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Guidance for Classification and Construction

Part 1 Seagoing Ships

GUIDANCE FOR THE DESIGN, CONSTRUCTION AND TESTING OF PUMPS

Volume v

2024 Edition

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Part 1 Seagoing Ships

GUIDANCE FOR THE DESIGN, CONSTRUCTION AND TESTING OF PUMPS

Volume v

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Amendments to the preceding Edition are marked by red colour and expanded text.

However, if the changes involves the whole section or sub section normally only the title will be in red colour.

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Foreword

This 2024 edition of Guidance for the Design, Construction and Testing of Pumps (Pt.1, Vol.v) replaced the 1996 edition of Regulation for the Design, Construction and Testing of Pumps (Pt.1, Vol.v).

In this edition, new amendments are introduced which are mainly derived from internal reviews and development, inputs from BKI Branch Offices and Technical Division BKI Head Office.

This Guidance accommodates the provisions as a basis to design, construct, and test of pumps for handling of liquids which consist of 4 Sections and 1 Annex namely:

Section 1 General

Section 2 Design and Construction

Section 3 Testing

Section 4 Cargo and Fuel Pump for Liquefied Gases

Annex A Illustration of Principles of Pumps

The summary of previous edition including the implementation date are indicated in Table below:

	Edition/ Rule Change Notice (RCN)	Effective Date	Link
1	Edition 1996	1996	🔗

Note:

- *Full previous edition and amendments including its amendment notice is available through link above*

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Further queries or comments concerning this Guidance are welcomed through communication to BKI Head Office.

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Guidance Amendment Notice

Table 1- Amendments Incorporates in This Notice

These amendments will come into force on 1st April 2024.

Paragraph	Title/Subject	Status/Remark
Section 1 - General		
1.A	**General**	
-	-	To change Regulation into Guidance and added an explanation of mandatory type test requirements for hydraulic pumps and motors
1.B	**Definition**	
-	-	To change centrifugal pump into rotodynamic pump and added liquid ejectors as pumps covered in the Guidance
1.C	**Document to be submitted**	
-	-	To add information that sectional drawings for pumps handling certain media must be submitted electronically for approval
Section 2 - Design and Construction		
2.A	**Materials**	
2.A.1	Approved materials	To add pressurized parts attached to the pumps as an object covered by the Guidance
2.A.2	Requirements on material manufacturers	To add new requirements on pump casing manufacturers
2.A.3.1	Cast iron with lamellar graphite (at least EN-GJL-200)	The material application limits for pump casings have been changed to be presented in paragraph form with additional information to be more detailed
2.A.3.2	Nodular cast iron (Elongation A_5 at least 12%)	Same as above
2.A.3.3	Steel and cast steel fro general applications	Same as above

Paragraph	Title/Subject	Status/Remark
2.A.3.4	Cast copper alloys	Same as above
2.A.3.5	Aluminium casting alloys	Same as above
2.A.3.6	Plastics	Same as above
2.C	**Rated output of Prime Mover**	
2.C.1	General requirements	To add subtitles for paragraph 1 and added information that the rated output of the pump prime mover must be capable for operating under all anticipated conditions
2.C.2	Prime movers for rotodynamic pumps	To add an explanation that the rated power values in Table 2.1 are for rotodynamic pumps operating in closed piping systems and added new requirements of prime movers for pumps operating in open piping systems
2.C.3	Prime movers for positive displacement pumps	To add new requirements of prime mover for positive displacement pumps
2.F	**Emergency Fire Pumps**	
-	-	To add new requirements regarding the pump type of emergency fire pumps
Section 3 - Testing		
3.A	**Testing of Materials**	
3.A.2	-	To add types of inspection documents that must be provided for pump casing materials other than those mentioned in paragraph 1.
3.A.3	-	To add new requirement regarding NDT
3.B	**Pressure Testing**	
3.B.1.1	-	To replace centrifugal pumps by rotodynamic pumps
3.B.1.2	-	To add statement regarding maximum pressure to be considered
3.B.2	-	To add new requirement regarding hydrostatic pressure testing
3.C	**Performance Testing**	
3.C.1	-	To add several types of pumps that are subject to final inspection and hydraulic test

Paragraph	Title/Subject	Status/Remark
3.C.3	-	To add some words for clarification
3.C.9	-	To add new requirements regarding capacity testing of cargo pumps for liquefied gas and shaft driven deep well pumps
Section 4 - Cargo and Fuel Pumps for Liquefied Gases		
4.A	**General**	New requirements for the approval of pumps for handling liquid gases
4.B	**Documentation**	
4.C	**Design and Construction**	

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Section 1 General

A. General

This Guidance apply to the design, construction and testing of pumps for handling of liquids.

The application of this Guidance covers pumps whose capacity in accordance with Rules for Machinery Installations (Pt.1 Vol.III), Sec. 11, D. have to be verified in the manufacturer's works. Pumps and motors of hydraulically operated systems in accordance with Rules for Machinery Installations (Pt.1 Vol.III), Sec.14 are to be subjected to a type test according to Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W), Sec.3, L.

These Guidance may be similarly applied to other pumps as appropriate.

B. Definition

For the purpose of this Guidance, liquid pumps include:

— rotodynamic pumps

— side channel pumps

— rotary and oscillating positive displacement pumps

— liquid ejectors

For the illustration of principles of pumps, see Annex A.

For pumps of other designs, the requirements shall be agreed on case by case basis.

C. Documents to be Submitted

In the case of pumps for handling liquid gases, dangerous chemicals, and liquid foodstuffs, sectional drawings together with details relating to the proposed materials and operating conditions are to be submitted electronically for approval.

Approval of drawings is not normally required for other pumps.

In individual cases and depending on the design and application BKI does, however, reserve the right to call for the documentation necessary to an assessment of the pump in question.

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Section 2 Design and Construction

A. Materials

1. Approved materials

The materials of the pump components shall be suitable for the proposed applications. They are to be selected with due regard to the operating conditions and the nature of the liquid to be handled. Rules for Materials (Pt.1 Vol.V) are to be observed. This Guidance apply analogously to pressurized parts attached to the pumps.

Where the working temperature of the liquid to be pumped is ≤ −10°C, the choice of materials is subject to the requirements of Rules for Materials (Pt.1 Vol.V).

Where dangerous chemicals are to be pumped, evidence is to be supplied to BKI attesting the suitability of the materials used.

2. Requirements on material manufacturers

Casings for pumps intended to be used for piping systems of pipe class I and II shall be manufactured by BKI approved manufacturers. For the use in pipe class III piping systems an approval according to other recognized standards may be accepted.

3. Limits on the application of materials for pump casings

3.1 Cast iron with lamellar graphite (at least EN-GJL-200)

Max. allowable working temperature, t_{perm} ≤ 200°C

Max. allowable working pressure, $p_{e,perm}$ ≤ 16 bar

Limitations:

a) for boiler water, $p_{e,perm}$ ≤ 10 bar

b) for liquid fuels, lubricating oil, t_{perm} ≤ 60°C

c) for flammable hydraulic fluid, $p_{e,perm}$ ≤ 7 bar

Not permitted:

a) for casings of circulating pumps for heat-transfer oil

b) for casings of pumps for handling of dangerous chemicals

3.2 Nodular cast iron (Elongation A_5 at least 12 %)

Max. allowable working temperature $t_{perm} \leq 300^{o}C$ for nodular cast iron in normal quality

Max. allowable working temperature $t_{perm} \leq 350^{o}C$ for nodular cast iron in special quality according to Rules for Materials (Pt.1 Vol.V), Sec. 8, B, acceptable for casings of circulating pumps for heat transfer oil.

3.3 Steel and cast steel for general applications

Max. allowable working temperature, $t_{perm} \leq 300^{o}C$

3.4 Cast copper alloys

Max. allowable working temperature, $t_{perm} \leq 200^{o}C$ for copper and aluminium brass,

Max. allowable working temperature, $t_{perm} \leq 300^{o}C$ for copper nickel alloys

3.5 Aluminium casting alloys

Max. allowable working temperature $t_{perm} \leq 200^{o}C$ with the approval of BKI.

3.6 Plastics

The use of plastics requires the approval of BKI in the individual case of application.

4. Casing repairs

Casting defects in pump casings may be repaired only by recognized methods. BKI Surveyor is to be notified prior to the execution of the repair.

B. Protection Against Excessive Pressure

1. Rotodynamic pumps must be so designed that they can be operated for a short time without damage even with the discharge line closed.

2. Positive displacement pumps must be protected against excessive pressure increases in the pump casing by fitting relief valves which cannot be adjusted to the closed position.

3. Pumps which do not clearly conform to one of these two designs must comply with requirement 1. or 2.

C. Rated Output of Prime Mover

1. General requirements

The rated output of the prime mover is to be determined in such a way as to ensure the reliable operation of the pump under all anticipated operating conditions. It is required to be compatible with the mode of operation, the characteristic curve of the pump and with the properties of the liquid to be pumped.

2. Prime movers for rotodynamic pumps

By the way of a guide, the values in Table 2.1 can, for example, normally be regarded as adequate in the case of rotodynamic pumps intended for operation in closed piping systems, e.g. fresh cooling water systems, brine systems, thermal oil systems:

Table 2.1: Rated power of prime mover

Rated power of pump P_N [kW]	Rated power of prime mover P_M [kW]
up to 10	> 1.2 P_N
up to 50	1.2 - 1.1 P_N
over 50	1.1 P_N

Prime mover for pumps intended for operation in open piping systems, e.g. fire and emergency fire systems, ballast and bilge systems shall be rated for the entire capacity range of the pump. Unrestricted operation is to be ensured including direct (non throttled) discharge over board at maximum inlet head (max. draught). The rated output of the prime mover shall include a reserve power of not less than 10 %.

3. Prime movers for positive displacement pumps

Prime movers of positive displacement pumps shall be rated for short circuit operation at maximum viscosity, i.e. the total flow is returned to the suction side via the relief valve.

D. Branches, Connections

1. As far as possible, inlet and outlet branches shall be designed for the same rated pressure.

2. Pipe connections are to be executed in such a manner that no unpermissible forces and moments are exerted on the pump.

E. Circulating Pumps for Heat-Transfer Oil

1. The shaft sealing of circulating pumps for heat-transfer oil must be so designed that oil leakage cannot occur in an unacceptable manner and unacceptable leakage rate.

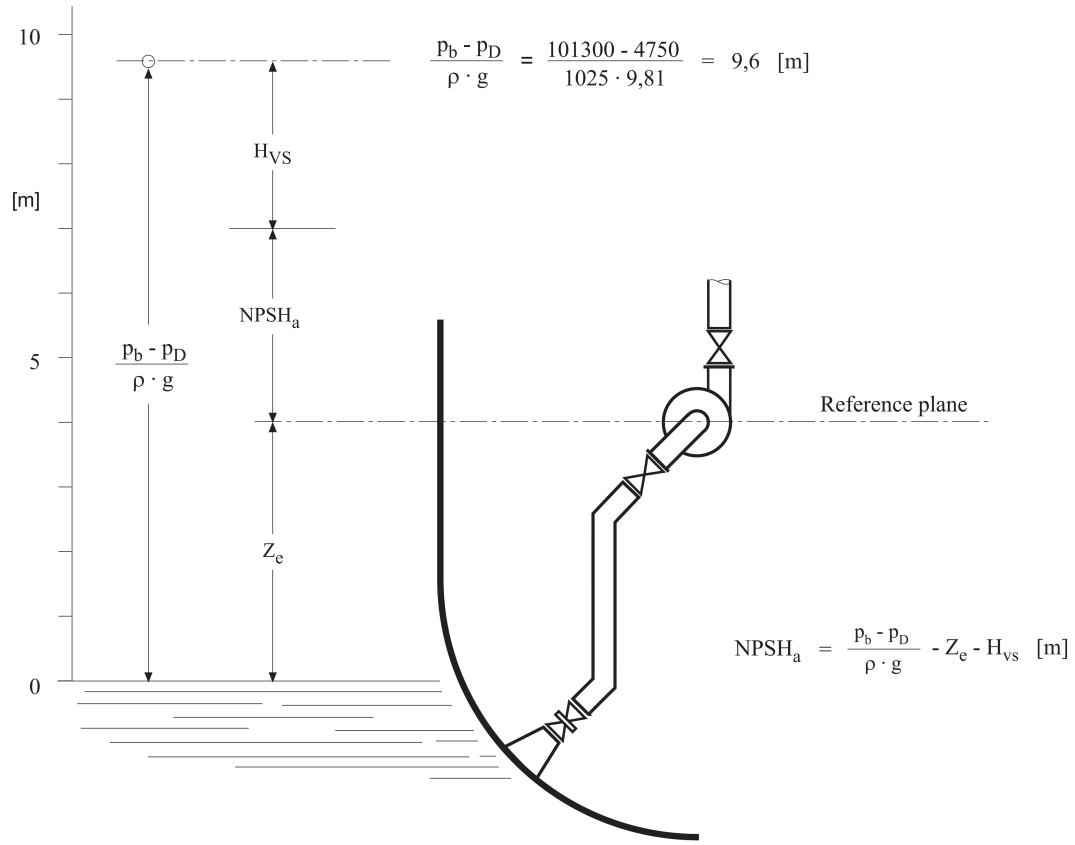
2. For shaft seals and/or bearings fitted with a cooling system the circulation flow is to be monitored.

F. Emergency Fire Pumps

1. Emergency fire pumps shall be of self-priming type.

2. For emergency fire pumps installed above the water line in light condition of the ship, the NPSH [1)] of the pump ($NPSH_{req}$) should be about 1 m lower than the NPSH value of the plant ($NPSH_a$). Details for determining NPSHa are given in Figure .2.1.

[1)] NPSH = Net Positive Suction Head, see also ISO 9906.



$NPSH_a$	[m]	Net Positive Suction Head available
H_{VS}	[m]	loss of head in the suction pipe
Z_e	[m]	distance between water line in light condition and center line of the impeller
ρ = 1025	[kg/m^3]	density of seawater
p_b = 101300	[N/m^2]	atmospheric pressure
p_D = 4750	[N/m^2]	vapor pressure of seawater at t = 32° C

Figure 2.1: Calculation of $NPSH_a$ for emergency fire pumps which are installed above the water line in light condition

Section 3 Testing

A. Testing of Materials

1. The following pump casings are subject to material testing and certification in accordance with BKI Rules:

- casings of boiler water circulating pumps with a permitted working pressure of $p_{e,perm} \geq 10$ bar
- casings of pumps for handling liquids with a working temperature of $t_{perm} \leq -10$ °C
- casings of pumps for handling dangerous chemicals

2. For all other pumps, the casing materials may be attested by a test report 2.2 according to EN 10204 or ISO 10474. The same procedure is also to be applied to the materials used for rotating components.

3. Type and scope of non-destructive material tests are to be agreed between the pump manufacturer and the foundry appropriate to the application requirements, for example, in case of pumps handling chemicals or liquid gases.

B. Pressure Testing

1. All pump components exposed to internal pressure (casing, cover, seal plate) are to be subjected to a hydrostatic pressure test. The following test pressure p_p at least is to be applied:

$p_p = 1{,}5\ p_{e,perm}$ where $p_{e,perm} \leq 200$ bar
subject to a minimum of $p_p = 4$ bar

$p_p = p_{e,perm} + 100$ bar where $p_{e,perm} > 200$ bar

$p_{e,perm}$ = maximum allowable working pressure

1.1 In the case of rotodynamic pumps, the maximum allowable working pressure $p_{e,perm}$ is equal to the sum of the pressure in the suction branch and the maximum pressure difference according to the pump characteristic.

1.2 In case of positive displacement pumps, the maximum allowable working pressure $p_{e,perm}$ is equal to the pressure which occurs on the discharge side when the total flow is returned to the suction side via the relief valve. The maximum pressure at the suction branch shall be considered.

2. For the purpose of hydrostatic pressure testing, pump casings shall not be painted on their internal or external surfaces.

C. Performance Testing

1. The following pumps are subject to final inspection and to hydraulic performance testing in the manufacturer's works under the supervision of a BKI Surveyor:

- bilge pumps / bilge ejectors
- ballast pumps
- seawater cooling pumps
- fresh water cooling pumps
- cooling pumps for fuel injection valves
- fire pumps including pumps serving fixed fire extinguishing systems, e.g. sprinkler pumps
- emergency fire pumps
- pumps serving water spraying systems dedicated to cooling purposes (drencher pumps)
- condensate pumps
- boiler feedwater pumps
- boiler water circulating pumps
- lubricating oil pumps
- fuel oil booster and transfer pumps
- circulating pumps for thermal oil installations
- brine pumps
- refrigerant circulating pumps
- cargo pumps
- hydraulic pumps for controllable pitch propellers

Other hydraulic pumps/hydraulic motors, see Rules for Machinery Installations (Pt.1 Vol.III), Sec.14.

2. The following contractually agreed operating data are to be verified during the performance test:

- Volume rate of flow[1)], Q [m^3/h]
- Delivery head, H [m]
- Pump power input, P [kW]
- Speed of rotation, n [min^{-1}]

3. As a standard procedure the hydraulic performance test shall be performed on manufacturer's test bench. The procedure followed shall be based on recognized national or international Standards and Regulations (e.g. ISO 9906 – Rotodynamic pumps – Hydraulic performance acceptance test grade 1, 2 and 3).

If the contract provides for a performance test in accordance with one of the aforementioned standards or a comparable regulation the pump manufacturer is bound to hold the said standard available for consultation during the performance test.

4. If the performance test is conducted without the corresponding prime mover but with a test bench motor, deviations from the nominal speed of rotation nN may result which can be tolerated within specific limits. In case of rotodynamic pumps, the speed of rotation during testing shall be in line with ISO 9906. Accordingly, the speed of rotation during testing shall be within the range 50 % and 120 % of the specified speed. In order to translate the performance data Q, H and P measured at test speed n to the corresponding values for the specified speed n_N, the following equations may be applied:

$$Q_N = Q \cdot \left(\frac{n_N}{n}\right); \quad H_N = H \cdot \left(\frac{n_N}{n}\right); \quad P_N = P \cdot \left(\frac{n_N}{n}\right)$$

[1)] The volume rate of flow is defined as the usable volume rate which is delivered by the pump through its outlet cross-section (pressure socket).

5. For positive displacement pumps, the permissible deviations call for special agreement depending on the design involved.

6. Conversion of the measured power input P to the nominal power input PN is also required where the power input is measured with a liquid which differs as regards density and/or viscosity from the liquid specified in the contract. The effect of viscosity on the characteristics of pumps is shown in Figure .3.1.

7. Where the contract calls for verification of the NPSH value, an approximation formula is to be agreed between customer and supplier to enable the conversion to be made if the test speed differs from the nominal speed.

8. Where pumps subject to mandatory testing are hydraulically driven, the corresponding hydraulic motors and hydraulic pumps are to undergo a performance test, unless the pump is performance tested in conjunction with the entire unit.

9. In case of submerged electric driven cargo pumps intended for liquefied gases the capacity test is to be carried out with the design medium or with a medium below minimum working temperature. For shaft driven deep well pumps the capacity test may be carried out with water.

D. Other Tests

1. On positive displacement pumps the setting and correct dimensioning of the relief valve is to be checked. Generally, the set pressure, the opening pressure and the reseating pressure shall be measured and documented. Where a positive displacement pump is supplied without a relief valve, this point is to be noted in the Test Certificate.

2. With self-priming rotodynamic pumps as well as for rotodynamic pumps with attached or built-in suction aid, the functioning of the air intake stage is to be included within the scope of performance test.

3. During the performance test, the pump is to be checked for smooth running) and bearing temperature.

4. Where the performance test is carried out on the entire unit comprising the pump, coupling, prime mover and common baseplate, the alignment of the unit is to be checked. The fact that the test has been performed on the entire unit is to be noted in the Test Certificate.

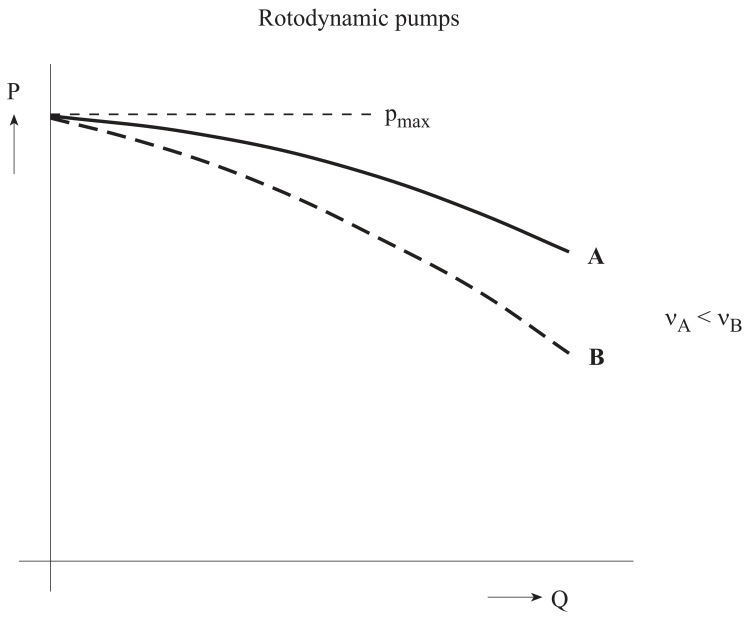
5. In case of performance testing of bilge ejectors the pressures shall be within $\pm$ 3 % of the nominal data. The resulting flow at the suction side may not deviate by more than – 5 % compared to the data sheet values stated by the manufacturer. Higher volume rate of flows are permitted.

In case of bilge ejectors the performance test of each individual pump may be replaced by type test procedure of respective pump type series agreed with BKI. In these cases proof of performance of the individual pump may then be limited to a comparison of dimensions relevant to pump performance with those from the type test.

E. Test Documents

1. The documents required for the various tests shall be supplied by the pump manufacturer to the Surveyor in good time and at the latest at the time of carrying out the tests.

2. A BKI Test Certificate is to be issued showing the results of the tests. Where the extent of the tests goes beyond that specified by BKI, the BKI Test Certificate may be supplemented by the pump manufacturer's own test report.



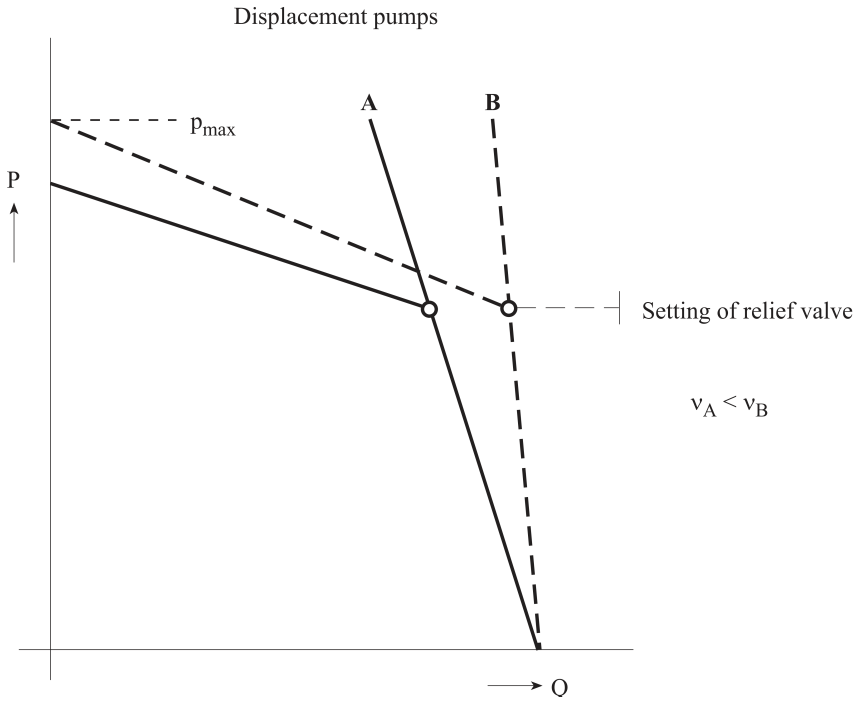


Figure 3.1: Effect of viscosity v on pump characteristic

Section 4 Cargo and Fuel Pumps for Liquefied Gases

A. General

The requirements of this Section apply to tests and inspection for the approval of pumps for handling liquid gases in accordance with the requirements in the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec. 5.

This Section also describes the applicable design requirements and how to document compliance with the requirements in order to obtain type approval certificate for the equipment.

B. Documentation

1. The following documentation and information shall be submitted:

- Proposed field of application, operating and service conditions as well as operational limitations
- Assembly drawing indicating the design pressure and temperature and type of operating fluid
- Sectional drawings at scale fully dimensioned
- Inspection and test plan (ITP) for pump fabrication
- Documentation of pump type performance testing as required by this document
- Documentation about electrical and automation mounting parts for pump operation.
- Type/specification of liquefied gas to be used as pump operating fluid
- Part lists covering all pump items with material specifications suitable to the operating conditions for liquefied gas systems and in accordance with Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX)
- Operational manual including cool down procedure for LNG start-up operation and information regarding life or operating time under fatigue or cyclic loads, and maintenance intervals
- Design loads in particular specification of cycling loads with maximum and minimum amplitude, working and design temperature
- Fatigue calculations
- Piping diagram including over pressure protection, if applicable.

C. Design and Construction

1. Pump design

The design and dimensioning of pumps for liquefied gas systems may include additional use of advanced calculation methods, e.g. finite element analysis.

For pumps cooled and lubricated by media flow, the arrangements that protect the pump from running dry shall be specified.

2. Pressurized pump components

For liquefied gas pumps where the leakage of media is affecting safe operation of the vessel (e.g. not submerged pumps), following applies.

2.1 The design of pump components subject to operating fluid pressure, e.g. pump casing and bolting, shall be carried out according to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.5.9, 5.12. The safety factors as specified in Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.4.23.3 shall be observed.

2.2 The design of pressurized pump items shall be carried out under consideration of cyclic loads, both thermal and pressurized. The design under cyclic loads shall be carried out according to a recognised pressure equipment code accepted by BKI.

3. Material

In addition to the requirement in Section 2.A, the materials for pump items subject to liquefied gas operating conditions shall comply with Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.5.12. Material certificates shall provide material properties for the sub-zero design temperatures, in particular charpy impact test results.

4. Testing

4.1 Prototype testing

Prototype testing is required for pumps for liquefied gas, and shall be performed as per Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.5.C.5.14.1.

4.2 Production testing

Product certificates are required for pumps for liquefied gas. Production testing of such pumps shall be witnessed by a representative of BKI. In addition to the requirements for production testing in Section 3, pumps for liquefied gas shall be tested according to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.5.C.5.14.2.

Annex A Illustration of Principles of Pumps

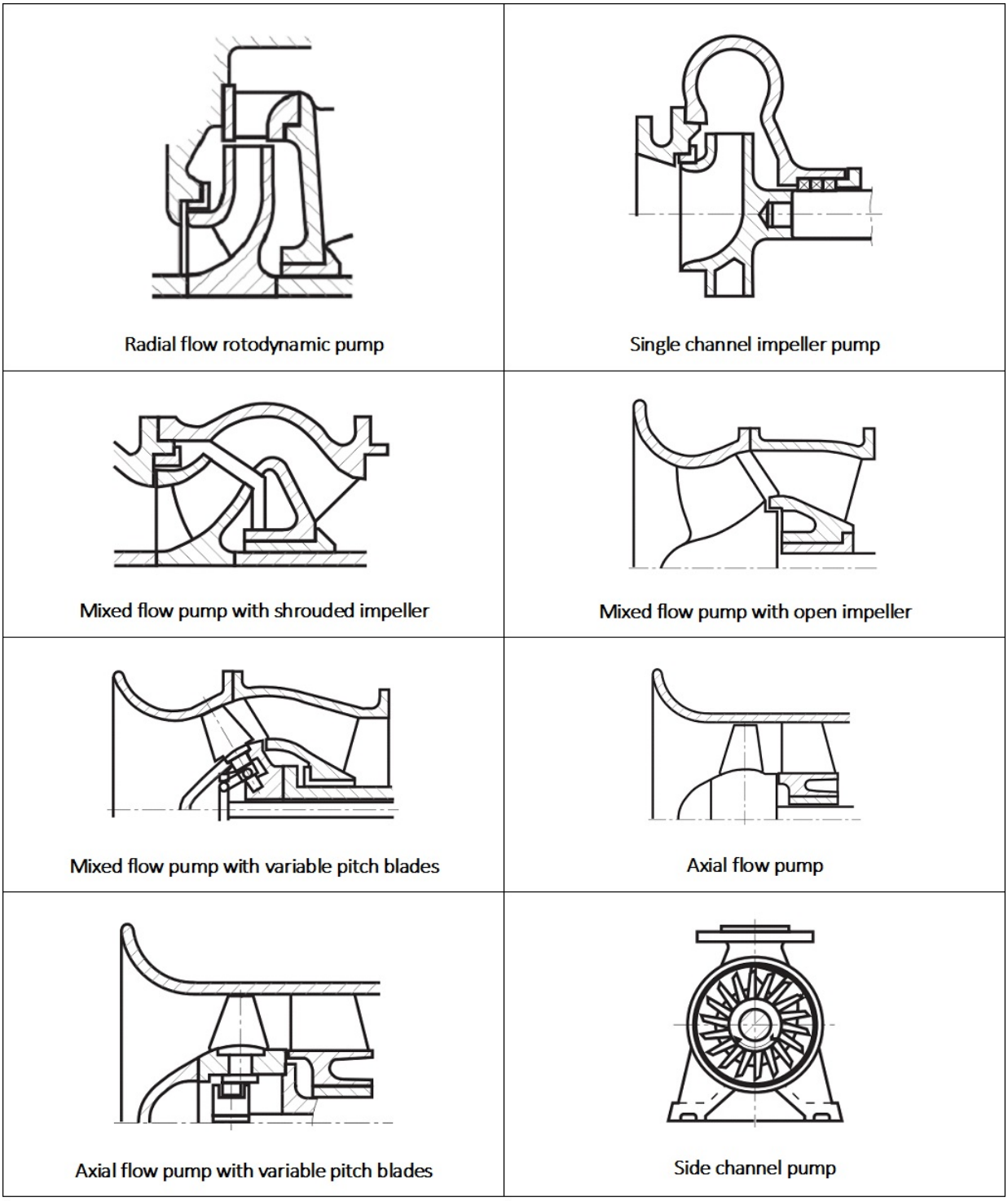


Figure A.1: Illustrations of the principles of rotodynamic pumps and side channel pump

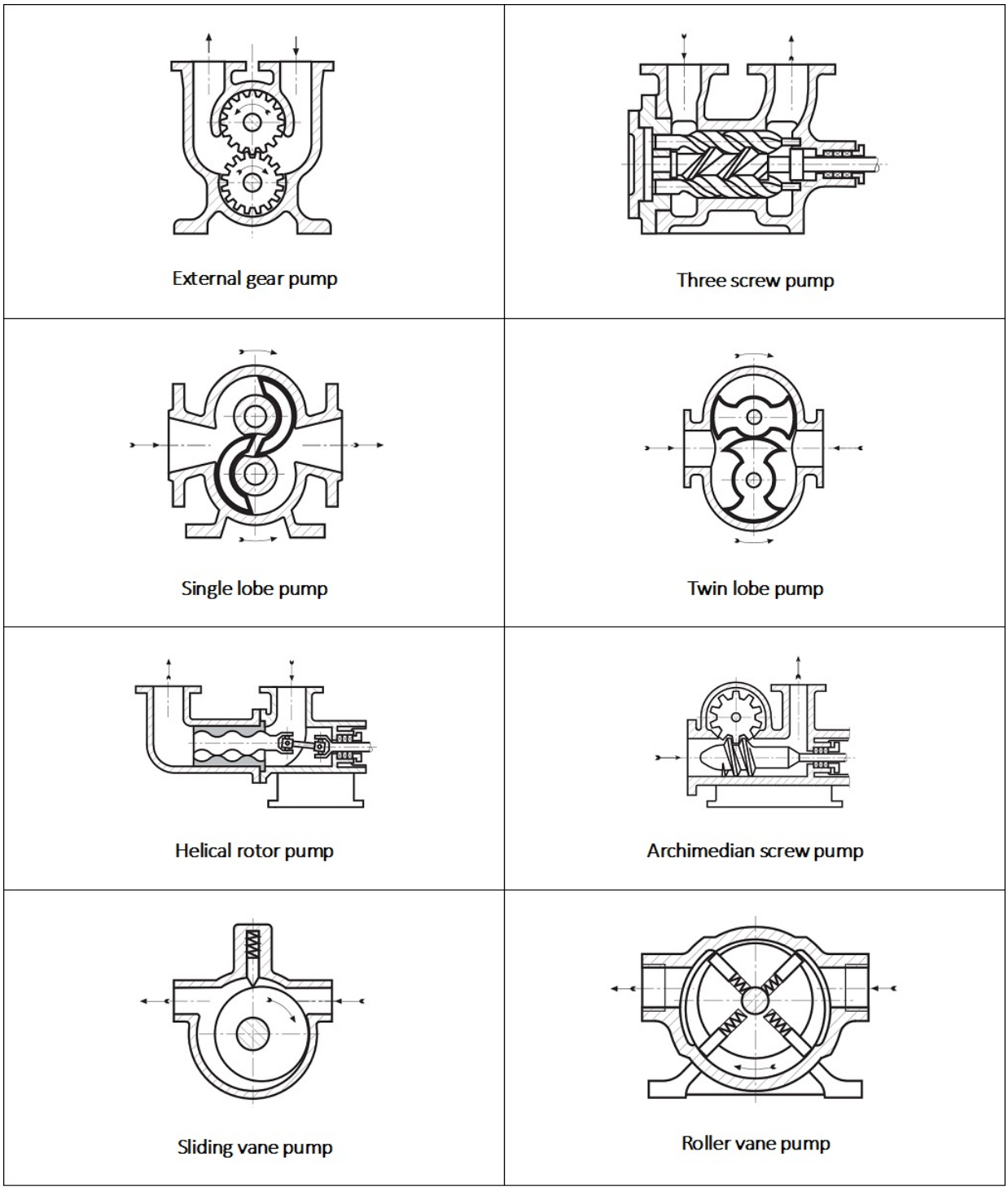


Figure A.2: Illustrations of principles of positive-rotary pumps

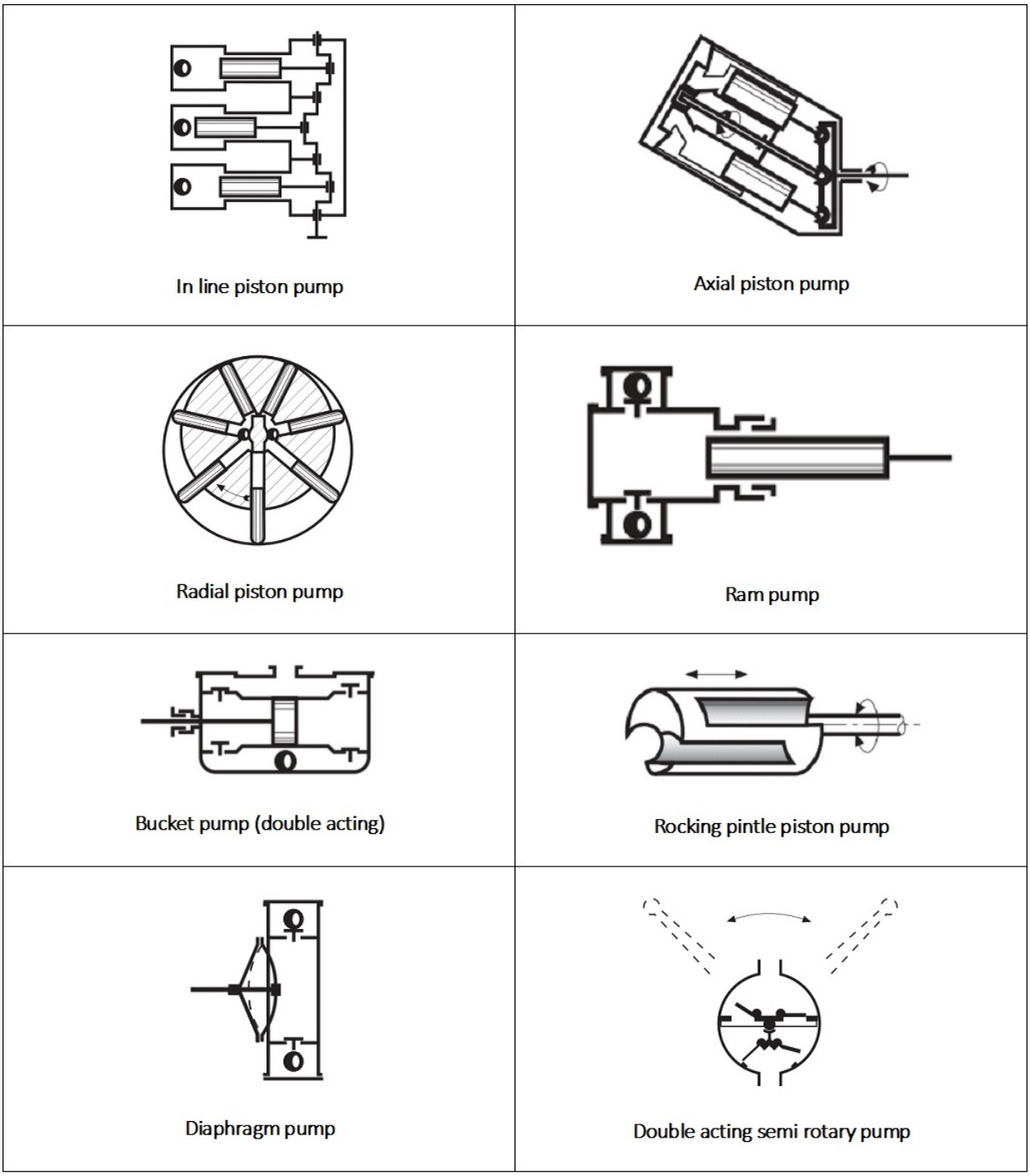


Figure A.3: Illustrations of the principles of reciprocating pumps

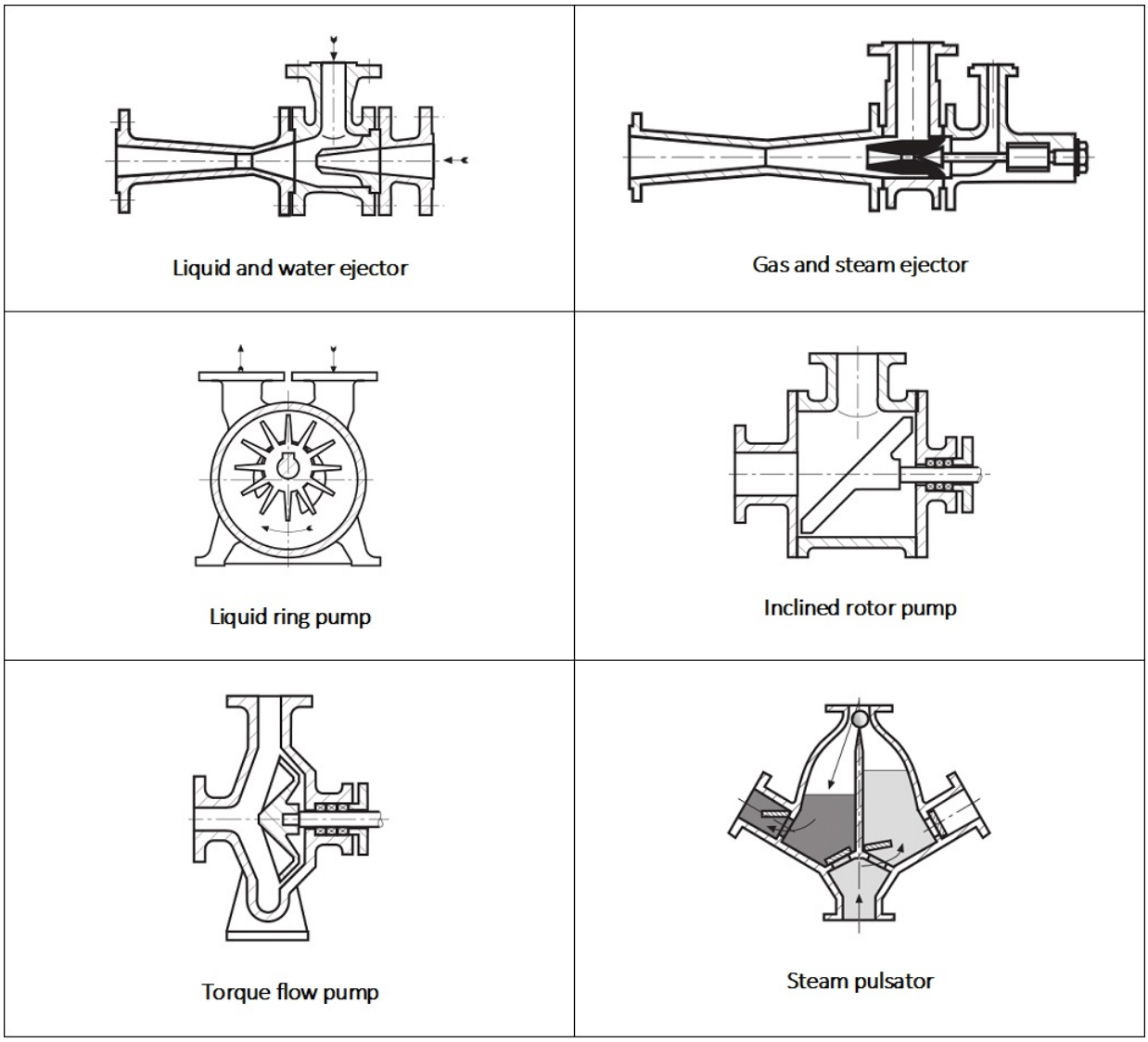


Figure A.4: Illustrations of the principles of other pumps