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Rotodynamic pumps — Forces and moments on flanges — Centrifugal, mixed flow and axial flow horizontal and vertical shafts pumps

ICS 23.080

British Standards

National foreword

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Rotodynamic pumps - Forces and moments on flanges - Centrifugal, mixed flow and axial flow horizontal and vertical shafts pumps

Pompes rotodynamiques - Forces et moments applicables aux brides - Pompes centrifuges, hélico-centrifuges et hélices à axes horizontal et vertical

Rotodynamische Pumpen - Zulässige Flanschenkräfte und Momente - Kreiselpumpen, Halbaxialaufpumpen und Axialpumpen mit horizontaler und verticaler Achse

This Technical Report was approved by CEN on 13 October 2008. It has been drawn up by the Technical Committee CEN/TC 197.

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Management Centre: Avenue Marnix 17, B-1000 Brussels

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Contents

Page

Foreword

This document (CEN/TR 13931:2009) has been prepared by Technical Committee CEN/TC 197 “Pumps”, the secretariat of which is held by AFNOR.

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

This document supersedes CR 13931:2000.

The pumps families are numbered sequentially, leaving room for the inclusion of additional types if required at a later date:

— horizontal shaft pumps: N° 1 to 8[1];

— vertical shaft pumps: N° 20 to 36[1].

The pump families are described and illustrated in Tables 2 and 5.

Annexes A and B are for information only.

1 Numbers 9 to 19 are reserved for potential new families of pumps.

1 Scope

This CEN Technical Report provides information for the calculation of maximum permissible forces and moments allowed on the flanges of various types of horizontal and vertical shaft rotodynamic pumps, caused by the reaction to pipework that is rigidly connected to the installation. This document does not take into account the effect of any elastic or deformable linkages, such as bellows, elastic joints, self butting sliding joints, etc.

This CEN Technical Report is not applicable to multistage monobloc pumps, whose outlets are remote from the installation plane, or to horizontal shaft pumps mounted vertically for installation reasons, such as, fixing to a vertical wall.

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.

EN 22858, *End-suction centrifugal pumps (rating 16 bar) - Designation, nominal duty point and dimensions (ISO 2858:1975)*

EN ISO 5199:2002, *Technical specifications for centrifugal pumps - Class II (ISO 5199:2002)*

API 610, *Centrifugal pumps for general refinery service*

3 Responsibilities of manufacturer and purchaser

3.1 General

The manufacturer should inform the purchaser of the family to which the equipment offered belongs.

The purchaser should calculate the loads applied to the pump at its flanges, considered for all possible relevant conditions (at ambient temperature, at operating temperature, at rest, under pressure).

The purchaser should ensure that the values of these loads do not exceed the corresponding calculated limits for the pump selected. If they do, the pipework should be modified to reduce the loads, or a different type of pump, capable of withstanding higher loads, shall be selected.

Both parties should agree on the type of baseplate to be provided (conventional, reinforced, concrete, etc.).

The basic values given in Tables 2 and 5 and Annex B correspond to the most common sizes of pumps; for larger sizes of pumps, the manufacturer shall indicate the limiting values.

3.2 Design considerations

Excessive loads transmitted to a pump by the piping can compromise smooth running and reduce the life of the pump, the coupling and perhaps the motor bearings, increase the demand for maintenance and, in the extreme, will cause failure. These adverse effects result from two distinct causes:

— displacement of the pump shaft end relative to that of the driver. The misalignment will overload the pump and driver bearings and, when a flexible coupling is used, increase its rate of wear.

— distortion of the pump casing, changing the internal clearances between the fixed and rotating parts, thus increasing wear and vibrations, sometimes leading to seizure. If mechanical seals are installed, parallelism of the faces will be upset, causing leakage and rapid breakdown.

It is for these reasons that limits must be set to the external forces and moments acting on the flanges. Manufacturers are responsible for verifying that the pump offered will operate satisfactorily when these limits are not exceeded.

4 Criteria adopted in setting limiting forces and moments

4.1 Shaft-end movement

The lateral displacement of the shaft-end, relative to a fixed point in space, is given in Table 1 for the various pump families, as a function of shaft size.

Table 1 — Criteria for forces and moments limitations

Type of pump	**Families**	**Shaft-end diameter** (mm)	**Displacement** (mm)
Standard (N) Modular	1A, 1B 3A 4A, 4B	< 30 (N24) 31-40 (N32) > 40 (N42)	0,15 0,20 0,25
Other horizontal Pumps	2, 3B, 3C 5A, 5B 6, 7, 8A, 8B, 8C	≤ 50 > 50 > 50	0,125 0,175 0,175
Vertical pumps	All (20A-36B)	All	0,150

4.2 Distortion of the pump casing

It is the responsibility of the pump manufacturer to verify that the loads applied on the flanges, in any of the permitted combinations, do not cause greater changes in internal clearance or disturbances to the mechanical seals than are allowed by his own design rules or those of the specifications imposed by the user, whichever are the more stringent.

4.3 Validity of force and moment values – Effects of materials and temperature

Unless indicated otherwise, the values for forces and moments are given for the basic material for the pump family (see Tables 2 and 5) and for a maximum permissible temperature as shown. For other materials and higher temperatures, the values shall be corrected by applying the modulus of elasticity relation, namely:

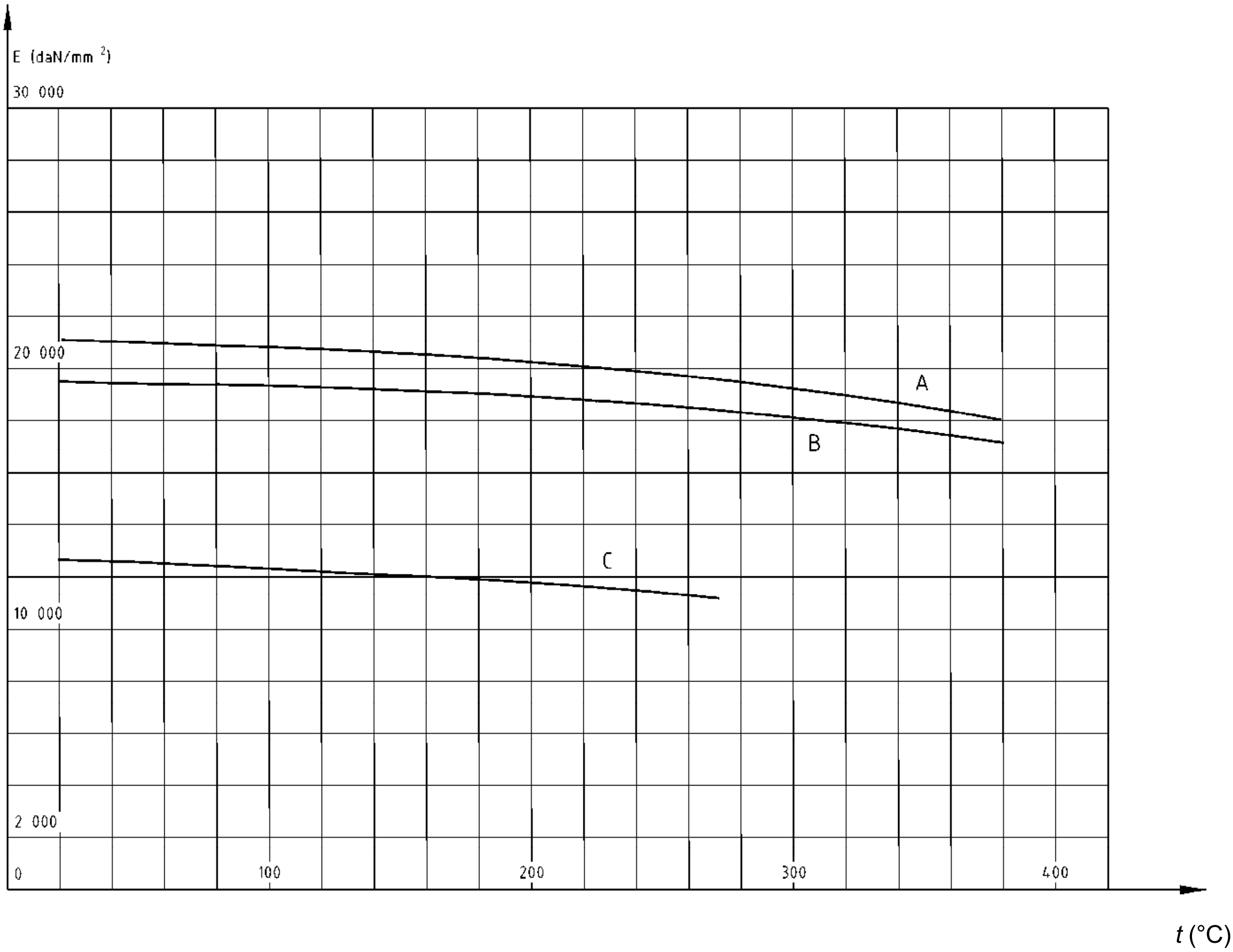
$$\frac{E_{\text{tm}}}{E_{\text{20b}}}$$

where

E_{20b} modulus of elasticity of the basic material at 20 °C

$E_{t.m}$ modulus of elasticity of the selected material at temperature t °C

For lamellar graphite cast iron, unalloyed steel and grade 18.8 stainless steel, refer to the graph in Figure 1.



Key

A Unalloyed steel

B Type 18.8 stainless steel

C Grey cast iron

Figure 1 — Variation of modulus of elasticity (*E*) as a function of temperature

5 Horizontal shaft pumps

5.1 Definition of pump families and summary of features

Pump families are defined on the basis of the most commonly used geometric configurations and the most frequent operating conditions. They are numbered from 1 to 8, as listed and described in Table 2.

Pumps with characteristics different from those in Table 2 should be subject to agreement between the parties concerned.

Table 2 — Characteristics of horizontal pump families

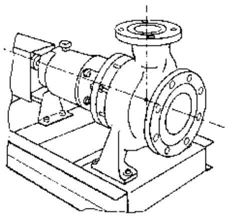
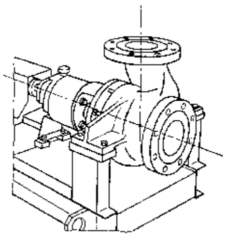
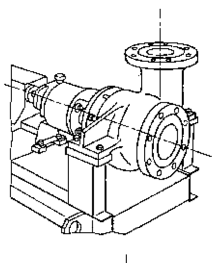
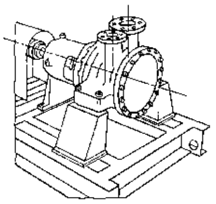
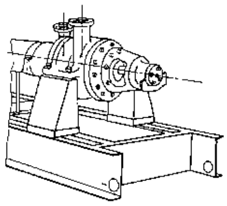
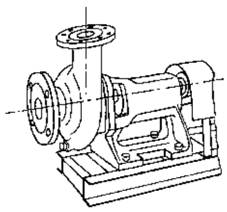
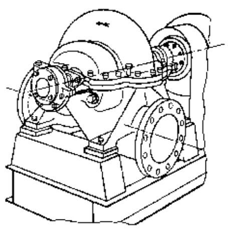
Family No. and Number of stages [1)]	**General Picture and description**	**Technical limits**			**Material**	**Remarks**	**Coefficients to apply to basic values**		**Additional possibilities** [2)]	
		Allowable Working		Flange DN_{max}						
		pressure bar	Temperature °C				Forces (N)	Moment (N.m)	Reinforced mounting	Other
1.A 1 stage		10	110	200 (Outlet)	Cast iron		x 0,50	X 0,50	yes	no
1.B 1 stage	Single stage, overhung bearing frame; feet on casing; mounted at base level.	16	250	200 (Outlet)	Cast steel	Dimensions in accordance with EN 22858.	x 1	x 1	yes	no
2 1stage	Axial inlet; outlet vertical on pump centreline.	10	110	500	Cast iron		x 0,40	x 0,40	yes	no
3.A 1 stage	 Single stage, overhung bearing frame; feet on casing; mounted at centreline level. Axial inlet; outlet vertical on pump centreline.	30	300	200 (Outlet)	Cast steel	Pump similar to EN 22858 but with casing mounted at centreline level.	x 1,2	x 1,2	yes	no
3.B 1 stage or 2 stages	  Single or two stage, overhung bearing frame; feet on casing; mounted at centreline level. Axial or overhead inlet; outlet vertical.	55	430	350	Cast steel	Equipment in accordance with API 610.	x 0,85	(- 500) on every axis x 1	yes	yes

Table 2 *(continued)*

<table>
<tr><th rowspan="3">Family No. and Number of stages [1]</th><th rowspan="3">General Picture and description</th><th colspan="3">Technical limits</th><th rowspan="3">Material</th><th rowspan="3">Remarks</th><th colspan="2">Coefficients to apply to basic values</th><th colspan="2">Additional possibilities [2]</th></tr>
<tr><th colspan="2">Allowable Working</th><th rowspan="2">Flange DN_{max}</th><th rowspan="2">Forces (N)</th><th rowspan="2">Moment (N.m)</th><th rowspan="2">Reinforced mounting</th><th rowspan="2">Other</th></tr>
<tr><th>pressure bar</th><th>Temperature °C</th></tr>
<tr><td>3.C
1 stage</td><td>
Single stage, impeller between bearings; feet on casing; mounted at centreline level.

Inlet vertical; outlet vertical.</td><td>55</td><td>530</td><td>450</td><td>Cast steel</td><td>Equipment in accordance with API 610.</td><td>x 1</td><td>x 1</td><td>yes</td><td>yes</td></tr>
<tr><td>4.A</td><td rowspan="2">
Single stage, overhung bearing frame; feet on bearing frame; mounted at base level.

Axial inlet; outlet vertical on pump centreline or tangential.</td><td rowspan="2">10</td><td rowspan="2">110</td><td rowspan="2">200</td><td>Cast iron</td><td rowspan="2"></td><td>x 0,35</td><td>x 0,35</td><td>yes</td><td>no</td></tr>
<tr><td>4.B</td><td>Cast steel</td><td>x 0,60</td><td>x 0,60</td><td>yes</td><td>no</td></tr>
<tr><td>5.A
1 stage or 2 stages</td><td>
Single or two stage; impeller between bearings; horizontal joint plane; feet on casing; mounted at base level.

Inlet and outlet perpendicular to shaft axis.</td><td>20</td><td>110</td><td>600</td><td>Cast iron</td><td></td><td>x 0,40</td><td>x 0,30</td><td>no</td><td>no</td></tr>
</table>

Table 2 *(continued)*

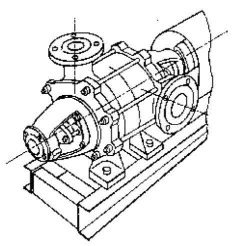
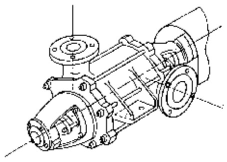
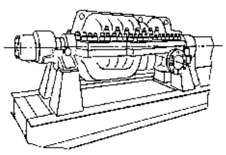
Family No. and Number of stages [1)]	General Picture and description	Technical limits			Material	Remarks	Coefficients to apply to basic values		Additional possibilities[2)]	
		Allowable Working		Flange DN_{max}						
		pressure bar	Temperature °C				Forces (N)	Moment (N.m)	Reinforced mounting	Other
5.B 1 stage or 2 stages	 Single or two stage; impeller between bearings; horizontal joint plane; feet on casing; mounted at base level. Inlet and outlet perpendicular to shaft axis.	120	175	450	Cast steel	Equipment in accordance with API 610.	x 1	x 1	yes	yes
6 Multi-stage	 Multi-stage; impellers between bearings; vertical joint plane; feet on casing mounted at base level. Inlet and outlet perpendicular to shaft axis.	15	110	150	Cast iron		x 0,30	(- 500) on resulting x 0,35	no	no

Table 2 *(end)*

Family No. and Number of stages [1)]	**General Picture and description**	**Technical limits** Allowable Working pressure bar	Allowable Working Temperature °C	Flange DN_{max}	**Material**	**Remarks**	**Coefficients to apply to basic values** Forces (N)	Moment (N.m)	**Additional possibilities** [2)] Reinforced mounting	Other
7 Multistage	 Multi-stage; impellers between bearings; vertical joint plane; feet on casing; mounted at centreline level. Inlet and outlet perpendicular to shaft axis.	40	175	150	Cast steel		x 0,72	(- 500) on resulting x 0,84	no	no
8.A 3 to 5 stages	 Muti-stage; impellers between bearings; horizontal joint plane; feet on casing mounted at centreline or base level. Inlet and outlet perpendicular to shaft axis.	150	175	350	Cast steel	Equipment in accordance with API 610.	x 1	x 1	yes	yes
8.B 6 to 10 stages							x 1	x 0,75	yes	yes
8.C 11 to 15 stages							x 1	x 0,50	yes	yes

1) In family 7, with brackets on ground, divide index by 1,2 or:

- Forces: x 0,6;
- Moments: (- 500 N.m) on resulting x 0,7.

2) For additional possibilities, see Annex B.

5.2 Calculation of maximum permissible forces and moments

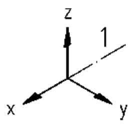
The basic values are given in Tables 3 or 4 depending on the pump family. These values are given for normal operation of the pump and are valid for conventional mounting.

The maximum permissible forces and moments are calculated by applying to the basic values the coefficients as given in Table 2 for the pump family.

It should be noted that the maximum forces and moments derived from basic values in Table 3 are applied in a different manner to those derived from Table 4. See 5.3 and 5.4.

In some cases, there are additional possibilities which allow an increase in the maximum values of forces and moments to be offered. These are described in Annex B.

Table 3 – Basic values of force and moments for horizontal pumps – Conventional mounting (pump families 1.A, 1.B, 3.A, 4.A and 4.B)



Key
1 shaft

	A[4)]	DN Inlet	DN Outlet	DN Impeller	Forces (N)			Moments (N.m)
					F_v[1)]	F_h[2)]	$\sum F$	$\sum M_t$[3)]
	9,5	50	32	125	2 500	1 900	3 150	400
Axial inlet.	8	50	32	160	2 500	1 900	3 150	350
	8	50	32	200	2 500	1 900	3 150	350
	10	50	32	250	2 500	1 900	3 150	400
Vertical	12	65	40 50	125	2 700	2 000	3 350	450
outlet on	11	65	40 50	160	2 700	2 000	3 350	450
axis of pump.	10,5	65	40	200	2 700	2 000	3 350	400
	14	65	40	250	2 700	2 000	3 350	500
	13	65	40	315	2 700	2 000	3 350	500
	16	80	50 65	125	2 900	2 100	3 600	550
	16	80	50 65	160	2 900	2 100	3 600	550
	14	80	50	200	2 900	2 100	3 600	600
	18,5	80	50	250	2 900	2 100	3 600	650
	17,5	80	50	315	2 900	2 100	3 600	650
	25	100	65 80	125	3 600	2 500	4 400	900
	27	100	65 80	160	3 600	2 500	4 400	950
	25,5	100	65	200	3 600	2 500	4 400	900
	25,5	100	65	250	3 600	2 500	4 400	900
	27	100	65	315	3 600	2 500	4 400	950
	38	125	80	160	5 000	3 100	5 900	1 400
	34	125	80	200	4 500	2 900	5 350	1 200
	34,5	125	80	250	4 500	2 900	5 350	1 250
	35	125	80	315	4 500	2 900	5 350	1 250
	39,5	125	80	400	5 100	3 150	6 000	1 450
	49	125	100	200	6 400	3 800	7 450	1 900
	50,5	125	100	250	6 600	4 000	7 700	2 050
	48	125	100	315	6 200	3 700	7 200	1 850
	44	125	100	400	5 700	3 400	6 650	1 650
	67,5	150	125	250	9 000	5 800	10 700	3 100
	63	150	125	315	8 300	5 200	9 700	2 800
	62	150	125	400	8 200	5 100	9 650	2 750
	74	200	150	250	10 000	6 500	11 950	3 500
	74	200	150	315	10 000	6 500	11 950	3 500
	74	200	150	400	10 000	6 500	11 950	3 500

1) $\frac{2}{3}\left|F_{z\,out}\right| + \left|F_{z\,in}\right| \leq F_v$

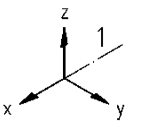
(out = outlet, in = inlet)

2) $\sqrt{F^2_{x\,in} + F^2_{y\,in}} + \sqrt{F^2_{x\,out} + F^2_{y\,out}} \leq F_h$.

3) $\sqrt{M^2_{x\,in} + M^2_{y\,in} + M^2_{z\,in}} + \sqrt{M^2_{x\,out} + M^2_{y\,out} + M^2_{z\,out}} \leq M_t$.

4) $A = \frac{\text{mass (kg)} \times \text{DN}_{out}}{D\,\text{impeller (mm)}}$

Table 4 – Basic values of force and moments for horizontal pumps – Conventionnal mounting (Pump families 2, 3.B, 3.C, 5.A, 5.B, 6, 7, 8.A, 8.B and 8.C)



Key 1 shaft	DN Flanges [1)]	Forces (N)				Moments (N.m)			
		F_y	F_z	F_x	$\sum F$	M_y	M_z	M_x	$\sum M$
	40	1 000	1 250	1 100	1 950	900	1 050	1 300	1 900
	50	1 350	1 650	1 500	2 600	1 000	1 150	1 400	2 050
	80	2 050	2 500	2 250	3 950	1 150	1 300	1 600	2 350
Horizontal	100	2 700	3 350	3 000	5 250	1 250	1 450	1 750	2 600
pump	150	4 050	5 000	4 500	7 850	1 750	2 050	2 500	3 650
	200	5 400	6 700	6 000	10 450	2 300	2 650	3 250	4 800
Top branch	250	6 750	8 350	7 450	13 050	3 150	3 650	4 450	6 550
	300	8 050	10 000	8 950	15 650	4 300	4 950	6 050	8 900
z-Axis	350	9 400	11 650	10 450	18 250	5 500	6 350	7 750	11 400
	400	10 750	13 300	11 950	20 850	6 900	7 950	9 700	14 300
	450	12 100	14 950	13 450	23 450	8 500	9 800	11 950	17 600
	500	13 450	16 600	14 950	26 050	10 250	11 800	14 450	21 300
	550	14 800	18 250	16 450	28 650	12 200	14 050	17 100	25 300
	600	16 150	19 900	17 950	31 250	14 400	16 600	20 200	29 900
	40	1 250	1 000	1 100	1 950	900	1 050	1 300	1 900
	50	1 650	1 350	1 500	2 600	1 000	1 150	1 400	2 050
	80	2 500	2 050	2 250	3 950	1 150	1 300	1 600	2 350
Horizontal	100	3 350	2 700	3 000	5 250	1 250	1 450	1 750	2 600
pump	150	5 000	4 050	4 500	7 850	1 750	2 050	2 500	3 650
	200	6 700	5 400	6 000	10 450	2 300	2 650	3 250	4 800
Side branch	250	8 350	6 750	7 450	13 050	3 150	3 650	4 450	6 550
	300	10 000	8 050	8 950	15 650	4 300	4 950	6 050	8 900
y-Axis	350	11 650	9 400	10 450	18 250	5 500	6 350	77 500	11 400
	400	13 300	10 750	11 950	20 850	6 900	7 950	9 700	14 300
	450	14 950	12 100	13 450	23 450	8 500	9 800	11 950	17 600
	500	16 600	13 450	14 950	26 050	10 250	11 800	14 450	21 300
	550	18 250	14 800	16 450	28 650	1 220	14 050	17 100	25 300
	600	19 900	16 150	17 950	3 125	14 400	16 600	20 200	29 900
	40	1 100	1 000	1 250	1 950	900	1 050	1 300	1 900
	50	1 500	1 350	1 650	2 600	1 000	1 150	1 400	2 050
	80	2 250	2 050	2 500	3 950	1 150	1 300	1 600	2 350
Horizontal	100	3 000	2 700	3 350	5 250	1 250	1 450	1 750	2 600
Pump	150	4 500	4 050	5 000	7 850	1 750	2 050	2 500	3 650
	200	6 000	5 400	6 700	10 450	2 300	2 650	3 250	4 800
End branch	250	7 450	6 750	8 350	13 050	3 150	3 650	4 450	6 550
	300	8 950	8 050	10 000	15 650	4 300	4 950	6 050	8 900
x-Axis	350	10 450	9 400	11 650	18 250	5 500	6 350	7 750	11 400
	400	11 950	10 750	13 300	20 850	6 900	7 950	9 700	14 300
	450	13 450	12 100	14 950	23 450	8 500	9 800	11 950	17 600
	500	14 950	13 450	16 600	26 050	10 250	11 800	14 450	21 300
	550	16 450	14 800	18 250	28 650	12 200	14 050	17 100	25 300
	600	17 950	16 150	19 900	31 250	14 400	16 600	20 200	29 900

1) For DN exceeding 600, agreement is to be reached between purchaser and manufacturer/supplier on the values of forces and moments.

5.3 Maximum permissible forces and moments on standardised or modular pump families

5.3.1 General

This applies to all pump families with basic values obtained from Table 3.

The values for forces and moments apply to all pump flanges all together and not to each flange separately.

Maximum permissible deformations are given in Table 1.

5.3.2 Composition of forces and moments

Whatever the direction of application of the forces and moments and their distribution on the pump flanges, the maximum permissible values remain within the framework of the following formula:

$$\left(\frac{\Sigma|F_{v}|}{F_{v}\max}\right)^{2}+\left(\frac{\Sigma|F_{h}|}{F_{h}\max}\right)^{2}+\left(\frac{\Sigma|M_{t}|}{M_{t}\max}\right)^{2}\leq 1$$

F_v max, F_h max, M_t max being the values given by the tables;

$\Sigma|F_v|$, $\Sigma|F_h|$, $\Sigma|M_t|$, being the algebric sums of the absolute values of the actual (or applied) loads to the pump flanges.

These sums do not take account of the direction of the stresses or of the distribution on each flange.

NOTE This formulation leaves the user completely free as regards the distribution of the various loads on the pump flanges, in the knowledge that the maximum value for each of the loads cannot be achieved simultaneously.

5.3.3 Possibility of adapting the tables to other pumps of similar design

The maximum permissible values on flanges are tabulated in Annex B of EN ISO 5199:2002 for many pump families according to their dimensions and conditions of installation.

If any pumps have no characteristics mentioned in these tables, the manufacturer/supplier is authorized to consider them as similar in one of the families of his choice, either a particular agreement should be signed between the buyer and the manufacturer/supplier for every particular case.

5.4 Other horizontal pump families

This applies to all pump families with basic values obtained from Table 4.

The values for maximum forces and moments apply to each flange taken separately.

5.5 Practical considerations for horizontal shaft pumps

A pump is not a static unit attached to pipework, but a precision machine, inside which a moving part turns at high speed, and which has tight clearances and high precision sealing devices as mechanical fittings. It is, therefore important, to stay below the maximum load limits given by this CEN Technical Report whenever possible.

This specification, agreed upon and jointly set up by manufacturers/suppliers and users in their mutual best interests, points out the following recommendations:

a) the initial alignment of the pump/driver coupling should be made with a great care and should be periodically checked according to the instructions of the pump or coupling manufacturer;

b) a coupling with a spacer piece having two articulated connecting points is always preferable, specially for a large pumping unit and/or pump handling fluids at temperatures exceeding 250 °C;

c) the piping connections, during initial erection, should be made strictly in accordance with current regulations and with the instructions provided by the pump manufacturer/supplier or designer of the piping system. A check is recommended every time partial or complete dismantling of the installation is undertaken;

d) in certain cases, according to the type of pump involved and the operating temperature during service, the initial alignment of the coupling may be made at a temperature higher than ambient.

The manufacturer/supplier and the user should strictly define the conditions for alignment and assembly of the coupling should the procedure in d) be adopted.

6 Vertical shaft pumps

6.1 Definition of pump families and summary of features

Pump families are defined on the basis of their configurations (installation types - position(s) of flange(s).

They are numbered from 20 to 36, as listed and described in Table 5.

Sub-divisions A and B correspond to:

— A grey cast iron construction;

— B steel construction.

6.1.1 Installation types

The arrangement of a vertical shaft pump may be based on a number of constraints, concerning design and/or application, the main ones being grouped as follows:

— restricted floor space;

— low or very low NPSHA (net positive suction head available) at ground level (see 6.2);

— ground water pumping (borehole, well, pit, tank, etc.);

— special problems.

There is, therefore, a very wide variety of, and range of uses for, vertical shaft pumps and it would be impractical to cover all sizes and variations. The types and sizes covered in this report are restricted as follows:

— by keeping to the flange range DN 40 to DN 600, which excludes "domestic" pumps, on the one hand, and, on the other, large pieces of equipment generally of unitary construction, frequently requiring specific discussion between the contracting parties concerned;

— by considering only designs for which the flanges are located close to the plane of fixing or installation, the maximum distance being defined below (see notes in Clause 3 of this document);

— by grouping all this equipment in accordance with three principles, enabling classification to be simplified, namely:

a) suspended shaft pumps generally used for transporting water (families 20.A, 20.B and 21.A, 21.B);

b) suspended shaft pumps generally used for transporting liquids other than water for specific sectors of activity, such as: petroleum, petrochemicals, chemicals, etc. (families 25.A, 25.B and 26.A, 26.B for submerged lift pumps - families 28.A, 28.B and 29.A, 29.B for tank lift pumps);

c) other vertical shaft pumps, known as "in line" (families 35.A, 35.B and 36.A, 36.B).

NOTE All other cases, consequently excluded from this standard, should be defined by pump manufacturers, who may, if they wish, or if there is felt to be a need, discuss the matter with their customers.

6.1.2 Position(s) of flange(s)

The flanges concerned may be either:

— outlet only (families 20, 21, 25 and 26)

  this is the case when the inlet is located in a borehole, well, pit or tank;

— outlet and inlet (families 28, 29, 35 and 36)

  this is typically the case when the pump is located inside a header tank or when the pump is of the "in line" type (families 35 and 36).

The outlet and inlet flanges may be located:

— above the installation plane (Figure 2);

— below the installation plane (Figure 3).

Figures 2 and 3 in Clause 6.2 represent their arrangements and show the maximum distances A and B to be observed.

NOTE Beyond the limit distances A and B, the manufacturer may, if he wishes, retain the indicated values for forces and moments, or reduce them.

Table 5 — Characteristics of vertical pump families

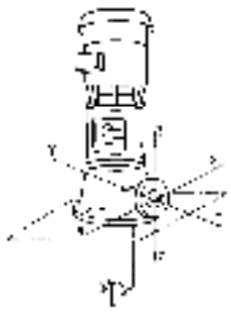
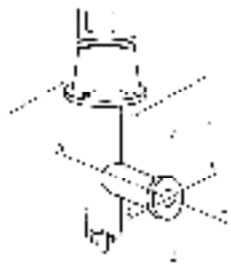
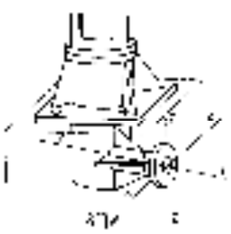
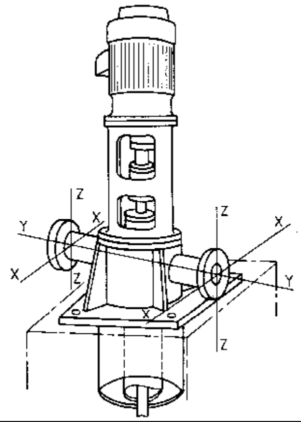
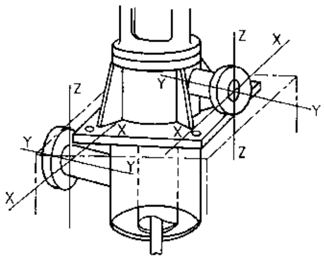
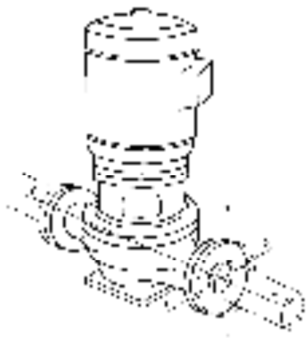
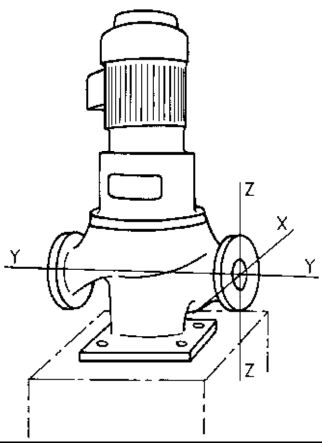
Family No. and Number of stages	General Picture and description		Technical limits			Material	Coefficients to apply to basic values		Additional possibilities 3)	
			Allowable Working Pressure bar	Allowable Working Temperature °C	Flange DN_{max}		Forces (N)	Moment (N.m)	Yes	No
20A 1)2)		Suction branch is sub-merged	20	60	50 to 600	Cast iron	x 0,3	x 0,3		X
20B 1)2)						Cast steel	x 0,6	x 0,6		X
21A 1)			20	60	50 to 600	Cast iron	x 0,1	x 0,1		X
21B 1)						Cast steel	x 0,2	x 0,2		X
25A 1)		Suction branch is sub-merged	30	0 to 110	40 to 350	Cast iron	x 0,375	(- 500) x 0,5		X
25B 1)			55	- 45 to 250		Cast steel	x 0,750	(- 500) x 1	X	
26A 1)			30	0 to 110	40 to 350	Cast iron	x 0,262	(- 500) x 0,35		X
26B 1)			55	- 45 to 250		Cast steel	x 0,525	(- 500) x 0,7		X

Table 5 *(end)*

Family No. and Number of stages	General Picture and description	Technical limits			Material	Coefficients to apply to basic values		Additional possibilities [3)]	
		Allowable Working		Flange DN_{max}		Forces (N)	Moment (N.m)	Yes	No
		Pressure bar	Temperature °C						
28A[1)]		30	0 to 110	40 to 350	Cast iron	x 0,375	(- 500) x 0,5		X
28B[1)]		55	- 45 to 250		Cast steel	x 0,750	(- 500) x 1	X	
29A[1)]		30	0 to 110	40 to 350	Cast iron	x 0,262	(- 500) x 0,35		X
29B[1)]		55	- 45 to 250		Cast steel	x 0,525	(- 500) x 0,7	X	
35A		30	110	40 to 150	Cast iron	x 0,5	x 0,5		X
35B			250	40 to 200	Cast steel	x 1	x 1	X[2)]	
36A		30	110	40 to 150	Cast iron	x 0,375	(- 500) x 0,5		X
36B			250	40 to 200	Cast steel	x 0,750	(- 500) x 1	X	

[1)] The allowable values of forces and moments for the families 20 to 29 are only valid when the distance between the centreline of the flanges on which the loads are applied and the installation or fixing plane is within the limits *A (mm)* ≤ 1,5 *DN.* (See 6.2 for definition of dimension A).

[2)] Except for prestressing on pipework.

[3)] For additional possibilities, see Annex B.

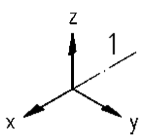
6.2 Calculation of maximum permissible forces and moments

The basic values are given in Table 6.

The maximum permissible forces and moments are calculated by applying to the basic values the coefficient as given in Table 5 for the pump family.

In some cases, there are additional possibilities which allow an increase in the maximum values of forces and moment to be offered. These are described in Annex B.

Table 6 — Basic values of forces and moments on vertical shaft pump flanges

 **Key** 1 shaft	**DN**	**Forces** (N)				**Moments** (N.m)			
		F_y	F_z	F_x	ΣF	M_y	M_z	M_x	ΣM
Horizontal pipes perpendicular to shaft on Y axis	40	1 000	1 250	1 100	1 950	1 300	900	1 050	1 900
	50	1 350	1 650	1 500	2 600	1 400	1 000	1 150	2 050
	80	2 050	2 500	2 250	3 950	1 600	1 150	1 300	2 350
	100	2 700	3 350	3 000	5 250	1 750	1 250	1 450	2 600
	150	4 050	5 000	4 500	7 850	2 500	1 750	2 050	3 650
	200	5 400	6 700	6 000	10 450	3 250	2 300	2 650	4 800
	250	6 750	8 350	7 450	13 050	4 450	3 150	3 650	6 550
	300	8 050	10 000	8 950	15 650	6 050	4 300	4 950	8 900
	350	9 400	11 650	10 450	18 250	7 750	5 500	6 350	11 400
	400	10 750	13 300	11 950	20 850	9 700	6 900	7 950	14 300
	450	12 100	14 950	13 450	23 450	11 950	8 500	9 800	17 600
	500	13 450	16 600	14 950	26 050	14 450	10 250	11 800	21 300
	550	14 800	18 250	16 450	28 650	17 100	12 200	14 050	25 300
	600	16 150	19 900	17 950	31 250	20 200	14 400	16 600	29 900

The basic values in Table 6 are only valid within the following limits of flange position and construction as given in a) and b) hereafter:

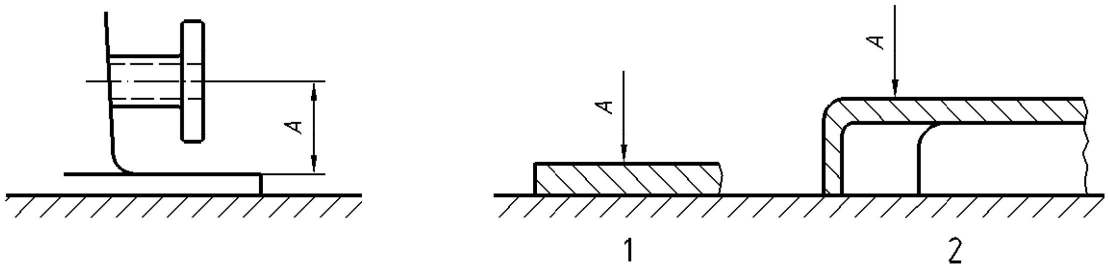
a) Flange position

If the distance between the axis of the flange and the installation or fixing plane meets the relevant conditions below.

— Flange above installation or fixing plane;

— A in millimetres ≤ 1,5 DN (flange DN).

NOTE 1 Starting from the upper surface of the fixing seating, dimension A, allowing the flange clearance, should be independent of the type of construction, sheet metal or casting (see Figure 2).



Key

1 Sheet metal construction

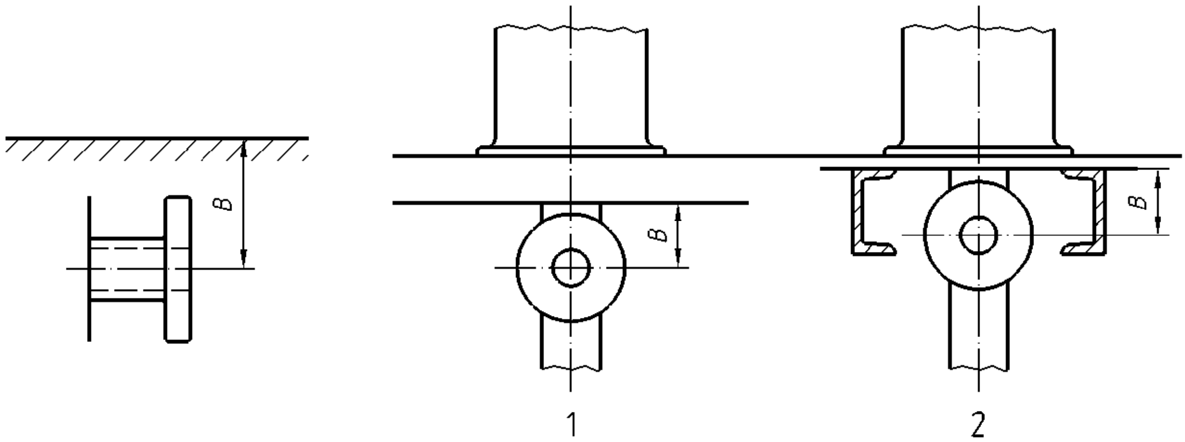
2 Cast construction

Figure 2 — Flange above installation or fixing plane

— Flange below installation or fixing plane;

— B in millimetres ≤ 18 $\sqrt{\text{DN}}$ (flange DN).

NOTE 2 Dimension B is only of importance in the immediate vicinity of the flange, allowing clearance for the latter. This dimension is taken from the surface situated below the installation plane (see Figure 3).



Key

1 Fixing on concrete slab

2 Fixing on metal support

Figure 3 — Flange below installation or fixing plane

b) Construction

If the construction is of cast steel type or of fabricated steel of equivalent thickness with continuous welding.

NOTE 3 Neither intermittent nor spot welded fabrication are considered sufficiently robust to be equivalent to cast steel construction.

For cast iron and cast steel constructions, see reduction coefficient in Table 5.

6.3 Maximum permissible forces and moments on pump flanges

6.3.1 General

The maximum permissible forces and moments are calculated by applying to the basic values the coefficients as given in Table 5 for the pump family.

Maximum permissible deformations are given in Table 1.

6.3.2 Suspended shaft pumps generally used for transporting water ("for water")

6.3.2.1 Families 20.A and 20.B

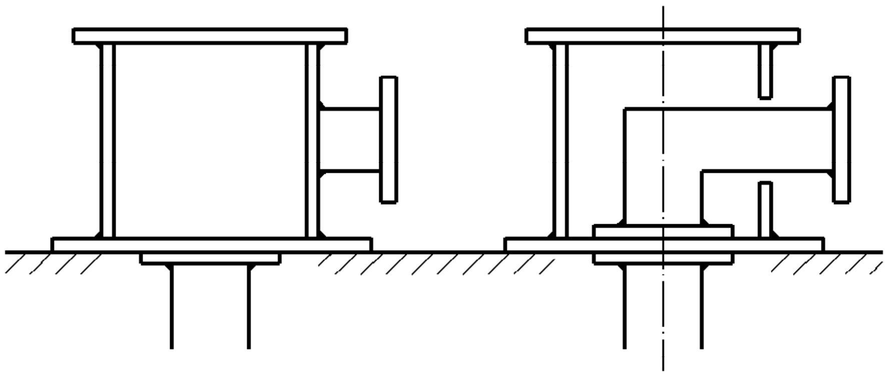
For these pump types this report considers only the forces and moments on the outlet flange. Appropriate means shall be provided to withstand loading on the submerged inlet and suspended part of the pump.

Where the pump is designed for a maximum operating pressure below 2 MPa (20 bar) (e.g. high specific speed, axial flow), steel fabrication may be used and the values of maximum forces and moments reduced by the ratio of maximum operating pressure / 2 MPa (20 bar) or 0,2 whichever is greater.

For fabricated sheet steel construction the values of forces and moments are calculated as for cast iron unless the requirements of 6.2.b have been satisfied.

Coefficients in Table 5 for these families are given for monobloc construction of the outlet elbow and pump mounting. Where a separate construction (two or more pieces) is used, calculated values should be divided by 2.

Figure 4 shows examples of "monobloc" and "separate" construction".



1 2

Key

1 Monobloc construction
Monobloc outlet elbow and seating
Highly rigid outlet flange

2 Separate construction
Separate outlet elbow and seating
Less rigid outlet flange

Figure 4 — Monobloc and separate construction

6.3.2.2 Families 21.A and 21.B

For these pump types this report considers only the forces and moments on the outlet flange. Appropriate means should be provided to withstand loading on the submerged inlet and suspended part of the pump.

6.3.3 "In line" pumps

The pump, while being fixed by pipework, may:

— rest, if necessary, on a concrete or metal support (see 6.3.3.1), or

— be fixed by its seating (see 6.3.3.2).

NOTE Since the loads imposed by pipework are due to the presence of fixed points which prevent the pipework from being deformed, it follows that the pipework will transmit lower loads to the flanges of the pump if the latter can move (family 35), than if it is acting as a fixed point (family 36). So if the pump can move (family 35) it is logical to allow that, the permissible values for the loads from the pipework to be higher than those permitted if the pump is acting as a fixed point (family 36).

6.3.3.1 Pump resting, if necessary, on a concrete or metal support - Families 35.A and 35.B

The pump can move under the action of loads.

NOTE In this special case, the flanges cannot be considered as fixed points in space. The purchaser should ensure that the loads transmitted through the pump are not excessive.

6.3.3.2 Pump fixed by its seating - Families 36.A and 36.B

The pump cannot move under the action of loads.

6.4 Practical considerations for vertical shaft pumps

Vertical pumps, other than the monobloc "in-line" type, have the special feature of a long or fairly long lineshaft, running in sleeve bearings spaced at regular intervals, often lubricated by the pumped liquid. As a result, smooth operation of the rotating assembly depends upon good alignment. This can only be ensured if the external loads applied to the pump flanges do not cause distortions greater than those allowed by the manufacturer/supplier.

In view of the design concept of vertical pumps and their sensitivity to misalignment, the present report limits the forces and moments on their flanges to values lower than those allowed on horizontal pumps.

Furthermore, visual assessment of distortion at the level of the coupling is not as easy as in the case of horizontal pumps, since the motor and its stool are often closely connected to the upper part of the pump. Such distortions can in fact only be related to a fixed reference point in space. Verification being difficult, the user should follow closely the recommendations given by the manufacturer/supplier.

Excessive constraints on the flanges, in addition to compromising good operation and/or reliability, usually give rise to:

— a vibration level greater than normal;

— difficulty in turning the rotor by hand at rest (at the operating temperature), when the mass of the rotor allows such hand-turning.

Annex A
(informative)

Horizontal shaft pumps - Calculation of forces and moments for reinforced and/or concrete mountings for families 2, 3.B, 3.C, 5.A, 5.B, 6, 7 and 8

The maximum values for the forces and moments for reinforced and/or concrete mountings should be calculated on the basis of the following relations:

— for forces:

$$F' = F\left(1{,}5 - \frac{12{,}5}{\text{DN of the flange}}\right)$$

— for moments:

$$M' = M\left(1 + \frac{\text{DN of the flange}}{250}\right)$$

assuming that, for moments, the multiplication factor is restricted to 2, in other words:

M' max ≤ 2 M,

with:

F' and M'	values for reinforced and/or concrete mounting;
F and M	values shown for conventional mounting.

NOTE For pumps, families 1.A, 1.B, 3.A, 4.A and 4.B, the maximum forces and moments for reinforced and/or concrete mountings were determined during tests that enabled basic curves to be produced (see 5.3.3).

Annex B
(informative)

Specifications relating to additional possibilities

B.1 General

Some provisions, such as pump stopped, pre-stressing, reinforced and/or concrete mounting are summarized below and are intended to help with the layout and calculation of pipework.

An indication of which of these possibilities are authorized for each pump family is given in the last column of Tables 2 and 5.

B.2 Horizontal pumps only

B.2.1 Pump stopped

The maximum permissible values for force (F_o) and moment (M_o) with the pump stopped relative to the values for the pump operating, respectively F_1 and M_1, are given in Table B.1.

NOTE It is important before starting the pump that these exceptional loads must return to the normal values for the pump operation.

Table B.1 — Maximum permissible forces and moments with the pump stopped

Re-alignment of coupling	Type of baseplate	Flange size	F_o/F_1	M_o/M_1
No	Conventional	All	≤ 1,2	≤ 1,2
	Reinforced	≤ 200	≤ 1,2	≤ 1,2
	Reinforced	250 and over	≤ 1,2	≤ 1,1
Yes	Conventional	All	≤ 1,4	≤ 1,4
	Reinforced	≤ 200	≤ 1,4	≤ 1.4
	Reinforced	250 and over	≤ 1,4	≤ 1.2
NOTE In no case may F_o/F_1 or M_o/M_1 exceed 1,4. Also, see the appropriate table for the values of F_1 and M_1, corresponding to the family and size of pump.				

B.2.2 Reinforced and/or concrete mounting

For family 1.A, 1.B, 2, 3.A, 3.B, 3.C, 4.A, 5.B, 8.A, 8.B and 8.C, the maximum permissible values to be taken into consideration for assembling the set on a reinforced and/or concrete mounting for normal operation may be obtained according to the calculation criteria given in Annex A.

The basic values applicable for the calculations are given in Tables B.2 and B.3.

For maximum permissible forces and moments applicable to each pump family, the coefficients given in Table 2 shall apply.

Table B.2 — Basic values of forces and moment - Reinforced and/or concrete mounting (pump families 1A, 1B, 3A, 4A, 4B) – Normal operation

Pipe Arrange-ment	A[4)]	DN Inlet	DN Outlet	DN Impeller	Forces (N)			Moments (N.m)
					F_v[1)]	F_h[2)]	ΣF	ΣM_t[3)]
Axial inlet.	9,5	50	32	125	4 500	3 100	5 450	900
	8	50	32	160	4 500	3 100	5 450	850
	8	50	32	200	4 500	3 100	5 450	850
	10	50	32	250	4 500	3 100	5 700	1 000
Vertical	12	65	40 50	125	4 800	3 300	5 800	1 100
outlet on	11	65	40 50	160	4 800	3 300	5 800	1 050
axis of pump	10,5	65	40	200	4 800	3 300	5 800	1 000
	14	65	40	250	5 000	3 500	6 100	1 250
	13	65	40	315	5 000	3 500	6 100	1 200
	16	80	50 65	125	5 200	3 600	6 300	1 400
	16	80	50 65	160	5 200	3 600	6 300	1 400
	14	80	50	200	5 200	3 600	6 300	1 250
	18,5	80	50	250	5 500	4 000	6 800	1 600
	17,5	80	50	315	5 500	4 000	6 800	1 550
	25	100	65 80	125	6 400	4 700	7 950	2 150
	27	100	65 80	160	6 400	4 900	8 200	2 300
	25,5	100	65	200	6 400	4 700	7 950	2 200
	25,5	100	65	250	6 400	4 700	7 950	2 200
	27	100	65	315	6 600	4 900	8 200	2 300
	38	125	80	160	8 300	6 300	10 400	3 350
	34	125	80	200	7 600	5 800	9 550	2 950
	34,5	125	80	250	7 600	5 800	9 550	2 950
	35	125	80	315	7 600	5 800	9 550	2 950
	39,5	125	80	400	8 300	6 300	10 400	3 450
	49	125	100	200	9 700	7 600	12 300	4 450
	50,5	125	100	250	9 900	7 900	12 650	4 500
	48	125	100	315	9 600	7 400	12 100	4 250
	44	125	100	400	8 900	7 000	11 300	3 850
	67,5	150	125	250	12 300	10 600	16 250	6 300
	63	150	125	315	11 700	9 700	15 200	5 750
	62	150	125	400	11 500	9 600	15 000	5 700
	74	200	150	250	13 200	11 700	17 650	6 850
	74	200	150	315	13 200	11 700	17 650	6 850
	74	200	150	400	13 200	11 700	17 650	6 850

1) $\frac{2}{3}\,|F_{z\,out}| + |F_{z\,in}| \leq F_v$

(out = outlet, in = inlet)

2) $\sqrt{F^2_{x\,in} + F^2_{y\,in}} + \sqrt{F^2_{x\,out} + F^2_{y\,out}} \leq F_h$.

3) $\sqrt{M^2_{x\,in} + M^2_{y\,in} + M^2_{z\,in}} + \sqrt{M^2_{x\,out} + M^2_{y\,out} + M^2_{z\,out}} \leq M_t$.

4) $A = \dfrac{\text{mass (kg)} \times \text{DN}_{out}}{D\,\text{impeller (mm)}}$

Table B.3 — Basic values of forces and moments - Reinforced and/or concrete mounting (pump families 2, 3B, 3C, 5A, 5B, 6, 7, 8A, 8B and 8C) – Normal operation

Pipe Arrangement	DN flanges	Forces (N)				Moments (N.m)			
		F_y	F_z	F_x	$\sum F$	M_y	M_z	M_x	$\sum M$
Vertical pipe	40	1 150	1 450	1 300	2 300	1 050	1 200	1 500	2 200
	50	1 700	2 050	1 850	3 250	1 200	1 400	1 700	2 450
	80	2 750	3 350	3 000	5 250	1 500	1 700	2 100	3 050
	100	3 700	4 600	4 100	7 200	1 750	2 050	2 450	3 650
	150	5 750	7 100	6 350	11 100	2 800	3 300	4 000	5 850
	200	7 750	9 650	8 600	15 000	4 150	4 750	5 850	8 650
	250	9 800	12 100	10 800	18 900	6 300	7 300	8 900	13 100
	300	11 750	14 600	13 050	22 800	8 600	9 900	12 100	17 800
	350	13 750	17 050	15 300	26 700	11 000	12 700	15 500	22 800
	400	15 750	19 500	17 500	30 550	13 800	15 900	19 400	28 600
	450	17 800	22 000	19 800	34 500	17 000	19 600	23 900	35 200
Horizontal pipe perpendicular to shaft	40	1 450	1 150	1 300	2 300	1 050	1 200	1 500	2 200
	50	2 050	1 700	1 850	3 250	1 200	1 400	1 700	2 450
	80	3 350	2 750	3 000	5 250	1 500	1 700	2 100	3 050
	100	4 600	3 700	4 100	7 200	1 750	2 050	2 450	3 650
	150	7 100	5 750	6 350	11 100	2 800	3 300	4 000	5 850
	200	9 650	7 750	8 600	15 000	4 150	4 750	5 850	8 650
	250	12 100	9 800	10 800	18 900	6 300	7 300	8 900	13 100
	300	14 600	11 750	13 050	22 800	8 600	9 900	12 100	17 800
	350	17 050	13 750	15 300	26 700	11 000	12 700	15 500	22 800
	400	19 500	15 750	17 500	30 550	13 800	15 900	19 400	28 600
	450	22 000	17 800	19 800	34 500	17 000	19 600	23 900	35 200
Horizontal pipe parallel with shaft	40	1 300	1 150	1 450	2 300	1 050	1 200	1 500	2 200
	50	1 850	1 700	2 050	3 250	1 200	1 400	1 700	2 450
	80	3 000	2 750	3 350	5 250	1 500	1 700	2 100	3 050
	100	4 100	3 700	4 600	7 200	1 750	2 050	2 450	3 650
	150	6 350	5 750	7 100	11 100	2 800	3 300	4 000	5 850
	200	8 600	7 750	9 650	15 000	4 150	4 750	5 850	8 650
	250	10 800	9 800	12 100	18 900	6 300	7 300	8 900	13 100
	300	13 050	11 750	14 600	22 800	8 600	9 900	12 100	17 800
	350	15 300	13 750	17 050	26 700	11 000	12 700	15 500	22 800
	400	17 500	15 750	19 500	30 550	13 800	15 900	19 400	28 600
	450	19 800	17 800	22 000	34 500	17 000	19 600	23 900	35 200

B.3 Horizontal and vertical pumps

B.3.1 Prestressing on the pipework

B.3.1.1 General

The use of prestressing should be exceptional. It is intended to reduce the maximum forces and moments so that they are compatible with the limits set by this document. This process should only be used with the agreement of the customer. This is the inversion of the direction of loads between those created by the prestressing and those caused by expansion, which, through reciprocal compensation, achieves the result.

The permissible rate of prestressing should remain lower than the maximum stresses able to be withstood by the pump flanges, in order to take account of the range of uncertainty which may be encountered:

— either because of additional stresses, which are difficult to monitor, resulting from the location tolerances at the moment of attachment; or

— because of a more or less rigorous superimposition of two opposing loads during operation.

B.3.1.2 Values

The maximum permissible prestressing values should not exceed 0,65 of the values authorized by this document.

B.3.1.3 Conditions of use

The use of prestressing should be exceptional. It may only be authorised under the following conditions:

— the pump is permanently fixed before attachment of the pipework,

— attachment is in accordance with current tolerances and regulations,

— the designer of the pipework has a perfect knowledge of all the loads and their directions and should take responsibility for their values,

— the designer of the pipework identifies, in accordance with his data and calculations, any adjustment device needed to bring about the agreed prestressing, these devices being carefully listed and shown on the pipework plans,

— the manufacturer of the pump should be permitted, in case of difficulties occurring during operation, to check by any appropriate means the actual loads on the pump flanges at maximum operating temperature and at ambient temperature.

B.3.2 Weighting or compensation formula

If the loads applied do not act simultaneously at their maximum values, it is permitted for one of the loads to exceed its maximum permissible value, providing the following additional conditions are met:

— any component of a force or moment is restricted to a maximum of 1,4 times the maximum permissible value provided that the resultant value (force or moment) remains unchanged or lesser;

— the actual forces and moments on each flange (inlet flange and outlet flange) is linked by the following relations:

$$\left(\frac{\Sigma|F|\text{actual}}{\Sigma|F|\text{max permissible}}\right)^2 + \left(\frac{\Sigma|M|\text{actual}}{\Sigma|M|\text{max permissible}}\right)^2 \leq 2$$

$\sum|F|$ and $\sum|M|$ are the arithmetic sums of the absolute values of forces and moments on each flange, both for the calculated values and for the maximum permissible values given in the document, according to the pump.

B.3.3 Limit of accumulation of possibilities

This accumulation enables advantage to be taken of several additional possibilities simultaneously, providing that taken together they do not require values greater than 2,4 times the values corresponding to the pump family in question during normal operation.

Bibliography

[1] EN ISO 9905, *Technical specifications for centrifugal pumps - Class I (ISO 9905:1994)*

[2] EN ISO 9908, *Technical specifications for centrifugal pumps - Class III (ISO 9908:1993)*

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