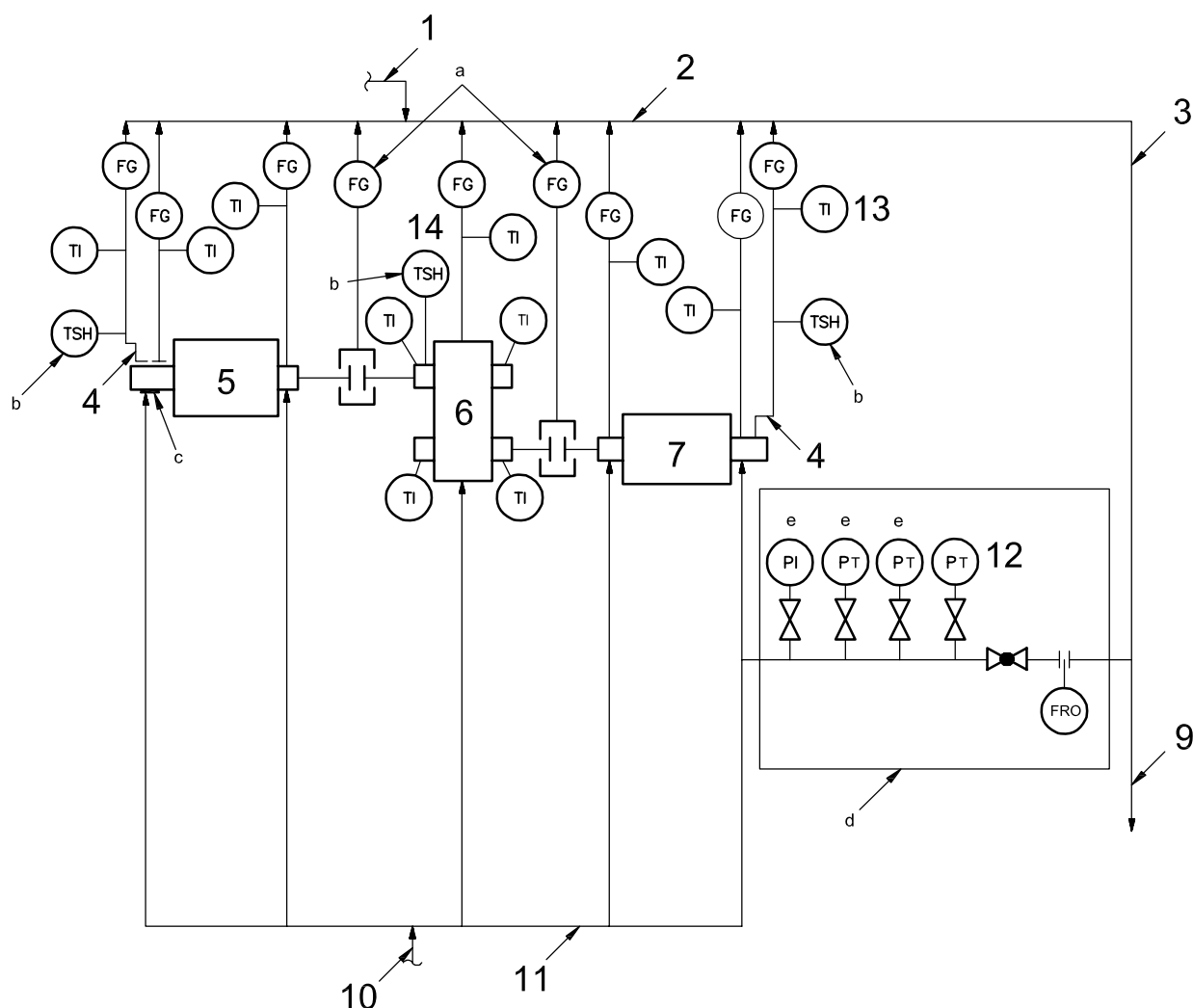
Key

- | | |
|--|---|
| 1 to start standby pump | 6 accumulator |
| 2 gas reference (Figure B.1) or downstream of flow element | 7 filter and cooler module (Figure B.20 or Figure B.21) |
| 3 alternate arrangement | 8 alternative control oil |
| 4 oil-supply header to equipment | 9 primary pumps (Figure B.22) |
| 5 oil-return header from equipment | 10 reservoir (Figure B.24) |
| | 11 alarm |

Figure B.12 — Basic oil supply module

- a Provision can be required to ensure adequate lube- and/or control-oil pressure when the seal-oil supply pressure is low relative to the lube- and/or control-oil pressure or to maintain the required oil-pressure differential above the cooling-water pressure.
- b When the module is specified for seal-oil applications, a direct-acting differential-pressure control valve or regulator shall be used.
- c The bypass valve may be deleted for a separate seal-oil system that utilizes the total oil flow from the pumps.
- d The check valve is omitted when (1) an accumulator is not used, (2) a direct-acting pressure control valve circuit is used, or (3) an emergency rundown tank is not used.
- e The check valve is omitted when a rotary primary pump or an accumulator is not used.
- f When required, the accumulator shall be of the bladder (Figure B.18) or direct-contact (Figure B.19) type.
- g The heat load can require that the supply to the direct-acting pressure control valve be downstream of the coolers.
- h The direct-acting pressure-control valve circuit is omitted when the module is specified for seal-oil systems (Figures B.4 and B.5).
- i The bypass direct-acting pressure control valve circuit is omitted when centrifugal pumps are used.

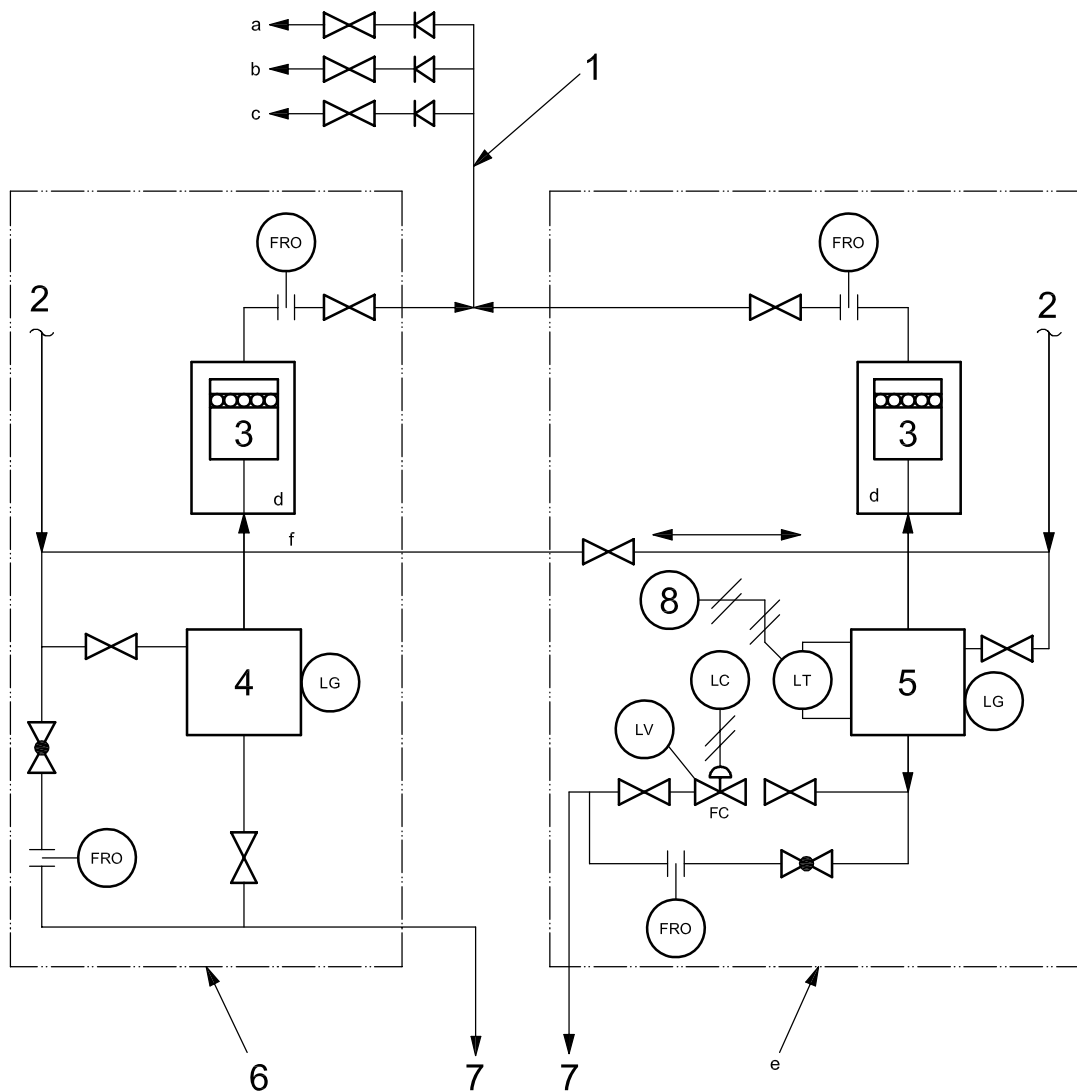
Figure B.12 — Basic oil supply module (*continued*)



Key

- | | |
|--|---------------------------------------|
| 1 from equipment outer-seal drains, control-oil drains, and the like, as necessary | 8 low lube-oil supply pressure trip |
| 2 lube-drain header | 9 drain |
| 3 oil-return header | 10 oil in |
| 4 thrust drain | 11 lube supply header |
| 5 driver | 12 low lube-oil supply pressure alarm |
| 6 gear | 13 alarm |
| 7 driven unit | 14 thrust alarm |
- a Drains are required on closed coupling guards. Figure B.13, option A: Flow glasses may be provided as an option.
- b An oil-drain high-temperature switch is not required if a thrust-bearing metal temperature detector is specified.
- c If required by the motor design, all connections shall be electrically insulated.
- d These components may be located on the gauge board.
- e Redundant transmitters may be provided for 2-out-of-3 voting.

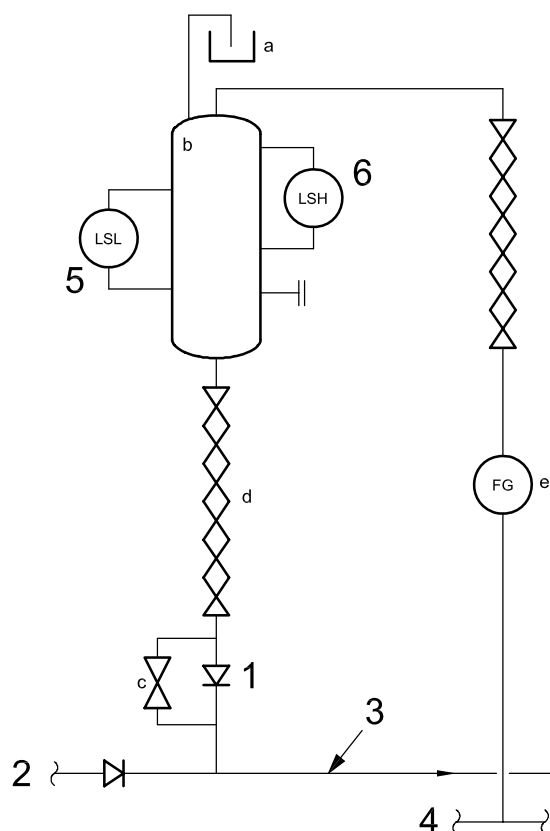
Figure B.13 — Equipment lube-oil supply and drain headers



Key

- | | |
|-------------------|---|
| 1 vent | 5 drain pot |
| 2 from inner seal | 6 typical arrangement for mechanical-float type traps |
| 3 mist eliminator | 7 separate drain outlet for each drain pot |
| 4 float trap | 8 high-level alarm |
- a Figure B.14, option A: The purchaser may specify a vent to the flare.
b Figure B.14, option B: The purchaser may specify a vent to the gas system.
c Figure B.14, option C: The purchaser may specify a vent to the suction of a lower pressure casing.
d Figure B.14, option D: The purchaser may specify mist eliminators.
e This line is omitted when the seals are not at the same pressure.

Figure B.14 — Inner oil seal drain traps

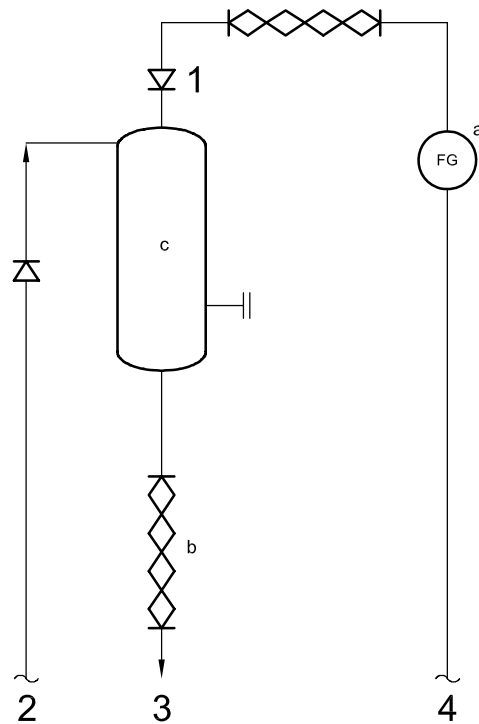


1 drilled check valve

- 2 lube-oil supply
- 3 to equipment
- 4 to reservoir or drain header
- 5 low-level alarm
- 6 permissive start

- a Figure B.15, option A: The purchaser may specify an atmospheric breather valve.
- b This tank shall be located at an elevation such that the static head is less than the equipment lube-oil trip pressure.
- c This valve is normally closed; it is opened only to fill the tank before the equipment is started. Figure B.15, option B: This valve may be solenoid-controlled to allow an automated start.
- d To reduce pressure-line losses, locate and design interconnecting piping as per system designer's recommendations.
- e Sight glass should be located near the reservoir in a visible location.

Figure B.15 — Emergency lube-oil atmospheric-type rundown tank

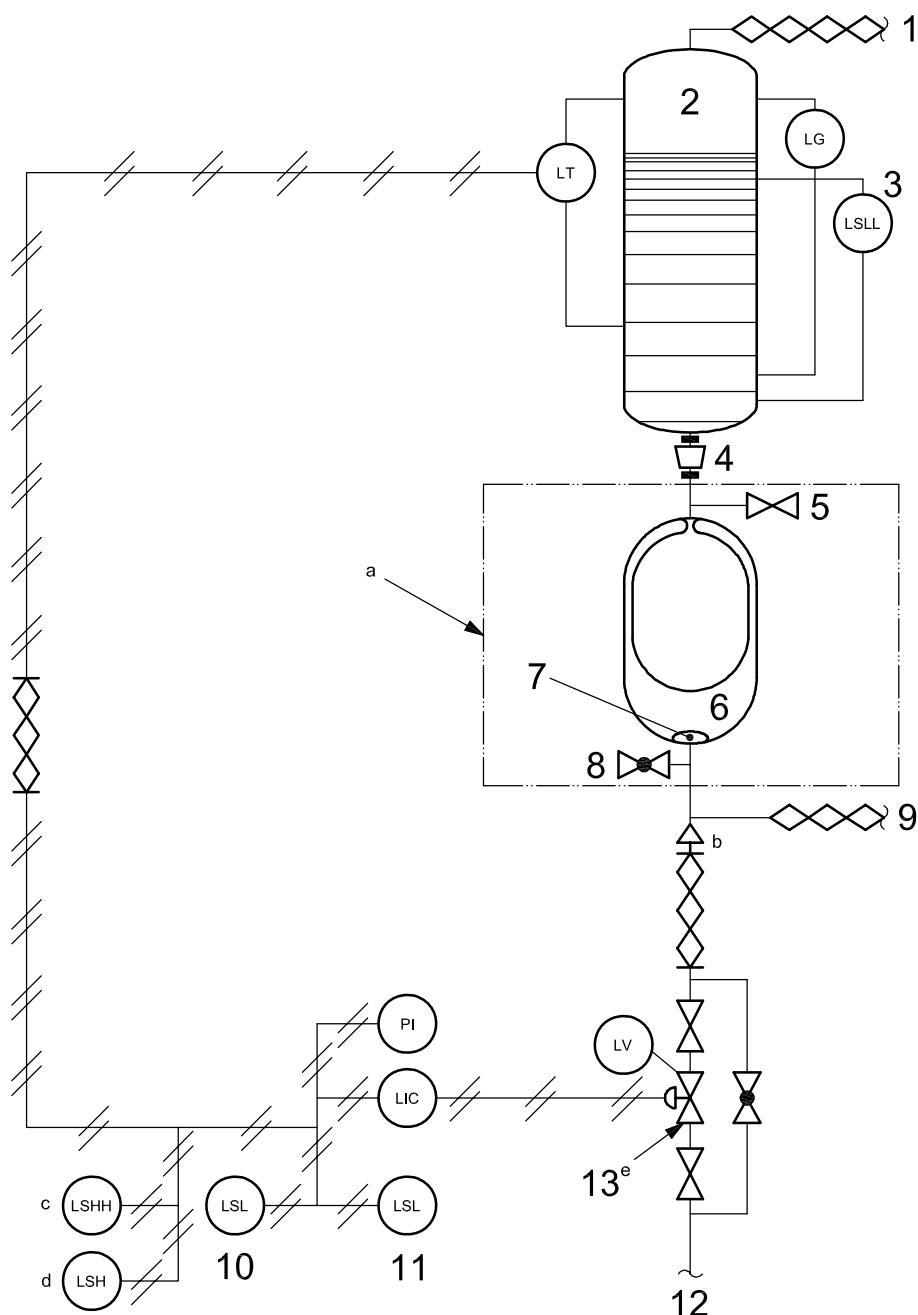


Key

- 1 float-type check valve
- 2 lube-oil supply
- 3 to equipment
- 4 to reservoir or drain header

- a Locate site glass near the reservoir in a visible location.
- b To reduce pressure-line losses, locate and design interconnecting piping as per system designer's recommendations.
- c This tank shall be located at an elevation such that the static head is less than the equipment lube-oil trip pressure.

Figure B.16 — Emergency lube-oil pressurized-type rundown tank



Key

- | | | |
|--|---------------------------------------|--------------------------------|
| 1 gas reference | 6 transfer-type (bladder-type) vessel | 11 to start standby pump |
| 2 overhead tank | 7 bladder-limiter device | 12 oil-in or oil-return header |
| 3 low low level to trip main driver | 8 vent | 13 control valve |
| 4 bottom outlet nozzle [w 150 mm (6 in)] | 9 to supply header or return header | |
| 5 drain or fill connector | 10 low-level alarm | |

a Figure B.17, option A: The purchaser may specify an accumulator with an isolation bladder.

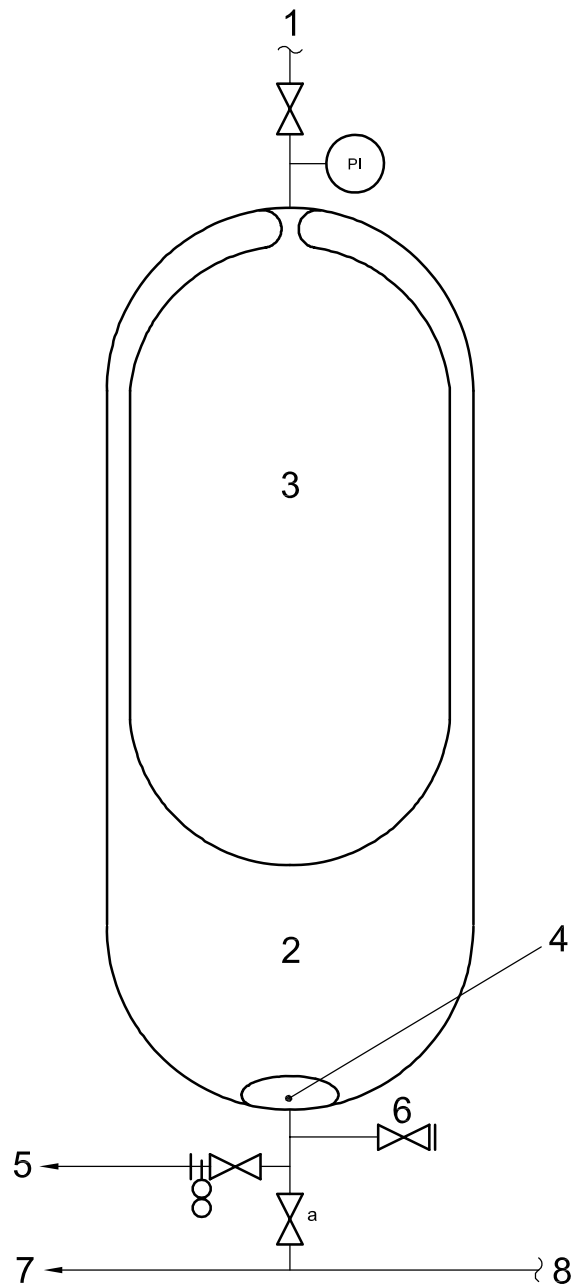
b The check valve is omitted when the overhead tank module is downstream of the seals.

c Figure B.17, option B: When the pump is for seal oil only, the purchaser may specify a signal to stop the pump.

d Figure B.17, option C: When the pump is for a combined lube- and seal-oil system, the purchaser may specify an alarm.

e Control valve should be in FO or FL position. Figure B.17, option D: The following are the failure actions for the loop-actuated control valve: FO in the supply header and FC in the return header.

Figure B.17 — Direct-contact-type overhead-tank module for seal-oil system, including optional transfer barrier (bladder-type) vessel

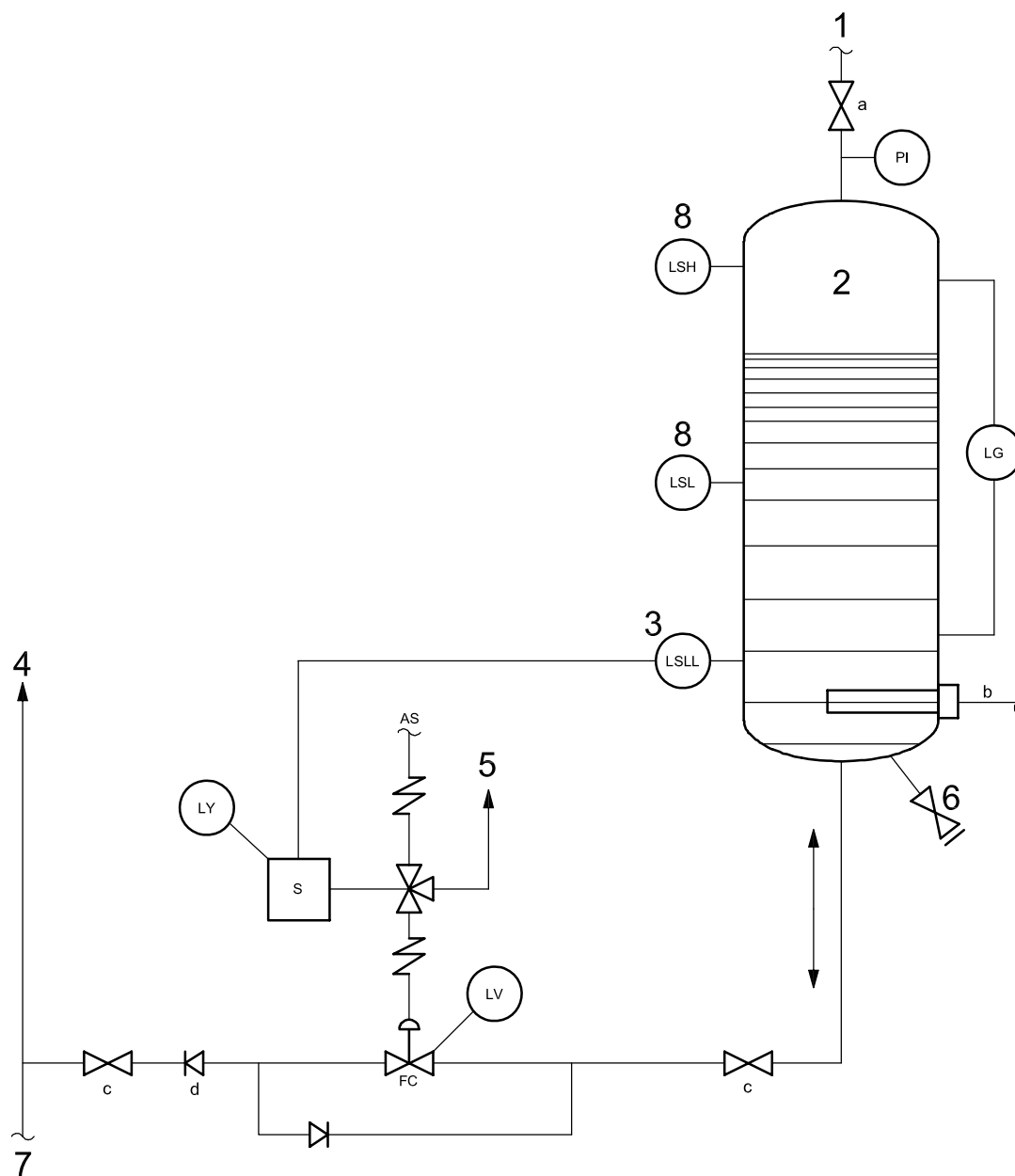


Key

- 1 charge gas
- 2 accumulator
- 3 bladder
- 4 bladder-limiter device
- 5 drain to reservoir
- 6 vent
- 7 oil out
- 8 oil in

^a The block valve may be locked open.

Figure B.18 — Accumulator — Manual precharge, bladder type



Key

- | | |
|--------------------|----------|
| 1 charge gas | 5 vent |
| 2 accumulator tank | 6 drain |
| 3 to close valve | 7 oil in |
| 4 oil out | 8 alarm |

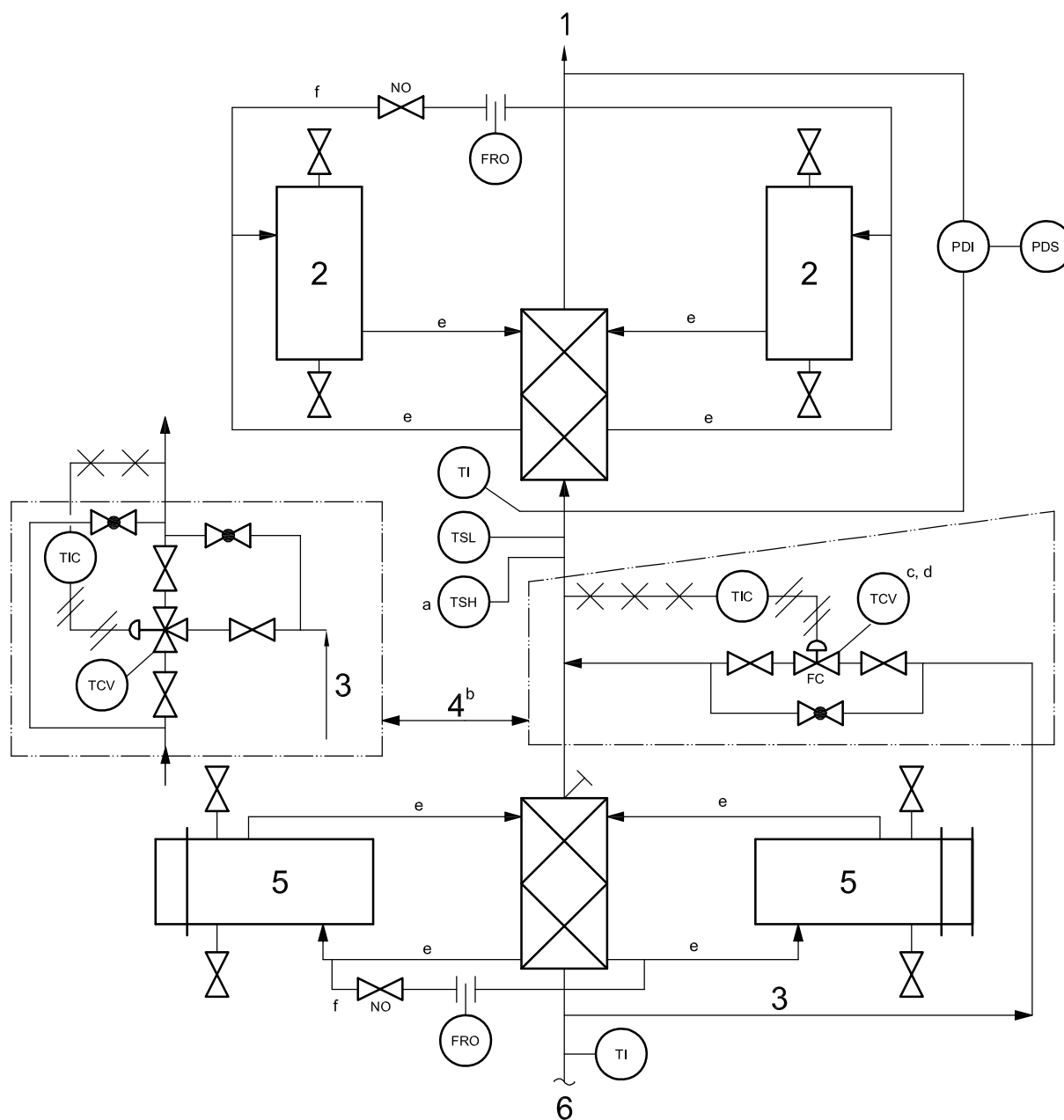
a Figure B.19, option A: The purchaser may specify a constant-pressure regulating system.

b Figure B.19, option B: The purchaser may specify an electric heater.

c The block valve may be locked open.

d Figure B.19, option C: A check valve with its seat or disk drilled reduces the recharging rate after an upset of the oil system. The purchaser should recognize that this can reduce the attenuation of pressure pulsations during system recovery.

Figure B.19 — Accumulator — Direct-contact, manual-precharge type

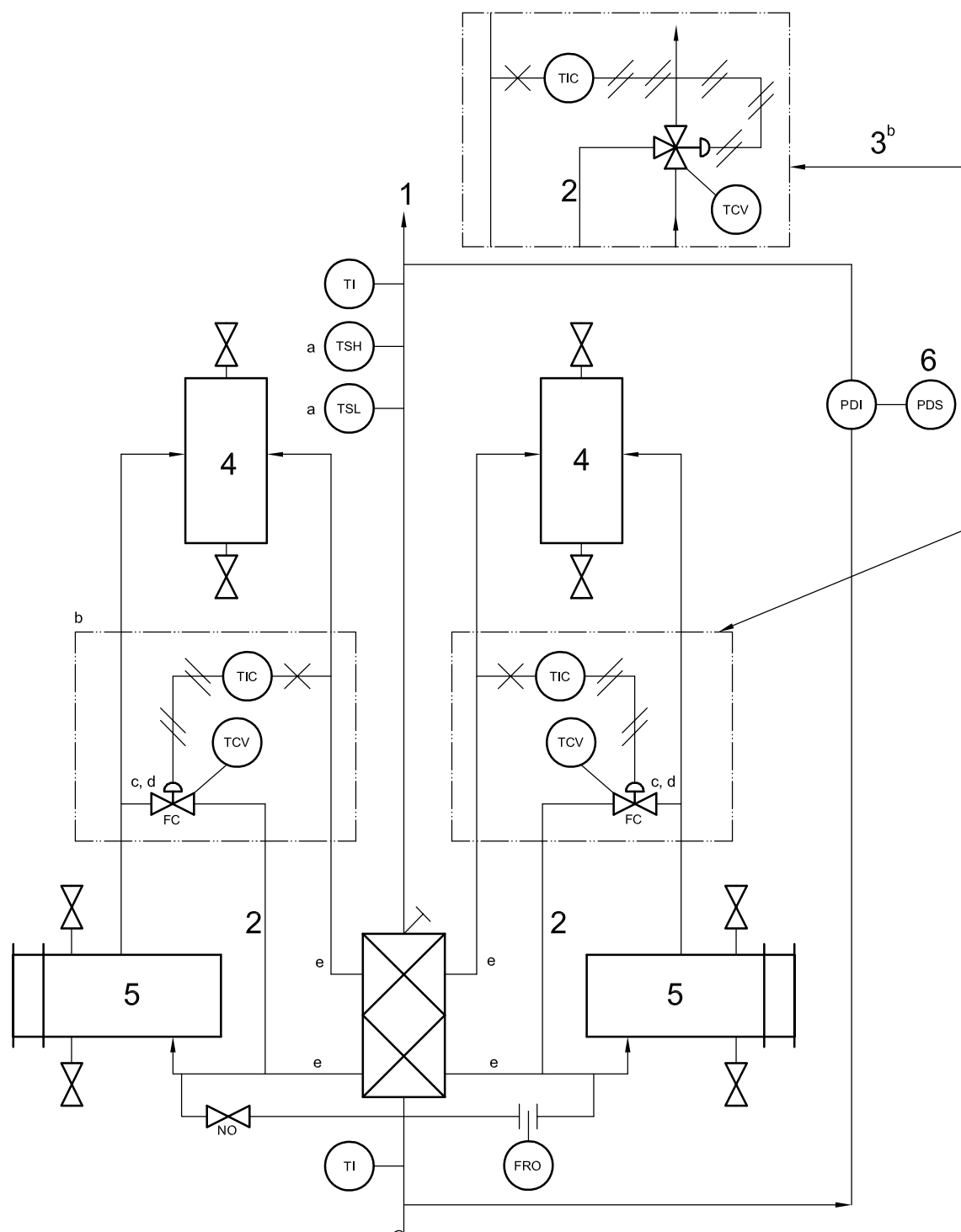


Key

- | | |
|-----------|---------------------------|
| 1 oil out | 4 alternative arrangement |
| 2 filter | 5 cooler |
| 3 bypass | 6 oil in |

- a Figure B.20, option A: The purchaser may specify a high-temperature switch (TSH) and/or a low-temperature switch (TSL).
- b Figure B.20, option B: The purchaser may specify a constant-temperature, three-way control valve as an alternative.
- c Figure B.20, option C: The purchaser may specify a bypass oil line and a constant-temperature, two-way control valve.
- d Figure B.20, option D: If the fail-closed (FC) feature of the direct-acting temperature-control valve is not acceptable, the purchaser may specify a valve with a FL feature.
- e Figure B.20, option E: The purchaser may specify tight shutoff requiring spectacle blinds.
- f The equalization/fill line between twin coolers and filters can be piped by the console vendor or can be integral with the transfer valve.

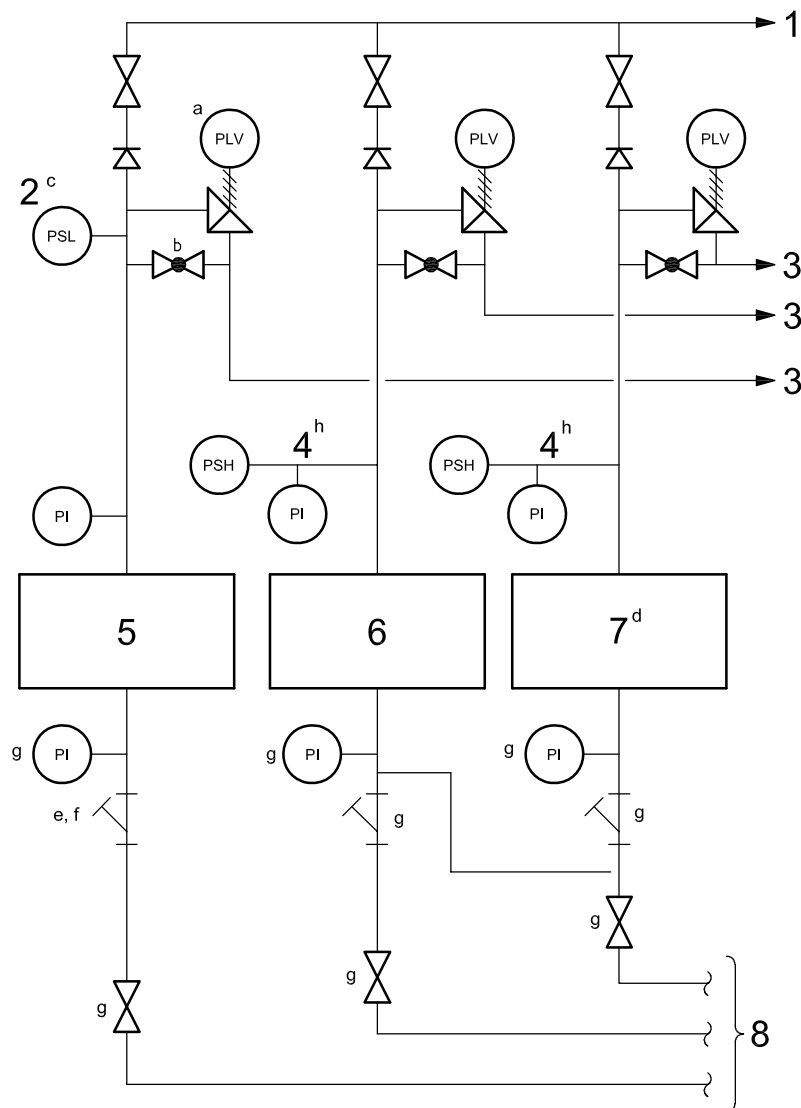
Figure B.20 — Twin oil coolers and filters with separate, continuous-flow transfer valves



Key

- | | | |
|-----------|-------------------------|----------|
| 1 oil out | 3 alternate arrangement | 5 cooler |
| 2 bypass | 4 filter | 6 alarm |
- a Figure B.21, option A: The purchaser may specify a high-temperature switch (TSH) and/or a low-temperature switch (TSL)
- b Figure B.21, option B: The purchaser may specify a constant-temperature, three-way control valve as an alternative.
- c Figure B.21, option C: The purchaser may specify a bypass oil line and a constant-temperature, two-way control valve.
- d Figure B.21, option D: If the FC feature of the direct-acting temperature control valve is not acceptable, the purchaser may specify a valve with a FL feature.
- e Figure B.21, option E: The purchaser may specify tight shutoff requiring spectacle blinds.

Figure B.21 — Twin oil coolers and filters with a single, continuous-flow transfer valve

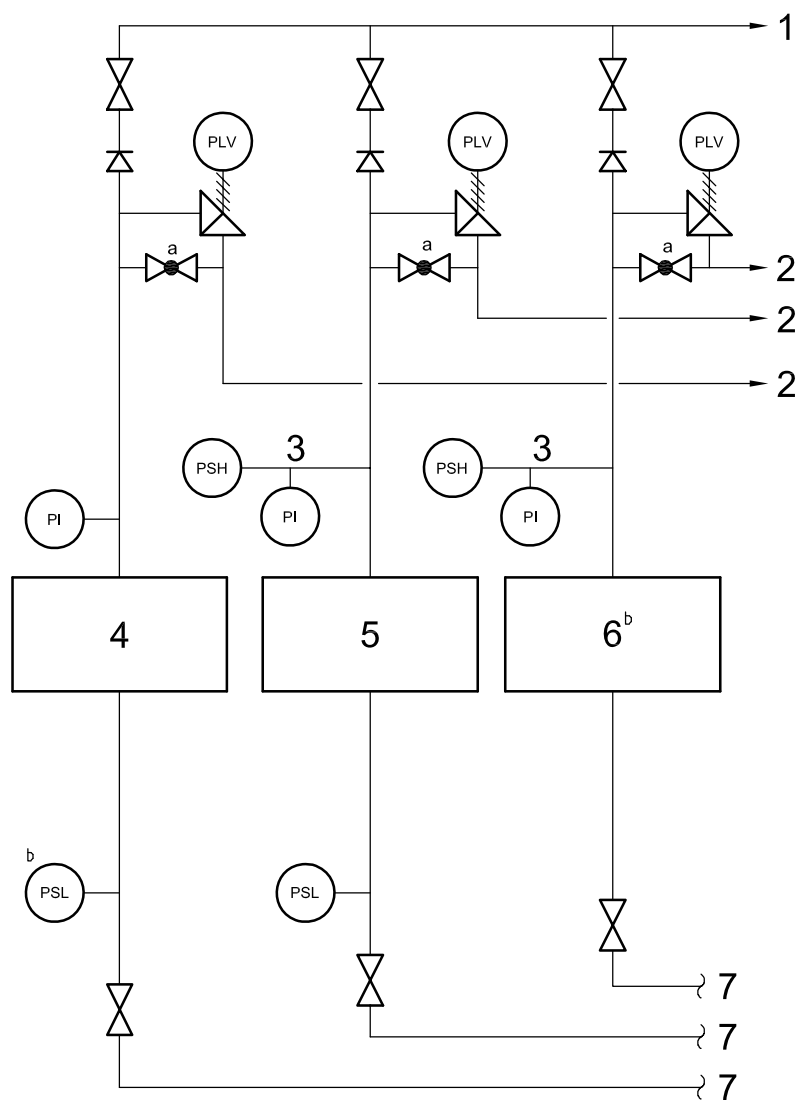


Key

- | | |
|--|-------------------------------|
| 1 to downstream equipment | 5 main pump |
| 2 to start standby pump | 6 standby pump |
| 3 individual return lines to reservoir | 7 emergency pump |
| 4 pump running alarm | 8 pump suction from reservoir |

- a The pressure-limiting valves (PLV) are omitted for centrifugal pumps.
- b Figure B.22, option A: The purchaser may specify a bypass valve to start.
- c Figure B.22, option B: The purchaser may specify an additional switch to start the standby pump (see Figure B.12).
- d Figure B.22, option C: The purchaser may specify an emergency pump.
- e For centrifugal pumps, the line strainers are omitted and temporary screens are provided.
- f A basket-type screen shall be used instead of a line strainer for the suction of pumps submerged in the reservoir.
- g These components are omitted for pumps submerged in the reservoir.
- h The pump running alarm can alternatively be accomplished in the motor control centre.

Figure B.22 — Primary (centrifugal or rotary) pump arrangement



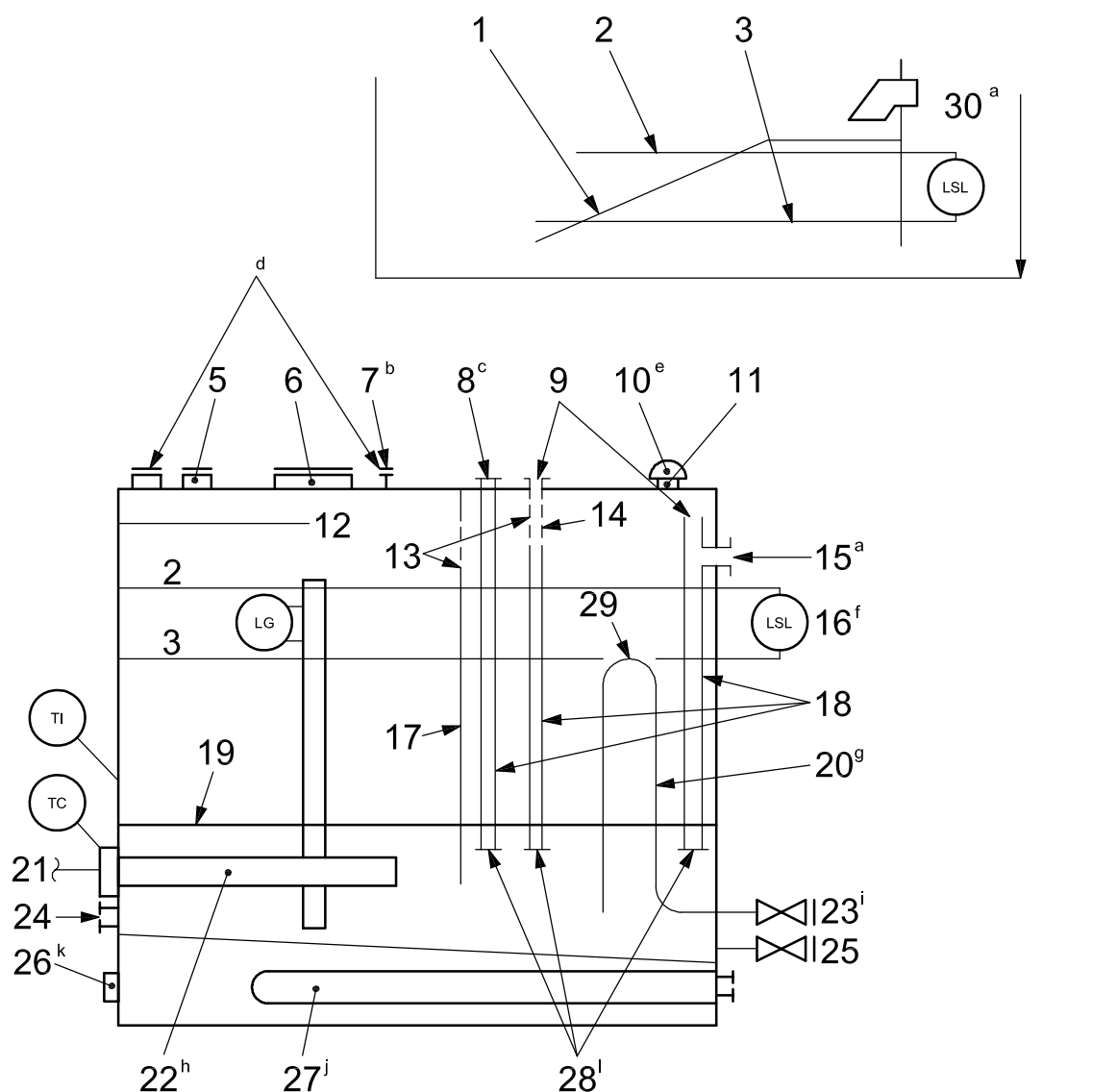
Key

- 1 to downstream equipment
- 2 individual return lines to reservoir
- 3 pump running alarm
- 4 main booster pump
- 5 standby booster pump
- 6 emergency booster pump
- 7 pump suction from reservoir

^a Figure B.23, option A: The purchaser may specify a bypass valve to start.

^b Figure B.23, option B: The purchaser may specify an alarm and/or a permissive start for the booster pumps or a low-pressure trip.

Figure B.23 — Booster (rotary) pump arrangement



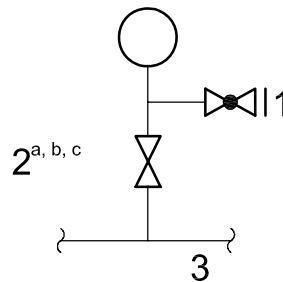
Key

- | | | |
|--|--|--|
| 1 sloped degasification tray | 11 fill opening with strainer | 21 electric supply |
| 2 maximum operating level | 12 rundown level | 22 electric heater |
| 3 minimum operating level | 13 equalizing vent holes | 23 conditioner suction connection |
| 4 spare plugged connection | 14 vent holes above rundown level to allow venting of rundown tank | 24 pump-suction connections |
| 5 plugged purge connection | 15 individual pressurized returns | 25 blind, flanged drain connection |
| 6 manway | 16 internal- or external-type float level indicator | 26 two tapped grounding pads |
| 7 vent connection | 17 baffle | 27 steam heater |
| 8 relief valve, control valve, conditioner and other pressurized oil returns | 18 stilling tube and static equalizer | 28 baffle attached to stilling tubes and pressurized oil returns to prevent stirring of bottom sediments |
| 9 open top | 19 pump minimum suction level | 29 hole, ≤ 6 mm to vent siphon breaker |
| 10 filter-breather cap | 20 siphon breaker | 30 alternative arrangement |

Figure B.24 — Oil reservoir

- a For non-pressurized gravity oil-return lines and fill openings, a stilling tube or sloped degasification tray arranged to prevent splashing and provide free release of foam and gas is required for every return inlet and spare connection.
- b A blind flange shall be provided for venting the reservoir. For seal-oil reservoirs, this vent shall be piped to a safe location by the purchaser.
- c Figure B.24, option A: The purchaser may specify a particular oil conditioner and other pressurized oil returns in addition to the spare top connection.
- d Purge and vent connections shall enter the top of the reservoir. No extension tubes or seals are permitted.
- e A filter-breather cap is not permitted on a reservoir containing seal oil.
- f An internal-type float shall be protected by a static-conducting shield.
- g Figure B.24, option B: The purchaser may specify a siphon breaker when an oil-conditioner suction connection is specified.
- h Figure B.24, option C: The purchaser may specify an electric heater.
- i Figure B.24, option D: The purchaser may specify an oil-conditioner suction connection.
- j Figure B.24, option E: The purchaser may specify a steam heater.
- k Figure B.24, option F: When specified, two tapped grounding pads positioned diagonally to each other shall be provided.
- l Individual oil returns shall be located away from the pump suction and arranged to provide the maximum residence time.

Figure B.24 — Oil reservoir (*continued*)

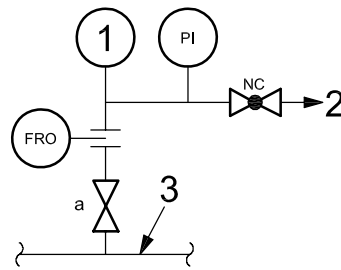


Key

- 1 vent/bleed
- 2 block
- 3 service line

- a Figure B.25, option A: If approved by the purchaser, a combination block and bleed gauge valve may be substituted for individual block and vent/bleed valves, except as specified in Footnote b.
- b Block, isolation and vent-bleed valves can be omitted for all instruments in trip service with owner's approval.
- c For services of less than or equal to 1 400 kPa (14 bar, effective; 200 psig), bleed valves may be omitted, except for arrangements shown in Figures B.26 and B.27 or when Footnote b applies.

Figure B.25 — Local instrument piping details — Pressure gauges, switches, and transmitters

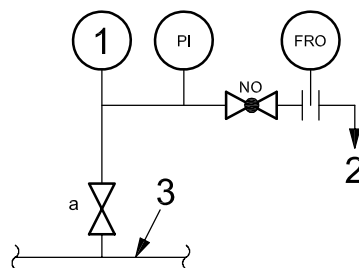


Key

- 1 alarm(s)
- 2 to reservoir or drain line
- 3 service line

^a The block valve may be locked open.

Figure B.26 — Local instrument piping details — Combined instrument system for low-pressure alarms and pump-start switches (typical design)



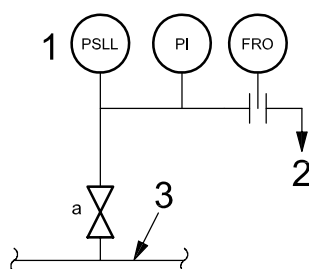
Key

- 1 alarm(s)
- 2 to reservoir or drain line
- 3 service line

^a Figure B.27, option B: The purchaser may specify a block valve. The block valve may be locked open.

NOTE This design is intended for cold climates and for pump-running alarm switches (high-pressure switches).

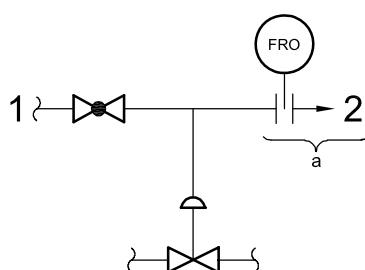
Figure B.27 — Local instrument piping details — Combined instrument system for low-pressure alarms and pump-start switches (alternative design)



Key

- 1 trip
- 2 to reservoir or drain line
- 3 service line
- a The block valve may be locked open.

Figure B.28 — Local instrument piping details — Low-pressure trip switch (alternative design)

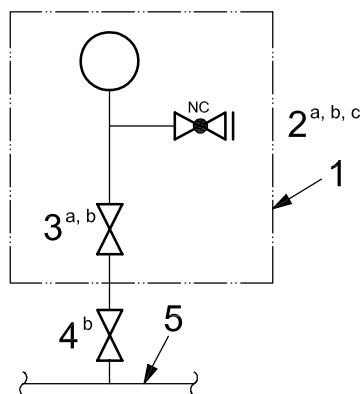


Key

- 1 signal
- 2 to reservoir
- a The reservoir and flow-restriction orifice are for oil service.

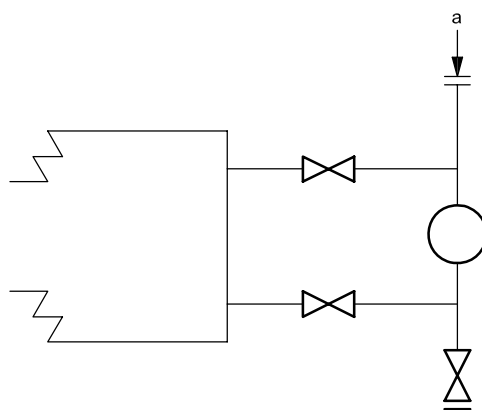
NOTE A diaphragm actuator is not required for air signals unless other devices are receiving the same signals.

Figure B.29 — Instrument piping details — Diaphragm actuator



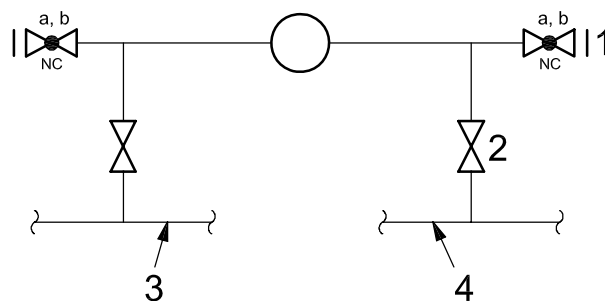
- Key**
- 1 gauge board
 - 2 vent/bleed
 - 3 isolation valve
 - 4 block valve
 - 5 service line
- a Combination isolation/bleed valve may be used.
- b Block, isolation and vent-bleed valves can be omitted for all instruments in trip service with owner's approval.
- c For services of less than or equal to 1 400 kPa (14 bar, effective; 200 psig), bleed valves may be omitted, except for arrangements shown in Figures B.26 and B.27 or when Footnote b applies.

Figure B.30 — Remote instrument piping details — Panel- and board-mounted gauges, switches and transmitters



- a This connection may be added to facilitate cleaning of the level indicator.

Figure B.31 — Instrument piping details — Externally connected level instruments



Key

- 1 vent/bleed
- 2 block
- 3 source a
- 4 source b

^a Block, isolation and vent-bleed valves can be omitted for all instruments in trip service with owner's approval.

^b For services of less than or equal to 1 400 kPa (14 bar, effective; 200 psig), bleed valves may be omitted, except for arrangements shown in Figures B.26 and B.27 or when Footnote a applies.

Figure B.32 — Local instrument piping details — Differential instruments, diaphragm actuators, indicators, switches, and transmitters

Annex C (informative)

Inspector's checklist

Table C.1 — Inspector's checklist

Item	Date Inspected	Inspected By	Status
1) Sound pressure level requirements met (4.1.5)			
2) Oil characteristics:			
a In accordance with specification (4.1.7)			
b Hydrotest compatible (ISO 10438-1:2007, 7.3.2.1)			
c Run-test compatible (7.3.3.5)			
3) Compatible rust preventatives used [ISO 10438-1:2007, 7.4.3 c), 7.4.3 d)]			
4) Lube-oil/seal-oil separation demonstrated, if applicable (4.1.6)			
5) System arrangement (4.1.12):			
a In accordance with drawings			
b Providing adequate clearances			
c Providing safe access			
d Adequate for maintenance (4.1.12, 4.1.13)			
6) ASME code stamp, if applicable (4.1.17):			
a Coolers			
b Filters			
c Accumulators			
d Lube-oil rundown tanks (4.9.2)			
e Drain traps			
f Other pressure vessels			
g Overhead seal-oil tanks (4.9.1.3)			
h Degassing drum (4.11.6)			
7) Welding operators and procedures qualified, e.g. Section IX of ASME Code:			
a Welding of pressure vessels (ISO 10438-1:2007, 4.6.1)			
1 Coolers			
2 Filters			
3 Accumulators			
4 Lube-oil rundown tanks			
5 Seal-oil tanks			
6 Degassing drum			
7 Other pressure vessels			
8 Oil conditioner			

Table C.1 (*continued*)

Item	Date Inspected	Inspected By	Status
b Welding of oil piping (10438-1:2007, 4.6.1)			
c Welding of oil reservoir, if specified, (4.3.11)			
d Dissimilar-metal welding and weld repairs (10438-1:2007, 4.6.1)			
e Verification of welds (ISO 10438-1:2007, 7.2.3.3)			
8) Welding procedures (other than above) (10438-1:2007, 4.6.3):			
a Baseplates			
b Panels			
c Non-pressure ducting			
d Other			
9) Baseplates:			
a Major components mounted directly on structural steel (4.2.1)			
b Adequate drain gutter (4.2.2)			
c Adequate lifting lug (distortion, damage) (4.2.4)			
d Metal decking (4.2.5)			
e Precoat for epoxy grout (4.2.7)			
10) Reservoir top sealed and sloped properly (4.3.2.1, 4.3.2.3)			
11) Manway openings adequate (4.3.4)			
12) Reservoir heaters adequate for the application (4.3.7)			
13) Clips provided:			
a Insulation clips (4.3.8)			
b Grounding clips (4.3.14)			
14) Pumps:			
a Piping vented or arranged to avoid air pockets (4.4.20)			
b Strainers installed and tabbed (4.4.21)			
c Alignment checked (4.4.31)			
d Mounting surfaces flat and parallel [4.4.32 a)]			
e Shims installed [4.4.32 b)]			
f Bolting and unbolting of piping demonstrated (7.3.3.11)			
g Jackscrews adequate [4.4.32 g)]			
15) Oil filters			
Drainability demonstrated [7.3.3.8 h)]			
16) Oil conditioner siphon breaker installed and demonstrated (4.3.10.2)			
17) Piping:			
a Examined and inspected in accordance with ISO 15649 (ISO 10438-1:2007, 5.1.1)			
b Fabricated in accordance with specification (ISO 10438-1:2007, 5.1.6)			
18) Oil drains shown to run not more than half full (ISO 10438-1:2007, 5.2.1)			

Table C.1 (*continued*)

Item	Date Inspected	Inspected By	Status
19) Electrical systems/panels (ISO 10438-1):			
a Wiring suitable (10438-1:2007, 6.4)			
b Spare terminal points adequate (10438-1:2007, 6.4.9)			
c Clearances adequate for maintenance (10438-1:2007, 6.4.10)			
d Fungus/corrosion protection provided (10438-1:2007, 6.4.11)			
e Wiring clearly labeled and isolated (10438-1:2007, 6.4.12)			
20) Material inspected as specified (list each component) (ISO 10438-1:2007, 7.2.2)			
21) Verification of compliance for buy-out items:			
a Equipment			
b Instrumentation			
c Piping, tubing, flanges and fittings			
d Electrical components			
22) Components inspected for cleanliness (list each) (ISO 10438-1:2007, 7.2.3.2)			
23) Hydrostatic tests:			
a Hydrotests certified (list each component) (ISO 10438-1:2007, 7.3.2.1)			
b Assembled oil system hydrostatic test performed (ISO 10438-1:2007, 7.3.2.1)			
c Chlorides in hydrotest liquid addressed adequately (ISO 10438-1:2007, 7.3.2.4)			
d Test pressures verified (ISO 10438-1:2007, 7.3.2.1, 7.3.2.3)			
24) Operational tests:			
a System cleanliness verified after operational tests (7.3.3.2).			
b All leaks corrected before starting [7.3.3.8 a)]			
c Limiting pressures verified [7.3.3.8 b)]			
d Filter-cooler changeover performed [7.3.3.8 c)]			
e Control valve response and stability demonstrated [7.3.3.8 d), 7.3.3.8 e)]			
f Pressure drop on pump trip checked/demonstrated [7.3.3.8 e)]			
g Transfer valve leakage demonstrated [7.3.3.8 h)]			
h System cleanliness after test demonstrated (7.3.3.9, 7.3.3.10)			
25) Painting [ISO 10438-1:2007, 7.4.3 a)]			
26) Preparation for shipment (ISO 10438-1):			
a Equipment cleaned and prepared properly [7.4.3 c)]			
b Items properly tagged [7.4.3 i)]			
c Storage/handling/installation instructions received (7.4.2, 7.4.7)			
d Piping and components adequately protected [7.4.3 j)]			
e Connections properly tagged (7.4.5)			
f Shipping documents included [7.4.3 i)]			

Bibliography

- [1] ISO 14120, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*
- [2] API STD 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*
- [3] API STD 661, *Air-Cooled Heat Exchangers for General Refinery Services*
- [4] ANSI/AMT B15.1, *Safety Standard for Mechanical Power Transmission Apparatus*
- [5] ASME B31.3, *Process Piping*
- [6] ASME BPVC-IX, *Boiler and Pressure Vessel Code — Section IX: Welding and Brazing Qualifications*
- [7] IEEE-841, *IEEE Standard for the Petroleum and Chemical Industry — Severe Duty Totally Enclosed Fan-cooled (TEFC) Squirrel Cage Induction Motors — Up to and Including 370 kW (500 hp)*
- [8] NEMA MG-1 *Motors and Generators*
- [9] ASTM B111, *Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock*
- [10] API STD 602, *Steel Gate, Globe and Check Valves for Sizes DN 100 and Smaller for the Petroleum and Natural Gas Industries*

Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and oil-control systems and auxiliaries —

Part 3: General-purpose oil systems

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Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and oil-control systems and auxiliaries —

Part 3: General-purpose oil systems

1 Scope

This part of ISO 10438, in conjunction with ISO 10438-1, specifies requirements for oil systems for general-purpose applications. These oil systems can provide lubrication oil, but not seal oil and can serve equipment such as compressors, gears, pumps and drivers.

NOTE The term “general-purpose” is defined in ISO 10438-1.

2 Normative references

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

ISO 10438-1:2007, *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 1: General requirements*

ISO 10438-2:2007, *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 2: Special-purpose oil systems*

ISO 13706:2005, *Petroleum, petrochemical and natural gas industries — Air-cooled heat exchangers*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

ISO 15649:2001, *Petroleum and natural gas industries — Piping*

ISO 16889, *Hydraulic fluid power — Filters — Multi-pass method for evaluating filtration performance of a filter element*¹⁾

API RP 686, *Machinery Installation and Installation Design*

IEC 60034 (all parts), *Rotating electrical machines*

TEMA, *Standards of the Tubular Exchanger Manufacturers Association*

NEMA MG1, *Motors and Generators*

1) To be published. (Revision of ISO 16889:1999)

3 Terms, abbreviated terms and definitions

For the purposes of this document, the terms, definitions and abbreviated terms given in ISO 10438-1 apply.

4 General

4.1 Basic design

- **4.1.1** This part of ISO 10438 covers general-purpose oil systems. Typical datasheets for general-purpose oil systems are in Annex A. Typical piping and instrument diagrams for general-purpose oil systems are in Annex B. Typical inspector checklists for general-purpose oil systems are in Annex C. General-purpose (GP) oil systems are divided into classes and are defined by a coding system that defines the major components supplied (see Table 1). The user shall choose the applicable class and code based upon the required minimum reliability targets for the equipment train. Various API standards have supplied minimum recommended systems as indicated in Table 2 for their equipment. Annex D is supplied as a reference to provide guidance on the selection of a system.

Table 1 — General-purpose oil system class types with standard configuration options

Equipment	Class I	Class II	Class III
Pump configuration	Shaft-driven main pump only	Shaft-driven main pump and motor auxiliary pump	Motor main and motor auxiliary pump
Positive displacement	P0	P0	P0
Centrifugal	N/A	N/A	P1
Reservoir part of equipment (i.e. gear case)	R0	R0	R0
External stainless reservoir	R1	R1	R1
Stainless pipe	Default	Default	Default
No reservoir heater included	H0	H0	H0
Reservoir heater	H1	H1	H1
Baseplate part of equipment	BP0	BP0	BP0
Stand-alone console, reservoir mounted (No baseplate)	BP1	BP1	BP1
Stand-alone console with full baseplate	BP2	BP2	BP2
Single cooler and single filter	C1F1	C1F1	C1F1
Single cooler and dual filter	C1F2	C1F2	C1F2
Dual cooler and single filter	C2F1	C2F1	C2F1
Dual cooler and dual filter	C2F2	C2F2	C2F2
Shell-and-tube cooler(s)	C0	C0	C0
Plate-and-frame cooler(s)	C1	C1	C1
Fin/Fan cooler	C2	C2	C2
Combined plv/pcv (not applicable to centrifugal pumps)	PV0	PV0	PV0

Table 1 (*continued*)

Equipment	Class I	Class II	Class III
Separate PCV	PV1	PV1	PV1
No thermostatic valve included	TV0	TV0	TV0
Thermostatic valve	TV1	TV1	TV1
No block-and-bypass valves included	BB0	BB0	BB0
Block-and-bypass valves around PCV	BB1	BB1	BB1

EXAMPLE 1 General-purpose system designations: Class I-P0-R1-H1-BP1-C1F2-C0-PV0-TV0-BB0

Shaft-driven main pump
 Positive-displacement pump
 External stainless steel reservoir
 Reservoir heater included
 Stand-alone console reservoir mounted equipment (no baseplate)
 Single cooler and dual filters
 Shell and tube cooler type
 Combined PLV and PCV
 No thermostatic valve
 No block and bypass valves

EXAMPLE 2 General-purpose system designations: Class III-P0-R1-H1-BP2-C2F2-C0-PV1-TV1-BB1

Motor-driven main and motor-driven auxiliary pump
 Positive-displacement pumps
 External stainless steel reservoir
 Reservoir heater included
 Stand-alone console with full baseplate
 Dual coolers and dual filters
 Shell and tube cooler type
 Separate PLV and PCV
 Thermostatic valve
 Block and bypass valves

Table 2 — Recommendations of minimum GP system class by equipment

Equipment type ^a	P&ID figure	Console class and code
ISO 13709 or API 610	B.1	Class II – P0-R1-H0-BP0-C1F1-C0-PV0-TV0-BB0
API 611	B.1	Class II – P0-R1-H0-BP1-C1F1-C0-PV0-TV0-BB0
ISO 13707 or API 618	B.2	Class II – P0-R0-H1-BP2-C1F2-C0-PV0-TV1-BB0
API 672	B.3	Class II – P0-R0-H1-BP0-C1F2-C0-PV1-TV1-BB0
API 673	B.4	Class III – P0-R1-H1-BP1-C1F1-C0-PV0-TV1-BB0
API 674	B.5	Class I – P0-R0-H0-BP0-C1F1-C0-PV0-TV0-BB0
API 677	B.5	Class I – P0-R0-H0-BP0-C1F1-C0-PV0-TV0-BB0
NOTE 1 This table is presented for guidance in the selection of a lubrication system for the above referenced equipment.		
NOTE 2 The recommended base systems are based on the individual referenced equipment standard recommendations at the time of publication of this part of ISO 10438.		
^a The referenced equipment standards may suggest alternative base systems in editions published subsequent to this part of ISO 10438, or the user may select alternative systems based on his experience or a Failure modes and effects analysis (FMEA) as described in Annex D.		

4.1.2 The oil system supplied shall be capable of supplying sufficient quantities of clean, filtered oil at proper temperature and pressure for start-up and all operating conditions of the serviced rotating equipment.

4.2 General

4.2.1 The equipment (including auxiliaries) covered by this part of ISO 10438 shall be designed and constructed for a minimum service life of 20 years.

NOTE It is recognized that this is a design criterion.

- **4.2.2** The purchaser shall specify the design goal for uninterrupted operation (mission time) of the equipment.

NOTE Annex D is available as a guide for system reliability goals.

4.2.3 The oil system shall be suitable for general purpose applications as defined in ISO 10438-1:2007, 3.1.17. The system shall be designed as a separate console or may be designed to be integral with the baseplate of the equipment it serves. If components are spared, the design shall allow for transfer between and shutdown of the main and spared components of the system for maintenance without interrupting the operation of the system or the equipment the system serves. General-purpose systems supply lubricating oil only (i.e. no seal oil) and do not require an accumulator to cover transient conditions.

An accumulator may be specified in accordance with ISO 10438-2, however, it is normally not required on this class of equipment.

- **4.2.4** The purchaser shall specify the equipment's normal operating point and alternate operating points, including transients.
- **4.2.5** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor having unit responsibility. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified. In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for the equipment.
- **4.2.6** Where oil is supplied from a common system to two or more machines (such as a compressor, a gear and a motor), the oil's characteristics shall be specified by the purchaser on the basis of mutual agreement with all vendors supplying equipment served by the common oil system.

- **4.2.7** The system shall be designed to supply oil to all equipment specified.

4.2.8 Recycled oil originating upstream of the filters is preferred and is required when there is a possibility of an explosive mixture in the reservoir.

NOTE This is to minimize the potential for generation of static electricity (or a static charge) that can result when filtered oil bypasses the equipment and is recycled directly to the reservoir.

- **4.2.9** If specified, the arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

NOTE For some pre-engineered general purpose oil systems, purchaser input might be impractical.

- **4.2.10** If specified, minimum defined requirements for clearance around and access to components (especially clearance around and access to coolers, filters and hand valves) shall be incorporated as design requirements.

- **4.2.11** If specified, pumps, filters, strainers, coolers, traps, valves and all other components that retain oil under pressure and are external to the reservoir shall be made of steel.

4.2.12 Unless otherwise specified, pumps may be submerged in the reservoir and these may be made of cast iron.

- **4.2.13** If specified, valved vents, drains and piping shall be furnished to permit draining, cleaning and refilling of idle components while the equipment is in operation.

- **4.2.14** Unless otherwise specified, coolers, filters, overhead oil tanks, drain traps, accumulators and other pressure vessels shall be in accordance with the specified pressure design code. If specified by the purchaser, vessels shall be code stamped.

NOTE 1 Code stamping might not be applicable for pressure design codes other than ASME.

NOTE 2 Local jurisdictions can require a code stamp.

NOTE 3 Code stamping can require additional inspection over the life of the equipment.

- **4.2.15** The vendor shall advise the purchaser of, and both parties shall mutually agree upon, any special provisions that are necessary to ensure that an adequate back-up supply of lube oil is maintained in the event of complete failure of the primary lube-oil supply system. These provisions may include standby pumps, rundown tanks and special arrangements for equipment safety and protection when the equipment decelerates. Provisions shall be adequate for coast-down time and cool-off time, as applicable. The purchaser and the vendor shall mutually agree on the system and its components.

4.2.16 Block valves that interrupt the oil flow to the equipment shall not be installed in oil supply lines downstream of the filters unless the block valves are part of a component block and bypass arrangement.

4.2.17 When components that can require later removal for maintenance are installed using screwed connections, the connecting piping shall be provided with flanges such that the component can be removed without requiring cutting pipe or major disassembly of the unit.

4.3 Baseplates

4.3.1 The major components (pumps, filters, coolers and reservoir) shall be mounted directly on structural steel as a separate console or integrated with the equipment base.

NOTE Reference can be made to the baseplate section of the lubricated equipment specification for baseplate requirements when the console is integrated into the equipment base.

4.3.2 Unless otherwise specified, package baseplates shall be of the drain-gutter type with one or more drain connections at least DN 40 (NPS 1 1/2). Baseplates, mounted components and decking shall be arranged and installed to ensure drainage and avoid the retention of liquid. Sloping of the decking is not required.

- **4.3.3** If specified, sloped decking shall be furnished.

4.3.4 The baseplate shall be provided with lifting lugs for at least a four-point lift or other suitable means. The baseplate shall be designed so that after the components and all piping mounted on it are drained of oil, the package can be lifted without permanently distorting or otherwise damaging either the baseplate or any component mounted on it.

- **4.3.5** If specified, metal decking covering all walk and work areas shall be provided on the top of the baseplate. If furnished, metal decking shall be non-skid.

NOTE Decking might not be required when the grout pour is used to create a walking surface.

- **4.3.6** If specified, baseplates shall be suitable for installation in accordance with API RP 686. Unless otherwise specified, all baseplates shall be provided with at least one opening or hole in each bulkhead section through which grout can be poured and vented. Each opening shall have a clear area of no less than 125 cm² (20 in²) and no dimension less than 100 mm (4 in), and each shall permit filling and venting of the entire cavity with grout under the baseplate without creating air pockets. Each hole into which the grout is poured shall be accessible: no component or piping shall be disturbed and no tripping hazards in walk and work areas shall be created. Vent holes at least 13 mm (1/2 in) in diameter shall be provided for each bulkhead compartment. Each grout hole shall also be provided with steel curbing 13 mm (1/2 in) high to prevent accumulated oil or water from entering the grout. Vent holes shall be provided without curbing.
- **4.3.7** If specified, the baseplate shall be suitable for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

4.3.8 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation and grouted as specified in 4.3.6, accessibility for grouting under all load-carrying structural members shall be provided.

4.3.9 Levelling screws shall be provided in the proximity of each hold-down bolt.

4.4 Oil reservoirs

4.4.1 General

Reservoirs shall be separate or combined with the equipment baseplate and be rigid enough to prevent sagging and vibration. Components bolted to the reservoir shall be mounted on pads; no bolt holes shall extend into the reservoir.

4.4.2 Protection from dirt and water

Reservoirs shall be sealed to prevent dirt and water from entering. Top-surface openings shall be raised at least 6 mm (1/4 in) and shall have a gasket. When pumps, coolers or filters are mounted on top of the reservoir, the reservoir top may be provided with a drain rim or gutter and one or more drain connections.

NOTE For installations on an existing equipment base, a drain rim or gutter might not be required on the reservoir.

4.4.3 Oil connections and internal piping

4.4.3.1 All oil return flow streams shall be hydraulically located as far away from the pump suction connections as possible.

NOTE The use of the term "hydraulically located as far away" is intended to convey the concept that return flow streams can be directed by internal piping or baffling to avoid disturbing the oil flow at pump inlets. This internal piping or baffling can

be used in lieu of external connections physically located such a distance from the pump suction that they avoid disturbing the oil flow at the pump inlets.

4.4.3.2 All atmospheric oil return connections (including fill connections) shall be located above the maximum operating level and shall transport oil (via open-top stilling tubes or degassing trays) as shown in ISO 10438-2:2007, Figure B.24. Stilling tubes shall have bottom baffles.

4.4.3.3 Pump suction connections shall be located at least 50 mm (2 in) above the reservoir bottom.

4.4.3.4 Reservoir pipe connections 40 mm (1 1/2 in) and larger shall be flanged.

4.4.4 Manways and drains

4.4.4.1 Reservoirs shall be furnished with a valved and blind-flanged or plugged-drain connection.

- **4.4.4.2** If specified, to ensure complete drainage, the bottom of each reservoir shall be sloped to a low point drain.
- **4.4.4.3** If specified, a drain connection (with a valve and a blind flange) at least 50 mm (2 in) in diameter shall be provided.

4.4.4.4 Reservoirs shall be provided with unobstructed access for direct interior visual inspection and cleaning. Manways, if required, shall be at least 600 mm × 600 mm in diameter (24 in × 24 in). If manway-sized access is not required for inspection or cleaning, a minimum 150 mm × 150 mm (6 in × 6 in) port or ports shall be provided.

4.4.5 Features and appendages

The oil reservoir shall have the following features and appendages:

- a) capacity to settle moisture and foreign matter adequately and to provide allowance for rundown from the entire system;
- b) provisions to eliminate air and minimize migration of foreign matter to each pump suction;
- c) reservoir-level indicator, such as a dipstick, level gauge, or bulls eye;
- d) if specified, an oil level glass arranged to cover the span from at least 25 mm (1 in) above the rundown level to 50 mm (2 in) below the pump suction-loss level. The oil level glass shall be located as far away as possible from the oil return lines and be visible from the perimeter of the unit. The maximum and minimum operating levels, rundown level and suction-loss level shall be indicated on the glass. If more than one level glass is provided, they shall be offset. The top glass shall be of the weld pad type;
- e) weatherproof, corrosion-resistant filter-breather cap at least 50 mm (2 in) in diameter with filtration rating of 10 µm beta 10 or better shall be provided (this connection may also be used as a fill opening);
- f) if specified, a fill opening at least 50 mm (2 in) in diameter that automatically closes (normally held shut by a spring) and is equipped with a stainless steel fine-mesh strainer basket that has an open area equal to 200 % of the internal pipe area;
- g) internal baffles that are not gas-tight;
- h) individual, non-pressurized reservoir return lines that shall enter the reservoir above the maximum operating level (see ISO 10438-1:2007, Annex F).

4.4.6 Capacity and configurations

- **4.4.6.1** If specified, a low-level alarm that actuates at the minimum operating level shall be provided.

4.4.6.2 The criteria for sizing a reservoir are given in a) and b) below.

NOTE Refer to ISO 10438-1:2007, Annex F.

- a) The working capacity between the minimum operating level (key item 3 in ISO 10438-1:2007, Figure F.1) and the suction-loss level (key item 4 in ISO 10438-1:2007, Figure F.1) shall be sufficient for at least 3 min of normal flow.
- b) The rundown capacity shall allow for all of the oil contained in all of the components, bearings housings, rundown tanks, control elements and vendor-furnished piping that drain back to the reservoir. The rundown capacity shall also allow for at least an additional 10 % of these volumes for the purchaser's interconnecting piping.

NOTE Rundown can cause some backup in the drain lines entering the reservoir.

4.4.7 Heating

- If specified, an electric heater shall be furnished in accordance with the following.
 - a) If an electric heater is specified, a thermostatically controlled, removable electric immersion heating element shall be provided for heating the charge capacity of oil before start-up in cold weather. The device shall have the capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start-up temperature within 12 h. Heater elements shall be sheathed in austenitic stainless steel or incoloy ²⁾; copper or copper-bearing materials shall not contact the oil. A level interlock device shall be furnished.

Electric immersion heaters should be level interlocked by the purchaser to be de-energized when the oil level drops below the minimum operating level.

For heating the lube oil to minimum starting temperature, many factors, including lube pump start-up minimum oil temperature, equipment minimum oil temperature, circulating heat loss, etc., shall be considered. Many of these factors are the responsibility of the installing contractor and should be coordinated with the console designer. Insulation, location and heat-tracing requirements shall be considerations of the installation.

- b) Direct-contact electric heaters shall have a maximum watt density of 2,32 W/cm² (15 W/in²).
- c) If specified, the heater shall be installed in a manner that allows the heater(s) to be removed during operation.
- d) The hot section of the heater element shall be located a minimum of 50 mm (2 in) below the minimum operating level.

4.4.8 Provision for insulation

- If specified, reservoirs shall be fitted with insulation clips. The purchaser shall furnish and install the insulation.

4.4.9 Plugged connections

- If specified, each reservoir shall be provided with one threaded and plugged connection above the rundown oil level of at least DN 25 (NPS 1). This connection may be used for such services as purge gas, makeup oil supply and oil conditioner return.

2) Incoloy is an example of a suitable product available commercially. This information is given for the convenience of users of this part of ISO 10438 and does not constitute an endorsement by ISO of this product. This term is used as an example only, and does not constitute an endorsement of this product by API.

4.4.10 Special features

- **4.4.10.1** If specified, a clearly accessible ladder with extended handrails and non-skid working surface shall be provided.
 - **4.4.10.2** If specified, handrails around the perimeter of the reservoir top shall be provided.
 - **4.4.10.3** If specified, non-skid surface decking shall be provided on the top of the reservoir.
- 4.4.10.4** For equipment mounted on the reservoir, the reservoir shall provide sufficient structural stiffness to properly support the equipment.
- 4.4.10.5** If the reservoir top is used as a personnel access area, it shall be designed to withstand a live load of 1 100 N (250 lbf) without permanent distortion.

4.4.11 Materials

- 4.4.11.1** Unless otherwise agreed upon between the purchaser and the vendor, reservoirs and all appendages (except ladders and handrails) welded to reservoirs shall be fabricated from austenitic stainless steel.
- 4.4.11.2** Reservoir nozzle connections shall be as specified in the piping section for oil service. (See Clause 5.)
- 4.4.11.3** Where reservoirs are integral with equipment or equipment baseplates, and where stainless steel inserts or cladding is not practical, coated carbon steel is acceptable upon purchaser approval.

NOTE Certain equipment, such as reciprocating compressors or gearboxes, that use crankcases or casings as reservoirs might be available only in alternate materials, such as cast iron.

4.4.12 Grounding

The reservoir shall be grounded either by grounding clips attached to the reservoir (for free-standing reservoirs) or through the attached base structure. In either case, two grounding clips or pads diagonally opposed to each other are required. The pads shall accommodate a 13 mm (1/2 in UNC) bolt.

4.5 Pumps and pump drivers

- **4.5.1** The oil system shall include an oil pump suitable for continuous operation. The purchaser shall specify whether centrifugal or rotary pumps shall be used. If specified, pumps shall conform to ISO 13709 or ASME B73.2 or ASME B73.3 for the centrifugal pumps and to API STD 676 for rotary pumps.

NOTE For the purposes of this provision, API STD 610 is equivalent to ISO 13709.

4.5.2 Each pump shall be driven separately.

4.5.3 Unless otherwise specified, the main oil pump (unless it is shaft-driven) shall be motor-driven.

When primary and standby pumps are motor-driven, it is recommended that the purchaser supply electric feeds from independent sources.

- **4.5.4** If specified, or required by the lubricated equipment supplier, an electric-motor-driven standby pump shall be provided for start-up and/or main-pump failure backup.

NOTE Standby pumps are not always required. Some equipment, such as equipment utilizing ring-oiled bearing lubrication, might not require pre-priming and use of a standby pump.

- **4.5.5** Motors shall comply with the area classification and shall comply with NEMA MG1 or applicable part(s) of IEC 60034.

"C-flanged" motors may be used for motors equal to or below 7,5 kW (10 hp).

4.5.6 The minimum criteria given in a) through c) shall be used when sizing pumps.

- a) In all cases, pumps shall be sized to deliver the required capacity when pumping lube oil at the highest temperature and the corresponding minimum viscosity (see 4.5.8).
- b) Each pump (main or standby) shall be capable of supplying the normal oil flow required by the equipment plus 20 % of the normal oil flow.
- c) Rotary pumps shall be capable of passing the total flow, as established in b), at the pressure-limiting valve set pressure while not exceeding 90 % of the pump manufacturer's maximum differential pressure rating at the minimum operating viscosity. The pump shall also be capable of operating continuously at the normal flow, pressure-limiting valve set pressure and minimum operating viscosity.

NOTE This selection criterion is required to avoid pump rotor contact during operation under extreme conditions.

4.5.7 The normal operating capacity of the centrifugal pumps shall be within 50 % to 110 % of their best efficiency point. From their normal operating point to shutoff, centrifugal pumps shall have a continuous rise in head of at least 5 % and, with the installation of a new impeller, shall be capable of a future increase in head of at least 10 %.

4.5.8 Pump drivers shall be sized in accordance with a) or b) as applicable.

- a) Centrifugal pumps shall deliver the specified system pressure across the pump's stable flow range when the temperature of the pumped oil is 10 °C (50 °F).
- b) Rotary pumps shall be capable of operating at the specified pump pressure-limiting valve setting (including accumulation) when the temperature of the pumped oil is 10 °C (50 °F).

4.5.9 Check valves shall be provided on each pump discharge to prevent the flow of oil backwards through a standby or idling pump.

Shaft-driven pumps may use a drilled check valve or an orificed line to prime the pump (see ISO 10438-1:2007, 4.5.6).

4.5.10 For rotary-pump systems, the vendor shall furnish external pressure-limiting valves that shall be installed on the pump or in the piping supplied by the vendor. This valve shall not be used for pressure control. Pressure-limiting valve settings, including an allowance for accumulation, shall be determined after all of the possible equipment and component failures are considered. The settings shall protect the oil-system components and piping. Fully accumulated pressure cannot exceed 110 % of the system design pressure.

4.5.11 Oil-pressure limiting valves (PLV) shall be pressure-modulating devices (as opposed to snap-acting or pop-type safety relief valves) with a pressure increase proportional to flow above the valve cracking pressure (that is, the pressure at which the valve begins to open). These devices shall be mounted external to the reservoir and shall operate smoothly, without chattering and without causing a drop in supply pressure to the equipment. Pressure-limiting valve piping shall be sized for the full flow of each pump; the valves shall not chatter and the piping shall not vibrate. The minimum pressure-limiting valve cracking pressure shall be 10 % or 170 kPa (1,7 bar; 25 psi) higher than the highest required operating pressure, including operation at 10 °C (50 °F), whichever is greater. To avoid unnecessary delay in opening, pressure-limiting valve takeoff points shall be located as close to the oil pump discharge as possible. Pressure-limiting valves shall not be used for continuous pressure regulation.

4.5.12 The oil system shall be provided with pressure-regulating devices that prevent fluctuation of the oil pressure to the equipment serviced by the lube-oil console when both the main and the standby pump are in operation or when either the main or the standby pump is in operation and the other pump is started, brought up to operating speed or stopped. Each device shall have an adequate response time and shall operate smoothly without hunting, chattering or producing pressure or flow transients that can cause a mechanical problem or shutdown of the equipment [see 7.3.3.7 e)]. These pressure-regulating devices shall be located so that an excessive rise in oil temperature resulting from a recirculation of uncooled oil is avoided (see, for example, ISO 10438-2:2007, Figure B.11). Where non-pressure-regulating PLV's are used, the pressure-regulating valve shall be selected such that the PLVs do not lift during two-pump operation.

NOTE Additional supply pressure is acceptable during two-pump operation as long as this over-pressurization is compatible with the equipment serviced by the lube oil-console.

4.5.13 All pumps (except shaft-driven pumps) shall be installed with flooded suctions to ensure self-priming and shall be installed with suction-block valves (unless the pumps are inside the reservoir) and with discharge-block and check valves. Vertically mounted pumps shall be continuously vented to assure the entire pump remains flooded. Shaft-driven pumps shall have adequate provision for priming and be of positive displacement design. Suction piping shall be continuously vented or arranged to avoid pockets in which air can accumulate or become trapped. Each pump shall have a separate suction line from the reservoir. The pump-suction lines shall be designed to avoid excessive piping loads on the pump casing flanges. Designs for suction piping, suction-block valves, pump casings and all other components shall avoid the possibility of overpressure caused by leaking discharge check valves.

NOTE Reference can be made to API RP 686 for piping design for pump installation.

- **4.5.14** If specified, for the protection of externally mounted centrifugal pumps during flushing and for the initial operation of new oil systems, a removable strainer made from austenitic stainless steel and having an open flow area equal to 150 % of the cross-sectional area of the suction pipe shall be installed in the suction piping of each pump between the pump-suction flange and the block valve. The temporary strainer shall be identified by a protruding tab and shall have a mesh size adequate to stop all objects that can be injurious to the pump. The piping arrangement shall permit the removal of the strainer without disturbing the alignment of the pump. The maximum strainer hole size shall be 3 mm (1/8 in).

NOTE Strainer can be cone-, basket- or Y-type.

4.5.15 Unless otherwise specified, for rotary pumps, a permanent Y-type strainer with an austenitic stainless steel basket having a minimum open flow area equal to 150 % of the cross-sectional area of the suction pipe shall be installed in the suction piping of each pump. The strainer shall have a mesh size in accordance with the pump manufacturer's recommendation. A blowdown/drain valve shall be provided on strainers. Strainers can require use of a bushing for blowdown connections if required by space limitations. These bushings shall be rated for the pressure rating of the pipe as a minimum. The maximum strainer hole size shall be 3 mm (1/8 in).

NOTE 1 Strainer bodies can require removal from the system for basket access.

NOTE 2 Elimination of these bushings can raise pump-suction connections.

4.5.16 If a standby pump is furnished (4.5.4), in order to maintain satisfactory system operation when the main pump fails to meet system requirements, the vendor shall furnish an automatic start-up control for the standby oil pump. The start-up control of the standby pump shall be actuated by low oil-supply pressure. Motor control centres shall be provided by the purchaser. The control system shall have a manual reset.

Scope of supply for controls and reset should be mutually determined by the purchaser and the vendor. The lube-console manufacturer normally provides only a pressure-sensing device.

4.5.17 Removable coupling guards shall be furnished.

4.5.18 A non-spacer elastomeric coupling with the following characteristics is acceptable for power ratings up to 22 kW (30 hp).

- a) Couplings and coupling-to-shaft junctures shall be rated for at least the maximum driver power (including any motor service factor).
- b) To assure that the connected machinery is accurately aligned, the total indicator reading of coupling registration and alignment surfaces shall be controlled within specific limits. For all pumps, the coupling surfaces normally used for checking alignment shall be concentric with the axis of coupling hub rotation within the following limits: 13 µm (0,000 5 in) total diameter, with a minimum applicable tolerance of 25 µm (0,001 inch) total indicator reading and a maximum of 75 µm (0,003 in) total indicator reading. All other diameters not used for location, registration or alignment shall be to the coupling manufacturer's standard, provided balance requirements are met.

4.5.19 For drivers larger than 7,5 kW (10 hp), mounting plates shall be provided with the following specifications.

NOTE Reference can be made to 4.5.5, second paragraph.

- a) If specified, mounting pads shall be provided for each pump and its driver. Pads shall be at least 25 mm (1 in) larger than the feet of the mounted equipment to allow for leveling of the console or package baseplate without removal of the equipment. The pads shall be fully machined, flat and parallel. Corresponding surfaces shall be in the same plane within 125 $\mu\text{m}/\text{m}$ (0,002 in/ft) of distance between the pads. To prevent distortion, machining of mounting pads shall be deferred until welding on the baseplate in close proximity to the mounting pads has been completed. This tolerance shall be met at the time of assembly at the vendor's shop between coupled rotating pieces of equipment. The coupled pieces shall be capable of being re-aligned in the field when the console is properly installed in accordance with API RP 686.
- b) Pumps and drivers shall be mounted on a machined surface. All pads for oil pumps and drivers shall be machined to allow for the installation of stainless steel shims; shim packs, at least 3 mm (1/8 in) thick, shall be placed under the feet of each component.

NOTE Due to mounting surface tolerances on purchased pumps and drivers, it can be necessary to install shims of different thicknesses under each foot. Additionally, shims under the pump are required to allow future shimming of a replacement pump to the inlet pipe. (The small-PD pump tolerance equals 130 μm (0,005 in) from foot to foot, and the NEMA motor and large-PD pump tolerance equals 260 μm (0,010 in) from foot to foot.)
- c) To minimize misalignment of the pump and driver shafts due to piping-load effects, the pump and its baseplate shall be constructed with sufficient structural stiffness to limit total misalignment to the values specified in 4.5.18 b).
- d) When the pump and driver are mounted on the console without a separate sub-base, the pump and driver shall be affixed to a structural member of the console base rather than merely being attached to deckplate or other non-structural components.
- e) If specified, or when drivers exceed 45 kg (100 lb), transverse- and axial-alignment positioning jackscrews shall be provided for all pump drivers. The lugs holding these positioning screws shall be attached to the baseplate so that the lugs do not interfere with the installation or removal of the component. Alignment-positioning screws shall be at least the same size as the jackscrews furnished with each component.
- f) Supports, jack screws and their attachments shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews when provided.

4.6 Coolers

4.6.1 General

4.6.1.1 Unless otherwise specified, coolers shall be provided to maintain the oil-supply temperature at or below 50 °C (120 °F).

NOTE Under certain ambient site conditions or with certain viscosities of oil, it can be necessary to operate with an oil-supply temperature greater than 50 °C (120 °F).

4.6.1.2 Coolers (if required by 4.6.1.1) shall be in accordance with the requirements as follows, and unless otherwise specified shall be shell-and-tube type.

- a) If specified, a plate frame or fin-fan cooler shall be supplied. The vendor shall include in the proposal complete details of any proposed air-cooled or plate frame cooler.

NOTE Reference can be made to 4.6.3 for plate frame coolers and to 4.6.4 for fin-fan coolers.

- b) If specified, the vendor shall supply connections for installation of the purchaser's fin-fan oil cooler(s) off the oil console.
- c) When the purchaser supplies the off-console cooler(s), the elevation and runback volume shall be provided to the console supplier in order to properly size pressure drop criteria for the oil side, which shall be mutually agreed upon between the vendor and purchaser.
- d) Unless otherwise specified for duplex cooler arrangements, the equalization/fill valve shall be locked or car sealed in the open position with the equalization/fill line orifice thermally sized by the vendor to provide thermal overprotection.
- e) If specified in lieu of the requirements of d) for duplex cooler arrangements, the vendor shall provide thermal over-pressure protection of the oil side of the coolers by providing separate thermal relief valves.
- f) If specified, a cooling water system or systems shall be designed for the following conditions:

— Velocity over heat-exchange surfaces	1,5 m/s to 2,5 m/s	(5 ft/s to 8 ft/s)
— Maximum allowable working pressure	≥ 690 kPa	(≥ 100 psig)
— Test pressure ≥ 1,5 × MAWP	≥ 1,03 MPa	(≥ 150 psig)
— Maximum pressure drop	103 kPa	(15 psi)
— Maximum inlet temperature	30 °C	(90 °F)
— Maximum outlet temperature	50 °C	(120 °F)
— Maximum temperature rise	20 K	(30 °R)
— Minimum temperature rise	10 K	(20 °R)
— Fouling factor on water side	0,35 m ² K/kW	(0,002 hr·ft ² °F/Btu)
— Carbon steel corrosion allowance	1,5 mm	(0,063 in)

- g) Provision shall be made for complete venting and draining of the system or systems.

h) The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat-exchange surfaces result in a conflict. The criterion for velocity over heat-exchange surfaces is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. The purchaser shall approve the final selection.

i) Oil coolers shall have the following characteristics.

- 1) Each cooler shall be sized to accommodate the total cooling load.
- 2) Oil coolers shall not be located inside the reservoir.

- **4.6.1.3** If specified, an oil bypass line around the cooler with a temperature-control valve shall be included to regulate the oil-supply temperature. This includes oil systems where the purchaser supplies the cooler. In no case, however, shall oil bypass the filter. The control valve shall be in accordance with the following provisions a) to d).

NOTE When fouling or freezing of the water side of a cooler is a factor, and oil temperature is regulated by adjusting water flow through the cooler, it is possible for the cooler water-side to silt up or freeze and break at low water-flow rates.

a) Unless otherwise specified, the oil by-pass valve shall be a thermostatically operated three-port valve.

- b) If specified, the oil bypass valve shall be a flanged and pneumatically operated (air-to-open fail-close), two-port or three-port, temperature control valve. Failure of the control valve shall cause all the oil to pass through the cooler.

NOTE Three-port valves can direct the oil more advantageously due to system pressure drops and allows all of the oil to bypass the cooler; however, they can complicate bypass arrangements required for maintenance versus a two-port valve.

- c) If specified, the temperature control valve shall be provided with a manual override that permits operation independent of temperature conditions.
- d) The temperature control valve shall be sized to handle all oil flow passing through the cooler. For a three-way temperature control valve, the pressure drop should not exceed that through the cooler. For a two-way temperature control valve, pressure drop should not exceed 50 % of the pressure drop through the cooler.

4.6.1.4 The maximum allowable working pressure for coolers shall not be less than the maximum operating pressure of the system, shall not be less than the pressure limiting valve setting for the positive displacement pumps or shall not be less than the maximum discharge pressure (at the trip speed for the turbine drive) for the centrifugal pumps.

- **4.6.1.5** If specified, shell-and-tube or plate-frame coolers shall be suitable for use of a 150 °C (300 °F) heating medium, such as steam or a mixture of steam and water.

Steam may be used for auxiliary heating on start-up by sparging it into the cooling water. Steam should not be introduced directly into the cooler.

4.6.1.6 Both the water side and the oil side of the cooler shall be provided with valved vent/drain connections.

- **4.6.1.7** If specified, the coolers shall be fabricated with flanged vent and drain nozzles. Screwed and seal-welded or socket-welded pipe and flange additions to coolers after cooler certification is not acceptable.
- **4.6.1.8** If specified, cooler oil drains shall be manifolded together with filter clean-side oil drains.
- **4.6.1.9** If specified, vents on the oil side shall be piped back to the reservoir through flow indicators.

NOTE These vent lines are normally tubed.

4.6.2 Shell-and-tube coolers

4.6.2.1 In addition to the requirements of 4.6.1, shell-and-tube coolers shall be in accordance with the following.

- a) Shell-and-tube coolers shall have water on the tube side. Unless otherwise specified, a removable-bundle design is required for coolers with more than 0,5 m² (5 ft²) of heat-transfer area. Removable-bundle coolers shall be in accordance with TEMA Class C or other heat exchanger code specified and shall be constructed with a removable channel cover. Nominal tube outside diameter shall be at least 9 mm (3/8 in) and nominal tube wall thickness shall be at least 18 BWG (1,245 mm; 0,049 in). U-bend tubes may be supplied with purchaser's approval (see 4.6.2.2).

NOTE Some non-repairable coolers might be available in thinner tubes. 26 BWG [0,457 mm (0,018 in) in 3/8 tube] is commonly available.

- b) To prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure, unless otherwise specified.

- c) If specified, the oil-side operating pressure shall be lower than the water side operating pressure.

NOTE Concerns with oil leakage into the water, especially on once-through water systems, can outweigh equipment protection concerns.

- d) Unless otherwise specified, fin tubes or extended-surface tubes are allowed.

4.6.2.2 U-bend tubes are permitted when approved by the purchaser.

4.6.2.3 Unless otherwise specified, cooler shells, channels and covers shall be of steel; tube sheets shall be of brass and tubes shall be of a copper/zinc/tin non-ferrous material such as UNS C44300 (ASTM B111) (inhibited admiralty brass).

NOTE Naval brasses (60/40/1 and 70/30/1 copper/zinc/tin) are particularly resistant to impingement of high-velocity water and are commonly used in marine condensers. An alternate choice can be aluminium bronze material.

- **4.6.2.4** If specified, alternate materials shall be provided for cooler shells, tubes, channels and covers.

Alternate materials should be considered for salt- and brackish-water services. Tube materials such as 90-10 copper-nickel can be an appropriate choice for such services. Stainless steel tubes are generally not recommended because of chloride-cracking problems in salt- and brackish-water services and poorer heat-transfer characteristics.

4.6.3 Multi-plate type coolers

4.6.3.1 If specified, and in addition to the requirements of the general cooler section, multi-plate type coolers shall be in accordance with the following.

- a) Multi-plate coolers shall have plates of austenitic stainless steel for fresh-water cooling or titanium for brackish or salt water, or as specified by the purchaser.
- b) To prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure, unless otherwise specified.
- c) If specified, the oil-side operating pressure shall be lower than the water-side operating pressure.

NOTE Concerns with oil leakage into the water, especially on once-through water systems, can outweigh equipment protection concerns.

4.6.4 Air-cooled heat exchangers

4.6.4.1 Air-cooled heat exchangers are infrequently required on these systems and when provided are frequently specified using purchaser's specifications. Guidance is provided in 4.6.4.2 and 4.6.4.3 for when a detailed specification is not available.

- **4.6.4.2** The purchaser may specify sizing and configuration or connections only for purchaser separate supply of air cooled heat exchangers.

4.6.4.3 If specified, fin-fan type coolers shall be provided. If provided, in addition to the requirements of 4.6.1, they shall be in accordance with the following provisions a) to h).

- a) If specified, the cooler shall be provided with two fans. Each fan shall be capable of 100 % of the duty requirement.
- b) If specified, the cooler tubes shall be austenitic stainless steel.
- c) If specified, the header boxes shall be made of stainless steel plate. The header plug material shall be selected to prevent galling.
- d) An inlet header and an outlet header shall be provided for each cooler.
- e) If specified, vibration detectors shall be provided for each fan and shall alarm on high vibration.
- f) Belt drive requirements shall be in accordance with ISO 13706:2005, 7.2.

NOTE For the purposes of this provision, API STD 661 is equivalent to ISO 13706.

- g) Turbulence promoters may be used only with purchaser approval. When supplied, promoters shall be austenitic stainless steel.
- h) Cooler headers shall be made of carbon steel.

4.7 Filters

4.7.1 Duplex replaceable full-flow filter with replaceable elements or cartridges shall be provided. Filters shall provide a minimum particle removal efficiency, E_{PR} , of 90 % for 10 μm particles ($\beta_{10} \geq 10$), and a minimum E_{PR} of 99,5 % of 15 μm particles ($\beta_{15} \geq 200$), both in accordance with ISO 16889 when tested to a minimum terminal (end-of-test run) differential pressure of 350 kPa (3,5 bar; 50 psid). Filter installations shall be in accordance with the following provisions a) to g).

NOTE 1 Reference can be made to ISO 10438-1:2007, Annex D, for additional information concerning filter ratings.

NOTE 2 These filtration levels are based on the film thickness in hydrodynamic bearings. The film thickness of rolling-element bearings is typically in the range of 0,1 μm . Considerations of oil-film thickness and particle hardness can require even finer filtration levels.

- a) If specified, a single filter shall be provided.
- b) The filters shall be located downstream of the coolers.

NOTE Coolers can trap and release dirt and debris.

- c) The filters shall be piped in a parallel arrangement using a continuous-flow transfer valve (see 4.8).
- d) Filter cases and heads shall be suitable for operation at the maximum discharge pressure (at the trip speed for turbine drives) of centrifugal pumps or at a pressure not less than the pressure-limiting device setting of positive-displacement pumps.

- e) Filters that have covers weighing more than 15 kg (35 lbm) shall have cover lifters.
- f) The filters shall not be equipped with differential pressure-limiting valves or other valves that can cause bypass of unfiltered (dirty) oil around the filter elements.
- g) The filters shall be equipped with NPS-pipe-size plugged or blind-flanged vent and drain connections.

4.7.2 For duplex filter arrangements, the vendor shall provide for the equalization/fill valve to be locked or car sealed in the open position with the equalization/fill line orifice thermally sized by the vendor.

NOTE This provides thermal over-protection of the standby filter in addition to the primary function of pressure equalization for filling and switching filters.

- **4.7.3** If specified for duplex filter arrangements where the filters are not in accordance with 4.7.2, the vendor shall provide thermal over-pressure protection of the off-line filter.
- **4.7.4** If specified, duplex oil-filter clean-side oil drains shall be manifolded together with duplex cooler drains.
- **4.7.5** If specified, the filter vents shall be routed back to the oil reservoir.

NOTE These filter vent lines are normally run with tubing.

- **4.7.6** If specified, the filter vents lines specified in 4.7.5 shall have flow indicators.

NOTE These filter vent lines are normally run with tubing.

4.7.7 Oil-filter design shall be in accordance with the following provisions a) to p).

- a) Oil shall flow from the outside inward toward the centre of the filter element.
- b) Oil flow from the centre towards the outside of the filter element may be provided with purchasers approval.
- c) Adequate support of the filter elements shall be provided to prevent them from rupturing or to prevent unfiltered (dirty) oil from bypassing the elements and reaching the equipment.
- d) Centre posts and other hardware in contact with filtered oil that are not integral with the filter housing shall be made of stainless steel.
- e) The maximum number of filter cartridges permitted in one stack shall be two.
- f) If the cartridge-to-cartridge joint is not self-aligning, a collar shall be used between the stacked cartridges to ensure alignment.
- g) Filter stacks shall not exceed 1 m (3 ft).
- h) Stacked cartridges shall have adequate support and maintainable alignment.
- i) It shall be possible to drain oil from the filter housing while avoiding contamination of the downstream (clean) side with unfiltered (dirty) oil during replacement of the filter elements.
- j) Filter cartridge materials shall be water- and corrosion-resistant.
- k) Water-resistant filter cartridges shall not deteriorate if water contamination in the oil reaches 5 % by volume and the operating temperature, as high as 70 °C (160 °F).

- l) If specified, filter element media shall be non-hydrosopic. Clean filter cartridges shall not have more than two times the clean-filter pressure drop at the rated oil viscosity, flow and temperature with water contamination of up to 5 %.
- m) When a specific filter element or cartridge is required, the purchaser shall completely specify the make, the model number and the type of construction.
- n) Metal mesh or sintered metal filter elements are not acceptable.
- o) The pressure drop for clean filter elements or cartridges shall not exceed 30 kPa (0,30 bar; 5 psi) at an operating temperature of 40 °C (100 °F) and normal flow. Pressure drop across the total filter system may exceed these values by the amount of pressure drop across the transfer valve and other filter-system components.

NOTE The 30 kPa (0,30 bar; 5 psi) is the difference between the drop across the filter housing with no elements installed and the drop across the filter housing with clean elements installed.

- p) Elements or cartridges shall have a minimum collapsing differential pressure of 500 kPa (5 bar; 70 psi).

4.7.8 When the tops of filter housing covers are higher than 1,2 m (4 ft) above the console base, the vendor shall provide a step to facilitate their maintenance.

4.8 Transfer valves

4.8.1 Unless otherwise specified, the vendor shall supply individual transfer valves independently serving each cooler set and each filter set (see ISO 10438-2:2007, Figure B.20).

4.8.2 Transfer valves shall be two-way, six-ported continuous-flow valves. A single-body, six-port taper or a straight plug valve, with or without resilient seats, may be used; or two, three-way plug or ball valves permanently aligned and joined with a single operating lever may be used. Transfer valves shall conform to the following provisions a) to d).

- a) Tapered plug-type valves shall have provisions for plug lifting.
- b) Valves shall be designed so that, if the internal valve mechanisms fail, both flow paths shall not be blocked.
- c) Valves and assemblies shall be designed to prevent incorrect assembly.
- d) Transfer valves with resilient seats shall be capable of transfer without sliding contact. Resilient seats shall be positively retained.

4.8.3 Transfer valves shall have steel bodies. Valve stems and valve plugs or balls shall be made of stainless steel.

- **4.8.4** Spectacle blinds shall be provided, if specified or if required to assure tight shutoff.

NOTE 1 Transfer valves are not intended for use as tight shutoff devices for the maintenance of filters and coolers [see 7.3.3.7 g)].

NOTE 2 Transfer valves with resilient seats provide tighter shutoff.

4.9 Lube-oil rundown tanks

- **4.9.1** If specified, a separately mounted emergency lube-oil rundown tank (either atmospheric or pressurized) shall provide oil for the coast-down period specified by the purchaser. This tank shall be sized for not less than 3 min of normal operating lube-oil flow (see ISO 10438-2:2007, Figures B.15 and B.16). Unless otherwise specified, the tank shall be made of austenitic stainless steel.

Coast-down time shall be provided by the purchaser (normally the supplier of the equipment served by the oil system).

NOTE The minimum sizing criteria results in more than 3 min of coast-down oil flow due to supply-pressure decay.

4.9.2 A rundown tank shall be provided with a sight flow glass in the tank overflow line. The sight flow glass shall be located in an area that can be readily observed, such as the oil reservoir or equipment operating deck. A DN 150 (NPS 6) nozzle for accessing and inspecting the interior of the rundown tank shall be provided. Alternatively for atmospheric rundown tanks, a bolted cover can be provided in lieu of the DN 150 (NPS 6) nozzle for access and inspection. The vendor shall specify the allowable minimum and maximum height of the bottom outlet nozzle above the machine centreline; the maximum static head shall be less than the lube-oil trip pressure but not less than 30 kPa (0,30 bar; 5 psig) at the beginning of the coast-down.

4.9.3 When an atmospheric rundown tank is provided in accordance with ISO 10438-2:2007, Figure B.15, it shall be provided with low-level alarm and high-level permissive start functions. These functions may be served by a common device.

4.9.4 A pressurized tank (ISO 10438-2:2007, Figure B.16) shall be considered to be a pressure vessel and shall be designed in accordance with 4.2.14.

5 Piping

5.1 General

5.1.1 All piping shall be in accordance with ISO 10438-1:2007, Clause 5, unless otherwise specified in 5.1.2 and 5.1.3.

5.1.2 The radiographic requirements associated with pipe fabrication in accordance with the piping design code, e.g. ISO 15649, are not required (see ISO 10438-1:2007, 5.1.1).

- **5.1.3** If specified, radiographic requirements associated with pipe fabrication shall be in accordance with the specified code.

5.2 Oil piping

Piping shall be in accordance with ISO 10438-1:2007, Tables 4, 5 and 6.

5.3 Instrument piping

Piping shall be in accordance with ISO 10438-1:2007, Tables 4, 5 and 6.

5.4 Water piping

Piping shall be in accordance with ISO 10438-1:2007, Table 3, 5 and 6.

6 Instrumentation and electrical systems

6.1 Instrumentation shall be in accordance with ISO 10438-1:2007, Clause 6, except as modified in 6.2 to 6.4.

6.2 As a minimum, the vendor shall furnish and mount devices to facilitate the alarm and shutdown functions specified in Table 3. The alarm setting shall precede the shutdown setting.

Table 3 — Conditions requiring alarms and shutdowns

Condition	Alarm	Shutdown
Low pressure to start standby oil pump ^a	x	—
Low pressure to lubricated equipment	x	x
Pump running for each standby and emergency pump ^b	—	—
High oil temperature leaving cooler	—	—
Low level for oil reservoir	—	—
High level for atmospheric lube-oil rundown tank (optional) ^a	x	—
High differential pressure for each oil-filter set ^c	x	—
^a If applicable. ^b Not required if the purchaser's alarms are from the motor control centre. ^c The differential pressure indicator shall span the filter-cooler set when a single continuous-flow-transfer valve is used.		

- **6.3** Unless otherwise specified, the requirements of ISO 10438-1:2007, 6.2.1.1, are not applicable.

NOTE ISO 10438-3 systems require shutdown for maintenance of instrumentation unless optional redundant instrumentation is provided.

6.4 The requirements of ISO 10438-1:2007, 6.3.9.3, apply, except that flow indicators may have screwed connections.

7 Inspection, testing and preparation for shipment

7.1 General

- If specified, the purchaser's or the vendor's representative shall indicate compliance in accordance with the inspector's checklist (Annex C) by initialling, dating and submitting the completed checklist to the purchaser before shipment.

7.2 Inspection

The oil system furnished shall meet the cleanliness requirements of 7.3.3.8 a) and 7.3.3.8 b).

7.3 Testing

7.3.1 General

7.3.1.1 Equipment shall be tested in accordance with 7.3.2 and 7.3.3. Other tests may be specified and shall be jointly developed by the purchaser and the vendor.

- **7.3.1.2** The purchaser shall specify whether the purchased oil system is used during the shop testing of the equipment.
- **7.3.1.3** Complete-unit tests or other tests of the oil system and the equipment it serves shall be performed in place of or in addition to separate tests of the oil system as specified by the purchaser. Details of these tests shall be developed jointly by the purchaser and the vendor.
- **7.3.1.4** If specified, the vendor, by bolting and unbolting piping, shall demonstrate that the pump on its baseplate is in compliance with 4.5.18 b).

7.3.2 Hydrostatic test

The hydrostatic test is to be performed in accordance with ISO 10438-1:2007, 7.3.2.

7.3.3 Operational tests

7.3.3.1 Unless otherwise specified, the complete oil system shall be run in the vendor's shop to test its operation and cleanliness. The oil used shall be as mutually agreed and shall be compatible with the system oil (see 4.2.6).

7.3.3.2 At least 6 weeks before testing, the vendor shall submit to the purchaser, a complete description of the proposed test program.

7.3.3.3 The running tests shall be conducted under normal system operating conditions for at least 2 h. The operational tests may be done concurrently within the 2 h.

7.3.3.4 All filter elements shall be installed prior to the operational tests.

7.3.3.5 If console-mounted, the low-oil-pressure alarm, the standby-pump start and the shutdown switches purchased for the project shall be used for the operational tests.

7.3.3.6 All oil pressures and viscosities shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested.

7.3.3.7 The operational testing of the oil system shall be conducted in the sequence given in a) to g) as follows.

- a) The oil system shall be thoroughly checked for leaks; all leaks shall be corrected prior to testing.
- b) The limiting pressures shall be determined so that the subsequent proper operation of each pressure-limiting valve may be verified.
- c) A filter-cooler changeover shall be accomplished without the system delivery pressure dropping to the automatic-start setting of the standby pump.
- d) When a standby pump is furnished, It shall be demonstrated that, after a failure or trip of the main oil pump, the standby pump will start automatically and return the system to normal operating pressure without the delivery pressure dropping below the equipment's shutdown pressure.
- e) When a standby pump is furnished, it shall be demonstrated that the control valve or valves are capable of controlling the oil pressure when only one pump (either the main or the standby pump) is operating at the normal bearing-oil requirements and when both pumps are operating at normal bearing-oil requirements. The test shall be considered satisfactory when no abnormal conditions occur during the operational test. Some abnormal conditions are system instability, an excessive drop in delivery pressure, alarm or shutdown signals or other conditions that require operator attention.

NOTE A shaft-driven main pump can require a string test or field test to verify two-pump operation.

- f) All warning, protective and control devices shall be checked and adjustments shall be made as required.
- g) While the system is at maximum operating pressure, the internal side-to-side leakage around the plugs of continuous-flow transfer valves shall be demonstrated to be less than the drainage capability of the inactive filter housings. Leakage shall not exceed the expected or specified rates.

7.3.3.8 Conformity to the criteria for system cleanliness listed in a) to c) following shall be demonstrated.

- a) System cleanliness shall be demonstrated by the vendor after the operational tests.

- b) After 1 h of oil circulation at the design flow rate and a temperature of 66 °C to 71 °C (150 °F to 160 °F) or lower, as component design dictates, screens placed at all discharge terminations from the console or the packages and at other strategic points mutually agreed upon by the purchaser and the vendor shall be within the particle count limits listed in ISO 10438-1:2007, Table D.6. The screen mesh shall be No. 100 plain-weave, stainless steel wire with a diameter of 0,1 mm (0,004 in) and a 0,15 mm (0,006 in) opening. The largest particle dimension shall not exceed 0,25 mm (0,010 in) and the particles shall be randomly distributed on the screen. Piping, coolers and valves shall be hammered frequently during the test.

NOTE Reference can be made to ISO 10438-1:2007, Annex D, for a discussion of alternate methods of measuring oil cleanliness.

- c) If dismantling of the oil system is required to modify the system to improve operation, the initial running test shall not be conclusive and final tests shall be run only after corrections are made. In any event, the demonstration of cleanliness shall be conducted only after the final assembly.

7.4 Preparation for shipment

The oil system shall be prepared for shipment in accordance with ISO 10438-1:2007, 7.4.

8 Vendor's data

8.1 General

- If specified, a coordination meeting shall be held, within 4 to 6 weeks after order commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting, which, as a minimum, shall include review of the following items:
 - a) purchase order, scope of supply, unit responsibility, subvendor items and lines of communication;
 - b) datasheets;
 - c) applicable specifications and previously agreed exceptions;
 - d) schedules for transmittal of data, production and testing;
 - e) quality assurance program and procedures;
 - f) inspection, expediting and testing;
 - g) schemas and bills of material;
 - h) physical orientation of the equipment and piping in the auxiliary systems, including access for operation and maintenance;
 - i) plot plan and equipment layout;
 - j) other technical items.

8.2 Proposals

8.2.1 Proposal shall be prepared in accordance with ISO 10438-1:2007, 8.2.

8.2.2 Where equipment bases are used as reservoirs, the vendor shall include in the proposal retention time and working capacity as well as an experience list of similar systems with similar retention time and working capacity.

Annex A **(informative)**

Datasheets

This annex contains a link to datasheets in both SI and USC units, together with an explanatory note. To access the appropriate datasheet, click on "[Datasheet](#)", then the first page tab for Figure A.1 — Scope and attachments. Select the appropriate set of units from the menu available.

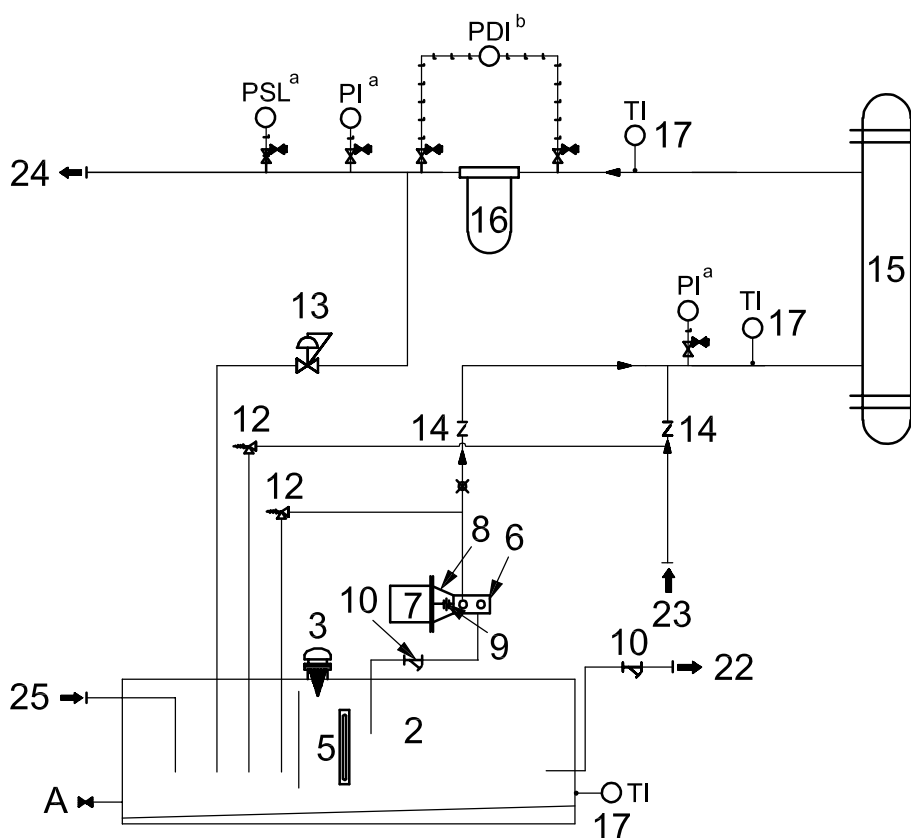
The options for units are the following:

- USC units;
- SI units (MPa);
- SI units (kPa);
- metric (kg/cm²);
- hybrid.

Piping and instrument diagrams

This annex contains complete system piping and instrument diagrams (P&IDs) for some common systems (All available variations are not included.) See Table 1 for console codes and Table 2 for base recommendations for various equipment.

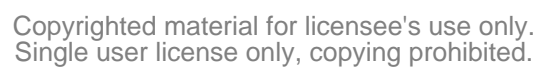
See Annex D for reliability guidance, which can be used to help determine options required for a given service.

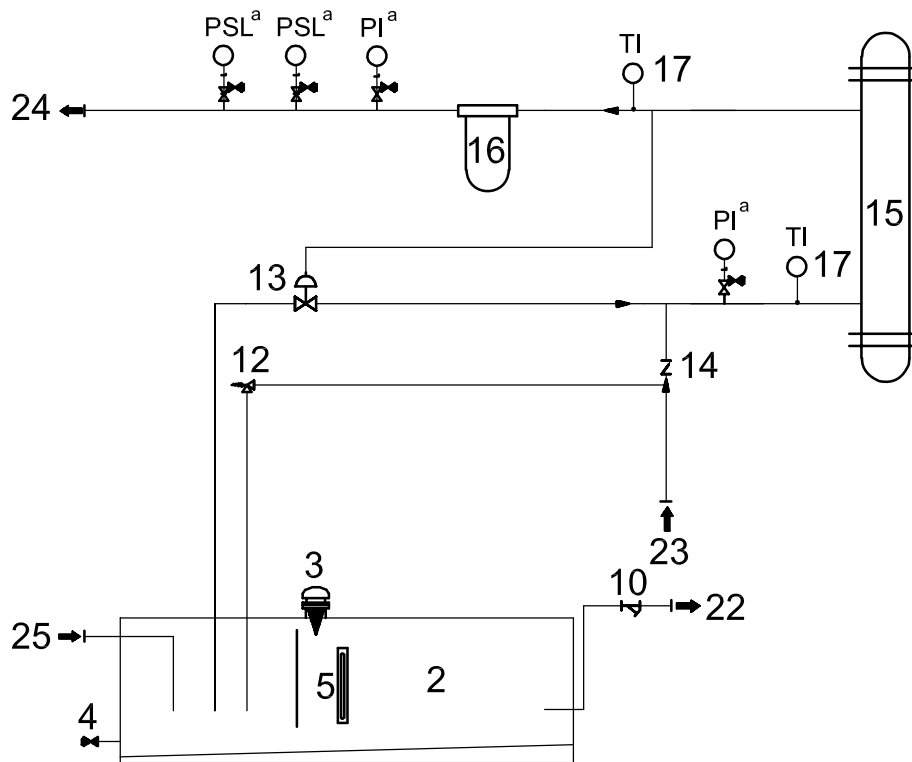


See Table B.1.

NOTE See Table 1 for console class and code description. In the title, “BP0” indicates that the baseplate is part of equipment; “BP1” indicates a stand-alone console, reservoir-mounted. The P&IDs are similar.

**Figure B.1 — Class II – P0-R1-H0-BP0-C1F1-C0-PV0-TV0-BB0 or
Class II – P0-R1-H0-BP1-C1F1-C0-PV0-TV0-BB0**



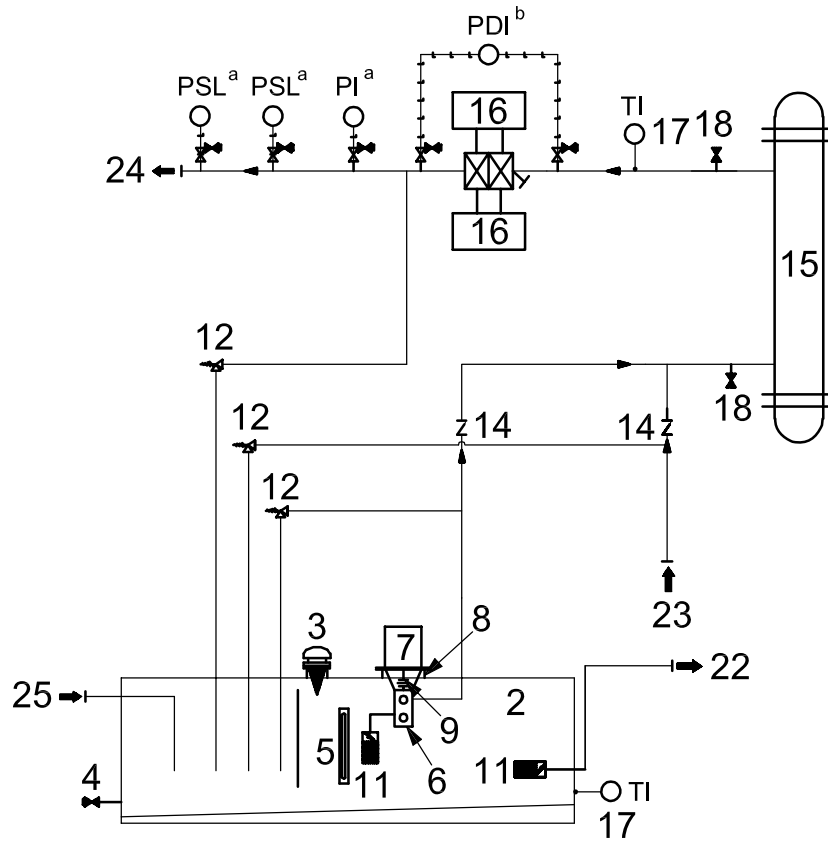


Key

See Table B.1.

NOTE See Table 1 for console class and code description.

Figure B.3 — Class II – P0-R0-H1-BP0-C1F2-C0-PV1-TV1-BB0

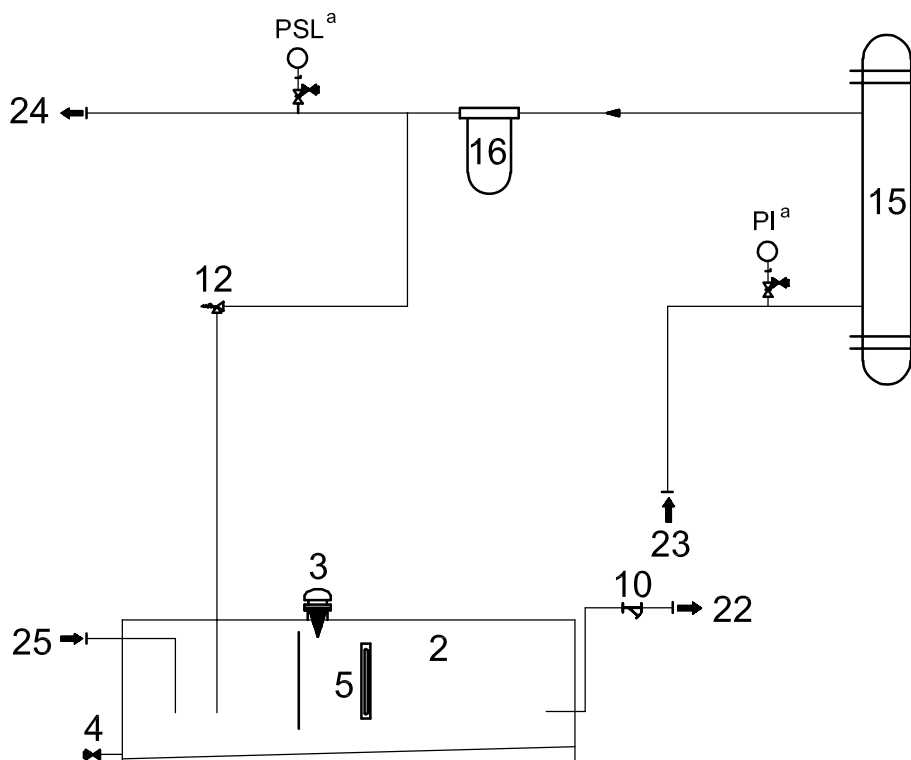


Key

See Table B.1.

NOTE See Table 1 for console class and code description.

Figure B.4 — Class III – P0-R1-H1-BP1-C1F1-C0-PV0-TV1-BB0



Key

See Table B.1.

NOTE See Table 1 for console class and code description.

Figure B.5 — Class I – P0-R0-H0-BP0-C1F1-C0-PV0-TV0-BB0

Table B.1 — Identification of key items in Figures B.1 to B.5

1	baseplate	15	cooler
2	reservoir	16	filter
3	filler/breather	17	thermowell
4	drain valve	18	vent
5	level gauge	19	drain
6	lube oil pump	20	reservoir heater
7	lube oil pump motor	21	temperature-control valve
8	pump/motor bracket	22	to shaft-driven pump
9	coupling	23	from shaft-driven pump
10	strainer	24	to equipment bearing housings
11	footvalve/strainer	25	from equipment-bearing housings
12	pressure limiting valve	a	See ISO 10438-2:2007, Figure B.25.
13	pressure control valve	b	See ISO 10438-2:2007, Figure B.32.
14	check valve		

Annex C (informative)

Inspector's checklist

Table C.1 — Inspector's checklist

Item	Date inspected	Inspected by	Status
1) Sound pressure level requirements met (4.2.5)			
2) Oil characteristics:			
a In accordance with specification (4.3.8)			
b Hydrotest compatible (ISO 10438-1:2007, 7.3.2.1)			
c Run-test compatible (7.3.3.1)			
3) Compatible rust preventatives used [ISO 10438-1:2007, 7.4.3 c), 7.4.3 d)]			
4) Lube-oil/seal-oil separation demonstrated (if applicable) (4.2.6)			
5) System arrangement (4.2.9):			
a In accordance with drawings			
b Providing adequate clearances			
c Providing safe access			
6) ASME code stamp (if applicable) (4.2.14):			
a Coolers			
b Filters			
c Accumulators			
d Other pressure vessels			
7) Welding operators and procedures qualified in accordance with section IX of ASME code:			
a Welding of pressure vessels (4.2.14):			
(1) Coolers			
(2) Filters			
(3) Accumulators			
(4) Other pressure vessels			
b Welding of oil piping (4.2.1)			
c Dissimilar-metal welding and weld repairs (4.2.14)			
d Verification of welds (ISO 10438-1:2007, 7.2.3.3)			
8) Welding procedures (other than above) (ISO 10438-1:2007, 4.6.3):			
a Baseplates			
b Panels			
c Non-pressure ducting			
d Other			

Table C.1 (*continued*)

Item	Date inspected	Inspected by	Status
9) Baseplates:			
a Major components mounted directly on structural steel (4.3.1)			
b Adequate drip rim (4.3.2)			
c Adequate lifting lug (distortion, damage) (4.3.4)			
d Metal decking (4.3.5)			
10) Reservoir top sealed properly (4.4.2)			
11) Manway openings adequate (4.4.4)			
12) Reservoir heaters adequate for the application (4.4.7)			
13) Clips provided:			
a Insulation clips (4.4.8)			
b Grounding clips (4.4.12)			
14) Pumps:			
a Piping vented or arranged to avoid air pockets (4.5.13)			
b Strainers installed and tabbed (4.5.14)			
c Alignment checked [4.5.18 b)]			
d Mounting surfaces flat and parallel [4.5.19 a)]			
e Shims installed [4.5.19 b)]			
f Bolting and unbolting of piping demonstrated (7.3.1.4)			
g Jackscrews adequate [4.5.19 e)]			
15) Oil filters:			
Drainability demonstrated [4.7.7 l)]			
16) Piping:			
a Examined and inspected in accordance with ISO 15649 (ISO 10438-1:2007, 5.1.1, 5.1.11)			
b Fabricated in accordance with specification (ISO 10438-1:2007, 5.1.6)			
17) Oil drains shown to run not more than half full (ISO 10438-1:2007, 5.2.1)			
18) Electrical systems/panels:			
a Wiring suitable (ISO 10438-1:2007, 6.4.1)			
b Spare terminal points adequate (ISO 10438-1:2007, 6.4.9)			
c Clearances adequate for maintenance (ISO 10438-1:2007, 6.4.10)			
d Fungus/corrosion protection provided (ISO 10438-1:2007, 6.4.11)			
e Wiring clearly labeled and isolated (ISO 10438-1:2007, 6.4.12)			
19) Material inspected as specified (list each component) (ISO 10438-1:2007, 7.2.2)			
20) Components inspected for cleanliness (list each) (ISO 10438-1:2007, 7.2.3.2.)			

Table C.1 (*continued*)

Item	Date inspected	Inspected by	Status
21) Verification of compliance for buy-out items:			
a Equipment			
b Instrumentation			
c Piping, tubing, flanges and fittings			
d Electrical components			
22) Hydrostatic tests:			
a Hydrotest certified (list each component) (ISO 10438-1:2007, 7.3.2.1)			
b Assembled oil-system hydrostatic test performed (ISO 10438-1:2007, 7.3.2.1)			
c Chlorides in hydrotest liquid addressed adequately (ISO 10438-1:2007, 7.3.2.4)			
d Test pressures verified (ISO 10438-1:2007, 7.3.2.2, 7.3.2.3)			
23) Operational tests:			
a System cleanliness verified after operational tests [7.3.3.8 a)]			
b All leaks corrected before starting [7.3.3.7 a)]			
c Limiting pressures verified [7.3.3.7 b)]			
d Filter-code changeover performed [7.3.3.7 c)]			
e Control-valve response and stability demonstrated [7.3.3.7 e)]			
f Pressure drop on pump trip checked/demonstrated [7.3.3.7 e)]			
g Transfer-valve leakage demonstrated [7.3.3.7 g)]			
h System cleanliness after test demonstrated [7.3.3.8 a)]			
24) Painting [ISO 10438-1, 7.4.3 a)]			
25) Preparation for shipment (all in ISO 10438-1)			
a Equipment cleaned and prepared properly [7.4.3 c)]			
b Items properly tagged [7.4.3 i)]			
c Storage/handling/installation instructions received (7.4.2, 7.4.7)			
d Piping and components adequately braced [7.4.3 j)]			
e Connections properly tagged (7.4.5)			
f Shipping documents included [7.4.3 i)]			

Annex D **(informative)**

Guidance to system reliability

Prior to the first edition of ISO 10438 (all parts) in 2003, the predecessor standard, API 614, was directed at systems where only the most critical reliability demands were required. ISO 10438-2 and ISO 10438-4 still require these high-reliability levels for critical non-spared equipment with long mission times. With the introduction of coverage for general-purpose systems in this, the second edition of this part of ISO 10438, a broad new class of systems was introduced for which it is necessary to better balance the initial cost and system reliability to maximize the effectiveness in meeting business requirements.

System design for less-than-critical systems is a trade-off between initial cost associated with taking too much risk vs. taking too little risk of meeting the reliability goal. This relates to the concept of under-investing vs. over-investing. (i.e. the trade-off between system reliability and initial cost) The real issues to determine are: What is the cost of unreliability and how much availability (or unavailability) can you afford?

Methods exist utilizing sophisticated software to aid in the determination of the probability that a particular system can meet the required mission time specified by the business. These methods require reliability data on individual components for input into the system analysis and require a level of sophistication and analysis that is not usually conducted on non-critical systems due to the level of complexity involved in the analysis.

While some sophisticated users take this approach to optimize design for a general-purpose system, the more commonly used approach taken is to provide guidance based on the past experiences of the user to aid in considering the deviations that can be taken from the base systems. (These deviations can either increase or decrease the system reliability and, inversely, the system cost depending upon the mission time and the business need.) These types of deviation decisions have historically been made based on experience, but require an individual or individuals with sufficient operating experience to recognize the potential risks involved in order to make an informed judgment.

One approach to help determine what additional options should be considered (or base requirements deleted) on a given system is to consider possible failure modes of the components and the actions that can be taken to mitigate the risk associated with a particular failure mode. A failure modes and effects analysis (FMEA) has been included in this annex to assist the user in this regard. The probability of a particular failure occurring within the mission time has not been provided due to a lack of industry data and effects of site variations on failure rate; however, the example given explains how a user can utilize the FMEA table to make design decisions based on his perception of the probability of a particular failure mode within the mission time considered.

The FMEA included as Table D.1 is a first attempt to document failure modes on type of equipment covered by ISO 10438 (all parts). The system used in the example has the following characteristics:

- equipment description: lubrication system;
- classification: general-purpose;
- design life of equipment: 20 years;
- mission of equipment: 24 months (provided as an example).

NOTE It is necessary that this be determined by the user (see 4.2.2).

While efforts have been made to make it as complete as possible, the user may wish to add failure modes and risk-reduction activities based on his own experiences.

EXAMPLE A user has an application for a lubrication system for an API 610 pump. The business has defined a required mission time of 21 months. In this particular plant, the cooling-water quality is poor and tube fouling has historically been a

problem. The user feels that this failure mode reduces the probability of the system reaching the 21 month mission time required for a single cooler. The API 610 base standard system has a single cooler; however, from the FMEA, under failure modes for a cooler, tube fouling is listed along with some possible risk-reduction activities that can be considered. These include purchasing dual coolers with a transfer valve for on-line switching, keeping the water-velocity high and purchasing coolers that have tubes that can be easily rodded out. In this case, due to the poor cooling-water properties, the user specifies that all of the options be taken into consideration in his specification. The use of dual coolers in this instance allows a run-to-failure for this failure mode without affecting the system availability by allowing the standby cooler to be used while the other cooler is repaired.

Table D.1 — Failure modes and effects analysis (FMEA)

Component	Sub-component	Failure mode of sub-component	Failure cause	Example risk reduction activity	Reference
Reservoir module		inadequate heat for start-up	low ambient, no heater provided	Provide an electric or steam heater.	ISO 10438-3:2007, 4.4.7
		corrosion	material susceptibility	This part of ISO 10438 requires consideration of SS or coatings if equipment casing is utilized as a reservoir.	ISO 10438-3:2007, 4.4.11.1, 4.4.11.3
		water contamination due to a steam-turbine-driven vertical pump	poor design	Consider electric-motor-driven vertical pumps or a horizontal steam-turbine-driven pump not located on the reservoir.	—
				Use an oil conditioner on the supplied connections.	ISO 10438-2:2007, 4.3.10, Figure B.24; see conditioner connections
		moisture due to condensation	high humidity	Use a nitrogen purge with the supplied connections. Use an oil conditioner on the supplied connections.	ISO 10438-3:2007, 4.4.9 ISO 10438-2:2007, Figure B.24; see conditioner connections
	heater - electric	oil foaming	inadequate retention time	Consider a longer retention time if a gear or other equipment that tends to entrain air in the oil is involved.	ISO 10438-3:2007, 4.4.6.2; ISO 10438-2:2007, 4.3.6.4
		burnt-out element	excessive heat at element, time	Test element continuity prior to start-up when it is needed in cold weather. Specify a heater that is removable during operation.	— ISO 10438-3:2007, 4.4.7
		loss of power	electrical feed failure	—	—
		inadequate heat into the system for start-up	low ambient, excessive system heat loss	Consider the design of the entire system.	ISO 10438-2:2007, 4.3.7.1, Note
		thermostat failure - contacts fail open or closed	defective thermostat	Specify a heater that is removable during operation.	ISO 10438-3:2007, 4.4.7 c)
	heater - steam	steam leak	coil corrosion	Use a steam heater design with coils external to the reservoir.	—
		inadequate heat into the system for start-up	low ambient, excessive system heat loss	Consider the design of the entire system.	ISO 10438-2:2007, 4.3.7.1, Note
	level gauge	clouded window	time, material	Clean the siteglass, provide separate transmitter or magnetic flag type level indicator.	—
		broken glass	impact	Provide armoured siteglasses; consider location.	—
	level transmitter	loss of signal	transmitter failure	Use a self-diagnosing transmitter, replace transmitter on-line.	—
	level switch	failure to operate	switch failure	Provide external cage-type housing that can be tested on line.	—

Table D.1 (*continued*)

Component	Sub-component	Failure mode of sub-component	Failure cause	Example risk reduction activity	Reference
Pump module	shaft-driven pump	pump failure	pump-drive failure (coupling or shaft), pump failure	Provide an auxiliary pump.	ISO 10438-3:2007, 4.5.4
				Provide two motor-driven pumps for on-line replacement.	—
	motor driven pump	pump failure	coupling failure, pump failure, motor failure	Provide an auxiliary pump.	ISO 10438-3:2007, 4.5.4
		loss of power	electrical feed	Separate electrical feeds on dual motor-driven pumps.	ISO 10438-3:2007, 4.5.3, second paragraph
		life of pump component	time	Provide a HOA or HA switch for auxiliary pump testing. Specify a larger, lower-speed pump.	ISO 10438-1:2007, 6.2.1.3 —
	submerged motor-driven pump	pump failure	pump component failure	Avoid submerged pumps if local regulations do not allow access while the unit is running.	—
Cooler module	shell-and-tube or multi-plate	tube or plate leak	corrosion, erosion, manufacturing defect	Consider dual coolers for on-line swapping and on-line repair.	—
				A header pressure-control module can keep water out of the oil in the event of failure.	ISO 10438-3:2007, 4.6.2.4
				Choose alternate materials to withstand corrosion.	—
		water side fouling	mis-operation, such as live steam injection for heating	Sparge steam through the water; operate coolers only under the conditions designed.	ISO 10438-3:2007, 4.6.1.6
				Consider dual coolers for on-line swapping and on-line repair.	—
			poor cooling water quality, time, corrosion	Keep water velocity high.	ISO 10438-3:2007, 4.6.1.2, 4.6.1.8
				Choose coolers with straight tubes that can be easily rodded out, or with easily replaceable standard designs.	—
				Choose alternate materials to better withstand corrosion.	ISO 10438-3:2007, 4.6.2.4
				Use a temperature-control bypass. Do not throttle cooling water.	ISO 10438-3:2007, 4.6.1.4
				Use a shell-in-tube rather than multi-plate, which is less susceptible to fouling.	—
		loss of utility water	utility system failure	Add cooling tower or utility water pump redundancy.	—
				Car seal open any valves used in the system.	—
	multi-plate	leak	gasket failure	Use a fully welded unit (throwaway).	—
	fin-fan	fan failure	motor, v-belt, bearings, fan blades	Use multiple fans.	ISO 10438-3:2007, 4.6.4.3
				Consider direct drive rather than v-belts.	—
		oil too cold	low ambient	Provide a temperature-controlled bypass valve; consider variable shutters.	ISO 10438-3:2007, 4.6.1.4

Table D.1 (*continued*)

Component	Sub-component	Failure mode of sub-component	Failure cause	Example risk reduction activity	Reference
Filter module		collapse filter	high Δp due to cold oil	Make sure that the standby cooler is adequately warmed using a bleed valve prior to switching.	—
			high Δp due to fouling	Consider use of a Δp transmitter to trend differential if in a service where fouling can be at a high level.	—
		incorrect filter element	incorrect element used	Standardize filter element, maintenance procedures.	—
Header pressure-control module	regulator	regulator fails closed	regulator failure	Specify blocks and bypasses to repair online.	schematic
Supply pressure-reducing module	regulator	regulator fails open	regulator failure	Specify blocks and bypasses to repair online.	schematic
Rundown tank module	—	inadequate capacity for specific driver and driven equipment needs	not feasible to make large enough	Provide lube-oil pump backup via alternate source (air, nitrogen, batteries, etc.).	—
	atmospheric type	fails to flow due to cold oil	low ambient	Insulate, heat or use pressurized-type rundown tank.	—
	level transmitter	loss of signal	transmitter failure	Use a self-diagnosing transmitter; replace transmitter on-line.	—
		no permissive start signal	empty tank	Failure to manually open fill bypass or failure in automated fill bypass system.	—
Piping		connection leak	excessively long term vibration	Provide gusseting, proper support.	—
			improper installation	Use API RP 686 installation guidelines.	—
Tubing		connection leak	external loading	Revise support design; use pipe as alternative.	—
Instrumentation	pressure gauge	leak due to failed bourdon tube	fatigue, corrosion	Keep block valves closed unless actually reading pressure.	ISO 10438-1:2007, 6.3.8
				Allow replacing of blocks and bleeds on-line.	—
	pressure switch	difficult to read due to vibration	vibration, location	—	ISO 10438-1:2007, 6.3.8.2
		switch fails to act when needed	various	Use transmitters that have on-line fault-detection, assuming proper response time of system can be attained.	ISO 10438-1:2007, 6.3.2
				Periodically test switches and use multiple switches.	—
	pressure transmitter	fails to operate	internal failure	Use multiple transmitters and voting for trip signals.	—

Bibliography

- [1] ANSI/API STD 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*
- [2] ANSI/API STD 611, *General-Purpose Steam Turbines for Petroleum, Chemical and Gas Industry Services*
- [3] API STD 614, *Lubrication Shaft-Sealing and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services*
- [4] ANSI/API STD 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*
- [5] API STD 672, *Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services*
- [6] API STD 673, *Centrifugal Fans for Petroleum, Chemical, and Gas Industry Services*
- [7] ANSI/API STD 674, *Positive Displacement Pumps — Reciprocating*
- [8] API STD 676, *Positive Displacement Pumps — Rotary*
- [9] API STD 677, *General-Purpose Gear Units for Petroleum, Chemical and Gas Industry Services*
- [10] ANSI/ASME B31.3, *Process Piping*
- [11] ANSI/ASME B73.1, *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process*
- [12] ANSI/ASME B73.2, *Specification for Vertical In-Line Centrifugal Pumps for Chemical Process*
- [13] ASME B73.3, *Specification for Sealless Horizontal End Suction Metallic Centrifugal Pumps for Chemical Process*
- [14] ISO 13707, *Petroleum and natural gas industries — Reciprocating compressors*
- [15] ASTM B111, *Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock*

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Part 4: Self-acting gas seal support systems

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Part 4: Self-acting gas seal support systems

1 Scope

This part of ISO 10438 in conjunction with ISO 10438-1 specifies requirements for support systems for self-acting gas seals (dry gas seals), for example as described in ISO 10439 and ISO 10440-1. These systems can serve equipment such as compressors, gears, pumps and drivers.

NOTE For the purposes of this statement of scope, API 617 is equivalent to ISO 10439 and API 619 is equivalent to ISO 10440-1.

2 Normative references

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

ISO 10438-1:2007, *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 1: General requirements*

ISO 15649, *Petroleum and natural gas industries — Piping*

API RP 520, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries — Part I: Sizing and Selection*

API RP 520, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries — Part II: Installation*

API 526, *Flanged Steel Pressure Relief Valves*

ANSI/ASME B31.3, *Process Piping*

3 Terms, abbreviated terms and definitions

For the purposes of this document, the terms, abbreviated terms and definitions given in ISO 10438-1 apply.

4 General

4.1 System selection

Datasheets for system specifications are provided in Annex A.

Annex B provides schemas of typical system components and diagrams of typical, complete dry gas seal support systems and modules. These schemas and diagrams illustrate the general philosophy and requirements of this part of ISO 10438 and are included to assist the purchaser in the selection of an appropriate system. The purchaser and the vendor shall mutually agree upon an acceptable system.

Annex C provides an inspector checklist of typical items reviewed by the purchaser.

4.2 Basic design

4.2.1 The equipment (including auxiliaries) covered by this part of ISO 10438 shall be designed and constructed for a minimum service life of 20 years and at least 5 years of uninterrupted operation.

NOTE It is recognized that this is a design criterion.

- **4.2.2** If specified, the purchaser may specify the vendor responsible for each portion of the design, scope of supply, installation and performance of the dry gas seal system. If the purchaser is not the end user, then the end user shall approve the vendors specified.
- **4.2.3** The purchaser shall specify the equipment's normal operating point and all other operating points. Other parameters required for the design of the seal support system, such as gas composition, maximum and minimum flare pressure, maximum and minimum sealing pressure and settle-out pressure shall also be specified.

4.2.4 Unless otherwise specified, the lube-oil console and the dry gas seal module shall be mounted on separate skids.

4.2.5 The dry gas seal system shall be designed to serve the full range of equipment operating conditions specified. These conditions may include but are not limited to the following:

- a) settle-out pressures;
- b) process relief-valve settings;
- c) shop test and field run-ins;
- d) start-up conditions;
- e) gas composition.

NOTE This requires a detailed system review with the equipment suppliers, purchaser and owner, and is normally finalized at the coordination meeting.

4.2.6 Control systems shall provide adequate gas velocity across the labyrinths at all clearances, including minimum labyrinth clearance to twice the maximum design labyrinth clearance to prevent migration of contaminants from the process gas.

NOTE In a flow-control system, velocity across the labyrinths decreases as clearances increase.

4.2.7 All gas streams (including alternate, backup, start-up sources) into the seal shall be provided at a temperature of at least 20 K (35 °R) above their dew point in order to preclude the possibility of liquid entering the dry gas seal.

NOTE 1 On some systems, the discharge temperature of the compressor gas stream might not provide this dew-point margin.

NOTE 2 In some cases, this can require heaters and/or heat tracing by the owner.

The dew-point margin shall be maintained throughout the seal and not just at the supply connections.

In some cases, alternate gases to the process gas should be considered for start-up or dew-point reasons.

- **4.2.8** If specified, additional provision for seal-gas conditioning as specified by the purchaser shall be furnished.

NOTE Gas conditioning can involve heat tracing, alternate seal-gas sources, coalescing filters, or other provisions.

4.2.9 Valved vents, drains and piping shall be furnished to permit draining, cleaning and refilling of idle components, such as filter elements, while the equipment is in operation.

4.2.10 Seal-gas module piping shall be arranged such that it can be manually drained prior to start-up to avoid the possibility of condensed liquids entering the seals.

This is also a requirement for interconnecting piping that shall be followed by the packager or installation contractor.

- **4.2.11** The purchaser shall specify when and where double block and bleed valves are required for isolating a component and how they are arranged.

NOTE Double block valves are normally provided where there are safety or environmental issues associated with the reliability of a single block valve.

- **4.2.12** Filters, drain traps and other pressure vessels shall be in accordance with the specified pressure design code. The purchaser shall specify if it is necessary that the vessels be code stamped.

NOTE 1 Most vessels for the gas seal module are smaller than the size required for the ASME code stamp.

NOTE 2 Code stamping might not be applicable for pressure design codes other than ASME.

NOTE 3 Reference can be made to ISO 10438-1:2007, 4.5.7. Local jurisdictions can require a code stamp.

4.2.13 The module and components shall perform on test and on its permanent foundation within the specified acceptance criteria. After installation, the performance of the module shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

- **4.2.14** The vendor shall advise the purchaser of, and both parties shall mutually agree upon, any special provisions that are necessary to ensure that an adequate backup supply of seal gas and seal buffer gas or seal separation gas is maintained in the event of complete loss of the main seal-gas supply source. These provisions may include alternate seal-gas supply sources, backup gas bottles and special arrangements for start-up, purge gas and settle-out conditions. Provisions shall be adequate for block-in vent or purge situations as applicable. The purchaser shall specify the required block-in time. The purchaser and the vendor shall mutually agree upon the backup system and its component requirements.

4.2.15 Block valves that interrupt the gas flow to the equipment shall not be installed in gas supply lines downstream of the filters unless the block valves are part of a component block and bypass arrangement.

4.2.16 The support structure shall be stainless steel or carbon steel and painted.

4.2.17 Dry-gas-seal system piping size and vents shall be sized to prevent over-pressurization of the bearing housings in the event of a failure of the seal.

This is a system requirement, which should be coordinated between the equipment supplier (seal housing connection sizes), dry-gas-seal system module designer (vent-piping sizes) and the installation designer (vent sizes and piping lengths).

4.3 Gas filters

4.3.1 General

4.3.1.1 The filters shall have a minimum efficiency of 98,8 % on particles less than or equal to 4 μm (beta ratio, $\beta_4 \leq 85$) and shall be in accordance with the dry gas seal manufacturer's requirements.

4.3.1.2 Gas filters shall be sized for a collapse differential pressure of at least 500 KPa (5 bar; 70 psi).

4.3.1.3 The filter element material shall be designed for the maximum gas temperature and shall be compatible with the gas filtered.

4.3.1.4 Unless otherwise specified, filters in flammable or toxic services shall have bolted covers.

4.3.1.5 Unless otherwise specified, the filter housings shall be stainless steel.

4.3.2 Particulate filter sizing

4.3.2.1 For differential-pressure control systems, filters shall be sized for a clean pressure drop of 21 kPa (0,21 bar; 3 psid) at twice the gas flow calculated at maximum labyrinth design clearance and at the design differential pressure.

4.3.2.2 For flow-control systems, filters shall be sized for a clean pressure drop of 10 kPa (0,10 bar; 40 in of water) at three times normal flow.

4.3.3 Coalescing filter sizing

When the gas contains liquids or moisture, coalescing filters shall be provided. If the knockout rates exceed 50 % of the coalescing capacity of the element, a mechanical separator shall be installed ahead of the filter assembly.

4.4 Transfer valves

4.4.1 For flammable or toxic service, there shall be no leakage into the isolated system (such as the standby filter). When an isolation system is designed such that total shutoff of flow adversely affects the seal, the vendor shall provide cautionary warning signs to that effect on the dry-gas-seal system module.

NOTE Four individual block valves or a combination of block valves and transfer valves can be required for positive isolation to transfer filters.

4.4.2 Transfer valves shall have steel bodies. Valve stems, plugs or balls shall be made of stainless steel.

4.5 Condensate traps

4.5.1 One condensate drain trap per coalescing filter shall be provided if condensate can be present at the coldest operating temperature in the seal gas and or the seal buffer gas. Gas downstream of the filter and trap shall be kept liquid-free.

NOTE For some services, heat tracing and/or drain traps at supply piping low points downstream of the control valve can be required.

4.5.2 Non-repairable float traps are acceptable for services below 3,1 MPa (31 bar; 450 psig) if approved by the purchaser.

4.5.3 A mechanical, float-type trap is permitted for gas pressures less than or equal to 6,8 MPa (68 bar; 1 000 psig).

Level-transmitter, control-type traps shall be used when gas fouling can interfere with the operation of mechanical, float-type traps.

4.5.4 For pressures greater than 6,8 MPa (68 bar; 1 000 psig), snap-acting level transmitter/controllers and separate control valves shall be used.

4.5.5 All low points upstream of filters shall have drain valves.

4.5.6 Traps configured as specified in 4.5.2 and 4.5.3 shall be furnished with reflex-type gauge glasses, magnetic level indicators or other types of level indication as specified. The inlet piping shall enter the seal traps above the condensate level of the traps.

4.5.7 Unless otherwise specified, drain lines for traps on the system module shall be manifolded and a flange connection supplied at the edge of the module.

5 Piping and tubing

5.1 The vendor shall furnish the dry-gas-seal module, including mounted appurtenances, located within the confines of the base area. All connections on the module for interconnecting piping to the equipment shall be flanged. Module interface flanges connected to tubing shall be supported from the module structure.

NOTE All mounted appurtenances are kept within the confines of the base area to keep work areas and walkways as free as possible from obstructions and to protect tubing from damage. Externally supported, flanged exit connections on tubing are used to protect the tubing from external loads.

The interconnecting system between the module and equipment should be rigid pipe. The interconnecting system is provided by the vendor as defined in the datasheets. Piping and tubing shall be austenitic stainless steel and shall be in accordance with ISO 10438-1:2007, Tables 1, 5 and 6 unless otherwise specified.

5.2 Unless otherwise specified, dry-gas-seal modules designed for working pressures (gauge) below 6 200 KPa (62 bar; 900 psi) shall have the gas flow lines manufactured from stainless steel tubing or stainless steel piping.

5.3 Unless otherwise specified, dry-gas-seal modules with working pressures (gauge) greater than 6 200 KPa (62 bar; 900 psi) shall have gas flow lines manufactured from stainless steel piping.

5.4 Instrument valves within the dry-gas-seal module on tubing lines shall be tubing valves.

5.5 Control valves shall have steel bodies and stainless steel trim. Where practical, valves shall be removable without removing piping or tubing.

NOTE Smaller valves can have threaded connections that require fittings to be disconnected.

5.6 Threaded connections in toxic and flammable service shall be used only as approved by the purchaser.

NOTE Small component size can dictate the use of threaded components. Seal welding is an acceptable alternative but results in maintenance implications.

6 Instrumentation, control and electrical systems

6.1 General

Instrumentation shall be in accordance with ISO 10438-1:2007, Clause 6, except as modified in 6.2 to 6.3.

6.2 Alarms and shutdowns

6.2.1 Unless otherwise specified, the vendor shall furnish and mount, as a minimum, the primary alarm and shutdown contacts specified in Table 1.

Table 1 — Conditions requiring alarms and shutdowns

Condition	Alarm	Shutdown
Seal-gas supply for all seal types ^a except double	x	—
Seal-gas supply for double seal	x	x
Seal-gas supply, high flow, for double seal	x	—
High vent-gas pressure or flow ^b	x	x ^f
High primary vent-gas pressure or flow on tandem seal or tandem seal with intermediate labyrinth ^c	x	—
High secondary vent-gas pressure or flow on tandem seal or tandem seal with intermediate labyrinth ^c	x	—
Secondary seal-gas pressure or flow ^d	x	—
Separation-gas pressure or flow ^e	x	—
Low seal-gas, buffer-gas or separation-gas differential pressure or flow	x	—
High differential pressure for each filter set	x	—
^a See Annex D for seal configurations. ^b As an alternative, the pressure differential, Δp , across the inboard seal faces of a double seal can be alarmed. ^c If secondary vent gas is not monitored, then high primary vent gas shall be a shutdown. If both primary and secondary flows are high, the unit should shutdown. If primary vent gas is at a sustained high level, the unit should undergo a controlled shutdown. ^d Alarm on flow if pressure-controlled, and on pressure if flow-controlled. ^e Use as a permissive to start lube-oil system. ^f Shutdown for single seal only.		

- **6.2.2** Pressure or flow control and sensing shall be as specified or as mutually agreed.
- **6.2.3** The purchaser shall specify shutdown and alarms in accordance with one of the three arrangements detailed in ISO 10438-1:2007, 6.2.3.

6.3 Instrumentation

6.3.1 Flow indicators

6.3.1.1 Unless otherwise specified, the flow indicators shall be of the armoured type and have an internal magnetic float or rotameter design or an integral orifice and differential-pressure (DP) cell.

- **6.3.1.2** If specified, turbine flow transmitters shall be supplied.

6.3.1.3 Unless otherwise specified, flow meters in inert separation-gas services may be of the plastic rotameter design.

- **6.3.1.4** If specified, seal-gas flow measurement shall be by an electronic device such as a linear mass flow meter, venturi or turbine type. The purchaser shall specify whether the readout device is supplied by the module manufacturer or by the purchaser.

6.3.2 Relief valves

6.3.2.1 The vendor shall furnish the relief valves that are installed on equipment or piping that the vendor is supplying. Other relief valves related to equipment or piping outside the system that the vendor is supplying shall be furnished by the purchaser. The vendor's quotation shall list all relief valves and shall clearly state that these valves shall be furnished by the vendor. Only relief valves for gas service are required to meet the limiting relief-valve requirements specified in 6.3.2.2.

6.3.2.2 The sizing, selection and installation of gas relief valves shall meet the requirements of API 520, Parts I and II. Relief valves shall be in accordance with API 526. The vendor shall determine the size and set pressure of all relief valves within his scope of supply and recommend the size and setting of relief valves supplied by others required to protect the equipment he supplies. Relief-valve sizes and settings shall take into account all possible modes of equipment failure.

6.3.2.3 Unless otherwise specified, relief valves shall have steel bodies.

6.3.2.4 Unless otherwise specified, relief valves shall be arranged such that they can be removed for testing without shutting down the equipment.

6.3.3 Rupture disks

6.3.3.1 Where rupture disks are used, a positive indication shall be provided to indicate rupture disk status.

6.3.3.2 Where rupture disks are used, they shall be set sufficiently high to avoid spurious ruptures and shall be designed to avoid failures from causes other than over-pressurization.

6.3.3.3 Rupture disks shall be arranged such that they can be replaced without shutting down the equipment.

7 Inspection, testing and preparation for shipment

7.1 General

7.1.1 Inspection, testing and preparation for shipment shall be carried out in accordance with ISO 10438-1:2007, Clause 7, unless otherwise specified in 7.2 to 7.4 of this part of ISO 10438.

- **7.1.2** If specified, the purchaser's or the vendor's representative or both shall indicate compliance in accordance with the inspector's checklist (Annex C) by initialling, dating and submitting the completed checklist to the purchaser prior to shipment.

7.2 Inspection

Inspections shall occur in accordance with ISO 10438-1:2007, 7.2.

7.3 Testing

7.3.1 General

7.3.1.1 Equipment shall be tested in accordance with the requirements of 7.3.3 and ISO 10438-1:2007, 7.3. The purchaser and the vendor shall mutually agree if a pneumatic test in accordance with ISO 15649 or ANSI/ASME B31.3 at 110 % of design pressure may be substituted. Other tests may be specified and shall be jointly developed by the purchaser and the vendors.

- **7.3.1.2** If specified, the dry-gas-seal module shall be used during the main equipment's mechanical run test.

Gas conditions during the mechanical run or factory performance run should be considered in the dry gas seal module design.

7.3.2 Piping spools

Piping spools may be hydrotested individually in accordance with ISO 10438-1:2007, 7.3.2.

It is not recommended to hydrotest the system due to concerns with water being left in the system.

NOTE 1 Reference can be made to 7.3.3.1 for gas leak test requirements.

NOTE 2 ISO 15649 does not require hydrotesting when a pneumatic test is performed.

7.3.3 Operational tests

7.3.3.1 A gas leak test at 110 % of maximum allowable working pressure shall be performed on the system.

7.3.3.2 Unless otherwise specified, test gas shall be helium for seal gas of relative molecular mass 12 or less and air or nitrogen for seal gas of relative molecular mass greater than 12. Test gas shall be clean and dry.

7.3.3.3 A cleanliness test of the dry-gas-seal module shall be conducted at the vendor's shop with the job filter or new test filter (of equal filtration capability) elements installed. A 100 mesh screen shall be fastened to the outlet of the module flange for each gas line from the module. The module shall be blown for a 5 min period with a nominal 700 kPa (7 bar; 100 psig), dry-filtered [dew point not greater than -7°C (20°F) and filtered to $\beta_2 \geq 10$] gas. The screen shall be inspected for discoloration and cleanliness. Any hard particles or discoloration shall be cause for rejection.

- **7.3.3.4** If specified, a functional test proposed by the vendor and agreed to by the purchaser of the dry-seal-gas module shall be performed at the vendor's shop.

7.4 Preparation for shipment

The dry-seal-gas module shall be prepared for shipment in accordance with ISO 10438-1:2007, 7.4.

8 Vendor's Data

8.1 Proposal

The seal vendor's proposals shall incorporate requirements for the dry-seal-gas module to allow successful uninterrupted operation of the seal system for a minimum of 5 years.

8.2 Spare parts

The vendor shall ship the unit with clean filter elements installed.

Annex A **(informative)**

Datasheets

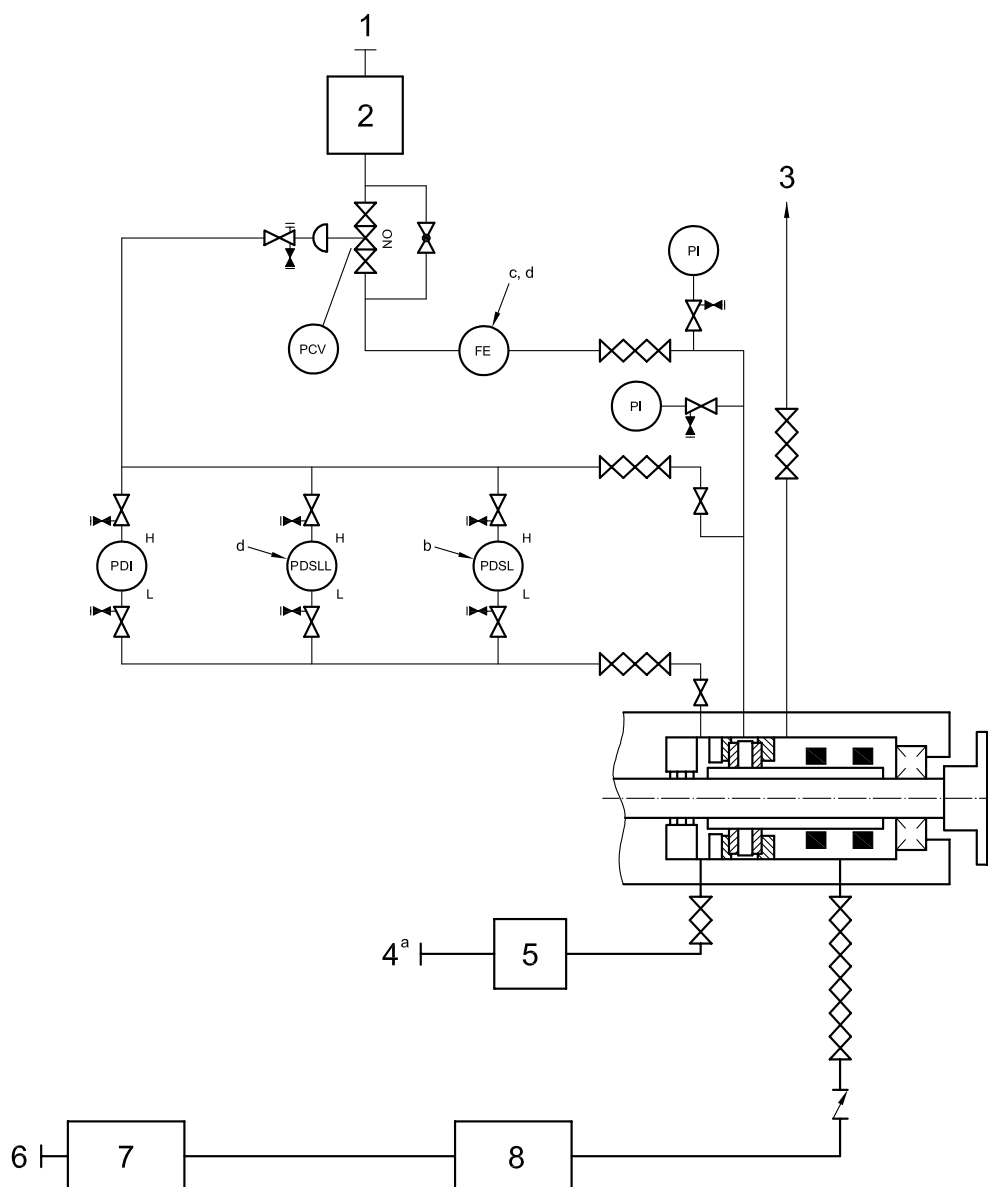
This annex contains a link to datasheets in both SI and USC units, together with an explanatory note. To access the appropriate datasheets, click on "[Datasheet](#)", then on the page tab for the corresponding figure (Figure A.1 — Dry-gas-seal module; Figure A.2 — Application data for a dry-gas-seal module). Select the appropriate set of units from the menu available on the first page.

The options for units are as follows:

- USC units;
- SI units (MPa);
- SI units (kPa);
- metric (kg/cm²);
- hybrid.

Annex B (informative)

Piping and instrument diagrams



Key

- | | |
|--|---|
| 1 seal-gas supply | 5 seal buffer gas, inlet filter module (Figure B.5) |
| 2 gas seal filter module (Figure B.5) | 6 separation gas |
| 3 vent gas (composed of seal and separation gas) to flare or safe area | 7 separation-gas filter module (Figure B.5) |
| 4 seal buffer gas supply | 8 separation-gas inlet module |

Figure B.1 — Double dry gas seal system

- ^a Required if process gas is saturated or contains fines; recommended in any event.
- ^b Required to ensure seal-gas flow across gas seal surfaces.
- ^c Figure B.1, option A: Flow element to monitor condition of seal.
- ^d Refer to Table 1. Loss of seal gas to a double seal can cause immediate seal damage.

NOTE Reference can be made to Annex D for terminology, to ISO 10438-1:2007, Clause 3, for definitions and to ISO 10438-1:2007, Annex B for symbols.

Figure B.1 — Double dry gas seal system *(continued)*



Key

- | | | | |
|---|--|----|--|
| 1 | primary vent to safe area or flare | 8 | balance line (multi-stage beam-type compressor with equalized seals) |
| 2 | secondary seal-gas supply | 9 | compressor |
| 3 | primary seal-gas supply (normally filtered process gas from discharge or secondary supply) | 10 | separation gas |
| 4 | filter module (Figure B.5) | 11 | separation-gas filter module |
| 5 | primary vent-outlet module | 12 | separation-gas inlet module |
| 6 | primary seal-gas-inlet module | 13 | secondary vent |
| 7 | secondary seal-gas-inlet module | | |

^a Test valve.

^b Check valve normally supplied by purchaser.

NOTE This seal type only leaks secondary seal gas to atmosphere. The gas for the secondary seal is, therefore, normally chosen to be an inert gas such as nitrogen.

Figure B.2 — Tandem dry gas seal with intermediate labyrinth system *(continued)*

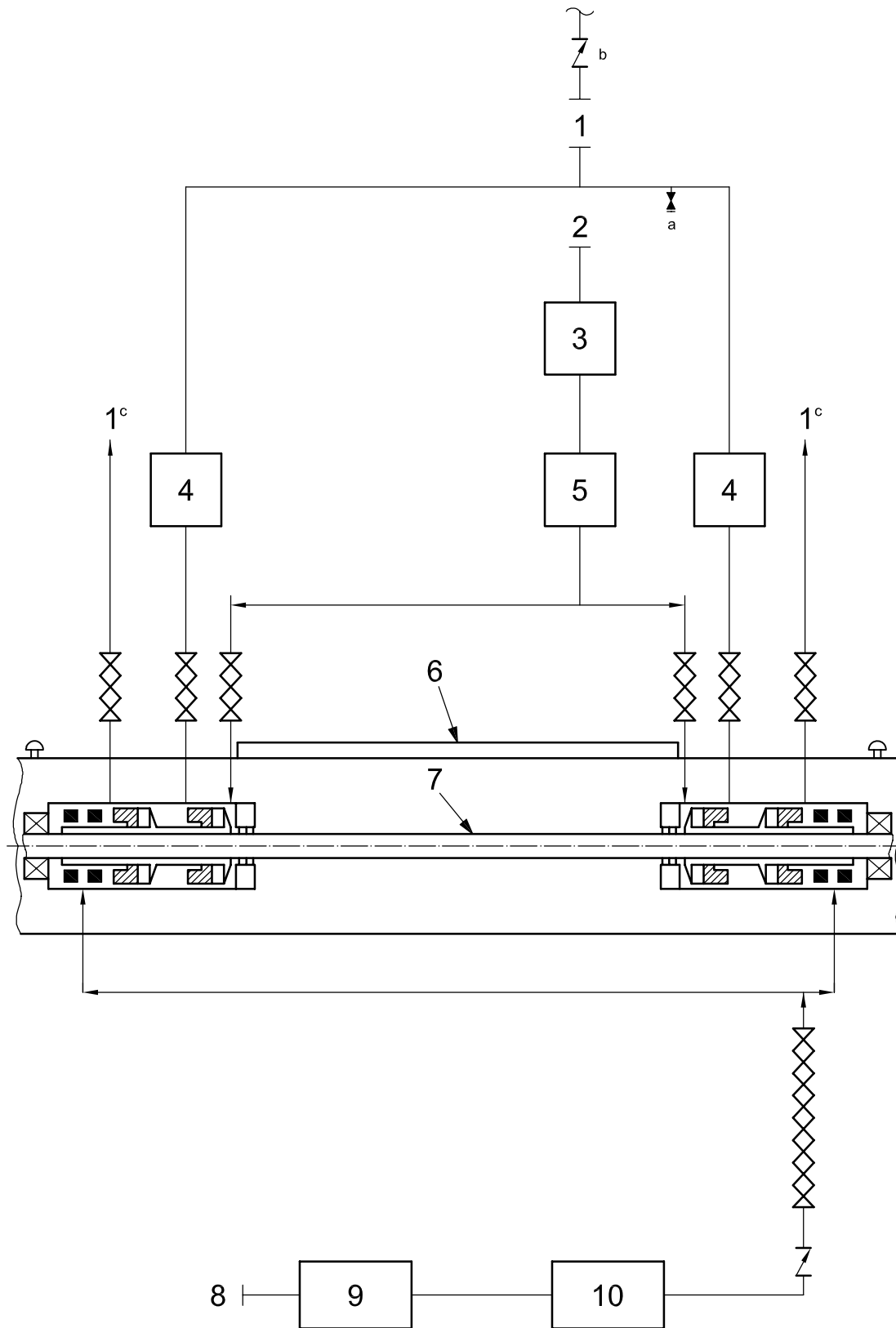


Figure B.3 — Tandem dry gas seal system

Key

- | | |
|--|---|
| 1 secondary vent to flare or safe area | 7 compressor |
| 2 seal-gas supply | 8 separation gas |
| 3 seal-gas filter module (Figure B.5) | 9 separation-gas filter module |
| 4 primary vent-gas outlet module (Figures B.15 or B.16) | 10 separation-gas inlet module (Figures B.18, B.19 or B.20) |
| 5 seal-gas inlet module (Figures B.8, B.9, B.10 or B.11) | |
| 6 balance line (multi-stage beam-type compressor with equalized seals) | |
- a Test valve.
- b Check valve normally supplied by purchaser.
- c If secondary vent is sent to flare, there is a potential to flow flare gas into the bearing housings. A customer-supplied check valve or other safeguards can be required.

Figure B.3 — Tandem dry gas seal system *(continued)*

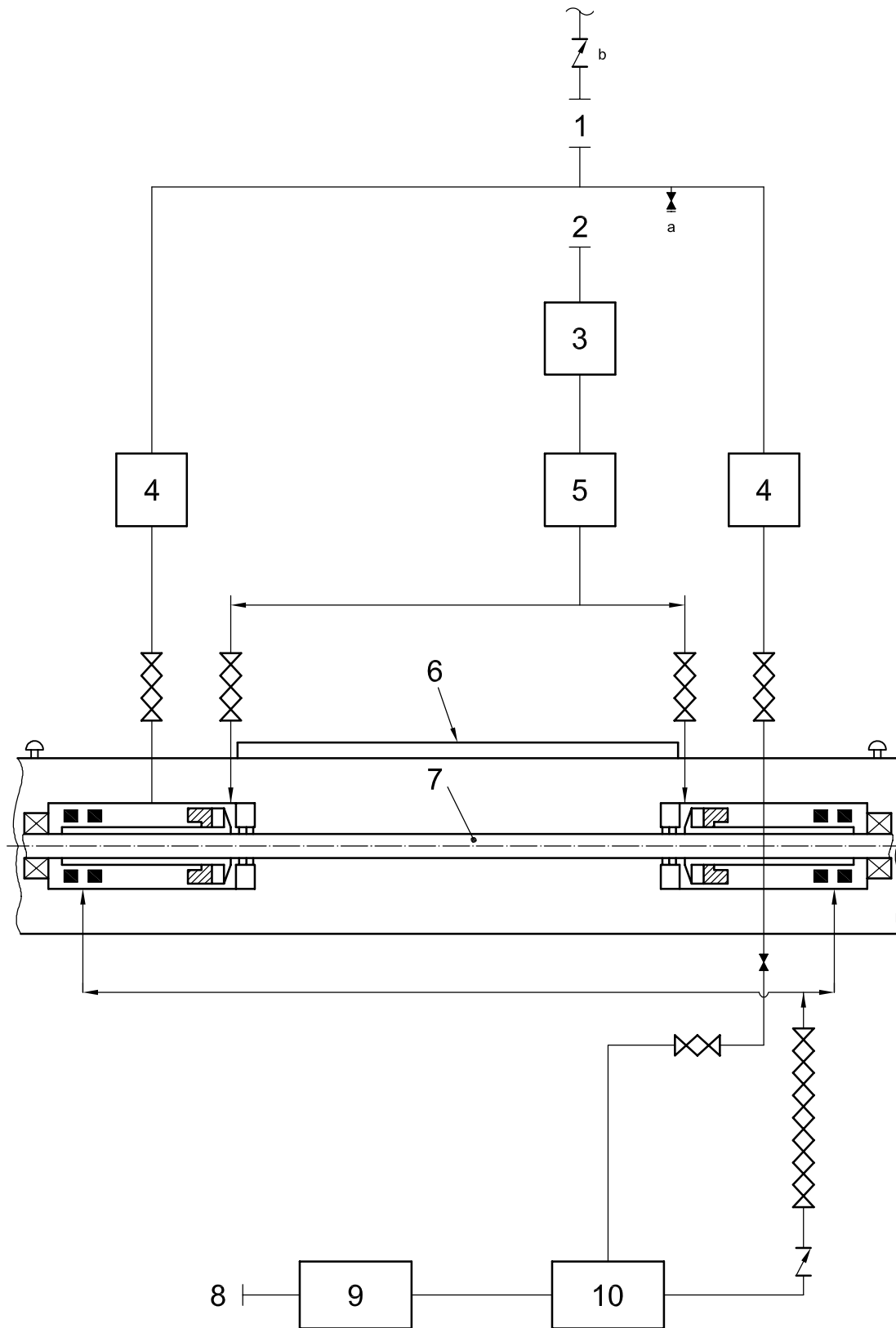


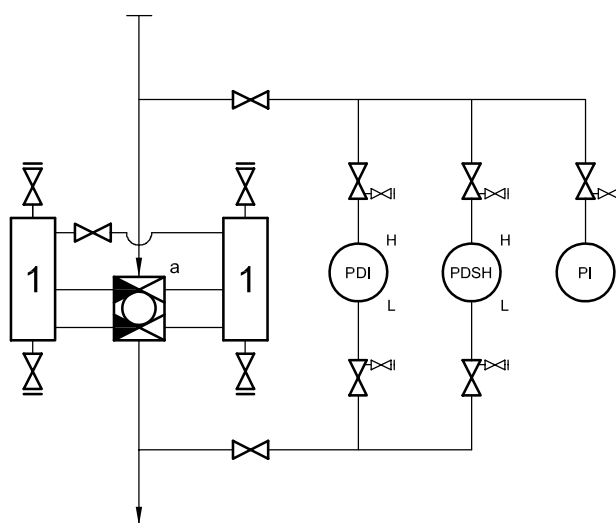
Figure B.4 — Single dry gas seal system

Key

- | | |
|--|---|
| 1 to flare or safe area | 7 compressor |
| 2 seal-gas supply | 8 separation-gas supply |
| 3 seal-gas filter module (Figure B.5) | 9 separation-gas filter module (Figure B.5) |
| 4 vent-gas outlet module (Figure B.15, B.16 or B.17) | 10 separation-gas inlet module |
| 5 seal-gas inlet module | |
| 6 balance line (multi-stage beam-type compressor with equalized seals) | |
- ^a Test valve.
- ^b Check valve normally furnished by purchaser.

NOTE This seal has no backup in the event of failure of the seal face.

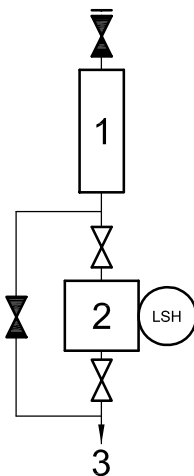
Figure B.4 — Single dry gas seal system *(continued)*



Key

- 1 filter
- ^a See Figure B.7 for arrangement with block valves instead of a transfer valve.

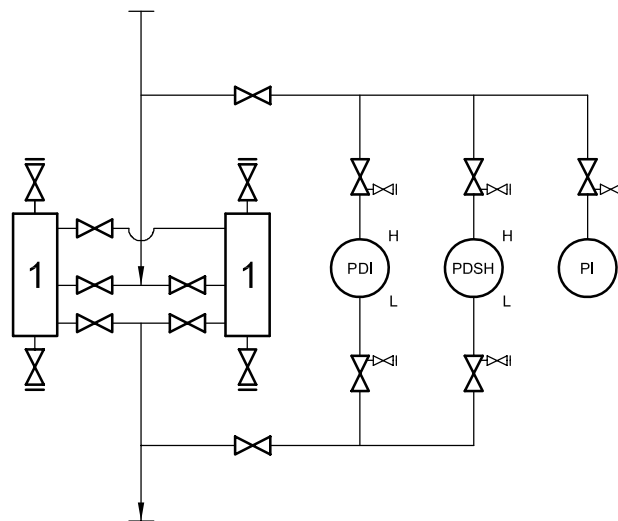
Figure B.5 — Filter module



Key

- 1 condensing filter
- 2 float trap
- 3 drain

Figure B.6 — Automatic liquid-drainer system for coalescing gas filters

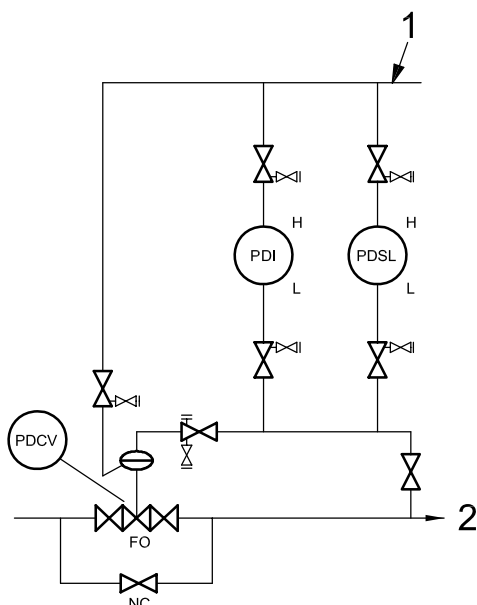


Key

- 1 filter

NOTE See Figure B.5 for arrangement with transfer valve.

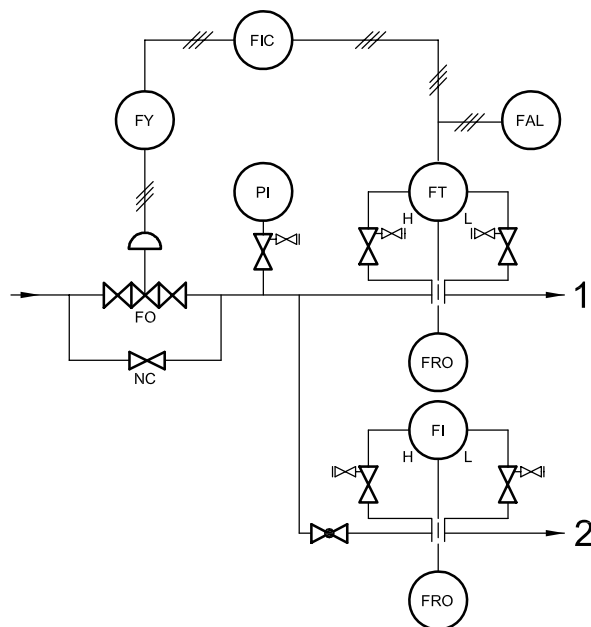
Figure B.7 — Filter module with individual block valves substituted for transfer valve



Key

- 1 seal-gas reference pressure at balance piston chamber
- 2 to seals

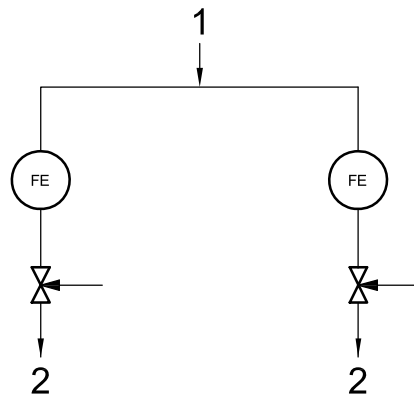
Figure B.8 — Differential-pressure control



Key

- 1 to discharge end seal
- 2 to inlet end seal

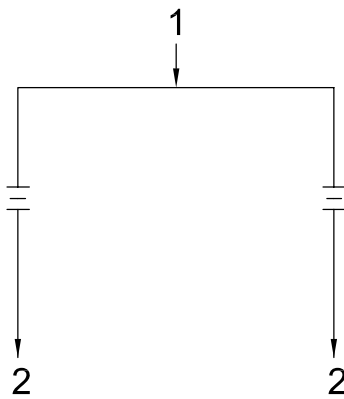
Figure B.9 — Flow-control arrangement 1



Key

- 1 seal-gas supply
- 2 to each compressor end seal

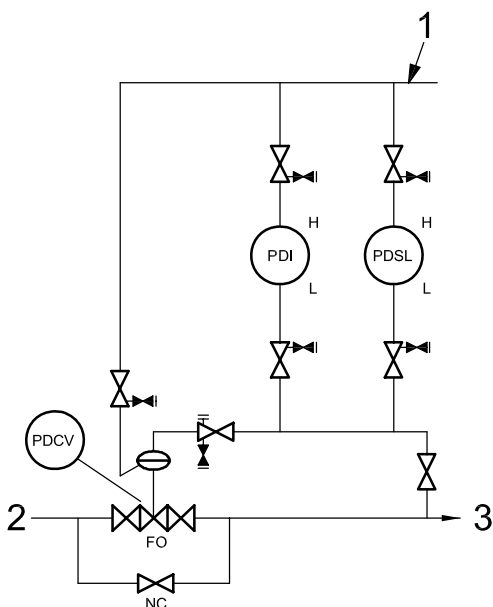
Figure B.10 — Flow-control arrangement 2



Key

- 1 seal-gas supply
- 2 to each compressor end seal

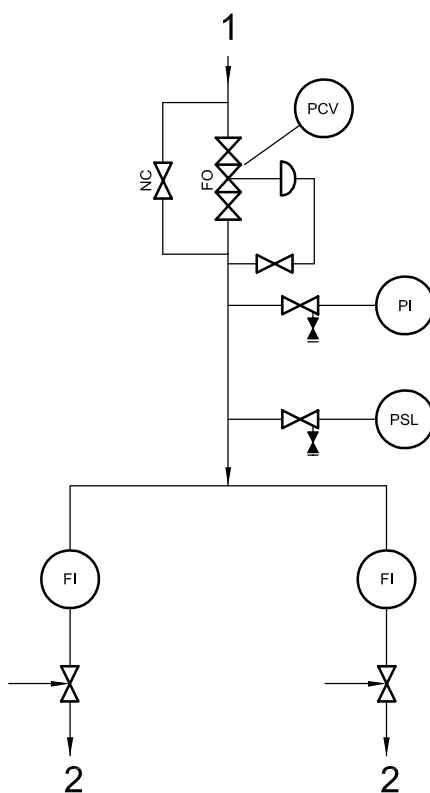
Figure B.11 — Flow-control arrangement 3



Key

- 1 primary vent
- 2 seal-gas supply
- 3 to seals

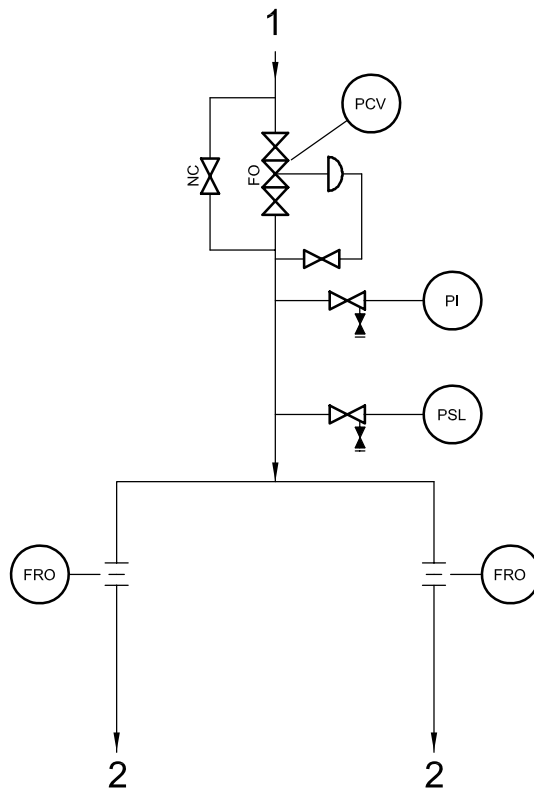
Figure B.12 — Differential-pressure control



Key

- 1 seal-gas supply
- 2 to each compressor seal

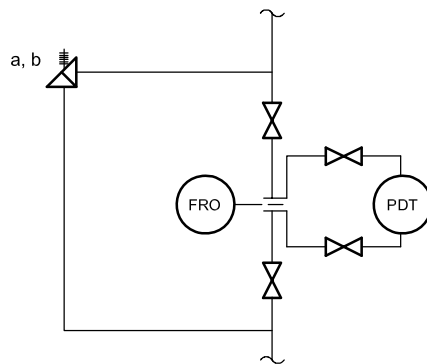
Figure B.13 — Flow-control arrangement 1



Key

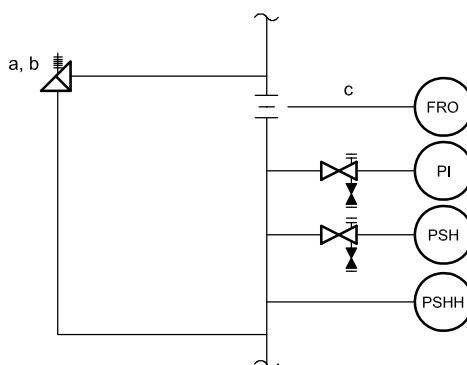
- 1 seal-gas supply
- 2 to compressor

Figure B.14 — Flow-control arrangement 2



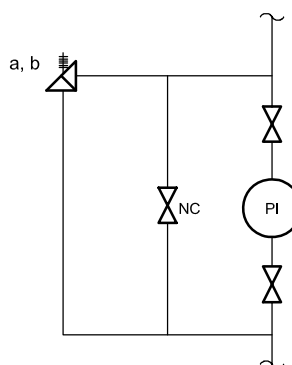
- ^a When over-pressure protection is required for the system, a relief device shall be provided.
- ^b Relief valve shown; rupture disk may be substituted.

Figure B.15 — Flow measured by differential pressure



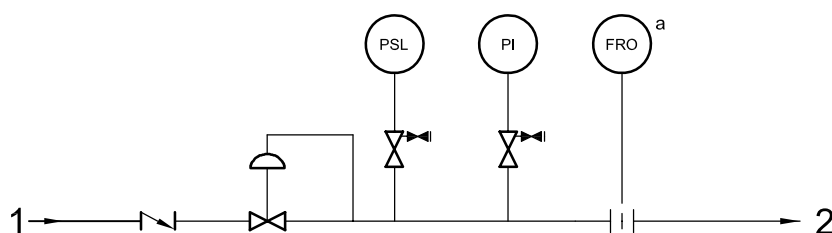
- a When over-pressure protection is required for the system, a relief device should be provided.
- b Relief valve shown; rupture disk may be substituted.
- c This option is not for use when high back-pressure can cause false shutdowns.

Figure B.16 — Flow monitored by back-pressure



- a When over-pressure protection is required for the system, a relief device should be provided.
- b Relief valve shown; rupture disk may be substituted.

Figure B.17— Flow measuring

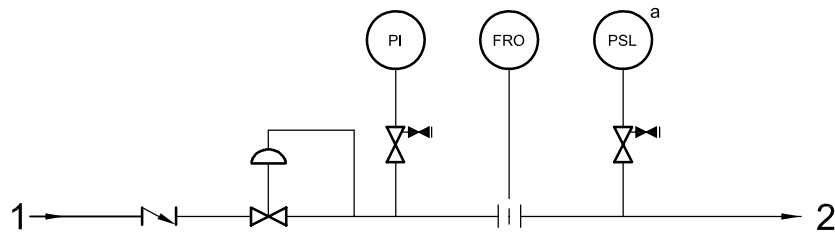


Key

- 1 separation-gas supply
- 2 to compressor

- a It is necessary that the FRO be properly sized to regulate flow through the seal.

Figure B.18— Separation-gas module (arrangement 1) — Buffered labyrinth with a remote vent

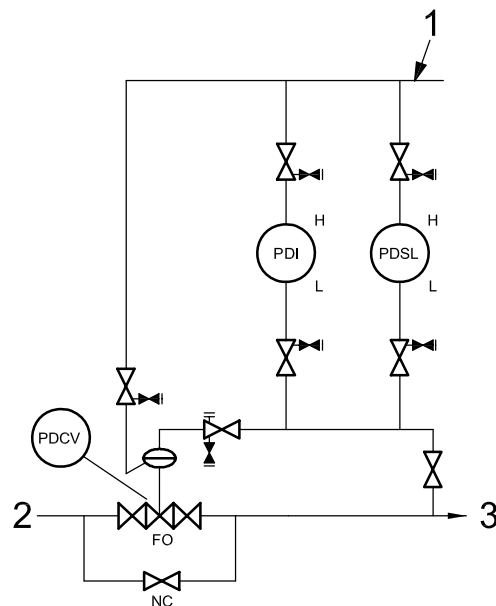


Key

- 1 separation-gas supply
- 2 to compressor

^a Flow is regulated by the relatively tight circumferential seal. PSL is arranged to sense plugging of FRO as well as loss of separation gas.

**Figure B.19 — Separation-gas modules (arrangement 2) —
Buffered circumferential seal with a remote vent**



Key

- 1 seal-gas reference pressure or flare-gas back-pressure
- 2 separation-gas supply
- 3 to separation seals

Figure B.20 — Separation-gas module (arrangement 3)

Annex C (informative)

Inspector's checklist

Table C.1 — Inspector's checklist

Item	Date inspected	Inspected by	Status
1) Datasheets for system specification complete (4.1)			
In accordance with purchase order (4.1)			
2) Specified operating conditions provided (4.2.3)			
3) Test gas specified			
4) Seal-gas flow range in accordance with 4.2.6			
5) All temperature controls working in accordance with 4.2.7			
6) Valved vents, drains and piping furnished to permit draining, cleaning and refilling (4.2.9)			
7) Seal-gas module can be drained manually (4.2.10):			
a In accordance with drawings			
b Providing adequate clearances			
c Providing safe access			
8) Double block and bleeds as required (4.2.11):			
a Coolers			
b Filters			
c Other			
9) Pressure vessels in accordance with specified pressure design code (4.2.12)			
All code stamp requirements identified and supplied if required			
10) Test acceptance criteria identified (4.2.13)			
11) Backup gas test requirements specified (4.2.14)			
12) Block valves in accordance with 4.2.15			
13) Support structure stainless or carbon steel, painted (4.2.16)			
14) Verify correct filter elements installed (4.3)			
Filter housing stainless steel (4.3.1.5)			
15) Transfer valve total shutoff (4.4.1)			
Transfer valve material (4.4.2)			
16) Condensate traps (4.5)			
Drain lines for traps manifolded with flange (4.5.7)			
17) Low-point drain valves (4.5.5)			
18) All connections for piping on module flanged (5.1)			
Module interface flanges supported from the module structure (5.1)			

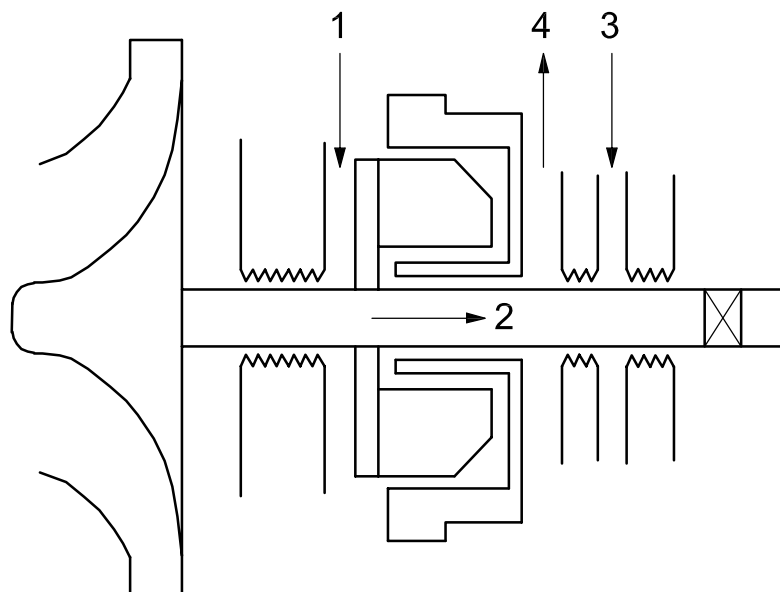
Table C.1 (*continued*)

Item	Date inspected	Inspected by	Status
19) Gas flow line material (5.2, 5.3)			
20) Control valve material (5.5)			
21) Threaded connections (5.6)			
22) Instrumentation (6.1)			
23) Alarms furnished and mounted (6.2.1)			
Functional test of alarm and shutdown setpoints (6.2.3)			
24) Flow indicators supplied as required (6.3.1)			
25) Relief valves (6.3.2)			
Steel bodies (6.3.2.3)			
26) Rupture disks (6.3.3)			
27) General inspection (7.2)			
28) Testing (7.3)			
a Operational test (7.3.3)			
b Cleanliness test (7.3.3.3)			
c Functional tests (7.3.3.4)			
29) Preparation for shipment (7.4)			
30) Spare parts (8.2)			

Annex D (informative)

Dry-gas-seal connection terminology and configurations

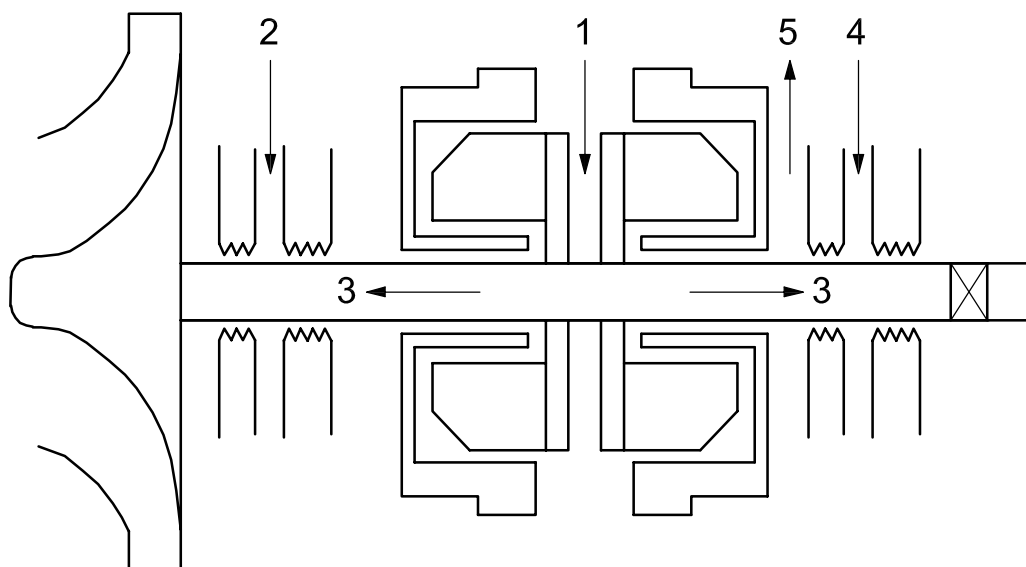
The following figures show common configurations of dry gas seals along with terminology associated with the connections. For detailed definitions of the seal connection terminology used, refer to the definitions in ISO 10438-1.



Key

- 1 seal-gas supply
- 2 seal-gas leakage
- 3 separation gas
- 4 vent gas

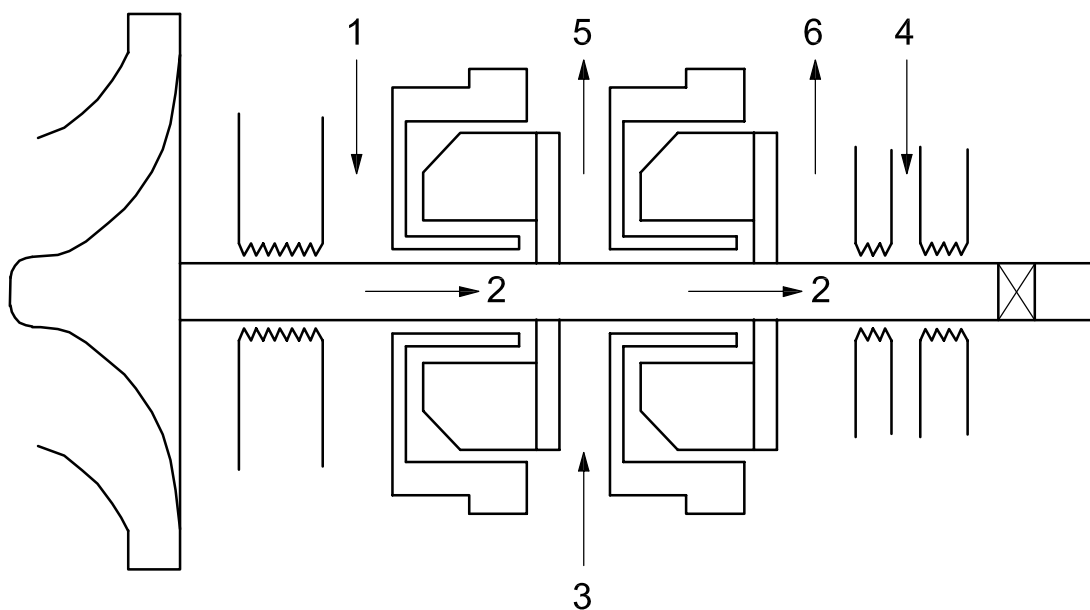
Figure D.1 — Single



Key

- 1 seal-gas supply
- 2 seal-buffer gas
- 3 seal-gas leakage
- 4 separation gas
- 5 vent gas

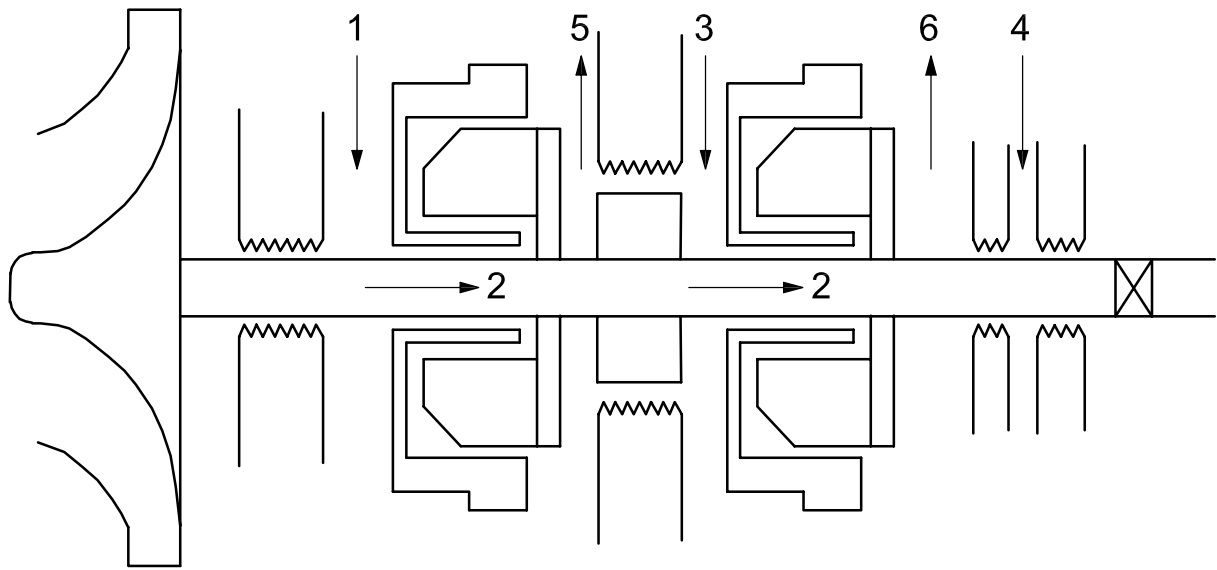
Figure D.2 — Double



Key

- | | |
|---------------------------------|----------------------|
| 1 seal-gas supply | 4 separation gas |
| 2 seal-gas leakage | 5 primary vent gas |
| 3 secondary seal gas (optional) | 6 secondary vent gas |

Figure D.3 — Tandem



Key

- 1 seal-gas supply
- 2 seal-gas leakage
- 3 secondary seal gas
- 4 separation gas
- 5 primary vent gas
- 6 secondary vent gas

Figure D.4 — Tandem with intermediate labyrinth seal

Bibliography

- [1] ISO 10439, *Petroleum, chemical and gas service industries — Centrifugal compressors*
- [2] ISO 10440-1, *Petroleum, petrochemical and natural gas industries — Rotary-type positive-displacement compressors — Part 1: Process compressors*
- [3] API STD 614, *Lubrication, Shaft-Sealing, and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services*
- [4] API STD 617, *Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services*
- [5] API STD 619, *Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries*



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