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REVISIONE		DESCRIZIONE	EL.	CON.	APP.

MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI

MAGISTRATO ALLE ACQUE

NUOVI INTERVENTI PER LA SALVAGUARDIA DI VENEZIA

CONVENZIONE REP. 7191 DEL 04-10-1991
ATTO ATTUATIVO REP. 8249 DEL 28-12-2007
ATTO ATTUATIVO REP. 8492 DEL 30-03-2011

INTERVENTI ALLE BOCCHE LAGUNARI PER LA REGOLAZIONE DEI FLUSSI DI MAREA

(CUP: D51B020000500D1 (A.A. 8249), D51B020000500H1 (A.A. 8492)

PROGETTO ESECUTIVO

WBS: MA.E1.14

BOCCA DI MALAMOCCO
CONCA DI NAVIGAZIONE
PORTE E OPERE ELETTROMECCANICHE

IMPIANTI MECCANICI
RELAZIONE DI CALCOLO

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- PROGETTO ESECUTIVO -

BOCCA DI MALAMOCCO – CONCA DI NAVIGAZIONE
PORTE E OPERE ELETTROMECCANICHE

IMPIANTI MECCANICI

RELAZIONE DI CALCOLO

INDICE

1. INTRODUZIONE

1.1. Generalità

La presente relazione studia le forze che si creano nel funzionamento della porta durante le fasi di apertura e chiusura sulle varie parti meccaniche ad essa connesse.

Alcuni apparati meccanici si interfacciano con parti strutturali, quali gli hydrofeet, i cilindri ed i dispositivi di trazione, oltre agli impianti civili quali i collegamenti dei dispositivi di trazione.

I calcoli sono eseguiti senza l'ausilio di programmi di calcolo specifici.

In diversi casi è stato possibile estrapolare i carichi di progetto dal documento n° MV036P-PE-M-A-R-4003 – Relazione di calcolo strutturale della porta.

L'analisi descritta in questo documento è riferita ad una sola porta, ma ha validità anche per la seconda, in luce della identica struttura e funzionamento.

1.2. Documenti di riferimento

Nel seguito, si fa riferimento ai seguenti documenti:

- MV036P-PE-MAR-4000 Criteri di progetto funzionale della porta
- MV036P-PE-MAR-5001 Criteri di progetto e Dati di riferimento
- MV036P-PE-MAR-4002 Relazione di calcolo strutture in acciaio principali
- MV036P-PE-MAR-4003 Relazione di calcolo strutture in acciaio secondarie

1.3. Scopo

Oggetto della presente relazione sono i componenti meccanici della porta, elencati di seguito secondo la numerazione specifica che assumono nel sistema. Per conoscere in dettagliato le parti meccaniche, si può consultare il documento MV036P-PE-M-A-L-4100

3. Meccanico

3.1. Sistema di trazione

3.1.1. Verricelli

3.1.2. Pulegge

3.1.3. Funi

3.1.4. Contrappesi

2. CONCLUSIONI

Le verifiche dei particolari meccanici, secondo le prescrizioni imposte dei relativi codici in materia, sono soddisfatte, e ne consegue la loro conformità ai requisiti di progetto.

3. DESCRIZIONI

3.1. Introduzione

Le strutture principali in acciaio sono calcolate nel documento MV036P-PE-M-A-R-4002 - Relazione di calcolo strutture in acciaio principali, mentre il calcolo dei particolari strutturali è riportato nel documento MV036P-PE-M-A-R-4003 - Relazione di calcolo strutture in acciaio secondarie.

Le azioni che sollecitano le parti meccaniche possono essere derivati dai risultati del calcolo delle strutture in acciaio principali e secondarie, ma non sempre ciò è possibile. In tali casi si devono analizzare direttamente le condizioni di carico a cui questi elementi sono soggetti, come descritto nel documento MV036P-PE-MMR-5001 - Criteri di progetto e Dati di riferimento.

In questo capitolo sono descritte le parti meccaniche analizzate ed i carichi specifici che agiscono su di esse.

3.2. Sistema di trazione

Descrizione:

Il sistema di trazione è il sistema che muove la porta e comprende le funi di trazione con annesse carrucole, l'unità di tensionamento, i tamburi e le trasmissioni meccaniche.

Le funi di trazione sono collegate da un lato alla porta, sulla struttura d'acciaio principale, e dall'altro su un tamburo alloggiato nel locale macchine; sono tenute in pre-tensionamento sfruttando il funzionamento a gravità di un meccanismo di tensionamento verticale a contrappesi.

I tamburi sono azionati da un motore elettrico collegato ad una scatola ingranaggi con due alberi d'entrata. Nel caso di disfunzione di un verricello o degli hydrofeet, la velocità della porta deve essere ridotta. In questo caso è un motore con riduttore ad ingranaggi, collegato manualmente al secondo albero d'entrata della scatola ingranaggi, ad avviare i tamburi, mentre il motore elettrico principale gira a vuoto (è in folle).

Disegni:

- MV036P-PE-MMD-5250 Disposizione funi di trazione linea 1
- MV036P-PE-MMD-5251 Disposizione funi di trazione linea 2
- MV036P-PE-MMD-5270 Verricelli
- MV036P-PE-MMD-5271 Pulegge - Particolari

– MV036P-PE-MMD-5273 Connettori Funi - Particolari

Carichi:

La forza di trazione risultante comprende i seguenti contributi:

– Attrito dell'acqua e "attrito secco" tra i cuscinetti e la struttura
– Forze di inerzia
– Disassamento

Sono possibili diverse condizioni e combinazioni. Lo studio dei carichi principali è presentato nell'allegato D1 di MV036P-PE-MAR-4003 - Relazione di calcolo strutture in acciaio secondarie.

Calcoli:

I calcoli e le scelte del materiale, per questi elementi, sono contenuti nell'allegato A di questo documento.

3.3. Parti meccaniche delle saracinesche di livellamento

Descrizione:

Le saracinesche di livellamento sono composte da dieci tubi, connessi sul lato laguna al rivestimento della porta ed alla struttura reticolare sul lato mare. Sul lato laguna, in corrispondenza di ogni tubo sono fissate alla porta due travi per diffondere il getto d'acqua, mentre sul lato mare il flusso potrà essere interdetto da valvole preposte. Azionate da cilindri, consistono in una struttura a piastre stagne che scorre verticalmente lungo una guida con all'interno dei cuscinetti ammortizzatori in UHMWPE. Le guarnizioni in UHMWPE attorno all'apertura del tubo fungono-da elemento di tenuta tra valvola e tubo stesso.

Il cilindro oleoidraulico, l'unità oleoidraulica e le tubazioni sono analizzati nell'allegato B di questo documento.

Disegni:

– MV036P-PE-MPK 5103 Impianto oleoidraulico - P & ID
– MV036P-PE-MAD-4350 Lay out di assieme delle saracinesche di livellamento
– MV036P-PE-MAD-4351 Connettori diffusori lato laguna
– MV036P-PE-MAD-4352 Valvole lato mare

- MV036P-PE-MAD-4353 Telai delle valvole
- MV036P-PE-MAD-4354 Supporto dei cilindri

Carichi:

Il cilindro oleoidraulico dovrà contrastare le forze di attrito che sviluppano le parti in movimento, a causa della forza impressa alla valvola per farla scendere e del suo peso proprio, e la forza di aspirazione.

Si veda l'allegato B di questo documento.

Calcoli:

I calcoli e le scelte del materiale per questi elementi sono riportati nell'allegato B a questo documento.

3.4. Sistema hydrofoot

Descrizione:

L'hydrofoot è composto da una piastra con quattro alloggiamenti, all'interno dei quali è pompata acqua in pressione. Le dimensioni del basamento, degli alloggiamenti e la pressione dell'acqua, consentono, in fase di esercizio, al basamento stesso di sollevarsi dalla soglia di scorrimento di circa 0.1 mm. Il flusso d'acqua, necessario per questa operazione, è ottenuto grazie all'impiego di una pompa di alimentazione (a bassa pressione) collegata ad una di spinta (ad alta pressione).

La soglia di scorrimento è rivestita con un tappetino in gomma.

La struttura è formata da un tubo interno, collegato in sommità ad un tubo esterno. Il buon raccordo fra i due diametri è fornito da due anelli in UHMWPE posti intorno al tubo interno. Le forze verticali sono trasferite da una compressione del tubo interno ad un anello imbullonato in cima al tubo esterno, il quale ddeformandosi mette in tensione i tralicci a cui è collegato. La tenuta stagna è realizzata con una guarnizione in corrispondenza delle testate dei tubi.

Sono calcolate le dimensioni del basamento, le dimensioni e la rigidezza del compensatore, la pressione e la portata d'acqua richiesti, la portata e la potenza della pompa.

Disegni:

- MV036P-PE-MAD-4370 Pianta tubazioni hydrojet
- MV036P-PE-MAD-4371 Dettagli tubazioni hydrojet
- MV036P-PE-MAD-4372 Pianta Hydrofoot

– MV036P-PE-MAD-4374 Collegamenti tubazioni hydrojet

Carichi:

Forza verticale massima sull'hydrofoot:	1350 kN
Forza verticale massima sull'hydrofoot (accidentale)	6000 kN
Forza orizzontale massima sull'hydrofoot (funzionamento normale)	100 kN
Forza orizzontale massima sull'hydrofoot (cattivo funzionamento)	300 kN

Calcoli:

I calcoli e le scelte del materiale per questi elementi si trovano nell'allegato C a questo documento.

3.5. Parti meccaniche delle camere di galleggiamento

Descrizione:

Le camere di galleggiamento servono nelle operazioni di galleggiamento durante il trasporto della porta, e nella vita di esercizio.

Nelle camere di galleggiamento, divise in compartimenti separati, il tempo richiesto per svuotare un gruppo di quattro serbatoi del volume totale di 160 m^3 è pari a 30 minuti. Inoltre la pressione dell'acqua sul fondo sarà approssimativamente di 0.1 Mpa.

Il compressore, scelto considerando le perdite di carico nel sistema, ha una portata di 350 Nm^3/h a 0,25 MPa, ed una potenza di 25 kW.

Nel documento MV036P-PE-MPK 5101 P.& I. - Impianto aria compressa, sono indicati i collegamenti alla porta, le tubazioni di collegamento tra il compressore d'aria, posizionato nel locale macchine, ed i due vani di alloggiamento della porta, il collegamento flessibile tra il vano di alloggiamento della porta e lo spazio di lavoro dell'hydrofoot e tra il collettore e le diramazioni per i vari comparti delle camere di galleggiamento.

Calcoli:

I calcoli per questi elementi si trovano nell'allegato D a questo documento.

3.6. Rampe di accesso (cilindri oleoidraulici)

Descrizione:

I mezzi accederanno alla parte superiore della porta transitando su rampe mobili che collegheranno la via di accesso alla viabilità principale sulla sommità della struttura.

L'unità oleoidraulica per le saracinesche di livellamento è usata anche per i cilindri oleoidraulici che movimentano la rampa di accesso.

Carichi:

Sono considerati i seguenti carichi su queste parti strutturali:

- Peso proprio;
- Carichi di traffico: 4.0 kN/m² ed un carico concentrato di 50 kN, come da documento MV036P-PE-MAR-4001 - Basis of design structural

Disegni:

- MV036P-PE-MAD-4310 – Pianta strada superiore
- MV036P-PE-MAD-4313 – Strada superiore Dettagli
- MV036P-PE-MPK 5103 - Impianto oleoidraulico - P & ID

Calcoli:

I calcoli per questi particolari si trovano nell'allegato B a questo documento.

ALLEGATO A

Sistema di Trazione

Project : Malamocco Navigation Lock

Onderdeel : Door traction System

Selection of ropes

See also Annex A

Required forces at the sliding door from calculation MVO 036P-PE-M-A-R 4003 Rev A2 dated 20-02-2004

Forces including acceleration.

A) Regular — Per winch $F_{TR;1} = 226^{*}$ kN

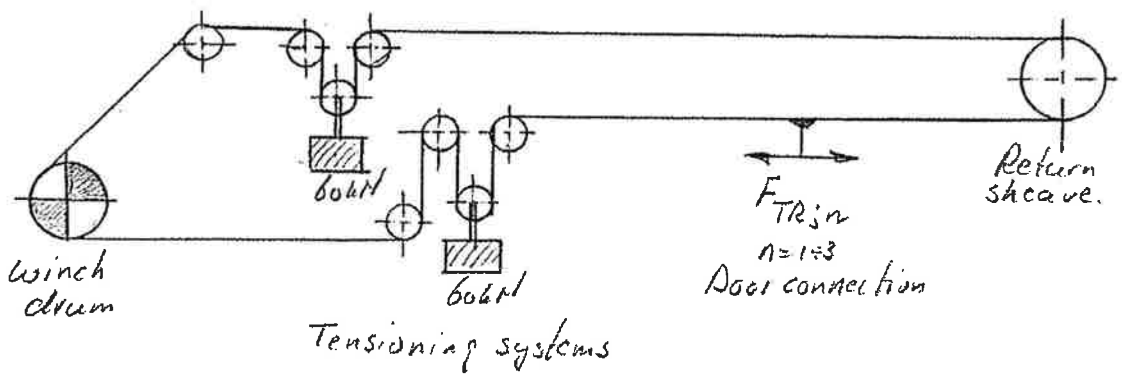
B) Malfunction of winch — One winch $F_{TR;2} = 351^{*}$ kN

C) Malfunction of hydrofoot — Per winch $F_{TR;3} = 312^{**}$ kN

* At water level +2600

** At waterlevel −1300

Rope Schema



Rope ϕ50 mm with F_{u}=2480 kN (minimum breaking force)

Make: Teufelberger Perfect or equivalent

Sheaves ϕ1158 mm (ctc)

Drum ϕ1250 mm (ctc)

Opgesteld : Co. Loch — Datum : 23-02-04 — Bladnummer : 1 — Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Calculation of ropes

Quick scan with safety factors according common practice

$$F_{rope\ max\ 1} = (F_{TR:1} + F_{Tension}) \times \frac{1}{\eta^5}$$

$$= \left(226 + \frac{60}{2}\right) \frac{1}{0{,}985^5} = 276\ kN$$

$$k_1 = \frac{F_u}{F_{max_1}} = \frac{2480}{276} = 8{,}98$$ (for horizontal loads) normal situation

$$F_{rope\ max\ 2} = (F_{TR:2} + F_{Tension}) \times \frac{1}{\eta^5}$$

$$= \left(351 + \frac{60}{2}\right) \times \frac{1}{0{,}985^5} = 411\ kN$$

$$k_2 = \frac{F_u}{F_{max_2}} = \frac{2480}{411} = 6{,}03$$ (for horizontal loads) exceptional situation

La fune di progetto avrà quindi un carico di rottura minimo di 2480 kN e un diametro di 50 mm.

Rope calculation according pr.CEN/TS 13001-3.2.

Proof of static strength

$$F_{Sd,s} \leq F_{Rd,s}$$

with $F_{Sd,s}$ is design rope force

$F_{Rd,s}$ is the limit design rope force

Opgesteld : W Loeh | Datum : 23-02-04 | Bladnummer : 2 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Rope calculation acc prCEN/TS 13001-3.2.

Cranes - General Design - Part 3.2 Limitstates

According chapter 5.3 Non vertical drives

$$F_{Sd,S} = \frac{F_{equ}}{n_p} \cdot \Phi \cdot f_{S1} \cdot f_{S2} \cdot \gamma_n$$

$F_{equ} = \Sigma F \times \gamma_p$ = equivalent internal force

n_p = number of falls = 1

Φ = dynamic factor for internal effects = 1

(forces required for acceleration in F_{TR} in included)
winch motor frequency controlled, no shocks)

f_{S1} = rope force increasing factor for reeving efficiency

f_{S2} = rope force increasing factor for non-parallel falls

γ_n = risk coëfficient = $1{,}05^n$ with $n = 1 \div 14$

Normal : (Regular loads) (for γ_p see Table 2)

Table 2:
$\gamma_p = 1{,}34$ for F_r
$\gamma_p = 1{,}22$ for F_t

$F_{equ} = F_{TR1} \times 1{,}34 + F_{pretension} \times 1{,}22$

$F_{equ} = 226 \times 1{,}34 + 30 \times 1{,}22 = 339$ kN

$n_p = 1$ $\quad \phi = 1$ $\quad f_{S1} = \frac{1}{\eta^5} = \frac{1}{0{,}985^5} = 1{,}0785$

$f_{S2} = 1$ $\quad \gamma_n = 1{,}05$

$F_{Sd,S1} = 339 \times 1{,}0785 \times 1{,}05 = 384{,}4$ kN

Extreme (exceptionel loads)

$F_{equ} = F_{TR2} \times 1{,}1 + F_{pretension} \times 1{,}22)$

$= 351 \times 1{,}1 + 30 \times 1{,}22 = 423$ kN

$F_{Sd,S2} = 423 \times 1{,}0785 \times 1{,}05 = 479$ kN

Opgesteld : W. Luch | Datum : 23-2-04 | Bladnummer : 3 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Choosen rope $\phi 50$

$\sigma = 1960\ N/mm^2$

$F_u = 2480$ kN (minimum breaking force)

$$F_{Rds} = \frac{F_u}{\gamma_{rb}} \quad \text{with} \quad \gamma_{rb} = 1{,}34 + \frac{5{,}0}{\left(\frac{D}{d}\right)^{0{,}8} - 4}$$

with D = is minimum D_{sheave} or $D_{drum} \times 1{,}125$

D = minimum 1158 mm or 1250 $\times 1{,}125 = 1406{,}2$ mm

$$\gamma_{rb} = 1{,}34 + \frac{5{,}0}{\left(\frac{1406{,}2}{50}\right)^{0{,}8} - 4} = 1{,}82$$

$$F_{Rds} = \frac{2480}{1{,}82} = 1362\ kN \quad > F_{sd,s_1} = 384{,}4\ kN$$

$$> F_{sd,s_2} = 479\ kN$$

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Proof of fatigue strength

The design rope force F_{Saf} shall be calculated for regular loads only, with partial safety factors γ_P, risk coefficent γ_n and rope efficiency set to 1

$$F_{Saf} = \frac{F_{equ}}{n_f} \times \xi^* \cdot f_{S_2}^*$$

$$= \frac{(226+30)}{1} \times 1 \times 1 = 256 \text{ kN} \quad \text{(incl. acceleration)}$$

The limit design rope force :

$$F_{Rdf} = \frac{F_u}{\sqrt[3]{S_r} \cdot \gamma_{rf}} \cdot f_f$$

with F_u = minimum breaking force
S_r = rope force history parameter
γ_{rf} = minimum rope resistance factor
f_f = factor of further influences

For the proof of fatigue strength it shall be proven that $F_{Saf} \leq F_{Rdf}$

Opgesteld : W. Loch
Datum : 14-01-04
Bladnummer : 5
Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

with $s_r = k_r \times \nu_r$

Rope force spectrum

$$k_r = \Sigma \left(\frac{F_{sd} f_i}{F_{sd} f}\right)^3 \cdot \frac{w_i}{w_{tot}} = \left(\frac{30}{256}\right)^3 \times 0{,}5 + \left(\frac{256}{256}\right)^3 \times 0{,}5 = 0{,}5$$

Load half of time at 30 kN (rope pre tension) and half of time at full load. (regular load)

Relative total number of bendings

$$\nu_r = \frac{w_{tot}}{w_D} \quad \text{with } w_D = 5 \times 10^5 \text{ (fixed)}$$

Expected number of bendings w_{tot}: 2x400 moves/year
5 bendings
25 year life time

$$\nu_r = \frac{2 \times 400 \times 5 \times 25}{5 \times 10^5} = 0{,}2$$

$s_r = k_r \times \nu_r =$

$s_r = 0{,}5 \times 0{,}2 = 0{,}1$

$\gamma_{rf} = 7$ minimum rope resistance factor

$$f_f = f_{f1} \times f_{f2} \times f_{f3} \times f_{f4} \times f_{f5} \times f_{f6} \times f_{f7}$$

f_{f1} from: $R_{Dd} = 10 \times 1{,}125^{\log_2\left(\frac{s_r}{0{,}004}\right)}$

$10 \times 1{,}125^{4{,}65} = 17{,}3$

$$f_{f1} = \frac{D/d}{R_{Dd}} = \frac{1{,}125 \times 900/38}{17{,}3} = \frac{26{,}6}{17{,}3} = 1{,}54$$

Opgesteld : W. Loch Datum : 14-01-04 Bladnummer : 6 Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door Traction System

Tensile strength factor

$$f_{f2} = \left(\frac{1770}{R_r}\right)^{0,4}$$

$$= \left(\frac{1770}{1960}\right)^{0,4} = 0,96$$

Fleet angle : sheave to sheave $\delta < 0,5°$
sheave to drum $\delta = 2,9°$ (max)

$$\delta = \sqrt[3]{\frac{\sum_{i=1}^{n} \delta_i^3}{n}} =$$

5 sheaves → n = 10

$$\delta = \sqrt[3]{\frac{9 \times 0,5^3 + 1 \times 2,5^3}{10}} = \sqrt[3]{1,675} = 1,18$$

$f_{f3} = 0,873$ from table 6

Rope lubrication : lubricated ropes $f_{f4} = 1$

Multi layers : → single layer $f_{f5} = 1$

Groove radius : Radius r = 20 mm, groove angle ω = 60° } $f_{f6} = 1$

Rope type : 6 – 10 outer strands $f_{f7} = 1$

Substituted into the formula :

$$f_f = 1,54 \times 0,96 \times 0,873 \times 1 = 1,2906$$

Filled in the formula : $F_{Raf} = \frac{F_u}{\sqrt[3]{S_{rx} f_f}} \cdot f_f$:

$$F_{Raf} = \frac{1354}{\sqrt[3]{0,1} \times 7} \times 1,2906 = 413 \text{ kN} > 256 \text{ kN} \quad ok$$

Opgesteld : W. Lock

Datum : 14-01-04

Bladnummer : 7

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door Traction System

Calculation of motor power

See also Annex B

- Lock speed : at normal function $v = 0{,}35$ m/s
  at malfunction $v = 0{,}06$ m/s

- Drum and drumspeed.
  Drum ⌀ 1250 mm
  At $v = 0{,}35$ m/s $n_{drum_1} = \frac{0{,}35 \times 60}{\pi \times 1{,}25} = 5{,}35$ rpm

  $v = 0{,}06$ m/s $n_{drum_2} = \frac{0{,}06 \times 60}{\pi \times 1{,}25} = 0{,}92$ rpm

- Traction forces (ΔF)

  * Including acceleration
  Excluding acc $F_1 = 187$ kN

			Per winch
Normal	$\Delta F_1 = 2 \times 226^*$ kN	@ $v = 0{,}35$ m/s	226 kN
One winch	$\Delta F_2 = 1 \times 351$ kN	@ $v = 0{,}06$ m/s	351 kN
Malfunction fool	$\Delta F_3 = 2 \times 312$ kN	@ $v = 0{,}06$ m/s	312 kN

- Required power per winch.

  $\eta = \eta_{sheaves}^6 \times \eta_{drive}$

Normal $P_1 = \frac{F \times v}{\eta} = \frac{187 \times 0{,}35}{0{,}985^6 \times 0{,}9} = \underline{80\ kW}$ $f_a = \frac{226}{187} = 1{,}21$

At malfunction : $P_2 = \frac{351 \times 0{,}06}{0{,}985^6 \times 0{,}9} = \underline{\underline{26\ kW}}$

resp.

$P_3 = \frac{312 \times 0{,}06}{0{,}985^6 \times 0{,}9} = \underline{\underline{23\ kW}}$

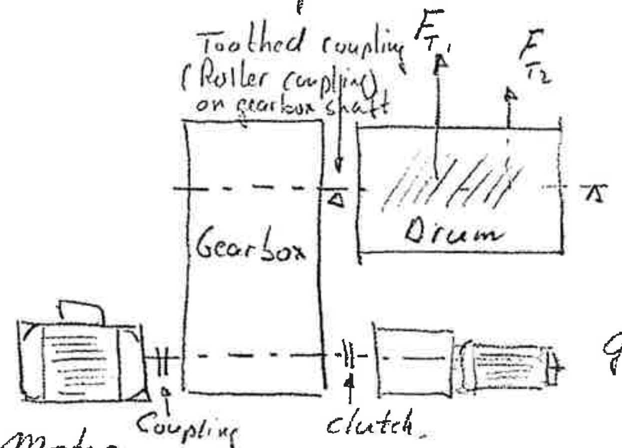
Opgesteld : W. Loch Datum : 14-01-04 Bladnummer : 8 Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door Traction System

Selection of gearboxes and motors

– Drive arrangement



$\Delta F = F_{T_1} - F_{T_2}$

$n_1 = 5{,}35$ rpm

$n_2 = 0{,}92$ rpm

Geared motor @ 27 kW
n = 257 rpm theoretical
torque M = 1003 Nm

Motor

n = 1500 rpm @ 80 kW torque: $\frac{9550 \times 80}{1500} = 509$ Nm (theoretical)

Selection: Motor 90 kW 1500 rpm · size 280M rated torque 581 Nm

– Gearbox selection

Motor n = 1500 rpm
drum n = 5,35 rpm

$i_{gearbox} = \frac{1500}{5{,}35} = 280{,}4$

With this gearbox ratio:

$n_{geared\ motor} = \frac{0{,}92}{5{,}35} \times 1500 = 258$ rpm @ 1003 Nm

(Vector R97 DV200L4
283 rpm, 1010 Nm)

Maximum torque at malfunction:

Gearbox : $M_{in} = 1003$ Nm (from geared motor) $M_{out} = 202\,548$ Nm = 203 kNm

Selection:

– Kumera $P_{1v} = P_1 \cdot f$ with $f = f_L \times f_a \times f_s$

$f = 1{,}2 \times 0{,}9 \times 1{,}1 = 1{,}188$

$P_1 \approx \frac{M \times n}{9550} = \frac{1003 \times 1500}{9550} = 157$ kW

$P_{1v} = P_1 \times f = 157 \times 1{,}188 = 187$ kW → LD 4630 (on foot) $P_1 = 265$ kW
TD 4630 (shaft mounted) $T_2 = 430$ kNm

This gives gearbox size: 4630

Opgesteld : W Lock Datum : 14-01-04 Bladnummer : 9 Rev. :

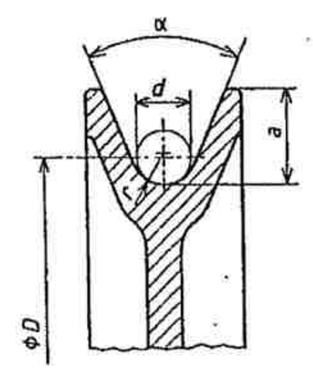
Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Winch details

Sheave and drum groove details

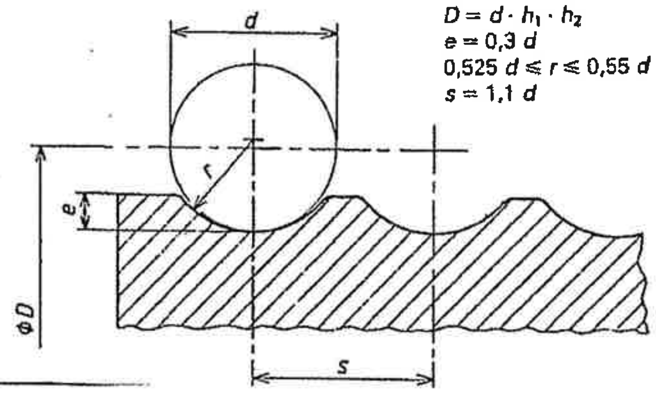
Sheave diameter D= 1158 mm (c.t.c. rope centre)
Shape of groove with d= 50 mm → r= 27 mm



$D = d \cdot h_1 \cdot h_2$
$a \geq 1{,}5\ d$
$45° \leq \alpha \leq 60°$
$0{,}525\ d \leq r \leq 0{,}55\ d$

Drum

Drum diameter D =1250 mm
Shape of groove with d=50 mm → r=27 mm



$D = d \cdot h_1 \cdot h_2$
$e = 0{,}3\ d$
$0{,}525\ d \leq r \leq 0{,}55\ d$
$s = 1{,}1\ d$

e = 15 mm

s = 55 mm

Opgesteld : W.Loch

Datum : 14-01-04

Bladnummer : 10

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction System

Length to be compensated by gravity tension system.

Maximum rope length under full tension is ca 130 m

maximum rope tension normal ca 265 kN
extreme ca 411 kN

$\Delta l = \frac{F \times l}{EA}$ with $E = 10{,}4 \times 10^4$ N/mm²
$A = 1913$ mm². (steel cross section)

$\Delta l = \frac{411 \times 130 \times 10^6}{10{,}5 \times 10^4 \times 1913} = 266$ mm

Structural elongation 1/4 %

$\Delta l = 0{,}25 \times \frac{130 \times 10^3}{100} = 325$ mm

Total 266 + 325 = 592 mm → Δh counterweight = 296 mm

Opgesteld : W. Loch

Datum : 14-01-04

Bladnummer : 10A

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction System

Winch details.

Drum length (between flanges)

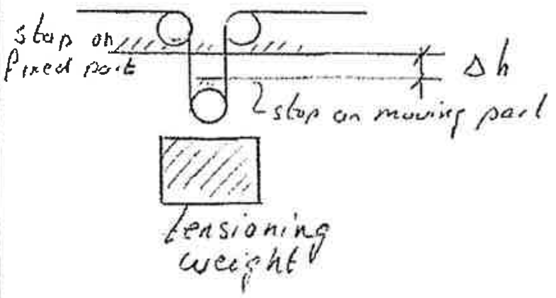
Drum ϕ1250 mm (c.t.c. rope centre)

Number of working grooves n:

- Travellength door : 53900 mm

$n = \frac{l}{\pi d} = \frac{53900}{\pi \times 1250} = 13{,}7$ } n = 14 grooves

Add: height difference tensioning system }

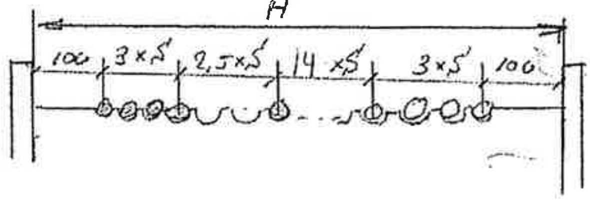


$\Delta h = 0$ when door sliding force in this part.

$\Delta h_{max} \leq \frac{14 - 13.33}{2} \times \pi \times 1250 = 1315$ mm when door sliding force in other part.

Number of fixed grooves n = 3.

Number of grooves between the two ropes n = 2,5



$S = 1{,}1\, d_{rope} =$ 55 mm

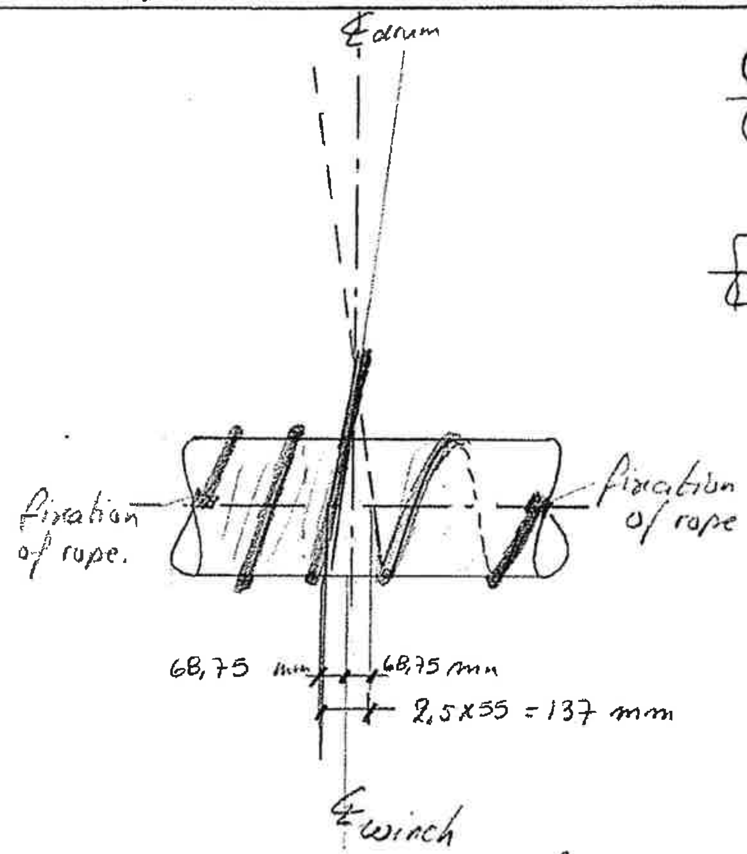
$A_{min} = 22{,}5 \times 55 + 200 = 1438$ mm

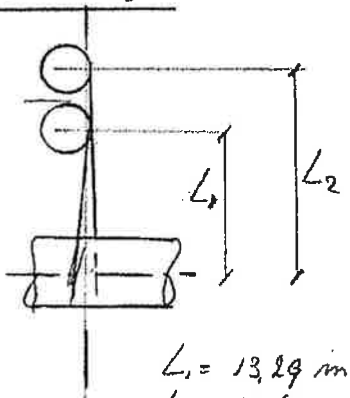
Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Winch details

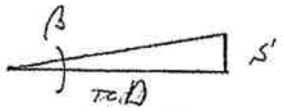
Distance between drum and sheave





$L_1 = 13{,}29$ m
$L_2 = 14{,}63$ m

Pitch angle on drum



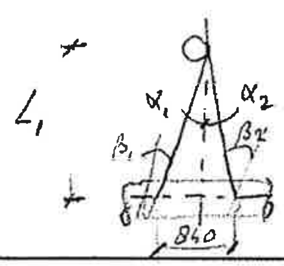
$\beta = \text{arctg}\ \frac{s}{\pi D}$

$\beta = \text{arctg}\ \frac{55}{\pi \times 1250}$

$\beta = 0{,}802°$

Fleet angle related to groove (β_1 and β_2)

working length on drum 14 x55 = 770 mm



$\alpha_1 = \text{arctg}\ \frac{68{,}75 + 9 \times 55}{13290}$

$\alpha_2 = \text{arctg}\ \frac{9 \times 55 - 68{,}75}{13290}$

$\alpha_1 = 2{,}43°$

$\alpha_2 = 1{,}83°$

$\beta_1 = 2{,}43 - 0{,}802 = 1{,}63$

$\beta_2 = 1{,}83 + 1{,}63 = 3{,}46°$

Opgesteld : W.Loch

Datum : 14-01-04

Bladnummer : 12

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door Traction System

Max allowable $\beta < 2.5°$

Note : By increasing the distance between the ropes

1) Either β_1 increases and β_2 decreases.

2) Or length L_1 and L_2 can be decreased.

3) Combination 1) and 2)

NB: The drum length will also increase.

Calculation of drum shell.

Drumshell calculation for rope ⌀50 mm

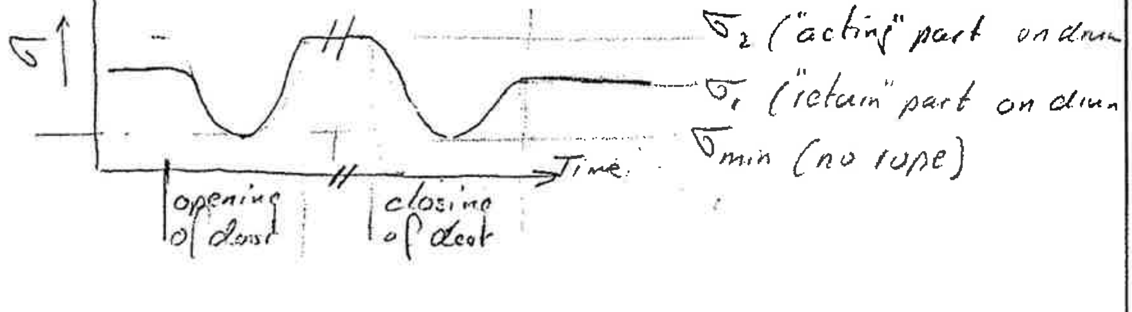
$F_{rope,1} = \frac{226+30}{\gamma^5} = 276$ kN "normal use"

$= \frac{351+30}{\gamma^5} = 411$ kN "extreme use"

Number of door moves during 25 years
max 2×400 moves/year (open and close)

max 25 × 2×400 = 20.000 moves

load on one cross section of drum



As number of load cycles $\leq 2\times10^4$
no fatigue calculation necessery for drum shell

Opgesteld : W. Lock

Datum : 14-01-04

Bladnummer : B

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction System

Thickness of drum shell (excluding allowance for inaccuracies and out of roundness in rolling etc)

$$T_D = \sqrt{(T_{BD}^2 + T_{BD} \times T_{DC} + T_{DC}^2)}$$

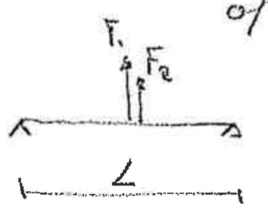
T_{BD} due to bending "as a beam"

$$T_{BD} = 1250 \frac{M}{D_m^2 \times F_b}$$

with F_b = perm. bending stress $\leq 0{,}69\ \sigma_{yield}$

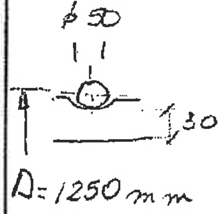
D_M = mean diameter of drum shell

M = bending moment due to beam action of unfactored rope load



$L \approx 2\,m$ $\quad F_1 = 411\ kN$

$F_2 = 30\ kN$



$M = \frac{1}{4} PL = 0{,}25 \times (411 + 30) \times 10^3 \times 2$ $\quad N/m$

$= 221{,}5 \times 10^3\ N/m$

$D_m \approx (1250 - 50 - 30) = 1170\ mm$

$$T_{BD} = 1250 \times \frac{221{,}5 \times 10^3}{1170^2 \times 0{,}69 \times 355} = 0{,}85\ mm.$$

Opgesteld : W. Loch

Datum : 14-01-04

Bladnummer : 14

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door Traction System

T_{DC} due to compressive stresses

$$T_{DC} = \frac{1000 \times K_{RL} \times P_{RS}}{p \times F_C} - 0{,}15\, d_r$$

d_r = rope diameter

F_C = permissible compressive stress = 300 N/mm² = MPa
material S355

K_{RL} = rope layer factor = 1 for single layer

P_{RS} = static rope load in kN

p = pitch of rope coils in mm

$$T_{DC} = \frac{1000 \times 1 \times 411}{55 \times 300} - 0{,}15 \times 50 = 17{,}40 \text{ mm}$$

$$T_D \geq \sqrt{(0{,}85)^2 + (0{,}85 \times 17{,}4) + 17{,}4^2} = 17{,}84 \text{ mm.}$$

Opgesteld : W. Loch

Datum : 14-01-04

Bladnummer : 15

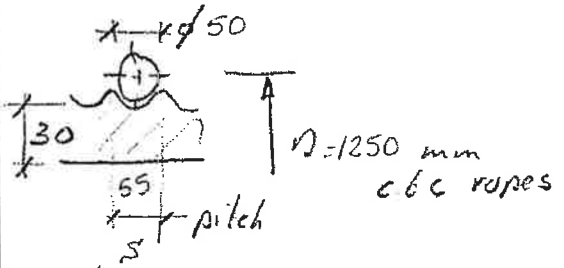
Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction System

Drum calculation according Ernst _ Die Hebezeuge

with $h = 1{,}15 \times 30 = 34{,}5$ mm



Extreme :

$$\sigma_a = 0{,}5 \frac{S'}{h \times s} = 0{,}5 \times \frac{411 \times 10^3}{34{,}5 \times 55} = \quad N/mm^2$$

$$\sigma_{ba} = 0{,}96\, S' \sqrt{\frac{1}{D \times h^3}} = \frac{0{,}96 \times 411 \times 10^3}{\sqrt{1250 \times 34{,}5^3}} = 55{,}1\ N/mm^2$$

$$\sigma_{max} = \sqrt{\sigma_a^2 + \sigma_{ba}^2 + \sigma_a \times \sigma_{ba}} = \sqrt{108^2 + 55^2 + 108 \times 55} = 144\ N/mm^2$$

$$\leq \frac{355}{1{,}5} = 275\ N/mm^2$$

Normal :

$$\sigma_a = 0{,}5 \times \frac{276 \times 10^3}{34{,}5 \times 55} = 73\ N/mm^2$$

$$\sigma_{ba} = \frac{0{,}96 \times 276 \times 10^3}{\sqrt{1250 \times 34{,}5^3}} = 37\ N/mm^2$$

$$\sigma_{max} = \sqrt{\sigma_a^2 + \sigma_{ba}^2 + \sigma_a + \sigma_{ba}}$$

$$\sqrt{73^2 + 37^2 + (73 \times 37)} = 97$$

According to Ernst _ Die Hebezenge $\sigma_{max\ allow} = 130\ N/mm^2$
For Fatigue life.

Opgesteld : W. Lock | Datum : 14-01-04 | Bladnummer : 16 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction System

Positioning of door

1) Acceleration.

Acceleration by frequency and torque controled winch drive.
First step is to set tension on the rope and move counterweights to required positions
Control by limit switches.
Second step is to set the required speed.
Torque is limited by freq. control unit. and PLC.

2) Deceleration.

Friction forces : Waterfriction (minimum at low-water LLWS −1300)
Hydro foot friction

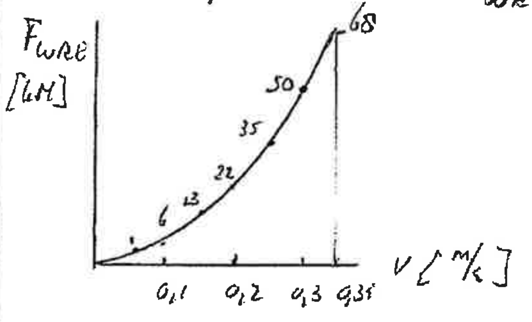
Brake force by motor torque.

Water friction $F_{WRE} = \frac{1}{2} \rho v^2 \cdot C_d \cdot A_{tot}$

$C_d = 1{,}41$

$A_{tot} : 769\ m^2$

$\rho = 1030\ kg/m^3$



Opgesteld : W.Lock
Datum : 30/1/04
Bladnummer : 17
Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Hydrofoot friction

a) Working hydrofoot (take $\mu_{min} = \frac{1}{2}\mu_{max}$

$F_{HFFR_1} = \mu \times G_{reff} = \frac{0{,}07}{2} \times 1000 = 35$ kN

b) Malfunctional hydrofoot $\mu = 0{,}3$. ($\mu = 0{,}3$ is extreme normal $\mu_{max} = 0{,}22$)

$F_{HFFR_2} = 0{,}3 \times 1000 = 300$ kN.

Brake force by motor torque.

First the counterweights have to be moved to the opposite high/low position.

a) Stop motor, door moves until counterweights are moved (controlled by swichtes), reverse torque by motor and controlled by PLC.

b) Reverse motor speed in a controlled way by PLC and limit switches on the counterweights. When limit switch is activated the reverse torque of the drive is controlled by the PLC.

Opgesteld : W. Loch — Datum : 30/1/04 — Bladnummer : 18 — Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

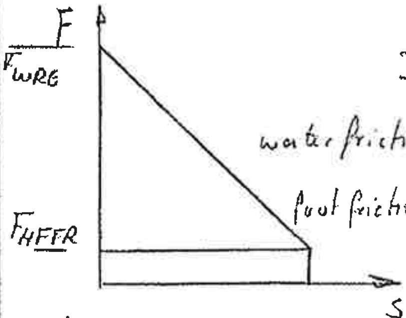
Braking distance

$m = m_{door} + m_{water}$

$m = 1300 \times 10^3 + 500 \times 10^3$ kg $= 1800 \times 10^3$ kg

Braking by friction forces.

Energie $= \frac{1}{2} m v^2 = \frac{1}{2} \times 1800 \times 0{,}35^2 = 110$ kJ.



In the force-travelling distance

water friction: - the F_{WRE} is roughly a straight declining line

foot friction: - the F_{HFFR} is a constant line.

Normal working hydrofoot:

Energie: $s \times \left\{ \frac{F_{WRE}}{2} + F_{HFFR} \right\} = \frac{1}{2} m v^2 = 110$ kJ

$s \times \left\{ \frac{68{,}4}{2} + 35 \right\} = 110$ kJ

$s_1 = 1{,}59$ [m]

Malfunction of hydrofeet

$\frac{1}{2} m v^2 = s_2 \times \left\{ \frac{68{,}4}{2} + 300 \right\} = 110$ kJ

$s_2 = 0{,}33$ [m]

- Take for normal operation a stopping distance of ca 5 m. In this way the drive torque is controlled by the PLC and the counter weights stay in the normal traction position.

Opgesteld : W. Loch

Datum : 30/1/04

Bladnummer : 19

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Buffers at gate

<u>Buffer calculation</u>

See also Annex C.

Number of buffers : 4 at each side. (2x2x4 at each door/lock combination)

Mass of gate : 1300×10^3 kg.

Mass of water : 500×10^3 kg.

Total mass : 1800×10^3 kg.

Speed of gate $v_{gate} = 0{,}35$ m/s

Maximum length to stop : 200 mm

Energy to stop $W = \frac{1}{2} m v^2 = \frac{1}{2} \times 1800 \times 10^3 \times 0{,}35^2$

$W = 110 \times 10^3$ Nm $= 110$ kJ

Buffer as emergency stop : size $\phi 250$ and $h = 200$ mm

Rubber Quality S

See documentation

Energy per buffer max $E = 1{,}5 \times 12500 = 18750$ [J]

Required number of buffers { $\frac{110 \times 10^3}{18750} = 5{,}9$ → Take $2 \times 4 = 8$ buffers

$F_{max} = \frac{110 \times 10^3}{8 \times 12500} \times 400 = 440$ kN ← End Force

(Energy to stop; normal end Force; normal energy cap by buffers)

Opgesteld : W. Loch | Datum : 30-1-04 | Bladnummer : 20 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Annex A

Loads to calculate with: part D from structural calculations MVO 036 P-PE-M-A-R 4003 Rev A2 dd 20-02-2004

Copies from - rope catalogue (Teufelberger)
rope sockets acc MEH 2729.

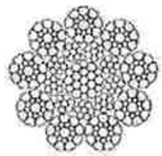
Opgesteld :

Datum :

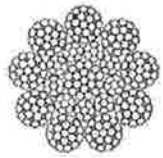
Bladnummer :

Rev. :

Pack2



9 x K19S - PWRC
Regular



9 x K25F - PWRC (K)
Regular

9 x K36WS - PWRC (K)
Regular

9 x K19S - PWRC Regular

9 x K25F - PWRC (K) Regular

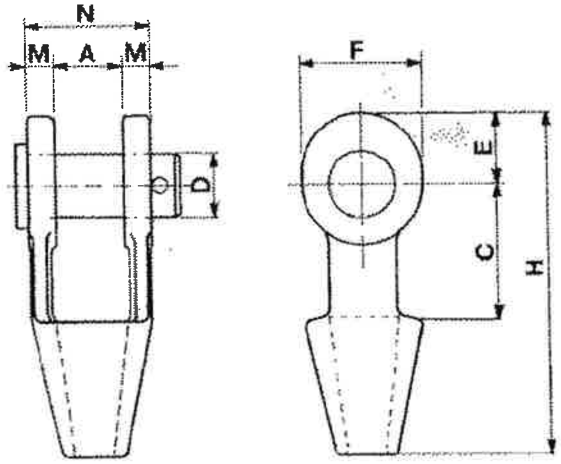
9 x K36WS - PWRC (K) Regular

Ø Fune Ø Rope Ø Cable Ø Seil	Ø Filo Ø Wire Ø Fil Ø Draht	Sezione Met. area Section Querschnitt	Massa Mass Masse Gewicht	Forza rottura min. (Extra) Min breaking force (Extra) F. de rupture min. (Extra) Mindestbruchkraft (Extra) Lucido Bright Claire Blank	 Zincato Galvanised Galvanisé Verzinkt	Formazione Construction Formation Seilaufbau	Avvolgimento parallelo Lang lay Cablage Lang Gleichschlag	Avvolgimento crociato Regular lay Cablage croisé Kreuzschlag
mm	mm	mm²	kg/m	kN	kN			
8	0.50	37.4	0.32	66.6	63.2	9 x K19S - PWRC		●
9	0.56	47.4	0.41	84.2	80.0	-		●
10	0.62	58.5	0.50	104	98.8	-		●
11	0.68	70.8	0.61	126	120	-		●
12	0.75	84.3	0.72	150	142	-		●
13	0.81	98.9	0.85	176	167	-		●
14	0.87	115	0.98	204	194	-		●
15	0.93	132	1.13	234	222	-		●
16	0.09	150	1.28	266	253	-		●
17	1.06	169	1.45	301	286	-		●
18	1.12	190	1.62	337	320	-		●
19	1.18	211	1.81	375	357	-		●
20	1.24	234	2.00	416	395	-		●
21	1.30	258	2.21	459	436	-		●
22	1.37	283	2.42	503	478	-		●
23	1.43	310	2.65	550	523	-		●
24	1.49	337	2.89	599	569	-		●
25	1.55	366	3.13	650	618	-		●
26	1.26	408	3.48	690	661	9 x K25F - PWRC (K)		●
28	1.36	473	4.04	808	767	-		●
30	1.46	543	4.63	927	881	-		●
32	1.55	618	5.27	1050	1000	-		●
34	1.65	687	5.95	1190	1130	-		●
36	1.75	782	6.67	1330	1270	-		●
38	1.84	871	7.44	1490	1410	-		●
40	1.94	965	8.24	1650	1570	-		●
42	1.71	1030	8.84	1820	1730	9 x K36WS - PWRC (K)		●
44	1.79	1140	9.70	1990	1890	-		●
46	1.87	1240	10.6	2180	2070	-		●
48	1.95	1350	11.5	2370	2250	-		●
50	2.03	1470	12.5	2560	2450	-		●
52	2.11	1590	13.5	2790	2650	-		●
54	2.20	1710	14.6	2950	2800	-		●
56	2.28	1840	15.7	3170	3010	-		●
58	2.36	1970	16.9	3400	3230	-		●
60	2.44	2110	18.0	3640	3450	-		●
62	2.52	2260	19.3	3770	3500	-		●
64	2.60	2400	20.5	4010	3730	-		●
66	2.68	2560	21.8	4270	3970	-		●
68	2.76	2710	23.2	4440	4130	-		●
70	2.85	2870	24.5	4700	4370	-		●
inch	inch	sq.inch	lbs/ft	lbs	lbs			
3/8	0.02	0.08	0.31	21200	20200	9 x K19S - PWRC		●
1/2	0.03	0.15	0.54	37700	35900	-		●
5/8	0.04	0.23	0.85	59000	56000	-		●
3/4	0.05	0.33	1.22	84900	80700	-		●
7/8	0.05	0.45	1.67	116000	110000	-		●
1	0.05	0.60	2.24	150000	142000	9 x K25F - PWRC (K)		●
1 1/8	0.05	0.76	2.83	189000	180000	-		●
1 1/4	0.06	0.94	3.50	234000	222000	-		●
1 3/8	0.07	1.14	4.23	283000	269000	-		●
1 1/2	0.07	1.30	5.03	338000	320000	-		●
1 5/8	0.07	1.55	5.75	395000	375000	9 x K36WS - PWRC (K)		●
1 3/4	0.07	1.80	6.66	458000	435000	-		●
1 7/8	0.08	2.08	7.65	526000	499000	-		●
2	0.08	2.35	8.70	598000	568000	-		●
2 1/8	0.09	2.65	9.83	662000	629000	-		●
2 1/4	0.09	2.97	11.0	742000	705000	-		●
2 3/8	0.10	3.31	12.3	803000	746000	-		●
2 1/2	0.10	3.67	13.6	889000	827000	-		●
2 5/8	0.11	4.04	15.0	960000	893000	-		●
2 3/4	0.11	4.44	16.5	1050000	980000	-		●

Teci
TREFOLO ROSSO

CAPICORDA IN ACCIAIO PER TESTE FUSE

TIPO AP



TIPO AP	PER FUNE Ø mm	PER FUNE Ø pollici	CARICO DI LAVORO kg	A mm	C mm	D mm	E mm	F mm	H mm	M max mm	N mm	PESO kg
13	10 ÷ 13	1/2	3 000	26	51	25,4	25	48	140	17	60	1,02
16	14 ÷ 16	5/8	4 500	32	64	30,2	32	57	171	18	69	1,70
19	17 ÷ 19	3/4	6 500	39	76	34,9	37	67	202	19	77	2,65
22	20 ÷ 22	7/8	8 600	46	89	41,3	45	80	235	24	95	4,47
26	23 ÷ 26	1	12 000	51	102	50,8	52	96	268	27	105	7,03
30	27 ÷ 30	1.1/8	17 000	58	114	57,1	59	105	300	33	124	10,9
35	31 ÷ 35	1.3/8	24 000	64	127	63,5	68	122	335	33	130	14,5
38	36 ÷ 38	1.1/2	28 400	78	165	69,8	79	146	413	40	158	21
42	39 ÷ 42	1.5/8	34 500	78	165	76,2	86	146	413	40	158	25
48	43 ÷ 48	1.7/8	45 000	89	178	88,9	95	165	463	40	169	39
54	49 ÷ 54	2.1/8	56 200	101	229	95,2	101	178	546	46	193	57
60	55 ÷ 60	2.3/8	70 400	114	254	108	115	197	597	54	222	75
67	61 ÷ 67	2.5/8	78 000	127	273	120,6	127	216	648	60	247	100
73	68 ÷ 73	2.7/8	100 000	133	279	127	134	229	692	73	279	143
80	74 ÷ 80	3.1/8	117 000	146	286	133	146	241	737	76	298	172
86	81 ÷ 86	3.3/8	132 000	159	298	140	156	254	784	79	317	197
92	87 ÷ 92	3.5/8	152 000	171	318	152	171	273	845	83	337	255
102	93 ÷ 102	4	187 000	191	343	177,8	197	318	921	89	369	355

Project : Malamocco Navigation Lock

Onderdeel : Door traction system

Annex B

Copies from - motor catalogue (Siemens)
- geared motor catalogue (Vector; SEW)
- helical gear unit (Kumera)

Opgesteld : Datum : Bladnummer : Rev. :

1LA Squirrel-Cage Motors

Basic Design

3

Selection and ordering data

Rated output	Frame size	Order No. For Order No. suffixes for voltage and type of constr. see table below	Performance at rated output: Rated speed	Efficiency η	Power factor p.f.	Rated current at 400 V	Rated torque	Lo.-rotor torque	Lo.-rotor current	Breakdown torque	Torque class	Torque characteristic acc. to pages 2/15 to 2/18	Moment of inertia J	Weight Type of constr. IM B 3 approx.
								For direct-online starting in multiples of rated torque	current	torque				
kW			rpm	%		A	Nm				CL		kg m²	kg
1500 rpm, 4-pole, 50 Hz														
0.06	56	1LA7 050–4AB..[7]	1305	56	0.78	0.20	0.43	1.9	2.8	2.0	13	10	0.00027	3.0
0.09		1LA7 053–4AB..[7]	1300	58	0.77	0.29	0.64	2.1	3.3	2.1	13		0.00027	3.0
0.12	63	1LA7 060–4AB..[7]	1350	56	0.70	0.44	0.85	1.9	2.7	1.9	13	10	0.0003	3.5
0.18		1LA7 063–4AB..[7]	1350	59	0.76	0.58	1.3	1.9	2.9	1.9	13		0.0004	4.0
0.25	71	1LA7 070–4AB..	1350	60	0.79	0.76	1.8	1.9	3.0	1.9	13	10	0.0006	4.8
0.37		1LA7 073–4AB..	1370	65	0.80	1.03	2.6	1.9	3.3	2.1	13		0.0008	6.0
0.55	80	1LA7 080–4AA..	1395	67	0.81	1.45	3.7	2.2	3.9	2.2	16	3	0.0015	8.0
0.75		1LA7 083–4AA..	1395	72	0.81	1.86	5.1	2.3	4.2	2.3	16		0.0018	9.4
1.1	90 S	1LA7 090–4AA..	1410	73	0.83	2.65	7.5	2.0	4.3	2.3	16	2	0.0028	12.3
1.5	90 L	1LA7 096–4AA..	1420	77	0.82	3.45	10	2.4	5.0	2.8	16	3	0.0035	15.6
2.2	100 L	1LA7 106–4AA..	1420	80	0.82	4.9	15	2.5	5.2	2.6	16	3	0.0048	24
3		1LA7 107–4AA..	1420	81.5	0.83	6.4	20	2.6	5.5	2.8	16		0.0058	26
4	112 M	1LA7 113–4AA..	1440	84.0	0.83	8.3	27	2.7	6.5	3.0	16	2	0.011	31
5.5	132 S	1LA7 130–4AA..	1455	86.0	0.81	11.4	36	2.4	6.3	3.1	16	3	0.018	45
7.5	132 M	1LA7 133–4AA..	1455	87.5	0.82	15.1	49	2.7	6.7	3.2	16		0.024	56
11	160 M	1LA7 163–4AA..	1460	88.5	0.84	21.4	72	2.4	6.3	2.9	16	3	0.040	76
15	160 L	1LA7 166–4AA..	1460	90.0	0.84	28.5	98	2.8	6.5	3.2	16		0.052	93
18.5	180 M	1LA5 183–4AA..	1460	90.5	0.83	35[1]	121	2.3	7.5	3.0	16	3	0.13	112
22	180 L	1LA5 186–4AA..	1460	91.2	0.84	41[1]	144	2.3	7.5	3.0	16		0.15	126
30	200 L	1LA5 207–4AA..	1465	91.8	0.86	55	196	2.6	7.0	3.2	16	3	0.24	170
37	225 S	1LA5 220–4AA..	1470	92.9	0.87	66[1]	241	2.8	7.0	3.2	16	3	0.32	215
45	225 M	1LA5 223–4AA..	1470	93.4	0.87	80[1]	293	2.8	7.7	3.3	16		0.36	235
55	250 M	1LA6 253–4AA..	1475	94.0	0.87	97	356	2.4	6.7	2.5	16	4	0.79	435
75	280 S	1LA6 280–4AA..	1480	94.7	0.86	132	484	2.5	6.7	2.7	16	4	1.4	610
90	280 M	1LA6 283–4AA..	1480	94.9	0.86	160[1]	581	2.5	6.8	2.7	16		1.6	660
110	315 S	1LA6 310–4AA..	1485	94.8	0.86	194	707	2.5	6.7	2.7	16	4	2.2	830
132	315 M	1LA6 313–4AA..	1485	95.5	0.87	230[1]	849	2.5	6.9	2.7	16		2.7	910
160	315 L	1LA6 316–4AA..	1485	95.8	0.87	275	1030	2.5	7.0	2.7	16		3.2	1060
200	315 L	1LA6 317–4AA..	1488	96.2	0.87	345	1280	2.6	7.0	2.7	16		4.2	1200
250	315	1LA8 315–4AB..	1488	96.0	0.88	425	1600	1.9	6.5	2.8	13	16	3.6	1300
315		1LA8 317–4AB..	1488	96.3	0.88	540[2]	2020	2.0	6.8	2.8	13		4.4	1500
355	355	1LA8 353–4AB..	1488	96.3	0.87	610[3][4]	2280	2.1	6.5	2.6	13	16	6.1	1900
400		1LA8 355–4AB..	1488	96.4	0.87	690[3][4]	2570	2.1	6.5	2.6	13		6.8	2000
500		1LA8 357–4AB..	1488	96.8	0.88	850[2]	3210	2.1	6.5	2.4	13		8.5	2200
560	400	1LA8 403–4AB..	1492	96.8	0.88	950[2]	3580	1.9	6.5	2.7	13	24	13	2800
630		1LA8 405–4AB..	1492	97.0	0.88	1060[3][4]	4030	1.9	6.8	2.7	13		14	3000
710		1LA8 407–4AB..	1492	97.0	0.89	690[3][5]	4540	1.9	6.8	2.7	13		16	3200
800	450	1LA8 453–4AC..	1492	97.0	0.88	780[3][5]	5120	1.6	7.0	2.6	10	24	23	4000
900		1LA8 455–4AC..	1492	97.1	0.88	880[3][4][5]	5760	1.6	7.0	2.6	10		26	4200
1000		1LA8 457–4AC..	1492	97.1	0.89	970[3][4][5]	6400	1.7	7.0	2.6	10		28	4400

Order No. suffixes

Motor type	Penultimate position: Voltage code 50 Hz: 230 VΔ / 400 VY	400 VΔ / 690 VY	500 VY	500 VΔ	690 VΔ	60 Hz: 460 VY	460 VΔ (for outputs see page 2/12)	Last position: Type of construction code: IM B 3	(extra charge) IM B 5	IM V 1 without canopy	IM V 1 with canopy	IM B 14 with small flange	IM B 14 with large flange	IM B 35
1LA7 050 to 1LA7 096	1	6	3	–	–	1	6	0	1	1	4	2	3	6
1LA . 106 to 1LA . 207	1	6	3	5	–	1	6	0	1	1	4	2[6]	3[6]	6
1LA . 220 to 1LA . 313	1	6	3	5	–	–	6	0	1	1	4	–	–	6
1LA6 316 and 1LA6 317	–	6	–	5	–	–	9 L2F	0	–	8	4	–	–	6
1LA8 315 to 1LA8 405	–	6	–	5	–	–	9 L2F	0	–	8	4	–	–	6
1LA8 407 to 1LA8 457	–	–	–	5	0	–	on request	0	–	8	4	–	–	6

Voltage code "**9**" for other voltages and/or frequencies.
Order Codes must be specified in this case (see page 2/10).

Please refer to pages 2/6 and 2/7 for types of construction.

1) Parallel feeders required for 230 V supply.
2) Parallel feeders required for 400 V supply.
3) Parallel feeders required for 500 V supply.
4) Parallel feeders required for 690 V supply.
5) Rated current at 690 V.
6) Only available for 1LA7 113 motors.
7) Provisionally available as of July 1999, 1LA5 will be supplied until then.

Geared motor

vervolg 30 kW motorvermogen P

toerental n r/min	T_{nom} in Nm uitgaande as	reductie-verhouding i 1:...	radiale belas-ting F_{Ra} N	bedrijfs-factor f_B	grootte		massa ca. kg	afm. pagina ....
207	1390	7,12	11700	1,45	R 97	DV200L4	330	251
237	1210	6,21	11400	1,55	RF 97	DV200L4	325	260
283	1010	5,20	10900	1,75				
327	880	4,50	10500	1,85				
718	400	2,05	3980	0,80	RX 101	DV200L4	300	266
817	350	1,80	3950	0,90	RXF 101	DV200L4	300	267

37 kW motorvermogen P

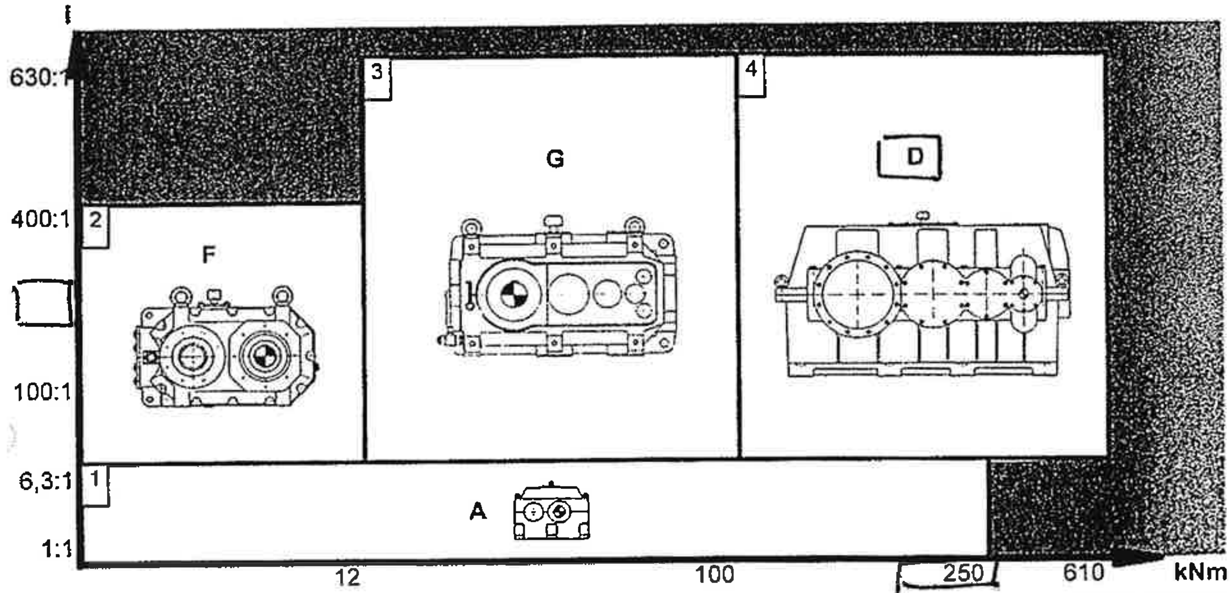
toerental n r/min	T_{nom} in Nm uitgaande as	reductie-verhouding i 1:...	radiale belas-ting F_{Ra} N	bedrijfs-factor f_B	grootte		massa ca. kg	afm. pagina ....
16	22400	93,19	120000	0,80	R 167	DV225S4	960	252
18	19900	82,91	120000	0,90	RF 167	DV225S4	880	261
20	17700	73,70	120000	1,00				
22	16200	67,40	120000	1,10				
25	14100	58,65	120000	1,30				
28	12400	51,76	120000	1,45				
33	10800	44,87	120000	1,65				
37	9600	39,92	120000	1,90				
43	8270	34,41	120000	2,2				
53	6720	27,96	120000	2,7				
48	7380	30,71	120000	1,35	R 167	DV225S4	840	252
60	5900	24,57	120000	2,4	RF 167	DV225S4	770	261
67	5250	21,85	120000	2,5				
77	4580	19,03	120000	3,5				
87	4080	16,98	120000	3,7				
22	16100	66,99	35000	0,80	R 147	DV225S4	650	252
24	14700	61,09	54200	0,90	RF 147	DV225S4	610	261
28	12700	52,87	63200	1,00				
32	11200	46,65	65900	1,15	R 147	DV225S4	650	252
36	9680	40,29	68200	1,35	RF 147	DV225S4	610	261
41	8570	35,64	69700	1,50				
49	7200	29,95	71100	1,80				
61	5810	24,19	72400	2,0				
72	4910	20,44	73000	2,4	R 147	DV225S4	630	252
82	4340	18,04	73400	2,4	RF 147	DV225S4	590	261
94	3760	15,64	73700	3,5				
106	3340	13,91	73900	3,8	R 147	DV225S4	630	252
					RF 147	DV225S4	590	261
39	9050	37,65	49400	0,90	R 137	DV225S4	500	251
45	7910	32,91	53600	1,00	RF 137	DV225S4	495	260
53	6690	27,83	55900	1,15				
61	5800	24,12	57300	1,40	R 137	DV225S4	490	251
67	5290	22,00	58000	1,50	RF 137	DV225S4	480	260
77	4580	19,04	57800	1,75				
88	4040	16,80	57300	2,0				
101	3490	14,51	56600	2,3	R 137	DV225S4	490	251
115	3080	12,83	55800	2,6	RF 137	DV225S4	480	260
136	2590	10,79	54400	3,1				
169	2090	8,71	52600	3,7				
194	1820	7,59	51900	2,8				
230	1530	6,38	50100	3,3				
285	1240	5,15	47800	3,7				

Product Ranges: Fields of Ratings

Tuoteryhmien käyttöalueet

Helical Gear Units

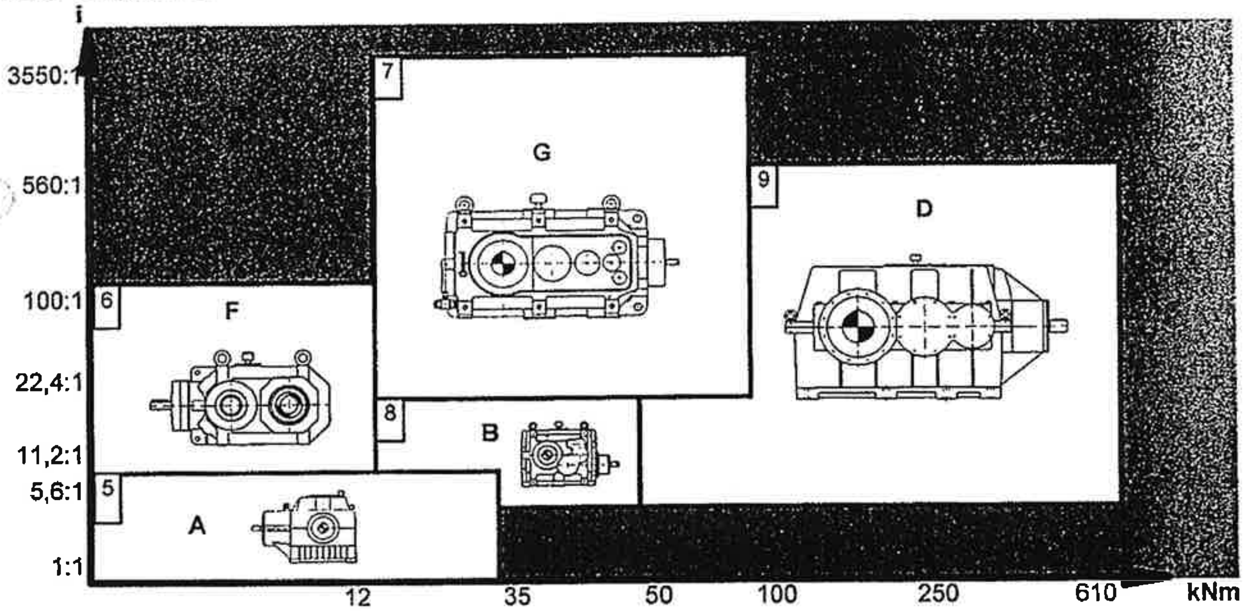
Lieriöhammasvaihteet



Output torque
Toisiovääntömomentti
(Laskentakaava ks. sivu 9810)
(Calculating formula, see page 9810)

Bevel Gear Units

Kartiohammasvaihteet



Output torque
Toisiovääntömomentti

Custom made Gear Unit
Please contact sales department

Erikoisvaihde
Pyydä erillinen tarjous

How to select?

Valintaohjeet

Output speed	n_2 [1/min]	Toisioakselin pyörimisnopeus
Input speed	n_1 [1/min]	Ensiöakselin pyörimisnopeus
Torque on the output shaft	T_2 [Nm]	Toisioakselille laskettu vääntömomentti
Calculated power on the input shaft	P_1 [kW]	Ensiöakselille laskettu teho
Reduction ratio	$i = \frac{n_1}{n_2}$	Välityssuhde
Efficiency of the gear unit	η	Vaihteen hyötysuhde

The relationship between the input power and the output torque is calculated from the following formulas:

Ensiötehon ja toisiovääntömomentin välinen yhteys lasketaan seuraavista kaavioista:

$$P_1 = \frac{T_2 \cdot n_2}{9550 \cdot \eta} \qquad T_2 = \frac{P_1 \cdot 9550 \cdot \eta}{n_2}$$

The following approximate values can be used as efficiencies:

Hyötysuhteina voidaan käyttää seuraavia ohjearvoja:

Helical gear units	Bevel gear units	η	Lieriövaihteet	Kartiovaihteet
1-stage	-	0.99	1-portaiset	-
2-stage	1-stage	0.98	2-portaiset	1-portaiset
3-stage	2-stage	0.97	3-portaiset	2-portaiset
4-stage	3-stage	0.96	4-portaiset	3-portaiset
–	4-stage	0.95	–	4-portaiset
–	5-stage	0.94	–	5-portaiset

Mechanical power transmission capacity

The selection capacity of the gear unit can be calculated by multiplying the input power of the gear unit by the service factors f_L, f_D and f_S.

Mekaaninen tehonsiirtokyky

Vaihteen valintateho saadaan kertomalla vaihteen laskettu ensiöteho käyttökertoimilla f_L, f_D ja f_S.

$$P_{1V} = P_1 \cdot f \;\; [kW] \qquad f = f_L \cdot f_D \cdot f_S$$

P_{1V} = the selection capacity on the input shaft
P_1 = the input power of the gear unit
f = application factor
f_L = load factor, taking into account any shock caused by the driving power source or the type of the load of the application
f_D = service factor determinated by the hours of daily service
f_S = starting frequency factor, according to the number of starts per hour

P_{1V} = vaihteen valintateho ensiöakselilla
P_1 = vaihteelle laskettu ensiöteho
f = käyttökerroin
f_L = käyttävän ja käytettävän koneen kuormitusluokasta aiheutuva kerroin
f_D = vaihteen päivittäisestä kuormitusajasta johtuva kerroin
f_S = vaihteen käynnistyksien lukumäärästä aiheutuva kerroin

Then, a gear unit will be selected from the power rating tables under the desired ratio and speed so that the capacity is equal to or higher than P_{1V}.

Tämän jälkeen valitaan tehotaulukosta vaihde, jonka teho tarkastettavalla välityssuhteella ja pyörimisnopeudella on suurempi tai yhtä suuri kuin P_{1V}.

Determination of thermal power transmission capacity

The calculated power on the input shaft must be lower than the thermal power (with selected cooling arrangement) which is taken from the power rating table and multiplied by the temperature factor f_T.

Termisen tehonsiirtokyvyn määrittäminen

Vaihteen ensiöakselille lasketun tehon tulee olla pienempi kuin tehotaulukosta saatava terminen teho (valitulla jäähdytysmenetelmällä) kerrottuna lämpötilakertoimella f_T.

$$P_1 \leq P_T \cdot f_T$$

Calculated power on the input shaft [kW]	P_1	Ensiöakselille laskettu teho [kW]
Thermal power	P_T	Terminen teho
Thermal factor	f_T	Lämpötilakerroin

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Selection Factors for Gear Units / Vaihteen valintakertoimet

Load Factor f_L / Kuormituskerroin f_L

Driving power source Käyttävä kone		Load classification of Driven machine Käytettävän koneen kuormitusluokka A	B	C	D
Electric motor Steam turbine	Sähkömoottori Höyryturbiini	1,00	1,20	1,50	1,80
Multi cylinder combustion engine Hydraulic and pneumatic motor	Monisylinterinen polttomoottori Hydrauli- tai pneum. moottori	1,20	1,50	1,80	2,20
Single cylinder combustion engine	Yksisylinterinen polttomoottori	1,50	1,80	2,20	2,50

Load classification / Kuormitusluokat

A= uniform load	A= tasainen
B= light shocks	B= heikkoja sysäyksiä
C= moderate shocks	C= kohtalaisia sysäyksiä
D= heavy shocks	D= voimakkaita sysäyksiä

see page 9813
kts. sivu 9813

Daily Service Factor f_D / Käyttöaikakerroin f_D

Daily service hours h/day Päivitt. käyttöaika h/vrk	<2h	<8h	<16h	>16h
f_D	0,9	1	1,12	1,25

Starting Frequency factor f_S / Käynnistystaajuuskerroin f_S

Starts/hour Käynnistyksiä/h		1	<20	<40	<80	<160	>160
Load factor f_L Kuormituskerroin	1,0	1	1,2	1,3	1,5	1,6	2,0
	1,2	1	1,1	1,2	1,3	1,4	1,7
	1,5	1	1,07	1,1	1,15	1,25	1,4
	1,8	1	1,05	1,05	1,07	1,1	1,1
	2,2	1	1	1	1	1	1
	2,5	1	1	1	1	1	1

Thermal factor f_T / Lämpötilakerroin f_T

Cooling system	Jäähdytys-menetelmä	Ambient temperature Ympäristön lämpötila	Duty cycle factor ED% Kuormituskäyttöaika/tunti ED% 100 %	80 %	60 %	40 %	20 %
Without additional cooling	Ilman ulko-puolista jäähdytystä	10	1,12	1,34	1,57	1,79	2,05
		20	1,00	1,20	1,40	1,60	1,80
		30 °C	0,88	1,06	1,23	1,41	1,58
		40	0,75	0,90	1,05	1,21	1,35
		50	0,63	0,76	0,88	1,01	1,13
Fan cooler	Tuuletinjäähdytys	10	1,15	1,38	1,61	1,84	2,07
		20	1,00	1,20	1,40	1,60	1,80
		30 °C	0,90	1,08	1,26	1,44	1,62
		40	0,80	0,96	1,12	1,29	1,44
		50	0,70	0,84	0,98	1,12	1,26

With other cooling systems please contact sales department

Muilla jäähdytysmenetelmillä pyydä erillinen tarjous

Selection table for Helical Gear Units — LD-4000 TD-4000 — Valintataulu lieriöhammasvaihteille

i	n1 1/min	4450 P1 kW	4500 P1 kW	4560 P1 kW	4630 P1 kW	4710 P1 kW
112:1	1500	235	340	430	640	970 *
	1000	160	230	290	420	640
	750	120	170	215	320	480
125:1	1500	215	310	390	570	870 *
	1000	145	205	260	380	580
	750	110	155	195	285	440
140:1	1500	195	275	350	510	750
	1000	130	185	230	340	500
	750	98	140	175	255	380
160:1	1500	175	245	320	460	670
	1000	115	165	210	310	450
	750	88	125	160	230	340
180:1	1500	155	220	275	410	620
	1000	105	150	185	275	420
	750	78	110	135	205	310
200:1	1500	140	195	240	360	550
	1000	92	130	160	240	370
	750	69	98	120	180	275
224:1	1500	120	175	220	330	490
	1000	80	115	150	220	330
	750	60	87	110	165	245
250:1	1500	105	150	195	290	430
	1000	71	100	130	190	285
	750	53	76	98	145	215
280:1	1500	94	135	180	265	380
	1000	63	91	120	175	255
	750	47	68	90	130	190
315:1	1500	83	120	160	230	330
	1000	55	80	105	155	220
	750	42	60	80	115	165
355:1	1500	74	105	135	205	295
	1000	50	70	91	135	200
	750	37	53	68	100	150
400:1	1500	67	85	125	195	260
	1000	45	57	82	130	175
	750	33	43	61	98	130
450:1	1500	60	75	110	175	220
	1000	40	50	73	115	150
	750	30	37	55	87	110
500:1	1500	53	67	98	150	195
	1000	36	44	65	100	130
	750	26,5	33	49	76	98
560:1	1500	49	58	86	130	175
	1000	33	39	58	88	115
	750	24,5	29	43	66	87
630:1	1500	44	54	80	120	150
	1000	29	36	54	82	100
	750	22	27	40	61	76

* Forced lubrication required — * Painevoitelu

	i	4450	4500	4560	4630	4710
T_2 [kNm]	250:1	155	225	285	430	610

i	ratio		välityssuhde
n_1	input speed	[1/min]	ensiöpyörimisnopeus
P_1	nominal power	[kW]	nimellisteho
T_2	output torque (calculated for i = 250:1, n1 = 1500)	[kNm]	toisiovääntömomentti (laskettu i = 250:1, n1 = 1500)

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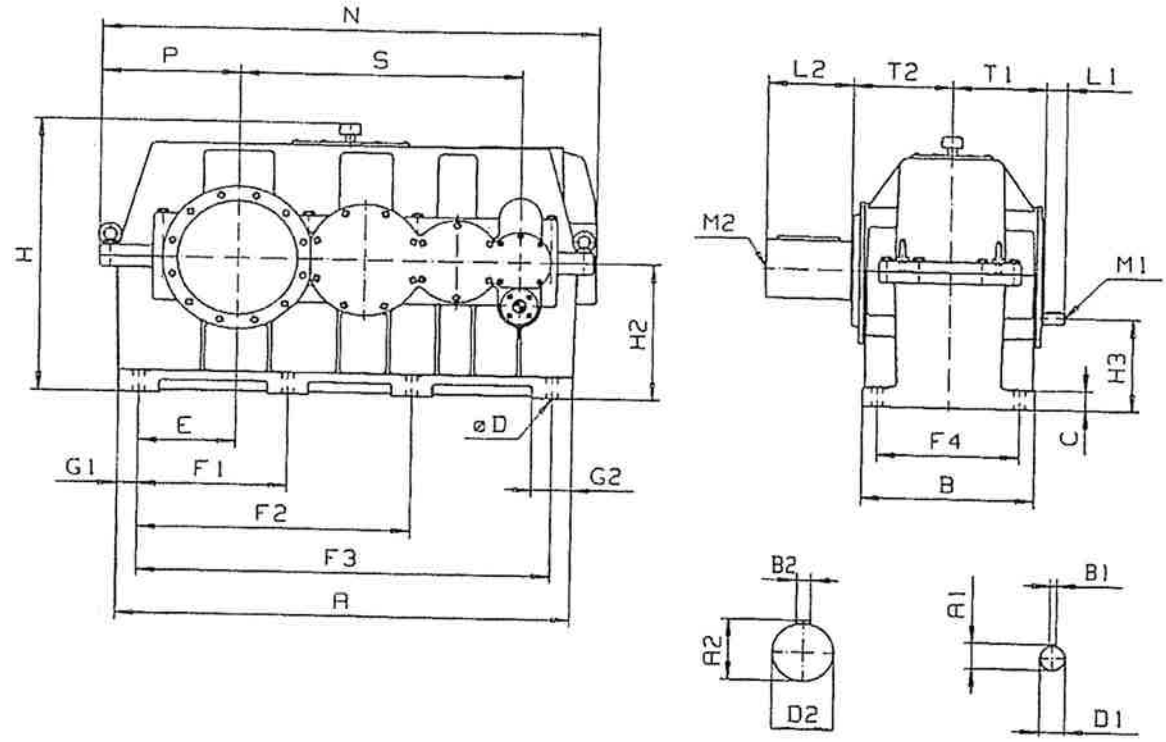
Helical Gear Unit
Lieriöhammasvaihde

LD-4000

i = 112:1 - 630:1



Size Koko	A	B	C	D	E	F1	F2	F3	F4	G1	G2	H	H2	H3	N	P	S	T1	T2
450	1530	650	80	39	345	540	970	1420	560	55	110	980	500	340	1730	500	990	350	360
500	1780	730	80	45	380	585	1070	1620	610	80	160	1080	560	380	1955	540	1105	385	415
560	2000	800	90	45	430	660	1210	1820	680	90	180	1205	630	430	2210	610	1240	420	455
630	2240	910	100	52	475	735	1350	2040	770	100	200	1360	710	485	2470	675	1395	470	515
710	2465	1020	112	52	535	830	1515	2260	870	112,5	225	1515	800	550	2710	760	1565	515	565

Size Koko	Input shaft Ensiöakseli										Output shaft Tolsioakseli				
	i ≤ 280					i > 280									
	D1	L1	A1	B1	M1	D1	L1	A1	B1	M1	D2	L2	A2	B2	M2
450	48k6	82	51,5	14	M16x36	42k6	82	45	12	M16x36	210m6	280	221	50	M36x71
500	55m6	82	59	16	M20x42	48k6	82	51,5	14	M16x36	240m6	330	252	56	M42x85
560	65m6	105	69	18	M20x42	50k6	82	53,5	14	M16x36	270m6	380	282	63	M48x100
630	70m6	105	74,5	20	M20x42	55m6	82	59	16	M20x42	300m6	380	314	70	M48x100
710	80m6	130	85	22	M20x42	65m6	105	69	18	M20x42	340m6	450	355	80	M52x100

Project : Malamocco Navigation Lock

Onderdeel : Buffers at gate

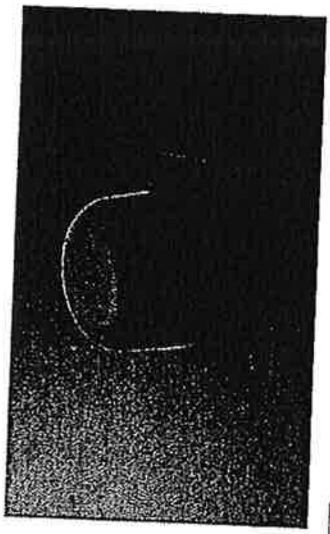
Annex C

Copies from Buffer catalogue

Opgesteld : Datum : Bladnummer : Rev. :

Gummipuffer

mit Grundplatte aus Stahl



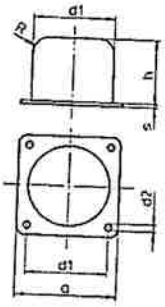
Bestell-Nr.	$W_{max.}$ [J]	F [kN]	Gewicht [kg]	d_1 [mm]	h [mm]	a [mm]	d_2 [mm]	R [mm]	s [mm]
017110-040x032 1)	57,5	9	0,09	40	35	50	5,5	-	2
017110-050x040 1)	90	13	0,17	50	43	63	6,5	-	2
017110-063x050 1)	200	25	0,36	63	54	80	6,5	-	3
017110-080	400	40	0,66	80	63	100	9,0	16	3
017110-100	800	63	1,33	100	80	125	9,0	20	4
017110-125	1600	100	2,45	125	100	160	11,0	25	4
017110-160	3200	160	5,20	160	125	200	11,0	32	6
017110-200	6300	250	9,70	200	160	250	13,0	40	6
017110-250	12500	400	19,30	250	200	315	13,0	50	8

1) Form konisch, siehe Zeichnung Gummipuffer Seite 11

Werkstoff
- Gummi: Qualität N oder S

mit verstärkter Grundplatte aus Stahl (Hüttenwerksausführung)

Bestell-Nr.	$W_{max.}$ [J]	F [kN]	Gewicht [kg]	d_1 [mm]	h [mm]	a [mm]	d_2 [mm]	R [mm]	s [mm]
017111-080	400	40	0,88	80	63	100	11	16	6
017111-100	800	63	1,82	100	80	125	13	20	8
017111-125	1600	100	3,25	125	100	160	17	25	8
017111-160	3200	160	6,50	160	125	200	17	32	10
017111-200	6300	250	11,30	200	160	250	21	40	10
017111-250	12500	400	22,60	250	200	315	21	50	12
017111-315	25000	630	41,20	315	250	400	21	63	12



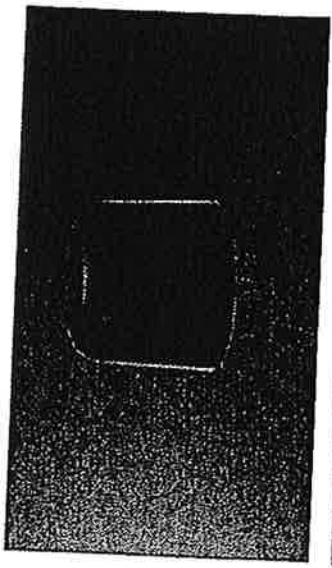
Werkstoff
- Gummi: Qualität N

mit Grundplatte aus V2A Stahl

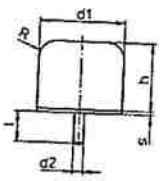
Bestell-Nr.	$W_{max.}$ [J]	F [kN]	Gewicht [kg]	d_1 [mm]	h [mm]	a [mm]	d_2 [mm]	R [mm]	s [mm]
017112-100	800	63	1,33	100	80	125	9	20	4
017112-125	1600	100	2,45	125	100	160	11	25	4
017112-160	3200	160	5,20	160	125	200	11	32	6
017112-200	6300	250	9,70	200	160	250	13	40	6
017112-250	12500	400	19,30	250	200	315	13	50	8

Werkstoff
- Gummi: Qualität S

mit einem Gewindebolzen und Stahlplatte



Werkstoff
- Schraube: Stahl, verzinkt
- Gummi: Qualität N oder S



Bestell-Nr.	$W_{max.}$ [J]	F [kN]	Gewicht [kg]	d_1 [mm]	h [mm]	d_2	l [mm]	R [mm]	s [mm]
017120-080	400	40	0,6	80	63	M 8	37	16	3
017120-100	800	63	1,1	100	80	M 12	36	20	4
017120-125	1600	100	2,1	125	100	M 16	46	25	4
017120-160	3200	160	4,4	160	125	M 16	44	32	6
017120-200	6300	250	8,4	200	160	M 20	49	40	6
017120-250	12500	400	16,3	250	200	M 20	47	50	8

Gummipuffer

. Werkstoffe

Höchste Elastizität und Reißfestigkeit zeichnen Naturkautschukvulkanisate aus. Sie besitzen eine hohe Kerbzähigkeit und gute Abriebfähigkeit. Unter allen Elastomeren haben sie die höchste mechanische und dynamische Belastbarkeit. Naturkautschuk ist unbeständig gegenüber polaren Flüssigkeiten, aliphatische, aromatische und chlorierte Kohlenwasserstoffe.
Öl oder Erdgas sind die Basisstoffe für den Synthesekautschuk. In früheren Jahren ein Substitutionsstoff für Naturkautschuk, hat der Synthesekautschuk zunehmend eigene Anwendungsgebiete gefunden. Heutzutage gibt es ein breites Spektrum von Synthesekautschukarten, deren Eigenschaften erst die Vielzahl von Anwendungen ermöglichten, die der Gummitechnik ihre Position in der modernen Technik verschaffte.
Darüberhinaus ist Gummi keine rein chemische Substanz, sondern ein Gemisch aus den unterschiedlichsten Stoffen. Die verschiedenen Beständigkeiten und mechanischen Eigenschaften sind nur durch ein Rezept, von einigen hundert Substanzen, zu verwirklichen.
Hierbei stellt der Kautschuk als makromolekulares Material die elastische Komponente des Gummis dar. Die mechanischen Eigenschaften wie Bruchdehnung, Rückprallelastizität, Festigkeit und Weiterreißwiderstand wird von ihm bestimmt. Durch die Vermischung von Chemikalien und Zuschlagstoffen mit dem Gummi, sowie durch den anschließenden Vulkanisationsprozeß entsteht daraus ein brauchbarer Werkstoff.
Die Vielzahl der Kombinationsmöglichkeiten einzelner Werkstoffe sowie die unterschiedlichsten Befestigungsmöglichkeiten bieten zu fast jedem Problem die geeignete Lösung.

Qualitätsstufen einzelner Werkstoffe

Internationale Kurzbezeichnung	NR Natur-Kautschuk	CR Chloroprene-Kautschuk	SBR Styrol-Butadien Kautschuk	EPDM Athylen-Propylen-Terpolymer	NBR Nitril-Butadien Kautschuk	VMQ Silikon-Kautschuk
Abriebwiderstand	2	2	2	3	2	5
Bruchdehnung	1	2	2	3	2	4
Einreißfestigkeit	2	2	3	3	3	6
Rückprallelastizität	2	3	3	3	3	3
Zerreißfestigkeit unverstärkt	1	3	5	5	5	6
Zerreißfestigkeit verstärkt	1	2	2	3	2	4
Temperaturbest. Heißluft	+90°C	+120°C	+100°C	+150°C	+130°C	+200°C
Temperaturbest. Kälte	-50°C	-30°C	-40°C	-40°C	-40°C	-80°C
Alkalienbeständigkeit	3	2	3	2	3	5
Alterungsbeständigkeit	3	2	3	1	3	1
Bezinbeständigkeit	6	2	4	5	1	5
elektrischer Isolierwiderstand	1	3	2	2	4	1
Öl- und Fettbeständigkeit	6	2	5	4	1	1
Ozonbeständigkeit	4	2	4	1	3	1
Säurebeständigkeit	3	2	3	1	4	5
Heißes Wasser	3	3	2	2	3	5

Die Qualitätsstufen der Eigenschaften einzelner Werkstoffe: 1=sehr gut; 2=gut; 3= befriedigend; 4=ausreichend; 5=mangelhaft; 6=ungenügend

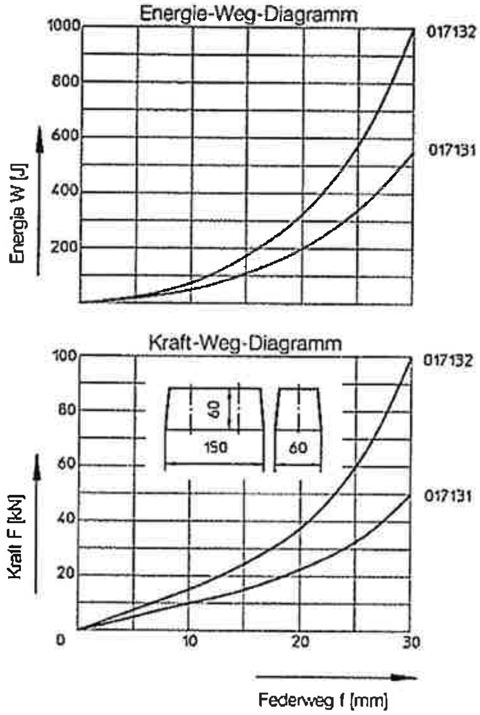
Wampfler-Standard-Qualität

N-Qualität
- hochelastisch, alterungsbeständig
- genügt allen normalen Einsatzbedingungen
- Einsatztemperatur: -30°C bis +70°C
- Härte: 70 ± 3 Shore A

S-Qualität
- seewasser-, ozon-, witterungs-, öl- und weitgehend säurebeständig
- Einsatztemperatur: -30°C bis +80°C
- Härte: 70 ± 5 Shore A

Gummipuffer

Belastungsdiagramme für Radpuffer



Belastbarkeit von Sicherheitspuffer

Werden Gummipuffer als Sicherheitspuffer mit geringer Belastungshäufigkeit eingesetzt, so kann eine 50 % höhere Energieaufnahme bei der Berechnung angesetzt werden.

Damit ist eine Erhöhung der Endkraft um ca. 55 % und die Verlängerung des Federweges auf 57 %h verbunden. Der Aufdehndurchmesser D erhöht sich auf ca. 1,6 d_1.

Beispiel

- Gummipuffer: ø 50 mm
- mögliche Energieaufnahme: W = 1,5 · 100 J = 150 J
- damit max. Endkraft: F = 1,55 · 16 kN = 24,8 kN
- maximaler Federweg: f = 0,57 · 40 mm = 22,8 mm
- Aufdehnungsdurchmesser: D = 1,6 · 50 mm = 80 mm

Somit kann bei einer vorhandenen Energie von 100 bis 150 J noch der preisgünstigere Gummipuffer ø 50 mm an Stelle des nächstgrößeren eingesetzt werden.

CEN/TC 147

Date: 2003-01

prCEN/TS 13001-3.2

CEN/TC 147

Secretariat: BSI

Cranes — General Design — Part 3.2: Limit States and Proof of Competence of Wire Ropes in Reeving Systems

Krane — Konstruktion allgemein — Teil 3.2: Grenzzustände und Sicherheitsnachweis von Drahtseilen in Seiltrieben

Grues — Conception générale — Partie 3.2 : Etats Limites et Verification de la Securité des Câbles de Systèmes de Mouflage

ICS:

Descriptors:

Document type: Technical Specification
Document subtype:
Document stage: Formal Vote
Document language: E

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Foreword

This document prCEN/TS 13001-3.2:2003 has been prepared by WG 2 "Cranes — Safety — Design — General" of Technical Committee CEN/TC 147 "Cranes — Safety", the secretariat of which is held by BSI.

This document is currently submitted to the Formal Vote.

CEN/TC 147 — Cranes/WG 2 "Design, general", the Secretariat which is held by DIN, will publish the existing Text as a Technical Specification (TS) in order to have a period of practical experience and to continue the work on this TS in order to be published in future as an European Standard (EN).

That is why, the TC asked for experience about the presented Technical Specification to be sent to:

Normenausschuss Maschinenbau (NAM) im DIN;
Secretariat of CEN/TC 147/WG 2,
Postbox 71 08 64,
60498 Frankfurt/Main

or via E-Mail:

nam@din.de

This European Technical Specification is one Part of EN 13001. The other parts are as follows:

- Part 1: General principles and requirements;
- Part 2: Load actions;
- Part 3.1: Limit states and proof of competence of steel structures;
- Part 3.3: Limit states and proof of competence of wheel/rail contacts;
- Part 3.4: Limit states and proof of competence of machinery.

Introduction

This European Technical Specification has been prepared to be a harmonized standard to provide one means for the mechanical design and theoretical verification of cranes to conform with the essential health and safety requirements of the Machinery Directive, as amended. This standard also establishes interfaces between the user (purchaser) and the designer, as well as between the designer and the component manufacturer, in order to form a basis for selecting cranes and components.

This Technical Specification is a type C standard as stated in EN 1070:1998.

The machinery concerned and the extent to which hazards are covered are indicated in the scope of this standard.

1 Scope

This Part 3.2 of the Technical Specification EN 13001 is to be used together with Part 1 and Part 2 and as such they specify general conditions, requirements and methods to prevent mechanical hazards of wire ropes in reeving systems of cranes by design and theoretical verification.

NOTE Specific requirements for particular types of crane are given in the appropriate Technical Specification for the particular crane type.

The following is a list of significant hazardous situations and hazardous events that could result in risks to persons during normal use and foreseeable misuse. Clauses 5 to 6 of this standard are necessary to reduce or eliminate the risks associated with the following hazard:

Exceeding the limits of strength.

This Technical Specification is applicable to cranes which are manufactured after the date of approval by CEN of this standard and serves as reference base for the Technical Specifications for particular crane types.

NOTE ENV 13001-3.2 deals only with limit state method according to EN 13001-1

2 Normative references

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

EN 292-1:1991, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology.*

EN 292-2:1991, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specifications.*

EN 292-2:1991/prA1:1991, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specifications.*

ENV 1070:1993, *Safety of machinery — Terminology.*

prEN 12385-4:2000, *Steel wire ropes — Safety — Part 4: Stranded ropes for general lifting applications.*

prEN 13001-1:1997, *Cranes — General Design — Part 1: General principles and requirements.*

prEN 13001-2:1997, *Cranes — General Design — Part 2: Load actions.*

prEN 13411-1:2001, *Terminations for steel wire ropes — Safety — Part 1: Thimbles for steel wire rope slings.*

EN 13411-2:2001, *Terminations for steel wire ropes — Safety — Part 2: Splicing of eyes for wire rope slings.*

prEN 13411-3:2001, *Terminations for steel wire ropes — Safety — Part 3: Ferrule and ferrule-securing.*

prEN 13411-4:2001, *Terminations for steel wire ropes — Safety — Part 4: Metal and resin socketing.*

prEN 13411-6:2002, *Terminations for steel wire ropes — Safety — Part 6: Asymmetric wedge sockets.*

ISO 4306-1:1990, *Cranes vocabulary.*

ISO 4309: 1990, *Wire rope for lifting appliances — code of practise for examination and discard.*

3 Definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this Technical Specification, the definitions given in ENV 1070:1993 and the basic list of definitions as provided in ENV 1991-1 apply. For the definitions of loads, clause 6 of ISO 4306-1 applies.

3.2 Symbols and abbreviations

The symbols and abbreviations used in this part of the EN 13001 are given in.Table 1

Table 1 — Symbols and abbreviations

Symbols, abbreviations	Description
a	Acceleration
C	Total number of working cycles (see EN 13001-1) during useful life of crane
D	Relevant diameter
D_{drum}	Minimum pitch diameter of drum
D_{sheave}	Minimum pitch diameter of sheave
D_{comp}	Minimum pitch diameter of compensating sheave
d	Rope diameter
$d_{bearing}$	Diameter of bearing or shaft
F_{equ}	Equivalent internal force
F_{gd}	Part of F_{equ} induced by gravity, exclusive mass of payload, amplified by γ_p
F_{gl}	Part of F_{equ} induced by gravity forces of mass of payload, amplified by γ_p
F_o	Part of F_{equ} induced by any other forces, amplified by γ_p
$F_{Rd,s}$	Limit design rope force for the proof of static strength
$F_{Rd,f}$	Limit design rope force for the proof of fatigue strength
$F_{Sd,s}$	Design rope force for the proof of static strength
F_r	Part of F_{equ} induced by resistancies, amplified by γ_p
$F_{Sd,f}$	Design rope force for the proof of fatigue strength
F_t	Part of F_{equ} induced by rope tightening forces, amplified by γ_p
F_u	Minimum rope breaking force
F_w	Part of F_{equ} induced by wind forces, amplified by γ_p
f_f	Factor of further influences
f_{f1}	Factor of diameter ratio influence
f_{f2}	Factor tensile strength of wire influence
f_{f3}	Factor of fleet angle influence
f_{f4}	Factor of lubrication influence
f_{f5}	Factor of multilayer drum influence

Table 1 *(concluded)*

Symbols, abbreviations	Description
f_{f6}	Factor of groove radius influence
f_{f7}	Factor of rope type influence
f_{S1}	Rope force increasing factor from rope reeving efficiency
f_{S2}	Rope force increasing factor from non parallel falls
f_{S3}	Rope force increasing factor from horizontal acceleration
f^*_{Si}	Rope force increasing factors in fatigue
g	Gravity constant
i	Index for cycles of lifting and lowering
k_r	Rope force spectrum factor
l_r	Number of ropes used during useful life of the crane
q	Height distribution
m_H	Mass of hoist load (see EN13001-2)
m_{Hr}	Mass of hoist load that is acting on the rope falls under consideration
m_{rod}	Rotatory rope driven mass
m_{trans}	Translational rope driven mass
n	Number of contact points passed by rope
n_f	Number of falls or reeving lines
n_{fs}	Number of fixed sheave between drum and moving part
n_m	Mechanical advantage
R_0	Minimum tensile strength of the wire used in the rope
R_{Dd}	Reference ratio of rope bending diameter to rope diameter
r_g	Groove radius
S_R	Class of rope force history
s_r	Rope force history parameter
t	Rope type factor
w	Number of relevant bendings per lifting movement
w_c	Bending count
w_D	Number of bendings at reference point
w_{tot}	Total number of bendings
z, z_i, z_{min}, z_{max}	Height coordinates
α	Angle of slope
β, β_{max}	Angles between falls and line of acting force
γ	Angle between gravity and projected rope in plane of F_h and g
γ_n	Risk coefficient
γ_p	Partial safety factor
γ_{rb}	Minimum rope resistance factor (static)
γ_{rf}	Minimum rope resistance factor (fatigue)
δ	Design fleet angle
ε	Angle between sheave planes
η_s	Efficiency of single sheave
η_{tot}	Total efficiency of rope drive
v_r	Relative total number of bendings
ϕ	Dynamic factor for inertial or gravity effects
ϕ^*	Dynamic factor for inertial or gravity effects in fatigue
ϕ_2	Dynamic factor for hoisting an unrestrained grounded load
ϕ_5	Dynamic factor for loads caused by acceleration
ϕ_6	Dynamic factor for testload
ω	Angle between the sheave groove sides

4 General

In all cranes running wire ropes are stressed by loads (described by a load spectrum) and by bendings. Both constitute the rope force history, classified in classes S_R (see 6.3.2). Classes S_R are used for the selection of the wire rope and diameters of drums and/or sheaves. They are independent of time.

The proof of competence for static strength and the proof of competence for fatigue strength shall be fulfilled for the selection of ropes and components. This standard is for design purposes only and should not be seen as a guarantee of actual performance.

To ensure safe use of the rope the discard criteria (see ISO 4309) shall be applied.

The wire rope should be in accordance with prEN 12385-4. Rope terminations shall meet the requirements of prEN 13411.

5 Proof of static strength

5.1 General

For the proof of static strength it shall be proven that for all relevant load combinations of EN 13001-2

$$F_{Sd,s} \leq F_{Rd,s} \quad (1)$$

where:

$F_{Sd,s}$ is the design rope force

$F_{Rd,s}$ is the limit design rope force.

5.2 Vertical hoisting

5.2.1 Design rope force

The design rope force $F_{Sd,s}$ in vertical hoisting shall be calculated as follows:

$$F_{Sd,s} = \frac{m_{Hr} \cdot g}{n_f} \cdot \phi \cdot f_{S1} \cdot f_{S2} \cdot f_{S3} \cdot \gamma_p \cdot \gamma_n \quad (2)$$

where:

m_{Hr} is the mass of the hoist load (m_H) or that part of the mass of the hoist load that is acting on the rope falls under consideration (see Figure 1). The mass of the hoist load includes the masses of the payload, lifting attachments and a portion of the suspended hoist ropes. In statically undetermined systems, the unequal load distribution between ropes depends on elasticities and shall be taken into account.

g is the gravity constant

n_f is the number of falls carrying m_{Hr}

ϕ is the dynamic factor for inertial and gravity effects as shown in 5.2.2

f_{S1} to f_{S3} are the rope force increasing factors as shown in 5.2.3 to 5.2.5

γ_p is the partial safety factor (see EN 13001-2)
γ_p = 1,34 for regular loads (load combinations A)
γ_p = 1,22 for occasional loads (load combinations B)

γ_p = 1,10 or exceptional loads (load combinations C)

γ_n is the risk coefficient (see EN 13001-2)

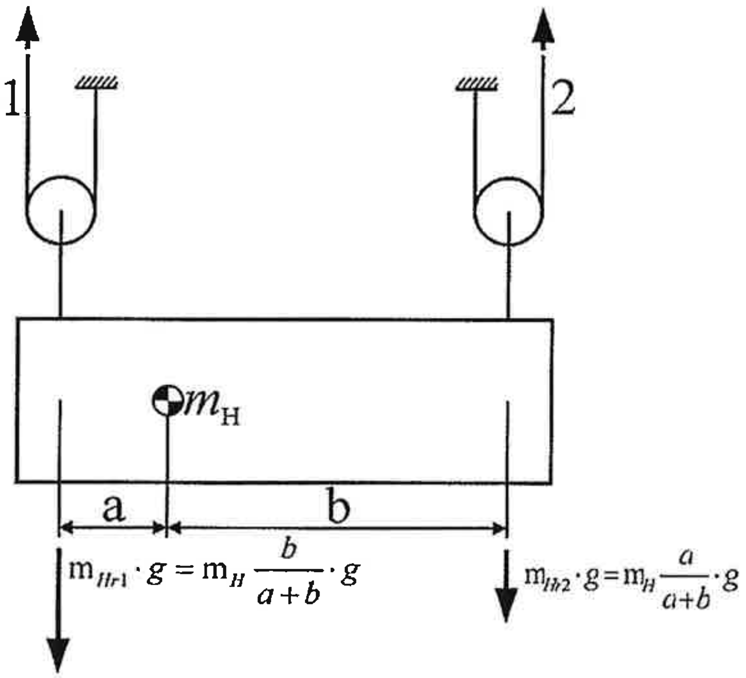


Figure 1— Example for the acting parts of hoist mass

5.2.2 Inertial and gravitational effects

5.2.2.1 Dynamic factors

For vertical hoisting the maximum inertial effects from either hoisting an unrestrained grounded load or from acceleration or deceleration shall be taken into account by the dynamic factor ϕ.

5.2.2.2 Hoisting an unrestrained grounded load

$$\phi = \phi_2 \tag{3}$$

where:

ϕ_2 is the dynamic factor for inertial and gravity effects when hoisting an unrestrained grounded load (see EN 13001-2)

5.2.2.3 Acceleration or deceleration of the hoistload

$$\phi = 1 + \phi_5 \cdot \frac{a}{g} \tag{4}$$

where:

ϕ_5 is the dynamic factor for loads caused by acceleration (see EN 13001-2)

a is the vertical acceleration or deceleration

g is the gravity constant

5.2.2.4 Testload

$$\phi = \phi_6 \qquad (5)$$

where:

ϕ_6 is the dynamic factor for testload (see EN 13001-2)

5.2.3 Rope reeving efficiency

The increase of the design rope force by the rope reeving efficiency is given by

$$f_{S1} = \frac{1}{\eta_{tot}} \qquad (6)$$

The total efficiency of the rope drive η_{tot} shall be calculated as follows:

$$\eta_{tot} = \frac{(\eta_S)^{n_{fs}}}{n_m} \cdot \frac{1 - (\eta_S)^{n_m}}{1 - \eta_S} \qquad (7)$$

where:

η_S is the efficiency of a single sheave:
η_S = 0,985 for sheave with roller bearing
η_S = 0,985 · (1 - 0,15 · $d_{bearing} / D_{Sheave}$) for sheave with plain bearing

Other values for η_S may be used if verified by test results for the applied rope, sheave or bearing.

n_m is the mechanical advantage (see example in Figure 2)

n_{fs} is the number of fixed sheaves between drum and moving part

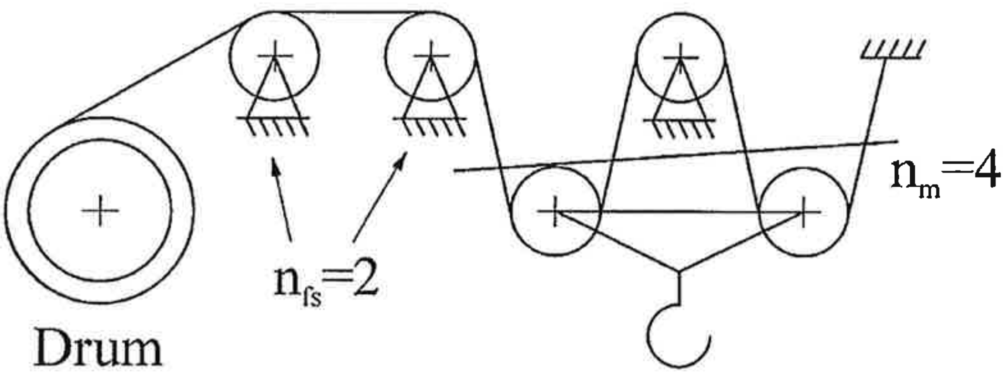


Figure 2 — Example for Rope Reeving Efficiency

5.2.4 Non parallel falls

When the rope falls are not parallel the rope force is increased. The rope force increasing factor f_{S2} shall be determined for the most unfavourable position. For simplification f_{S2} may be calculated by

$$f_{S2} = \frac{1}{\cos \beta_{max}} \qquad (8)$$

where:

β_{max} is the maximum angle between the falls and the direction of load (see Figure 3)

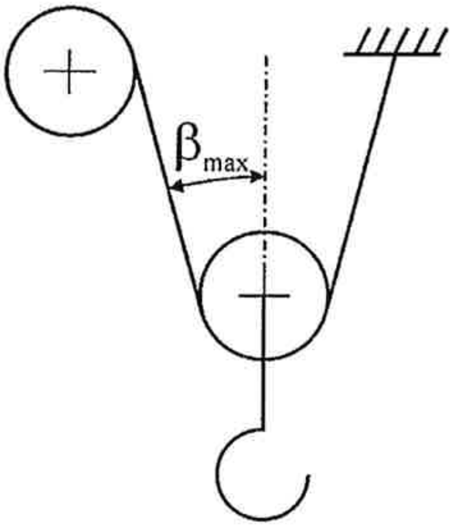


Figure 3 — Angle β_{max}

5.2.5 Horizontal forces on the hoist load

The rope force increasing effect of the horizontal forces (e. g. by crab or crane accelerations, wind) may be neglected in applications with free swinging loads.

However in applications with several non parallel ropes (rope pyramid, see Figure 4) the horizontal forces increase the rope force considerably. This effect shall be taken into account. For simplification the rope force increasing factor f_{S3} may be calculated by

$$f_{S3} = 1 + \frac{F_h}{m_H \cdot g \cdot \tan\gamma} \leq 2 \quad (9)$$

where:

F_h is the horizontal force on the hoist load

m_H is the mass of the hoist load

g is the gravity constant

γ is the angle between gravity and the rope projected in the plane of F_h and g

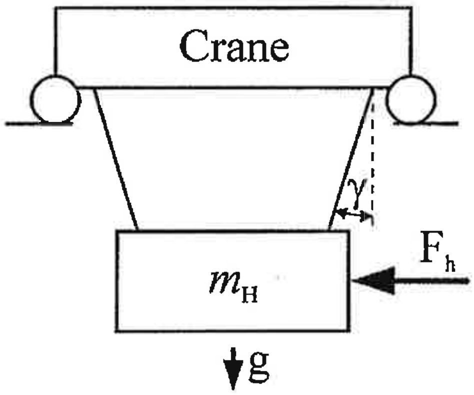


Figure 4— Horizontal force

5.3 Non vertical drives

5.3.1 Design rope force

The design rope force $F_{Sd,s}$ in non vertical drives (see examples in Figure 5 and Figure 6) shall be calculated as follows:

$$F_{Sd,s} = \frac{F_{equ}}{n_f} \cdot \phi \cdot f_{S1} \cdot f_{S2} \cdot \gamma_n \qquad (10)$$

where:

F_{equ} is the equivalent internal force acting on the rope falls under consideration as shown in 5.3.2. In statically undetermined systems, the unequal load distribution between ropes depends on elasticities and shall be taken into account.

n_f is the number of falls or reeving lines

ϕ is the dynamic factor for inertial effects as shown in 5.3.3

f_{S1}, f_{S2} are the rope force increasing factors as shown in 5.3.4 and 5.3.5

γ_n is the risk coefficient (see EN 13001-2)

$\gamma_n = 1{,}05$

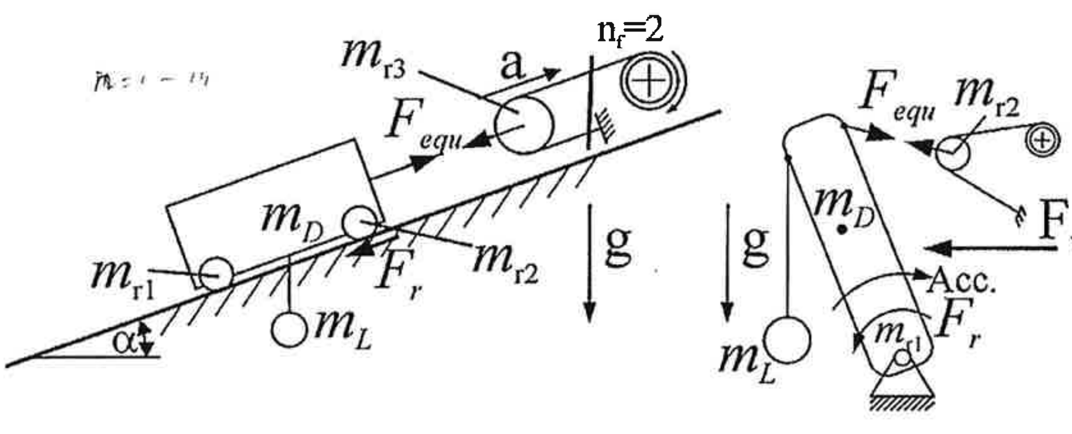


Figure 5 — Examples for non vertical drive

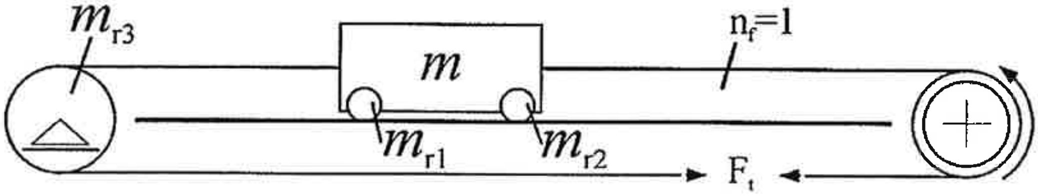


Figure 6— Example for rope tightening

5.3.2 Equivalent internal force

In general the load actions of gravity forces, resistances (e. g. rolling or gliding, wheels, bearings), rope tightening forces, wind forces and any other forces (e. g. buffer forces, forces from climatic effects) contribute to the equivalent internal force F_{equ} as illustrated in Formula 11. Those load actions shall be amplified by partial safety factors γ_p (see EN 13001-2) for the load combination under consideration, as given in Table 2.

$$F_{equ} = F_{gd} + F_{gl} + F_r + F_w + F_t + F_o \quad (11)$$

where:

F_{gd} is that part of F_{equ} that is induced by gravity forces of the rope driven masses, exclusive the mass of the payload, amplified by the relevant partial safety factor.

F_{gl} is that part of F_{equ} that is induced by gravity forces of the rope driven mass of the payload, amplified by the relevant partial safety factor.

F_r is that part of F_{equ} that is induced by resistances, amplified by the relevant partial safety factor.

F_w is that part of F_{equ} that is induced by wind forces, amplified by the relevant partial safety factor.

F_t is that part of F_{equ} that is induced by rope tightening forces (see example in Figure 6), amplified by the relevant partial safety factor.

F_o is that part of F_{equ} that is induced by any other forces, amplified by the relevant partial safety factor.

Table 2 — Partial safety factors γ_p

	Description	Regular loads Load combinations A	Occasional loads Load combinations B	Exceptional loads Load combinations C
F_{gd}	Gravitation on masses, exclusive mass of payload	1,22	1,16	1,1
F_{gl}	Gravitation on payload	1,34	1,22	1,1
ϕ	Inertia	1,34	1,22	1,1
F_r	Resistances	1,34	1,22	1,1
F_t	Rope tightening	1,22	1,16	1,1
F_w	Wind forces: In service	—	1,22	1,16
	Wind forces: Out of service	—	—	1,1
F_o	Snow and ice	—	1,22	1,1
	Temperature	—	1,16	1,05
	Buffer forces	—	—	1,1

5.3.3 Inertial effects

In non vertical drives the inertial effects from accelerations shall be taken into account by the dynamic factor ϕ calculated as follows:

$$\phi = 1 + \frac{\left(\sum m_{trans} + \sum m_{red}\right) \cdot a \cdot \phi_5 \cdot \gamma_p}{F_{equ}} \tag{12}$$

where:

Σm_{trans} is the sum of translational rope driven masses, referred to the coordinate of acceleration

Σm_{red} is the sum of rotatory rope driven masses (see examples in Figure 5 and Figure 6), referred to the coordinate of acceleration

a is the acceleration or deceleration

ϕ_5 is the dynamic factor for loads caused by acceleration (see EN 13001-2)

γ_p is the partial safety factor, as given in Table 2, line inertia

F_{equ} is the equivalent internal force

5.3.4 Rope reeving efficiency

The increase of the design rope force by the rope reeving efficiency is given by the rope force increasing factor f_{S1}, calculated as shown in 5.2.3, Formulae 6 and 7.

5.3.5 Non parallel falls

The increase of the design rope force by non parallel falls is given by the rope force increasing factor f_{S2}, calculated as shown in 5.2.4 and Formula 8.

5.4 Limit design rope force

The limit design rope force $F_{Rd,s}$ is given by

$$F_{Rd,s} = \frac{F_u}{\gamma_{rb}} \tag{13}$$

where:

F_u is the minimum breaking force of the rope as specified by the manufacturer

γ_{rb} is the minimum rope resistance factor.

The minimum rope resistance factor γ_{rb} is dependent on the geometry of the reeving system and is given by

$$\gamma_{rb} = 1,34 + \frac{5,0}{\left(\frac{D}{d}\right)^{0,8} - 4} \tag{14}$$

where:

D is the minimum relevant diameter: $D = \text{Min}(D_{sheave}\ ;\ 1,125 * D_{drum}\ ;\ 1,125 * D_{comp})$

d is the rope diameter.

Table 3 gives minimum rope resistance factors for selected ratios of D/d.

Table 3 — Minimum rope resistance factor γ_{rb}

D/d	11,2	12,5	14,0	16,0	18,0	20,0
γ_{rb}	3,06	2,75	2,52	2,30	2,16	2,05

6 Proof of fatigue strength

6.1 General

According to test results the fatigue strength of ropes in terms of number of bendings is approximately inversely proportional to the second power of the applied rope tension force. With the additional requirement that the ratio of the rope bending diameter D to the rope diameter d increases with the number of bendings w_{tot} according to

$$\frac{D}{d} \sim 1{,}125^{\log_2(w_{tot})} \tag{15}$$

(i.e. D/d increases by 1,125 for increasing w_{tot} by 2), the rope force to number of bendings relationship follows closely the power -3. Therefore this additional requirement is used in the classification of the rope force history.

When calculating the number of bendings, one lifting movement is considered to comprise both a lifting and lowering action. In non vertical drives to and from movements are treated respectively.

For the proof of fatigue strength it shall be proven that

$$F_{Sd,f} \leq F_{Rd,f} \tag{16}$$

where:

$F_{Sd,f}$ is the design rope force for fatigue

$F_{Rd,f}$ is the limit design rope force for fatigue.

6.2 Design rope force

6.2.1 Principle conditions

The design rope force $F_{Sd,f}$ shall be calculated for regular loads (load combinations A) only, with partial safety factors γ_p, risk coefficient γ_n and rope efficiency set to 1.

For vertical hoisting:

$$F_{Sd,f} = \frac{m_{Hr} \cdot g}{n_f} \cdot \phi^{\bullet} \cdot f_{S2}^{\bullet} \cdot f_{S3}^{\bullet} \tag{17}$$

where:

m_{Hr} is the mass of the hoist load (m_H) or that part of the mass of the hoist load that is acting on the rope (see Figure 1).

g is the gravity constant

n_f is the number of falls carrying m_{Hr}

$\phi^{\bullet}$ is the dynamic factor for inertial and gravity effects as shown in 6.2.2

$f_{S2}^{\bullet}$, $f_{S3}^{\bullet}$ are the rope force increasing factors as shown in 6.2.3 to 6.2.4

For non-vertical drives:

$$F_{Sdf} = \frac{F_{equ}}{n_f} \cdot \phi^* \cdot f_{S2}^* \qquad (18)$$

where:

F_{equ} is the equivalent internal force acting on the rope according to the principles of 5.3.2.

n_f is the number of falls or reeving lines

ϕ^* is the dynamic factor for inertial effects as shown in 6.2.2

f_{S2}^* is the rope force increasing factor as shown in 6.2.3

Instead of the rope force increasing factors f_{si}^* the factors f_{si} as given in clause 5 may be used.

Instead of the dynamic factor ϕ^* the factor ϕ as given in clause 5 may be used.

6.2.2 Inertial effects

As the inertial effects act for short time only, they do not affect all bendings. Therefore the dynamic factors ϕ^* may be calculated by

$$\phi^* = \phi \qquad \text{for } w = 1 \text{ or} \qquad (19)$$

$$\phi^* = \sqrt[3]{\frac{(w-1)+\phi^3}{w}} \qquad \text{for } w \geq 2$$

where:

w is the relevant number of bendings per lifting movement (see Annex A).

ϕ is the dynamic factor (see 5.2.2 or 5.3.3)

6.2.3 Non parallel falls

For the proof of fatigue strength the distribution of height and angle within the working range can be taken into account by

$$f_{S2}^* = \sqrt[3]{\int_{z_{\min}}^{z_{\max}} \frac{q(z)}{\cos^3 \beta(z)} \cdot dz} \qquad (20)$$

where:

z are height coordinates as shown in Figure 7.
z_{ref} is the reference height
The whole working range is from z_{min} to z_{max}.
The most frequent working range is from z_1 to z_2.

$\beta(z)$ is the angle between rope and line of the acting force

$q(z)$ is the height density of the crane use in the working range

$$\int_{z_{min}}^{z_{max}} q(z) \cdot dz = 1 \tag{21}$$

When the crane operates approximately equal on all heights of the most frequent working range, the density function is constant

$$q(z) = \frac{1}{z_2 - z_1} \tag{22}$$

and f^{*}_{S2} may be calculated as

$$f^{*}_{S2} = 1 + \left[\frac{1}{\cos \beta (z_2)} - 1 \right] \cdot \left(\frac{z_{ref} - z_2}{z_{ref} - z_1} \right)^{0,9} \tag{23}$$

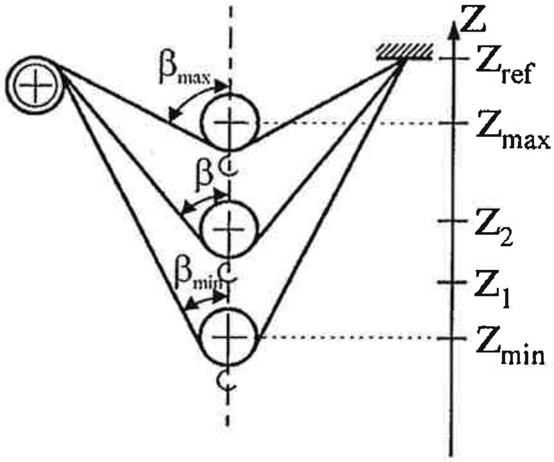


Figure 7 — Lifting positions

6.2.4 Horizontal forces in vertical hoisting

If horizontal acceleration and lifting acceleration act together regularly, f^{*}_{S3} shall be calculated by

$$f^{*}_{S3} = f_{S3} \tag{24}$$

where:

f_{S3} is the rope force increasing factor calculated from an average angle γ (see 5.2.5)

When horizontal forces and lifting acceleration do not act together regularly, f^{*}_{S3} may be set to 1.

6.3 Limit design rope force

6.3.1 Basic formula

The limit design rope force $F_{Rd,f}$ shall be calculated by

$$F_{Rd,f} = \frac{F_u}{\sqrt[3]{s_r} \cdot \gamma_{rf}} \cdot f_f \tag{25}$$

where:

F_u is the minimum breaking force of the rope as specified by the manufacturer

s_r is the rope force history parameter

γ_{rf} is the minimum rope resistance factor

f_f is the factor of further influences.

6.3.2 Rope force history parameter

In analogy to stress history parameter (see EN 13001-1), the rope force history parameter is given by

$$s_r = k_r \cdot v_r \tag{26}$$

where:

k_r is the rope force spectrum factor

v_r is the relative total number of bendings.

The rope force history parameter shall be determined either by direct use of formula (25) or simplified by selection of a class S_R from Table 4.

Table 4 — Classes S_R of rope force history parameter s_r

Class	S_R0	S_R1	S_R2	S_R3	S_R4	S_R5	S_R6	S_R7	S_R8	S_R9
s_r	0,008	0,016	0,032	0,063	0,125	0,25	0,5	1,0	2,0	4,0

6.3.3 Rope force spectrum factor

The rope force spectrum factor k_r is calculated by

$$k_r = \sum_{i=1}^{i_{max}} \left(\frac{F_{Sd,f,i}}{F_{Sd,f}} \right)^3 \cdot \frac{w_i}{w_{tot}} \tag{27}$$

where:

i is the index of one lifting movement with $F_{Sd,f,i}$

i_{max} is the total number of lifting movements per rope, considering all the working cycles, numbers of which per rope equals to C/l_r

$F_{Sd,f,i}$ is the design rope force in lifting movement i

$F_{Sd,f}$ is the maximum design rope force

w_i is the relevant number of bendings in one lifting movement i (see Annex A).

w_{tot} is the total number of bendings during the useful life of a rope.

C is the total number of working cycles during the useful life of the crane (see EN 13001-1)

l_r is the design number of ropes used during the useful crane life
(Guidance for l_r is given in the Annex B)

The total number of bendings w_{tot} is calculated by

$$w_{tot} = \sum_{i=1}^{i_{max}} w_i \tag{28}$$

where:

w_i is the relevant number of bendings per lifting movement (see Annex A).

i_{max} is the total number of lifting movements per rope

6.3.4 Relative total number of bendings

The relative total number of bendings is calculated by

$$v_r = \frac{w_{tot}}{w_D} \tag{29}$$

where:

w_{tot} is the total number of bendings during the useful life of a rope

w_D is the number of bendings at reference point: $w_D = 5 \cdot 10^5$.

6.3.5 Minimum rope resistance factor

The minimum rope resistance factor γ_{rf} shall be

$$\gamma_{rf} = 7 \tag{30}$$

6.4 Further influences on the limit design rope force

6.4.1 Basic formula

The factor f_f takes into account further influences on the limit design rope force:

$$f_f = f_{f1} \cdot f_{f2} \cdot f_{f3} \cdot f_{f4} \cdot f_{f5} \cdot f_{f6} \cdot f_{f7} \tag{31}$$

where:

f_{f1} to f_{f7} are the factors of influences as given in 6.4.2 to 6.4.7.

6.4.2 Diameters of drum and sheaves

As explained in 6.1 the additional requirement that the ratio *D/d* of the rope bending diameter *D* to the rope diameter *d* increases with the number of bendings w_{tot} according to Formula 15 is incorporated in Formula 24. *D* is the minimum relevant diameter

$$D = Min(D_{sheave}; 1{,}125 \cdot D_{drum}; 1{,}125 \cdot D_{comp}) \tag{32}$$

The reference ratio value of *D/d* is calculated by

$$R_{Dd} = 10 \cdot 1{,}125^{\log_2\left(\frac{s_r}{0{,}004}\right)} \tag{33}$$

Table 5 gives standardized values of R_{Dd} in terms of classes S_R:

Table 5 — Reference ratio R_{Dd}

Class	S_R0	S_R1	S_R2	S_R3	S_R4	S_R5	S_R6	S_R7	S_R8	S_R9
R_{Dd}	11,2	12,5	14,0	16,0	18,0	20,0	22,4	25,0	28,0	31,5

The factor f_{f1} is calculated by

$$f_{f1} = \frac{D/d}{R_{Dd}} \tag{34}$$

The chosen ratio D/d shall not be less than 11.2 and shall be selected such that f_{f1} becomes greater than 0.75.

6.4.3 Tensile strength of wire

A non-linear relationship between the tensile strength level R_r of the wire and the limit design rope force shall be taken into account by

$$f_{f2} = \left(\frac{1770}{R_r}\right)^{0,4}, \text{ for } R_r > 1770 \tag{35}$$

$f_{f2} = 1$, for $R_r \leq 1770$

where:

R_r is the level of requirement of breaking force (tensile strength) which is designated by a number (e. g. 1770, 1960 etc.), see prEN 12385-4.

6.4.4 Fleet angle

Fleet angles at sheaves or drums are illustrated in Figure 8. Fleet angles shall always be counted positive. For a selected point of the rope, the design fleet angle δ being associated with the most frequent working range shall be taken into account by factor f_{f3} according to Table 6. The design fleet angle is calculated by

$$\delta = \sqrt[3]{\frac{\sum_{j=1}^{n} \delta_j^3}{n}} \tag{36}$$

where:

δ_j is the fleet angle at the tangential contact point j of rope at drum or sheave (see Figure 8)

n is the number of contact points passed by the most bent part of the rope (See Figure 8 for an example with n = 6)

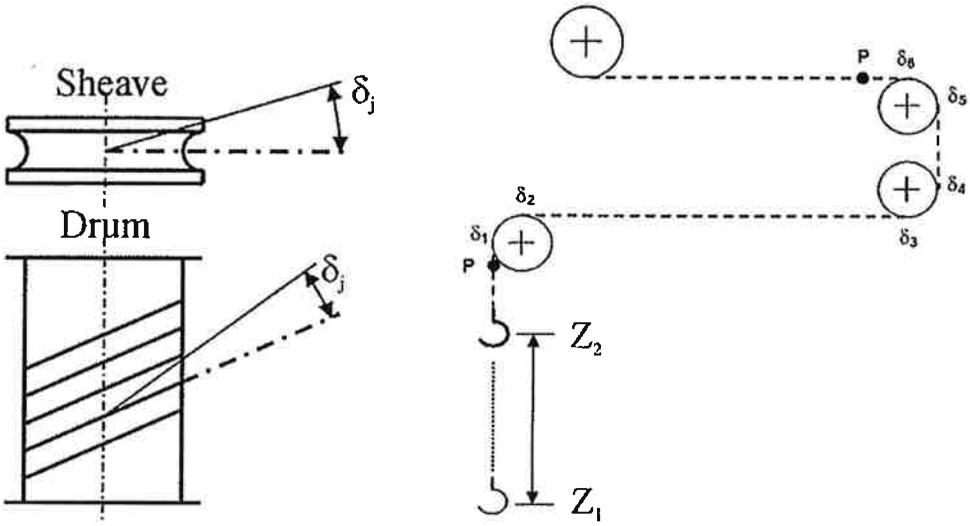


Figure 8 — Fleet angles

Table 6 — Factor f_{f3}

design fleet angle δ	non rotation resistant rope	rotation resistant rope
≤0,5°	1,0	1,0
1,0°	0,9	0,9
2,0°	0,75	0,7
3,0°	0,7	not covered
4,0°	0,67	
Intermediate values may be interpolated		

6.4.5 Rope lubrication

For lubricated ropes the factor f_{f4} is set to one. For ropes without lubrication (e. g. clean room) the factor f_{f4} shall be f_{f4} = 0,5.

6.4.6 Multilayer drum

Multilayer drums reduce the limit design rope force. A factor f_{f5} < 0.8 shall be applied.

6.4.7 Groove radius

The ratio of groove radius r_g to rope diameter d and the requirements for angle ω between the sides of a sheave (see Figure 9) shall be taken into account by f_{f6} according to Table 7.

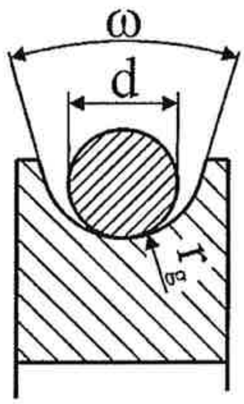


Figure 9 — Groove radius

Table 7 — Factor f_{f6}

r_g/d	ω	f_{f6}
0.53	≤60°	1
0.55		0.84
0.6	No requirement	0.75
0.7		0.63
0.8		0.58
≥ 1.0		0.54
Intermediate values may be interpolated		

6.4.8 Rope types

Differing bending fatigue performance of the various rope types shall be taken into account by the factor f_{f7}, given by

$$f_{f7} = \frac{1}{t} \tag{38}$$

where

t is the rope type factor.

In general for non-rotation resistant ropes with 6 to 10 outer strands, t = 1 is valid. For other rope types values of t in the range of 0.95 to 1.25 may be specified by the rope manufacturer.

Annex A
(normative)

Number of Relevant Bendings

One lifting movement comprises both a lifting and lowering action. The number of relevant bendings w of a rope during one lifting movement shall be established for the most unfavourable part of the rope by counting the sum of bending counts w_c according to Table A.1 and A.2.

When the loads in lifting and lowering are different (e. g. when loads are deposited at upper level), $w/2$ for the lifted load and $w/2$ for the lowered load shall be used. In these cases, both lifting and lowering are each considered as one lifting movement for the calculation of the rope force spectrum factor.

Table A.1 — Bending counts

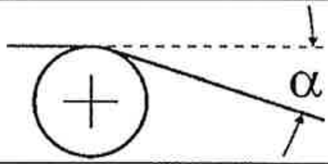
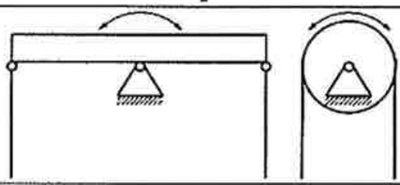
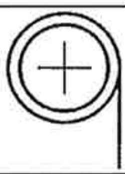
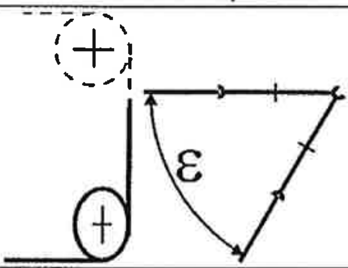
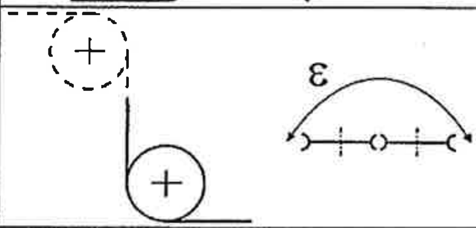
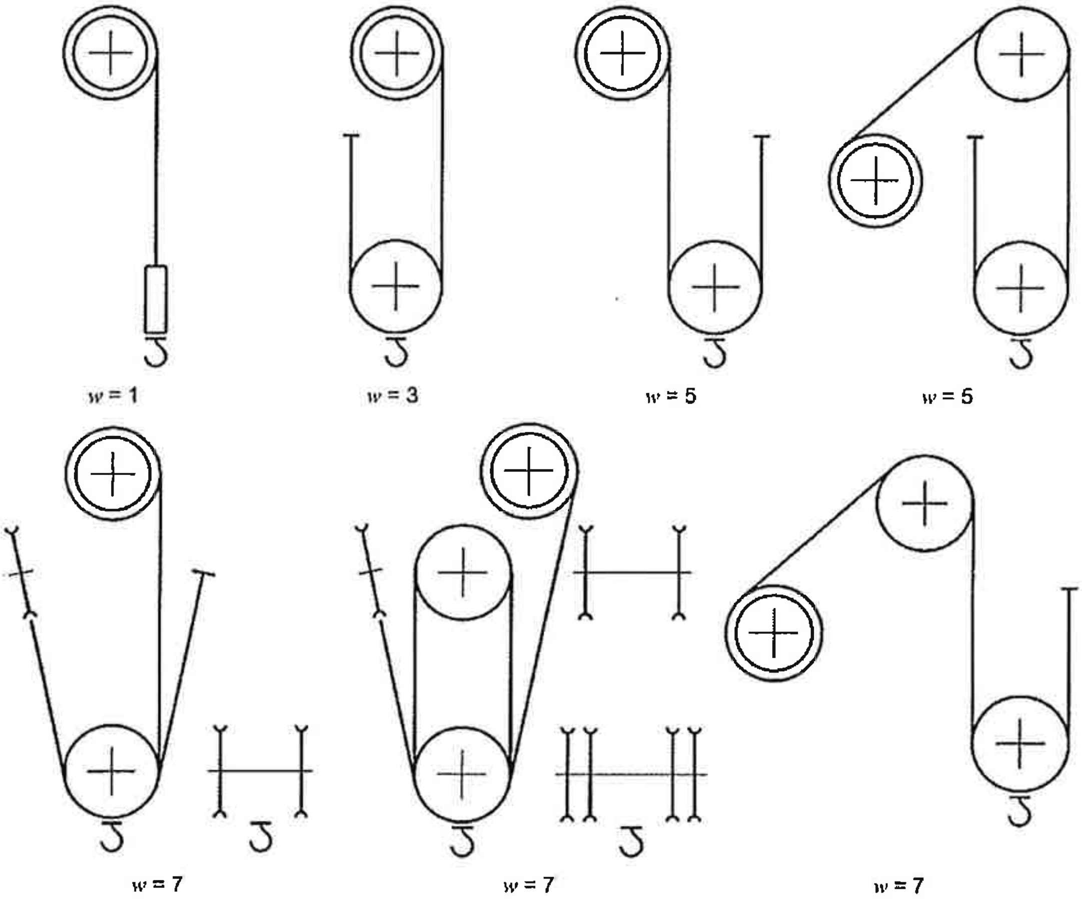
Type of bending	Illustration	Bending count
Any bending with a deflection angle α less than 5°		$w_c = 0$
Rope termination		$w_c = 0$
Compensating sheave/whip		$w_c = 0$
Drum		$w_c = 1$
Sheave with same sense bending (angle ε between planes less than 120°)		$w_c = 2$
Sheave with reverse sense bending (angle ε ≥ 120°)		$w_c = 4$

Table A2 shows examples assuming movements where the most unfavourable part of the rope runs from the drum over all sheaves.

Table A.2 — Examples for the number of relevant bendings w



If during the cycle the rope runs only over a part of the sheaves, *w* depends on the length of the stroke. Figure A.1 gives an example:

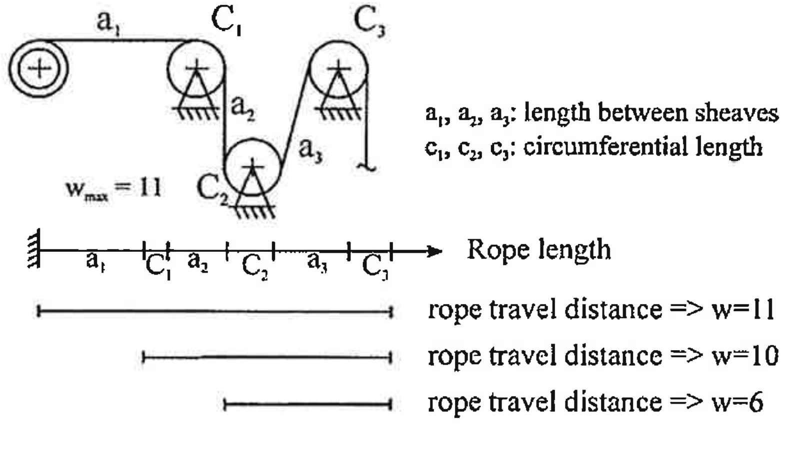


Figure A.1 — Number of relevant bendings

Annex B
(informative)

Guidance for selection of design number of hoist ropes used during the useful crane life

Item no.	Type of crane	Operation method	S-class (see EN 13001-3.1)	Number of ropes l_r
1	Hand-operated cranes		S0 – S2	1-2
2	Assembly cranes		S0 – S2	1-2
3	Powerhouse cranes		S1 – S3	1-3
4	Warehouse cranes	Intermittent operation	S4 – S5	3-6
5	Warehouse cranes, lifting beam cranes, scrapyard cranes	Continuous operation	S6 – S8	6-14
6	Workshop cranes		S3 – S5	2-6
7	Bridge cranes, skull cracker cranes	Grab, magnet, spreader	S6 – S8	6-14
8	Ladle cranes		S6 – S8	6-14
9	Pit cranes		S7 – S9	8-20
10	Stripper cranes, charging cranes		S8 – S9	10-20
11	Forging cranes		S6 – S8	6-14
12	Unloaders, stocking and reclaiming bridges, semi-portal cranes, portal cranes with trolley or slewing crane	Hook service	S4 – S6	3-8
13		Grab, magnet, spreader	S6 – S9	6-20
14	Travelling conveyor gantries with fixed or sliding conveyor(s)		S3 – S5	2-6
15	Shipbuilding cranes, slipway cranes, fitting-out cranes	Hook service	S3 – S5	2-6
16	Wharf cranes, slewing cranes, floating cranes, level-luffing slewing cranes	Hook service	S4 – S6	3-8
17		Grab, magnet, spreader	S6 – S8	6-14
18	High-capacity floating cranes, high capacity gantry cranes		S1 – S3	1-3
19	Shipdeck cranes	Hook service	S3 – S5	2-6
20		Grab, magnet, spreader	S4 – S6	3-8
21	Revolving lower cranes for construction service		S1 – S4	1-4
22	Erection cranes, derricks	Hook service	S1 – S3	1-3
23	Rail-mounted slewing cranes	Hook service	S3 – S5	2-6
24		Grab, magnet, spreader	S4 – S6	3-8
25	Locomotive cranes, licensed for in-train Haulage		S4 – S5	3-6
26	Loader cranes, mobile cranes	Hook service	S2 – S5	2-6
27		Grab, magnet, spreader	S4 – S6	3-8
28	High capacity loader and mobile cranes		S1 – S3	1-3

Annex C
(informative)

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[2] Feyrer, Klaus: Laufende Drahtseile — Bemessung und Überwachung. Renningen-Malsheim: Expert-Verlag 1998. ISBN 3-8169-1481-0

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Annex Y
(informative)

Selection of suitable set of crane standards for a given application

Is there a product standard in the following list that suits the application?	
prEN 13000: 1997	Cranes — Mobile cranes
WI 00147030	Cranes — Tower cranes
WI 00147031	Cranes — Slewing jib cranes
WI 00147032	Cranes — Bridge and gantry cranes
WI 00147033	Cranes — Offshore cranes — Part 1: General purpose offshore cranes
WI 00147044	Cranes — Offshore cranes — Part 2: Floating cranes
WI 00147042	Cranes — Power driven winches and hoists — Part 1: Power driven winches
WI 00147043	Cranes — Power driven winches and hoists — Part 2: Power driven hoists
prEN 12999: 1997	Cranes — Loader cranes
prEN 13157: 1998	Cranes — Hand powered cranes
prEN 13155: 1998	Cranes — Non-fixed load lifting attachments
WI 00147041	Cranes — Manually controlled load manipulating devices

YES → Use it directly, plus the standards that are referred to

NO ↓

Use the following:	
WI 00147005	Cranes — Terminology
prEN 13001-1: 1997	Cranes — General design — Part 1: General principles and requirements
prEN 13001-2: 1997	Cranes — General design — Part 2: Load actions
WI 00147008	Cranes — General design — Part 3.1: Limit states and proof of competence of steel structures
WI 00147049	Cranes — General design — Part 3.2: Limit states and proof of competence of wire ropes
WI 00147050	Cranes — General design — Part 3.3: Limit states and proof of competence of wheel / rail contacts
WI 00147051	Cranes — General design — Part 3.4: Limit states and proof of competence of machinery
prEN 13135-1: 1998	Cranes — Equipment — Part 1: Electrotechnical equipment
WI 00147011	Cranes — Equipment — Part 2: Non-electrotechnical equipment
prEN 13557: 1999	Cranes — Controls and control stations
EN 12077-2: 1998	Cranes safety — Requirements for health and safety — Part 2: Limiting and indicating devices
prEN 13586: 1999	Cranes — Access
WI 00147045	Cranes — Equipment for the lifting of persons — Part 1: Suspended baskets
WI 00147046	Cranes — Equipment for the lifting of persons — Part 2: Moveable cabins
prEN 12644-1: 1998	Cranes — Information for use and testing — Part 1: Instructions
prEN 12644-2: 1998	Cranes — Information for use and testing — Part 1: Marking
prEN 12644-3: 1998	Cranes — Information for use and testing — Part 1: Fitness for purpose

ALLEGATO B

Parti meccaniche delle saracinesche di livellamento

+ varie parti oleoidrauliche varie

Project : Malamocco Navigation Lock

Onderdeel : Levelling Sluices

Hydraulic System

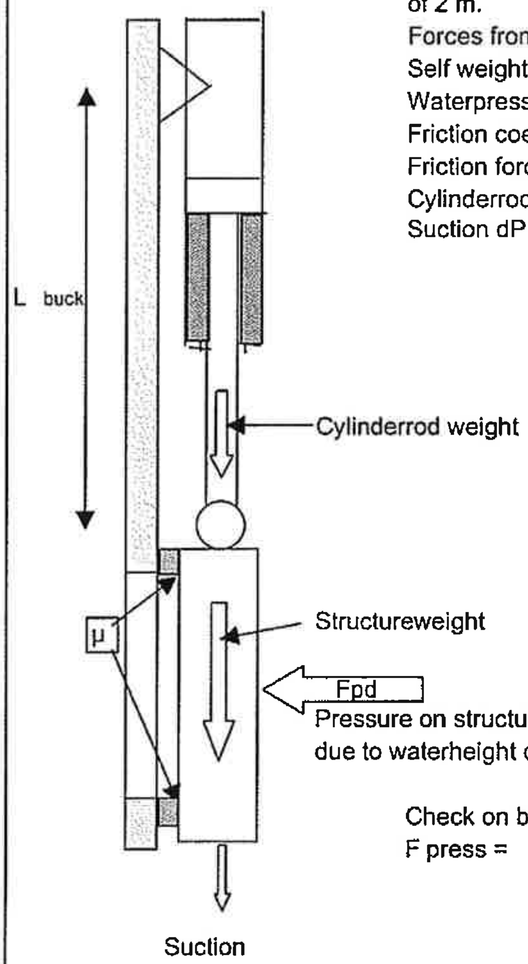
Cylinders

Forces at cylinder

From steelstructure calculation and maximum waterleveldifference of 2 m. see MVO 36 P PE MAR 4003

Forces from:

Self weight valve structure		50	kN
Waterpressure dP 2m	280 kN		
Friction coefficient μ =	0,22		
Friction force	Fpd*μ =	62	kN
Cylinderrod weight		2	kN
Suction dP 2 m A=0,2x2x2	dPxA	16	kN
	Total F	130	kN



Selection of hydraulic cylinder

Working Pressure p = 10 MPa with max 16 MPa
Cylinder test pressure 25 MPa

Required cross area at rod side
A = F/p = 129,6 cm2

Cylindersize:	160 x 90	A=	137	cm2
Stroke			2850	mm
Oil flow at v =	0,1 m/s	Q=	82,4	l/min

Pressure on structure	F@ 16 MPa	219	kN
due to waterheight difference	F@ 10 MPa	137	kN

Check on buckling Lbuck = 3100 mm Fbuck = 200 kN(s=3)
F press = 101 kN @ 16 MPa (From tables cylinders)

Cylinderspeed 0,005 m/s
Time for full stroke 570 sec

Required pump capacity per cylinder
Q = 4,12 l/min

Take one pump for 5 cylinders with mechanical divider
(Principal of mechanical divider is 5 gearpumps mechanically connected to each other, without drive, one feeding line and 5 separate outgoing lines with equal flow.)

Qpump required is : 20,6 l/min

Take Rexroth gearpump Type G2 size NG 16 with 23 l/min @ 1450 rpm and Ppump is 7,5 kW.

Author :	Date :	page :	Rev. :
W. Lock	13-07-2004		B

Project : Malamocco Navigation Lock

Onderdeel : Levelling Sluices

Slanting lifting of valve.

Water level difference 2 m

Pressure on each valve

$A = 2{,}37 \times 2{,}85 = 6{,}75\ m^2$

$\Delta p = 2 \times 1{,}03 \times 10^{-2}\ MPa$

$P = 139\ kN$ with $\mu = 0{,}15$

pressure on sliding material $P_m = \frac{139\,000}{2 \times (2370 + 2850) \times 150} = 0{,}1\ N/mm^2$

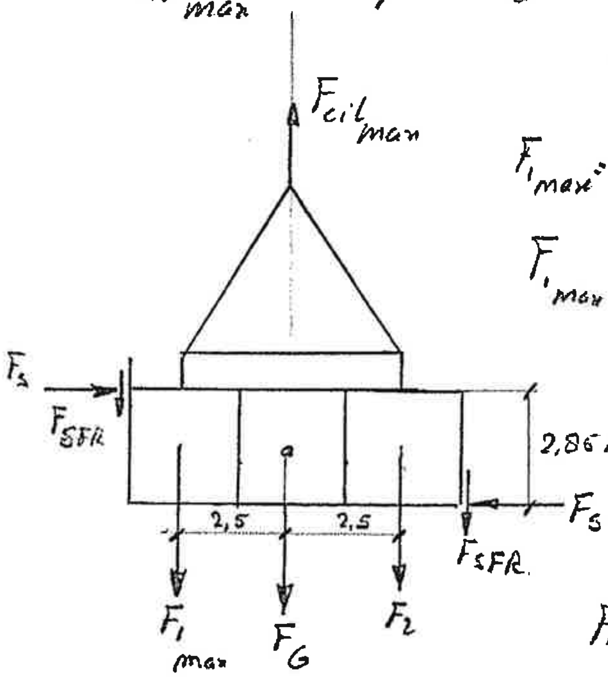
$F_{FRD} = 2 \times 139 \times 0{,}15 = 41{,}7\ kN$

Weight of structure $= 52\ kN = F_G$

Required cilinder force $= F_G + F_{FRD} = 52 + 41{,}7 = 93{,}7\ kN$

$F_{cil_{max}} = 219\ kN\ (@\ 16\ MPa)$

$F_{2_{min}} = P_2 \times \mu_{min} = 139 \times 0{,}1 = 13{,}9\ kN$



$F_{1_{max}} = F_{cil_{max}} - F_G - F_{2_{min}} - 2 \times \mu \cdot F_s$

$F_{1_{max}} = 219 - 52 - 13{,}9 - 2 \times \mu \times F_s$

$F_s = (F_1 - F_2) \times \frac{2{,}5}{2{,}85}$

$F_s = F_1 \times \frac{2{,}5}{2{,}85} - 13{,}9 \times \frac{2{,}5}{2{,}85}$

$F_s = 0{,}877 F_1 - 12{,}2\ kN$

$F_{1max} = 153{,}1 - 2 \cdot \mu F_s \quad (\mu = 0{,}22)$

(F_1, with $\mu = 0{,}22 \rightarrow F_1 = 139 \times 0{,}22 = 30\ kN$)

$F_{1max} = 158{,}5 - 0{,}386 F_1 \rightarrow F_{1_{max}} = 114{,}33\ kN$

Opgesteld : W. Lock

Datum : 12-02-2004

Bladnummer : 2

Rev. :

Project : Malamocco Navigation Lock

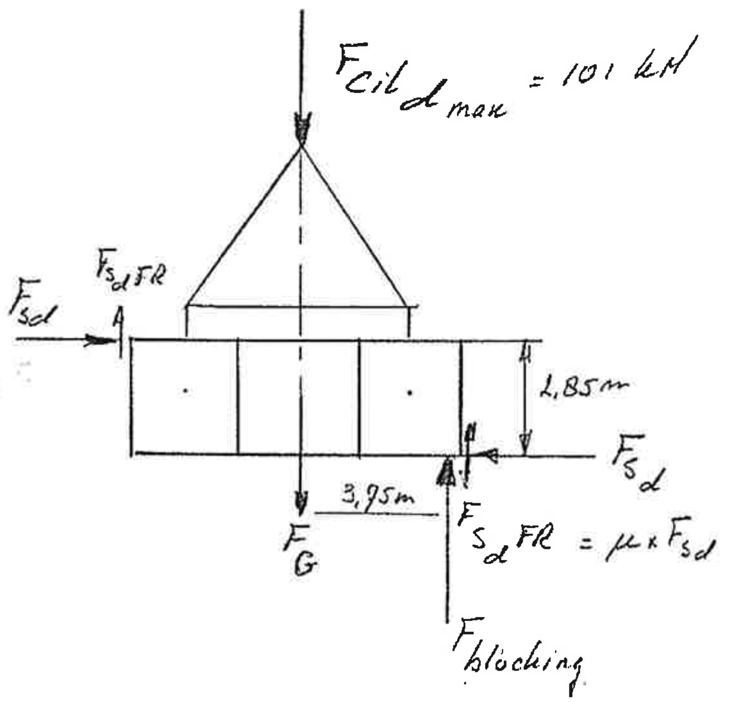
Onderdeel : Levelling Sluices

Slanting lowering of valve

No water level difference

weight of structure 52 kN = F_G

$F_{cil\ max;out}$ = 101 kN @ 16 MPa



$F_{blocking} + 2\mu F_{sd} = F_{cil} + F_G$

$F_{blocking} \times 3{,}75 = F_{sd} \times 2{,}85$ $\qquad F_{sd} = \frac{3{,}75}{2{,}85} F_{blocking}$

$F_{blocking} \times \left(1 + 2 \times \mu \times \frac{3{,}75}{2{,}85}\right) = F_{cil} + F_G$

$F_{blocking} \times \left(1 + 2 \times 0{,}22 \times \frac{3{,}75}{2{,}85}\right) = 101 + 52 = 153$ kN

$F_{blocking} = 96{,}9$ kN

$\mu = 0{,}1$

$F_{blocking} = 121{,}1$ kN

Opgesteld : W. Lock

Datum : 12-02-2004

Bladnummer : 3

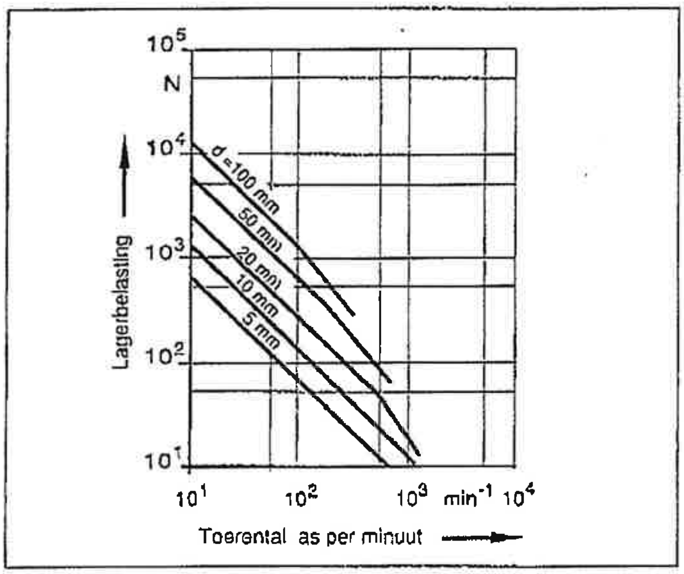
Rev. :

W.L.

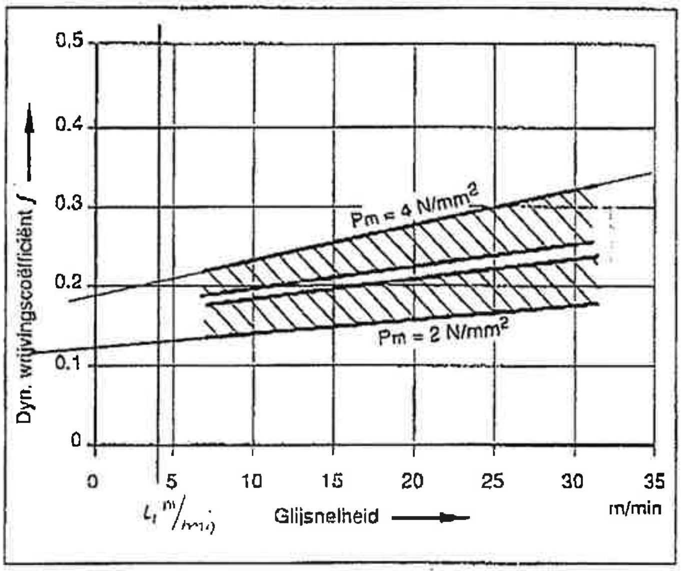
MULTILENE M

UHMWPE

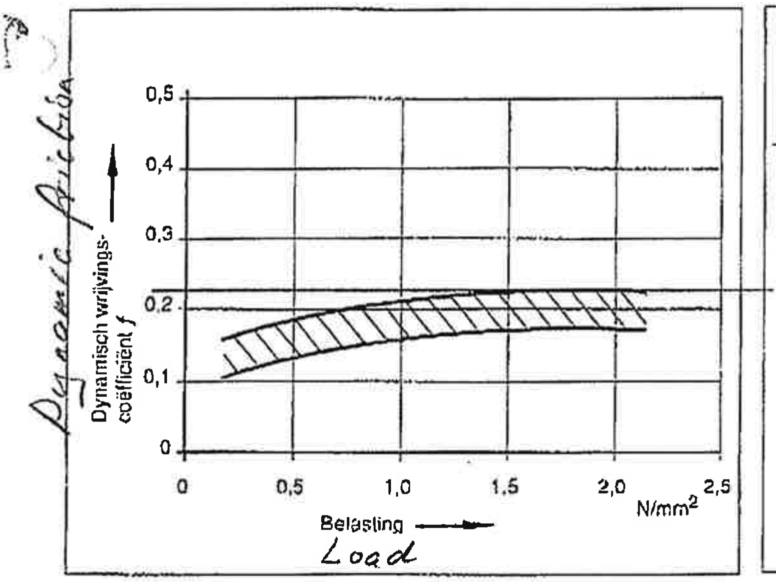
Advies-grenzen voor toelaatbare lagerbelasting van ongesmeerde Multilene M lagers!



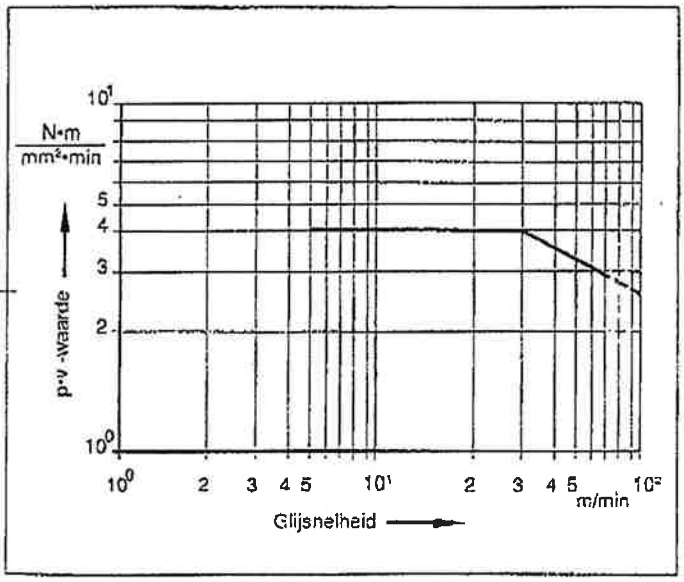
Wrijvingskoëfficiënt van Multilene M, afhankelijk van de wrijvingssnelheid, bij 0.26 resp. 1.24 N/mm² en 23°C



Dyn.wrijvingskoëfficiënt van Multilene M als funktie van de belasting (bij 10 m/min)



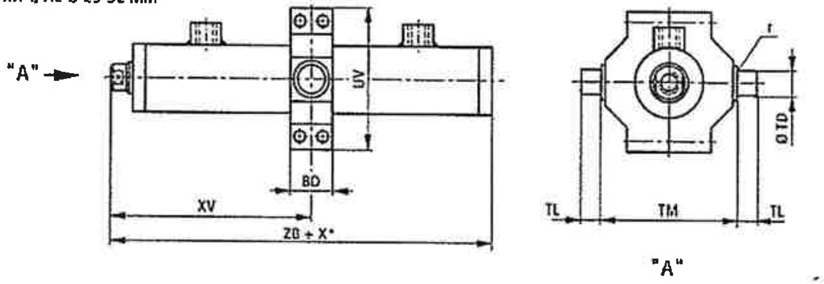
Max. toelaatbare lagerbelasting van Multilene M bij 23°C



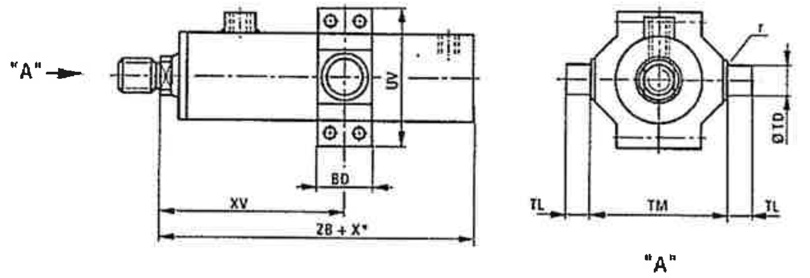
T.a.v. dhr. W. Cock fax: 040-6448556.

Befestigungsart MT4 / Mounting MT4 / Fixation MT4

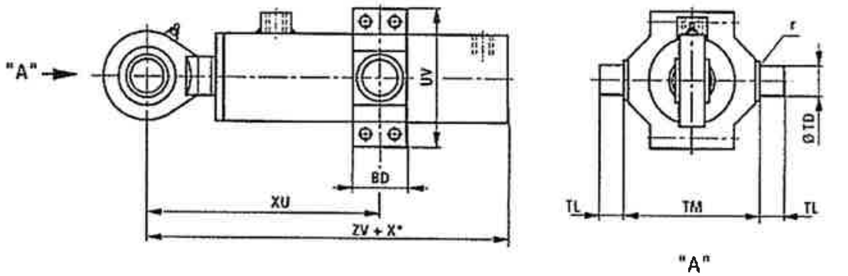
CDL1 MT4; AL-Ø 25-32 mm [1]



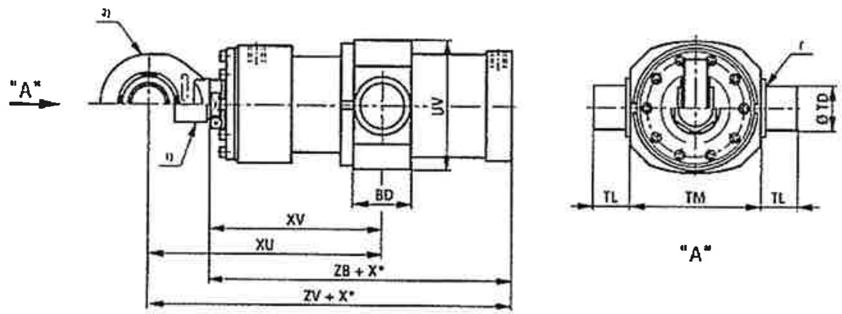
CDL1 MT4; AL-Ø 40-125 mm [1]



CDL1 MT4; AL-Ø 40-125 mm [2]



CDL1 MT4; AL-Ø 160-200 mm [1, 2]



Maße MT4 (in mm) / Dimensions MT4 (in mm) / Encombrement MT4 (en mm)

AL Ø	MM Ø	BD	r	TD	TL	TM h12	UV	XV [5] min	XV [5] max	XU [5] min	XU [5] max	ZB	ZV	X* [6] min
25	14	20	1	12_{f8}	10	63	64	68	47+X*	–	–	104	–	21
32	18	25	1	16_{f8}	12	75	75	78	50+X*	–	–	116	–	28
40	22	35	1,5	20_{f8}	16	90	86	94	71+X*	125	102+X*	124	155	23
50	28	40	1,5	25_{f8}	20	105	100	104	72+X*	141	109+X*	135	172	32
63	36	50	2	32_{f8}	25	120	126	119	82+X*	168	131+X*	159	208	37
80	45	65	2,5	40_{f8}	32	135	145	144	93+X*	204	153+X*	185	245	51
100	56	80	2,5	50_{f8}	40	160	175	162	93+X*	232	163+X*	202	272	69
125	70	100	3	63_{f8}	50	195	215	183	98+X*	269	184+X*	221	307	85
160	90	100	2,5	80_{f8}	63	240	250	265	120+X*	380	235+X*	268	383	147
200	110	125	3	100_{f8}	80	295	300	285	120+X*	425	260+X*	280	420	168

Bemerkungen

Hauptmaße auf Seite 8 und 9.

AL = Kolben-Ø
MM = Kolbenstangen-Ø
X* = Hublänge

1) = Kolbenstangenende "H"
2) = Kolbenstangenende "F"
5) = Lage Schwenkzapfen frei wählbar. Maß "XV/XU" bei Bestellung immer im Klartext in mm angeben.
6) = Min. Hublänge "X* min" beachten.

Notes

For main dimensions, see pages 8 and 9.

AL = Piston Ø
MM = Piston rod Ø
X* = Stroke length

1) = Piston rod end "H"
2) = Piston rod end "F"
5) = The location of the MT4 mounting is optional. Always indicate the dimension "XV/XU" in mm in clear text in the order.
6) = Please note the min. stroke length "X* min".

Remarques

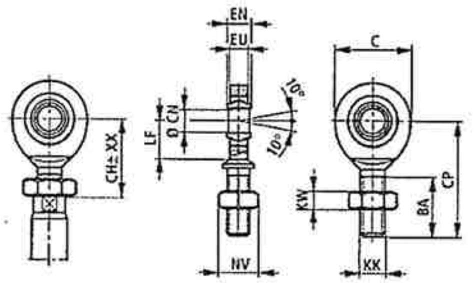
Cotes principales, voir pages 8 et 9.

AL = Ø de piston
MM = Ø de tige
X* = Course

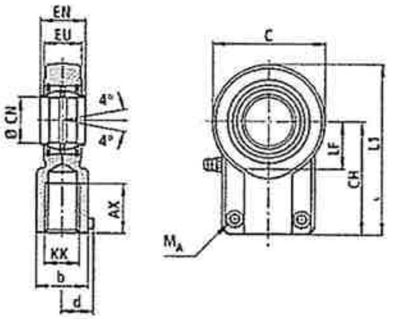
1) = Extrémité de tige "H"
2) = Extrémité de tige "F"
5) = La position de montage du tourillon est au choix. Préciser la cote "XV/XU" en clair dans le texte de la commande.
6) = Tenir compte de la course mini "X* min".

Gelenkkopf (in mm) / Self-aligning clevis (in mm) / Tenon à rotule (en mm)

AL-Ø 25-32 mm



AL-Ø 40-200 mm



ISO 6126
DIN 648 E

ISO 6982
DIN 24338

AL Ø	MM Ø	Bestell-Nr. Order no Num. de refer	KK	AX	b	BA	C	CH	CN[3]	CP max	d max	EN h12	EU	KW	L1	LF	NV	M_A[2] Nm	m[4] kg
25	14	371 250 003 1	M10	–	–	26	29	29	10	48	–	9	7	5	–	15	16	–	0,1
32	18	371 320 003 1	M12	–	–	28	34	35	12	54	–	10	18	6	–	18	18	–	0,1
40	22	371 400 002 1	M16x1,5	23	25	–	50	52	20	–	18,5	20	17	–	77	22	–	13	0,4
50	28	371 500 002 1	M20x1,5	29	30	–	62	65	25	–	18,5	25	21	–	97	27	–	13	0,7
63	36	371 630 002 1	M27x2	37	38	–	76	80	32	–	22	32	27	–	120	32	–	32	1,1
80	45	371 800 002 1	M33x2	46	47	–	97	97	40	–	26	40	32	–	147	41	–	32	2,1
100	56	371 980 002 1	M42x2	57	58	–	118	120	50	–	29	50	40	–	183	50	–	64	4,5
125	70	371 120 002 1	M48x2	64	70	–	142	140	63	–	37	63	52	–	211	62	–	80	7,6
160	90	374 700 003 1	M65x1,5	66	86	–	154	150	70	–	–	65	55	–	–	75	–	–	8,6
200	110	374 800 003 1	M80x2	81	102	–	176	170	80	–	–	74	60	–	–	80	–	–	12,0

Bemerkungen:

2) = Der Gelenkkopf muß immer gegen die Schulter der Kolbenstange geschraubt werden. Danach müssen die Klemmschrauben mit dem angegebenen Anzugsmoment angezogen werden.

3) = Toleranzen:
AL-Ø 25- 32 mm: -0,008
AL-Ø 40-125 mm: H7
AL-Ø 160-200 mm: M7

4) = Masse Gelenkkopf

Notes:

2) = The self-aligning clevis must always be screwed to the piston rod thread stop.
Subsequently, the clamping screws have to be tightened to the specified torque.

3) = Tolerances:
AL-Ø 25- 32 mm: -0,008
AL-Ø 40-125 mm: H7
AL-Ø 160-200 mm: M7

4) = Weight of the self-aligning clevis

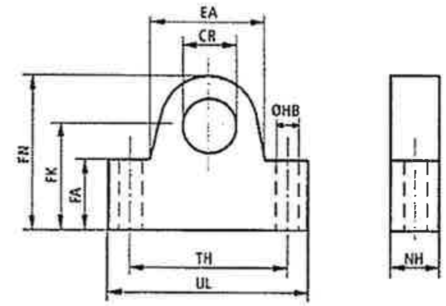
Remarques:

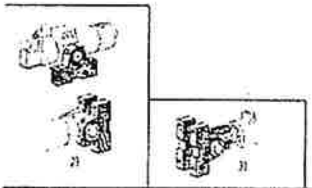
2) = Le tenon à rotule doit toujours être vissé sur l'épaulement de la tige.
Les vis de serrage doivent être serrées au couple de serrage spécifié.

3) = Tolérances:
AL-Ø 25- 32 mm: -0,008
AL-Ø 40-125 mm: H7
AL-Ø 160-200 mm: M7

4) = Masse du tenon à rotule

Lagerbock (in mm) / Mounting block (in mm) / Console (en mm)





AL Ø	MM Ø	AL Ø	MM Ø	Bestell-Nr. Order no Num. de refer	CR	EA max	FA	FK js12	FN	HB	NH	TH	UL	m[5] kg
–	–	25	14	237 012 412 1	10	20	20	34	45	9	16	40	60	0,36
25[4]	14[4]	32	18	237 012 512 1	12	20	20	34	45	9	16	40	60	0,35
32[4]	18[4]	–	–	237 013 212 1	16	24	25	40	53	11	20	50	76	0,65
40	22	40	22	237 014 012 1	20	35	27	45	63	11	20	60	86	1,0
50	28	50	28	237 015 012 1	25	54	35	55	77	14	24	80	110	1,9
63	36	63	36	237 016 312 1	32	65	40	65	92	18	30	110	150	3,5
80	45	80	45	237 018 012 1	40	82	45	76	112	22	32	125	170	5,1
100	56	100	56	237 019 812 1	50	106	60	95	138	27	40	160	210	9,7
125	70	125	70	237 011 212 1	63	140	70	112	168	33	50	200	260	18,7
160[4]	90[4]	–	–	371 160 012 1	80	175	85	140	215	39	62	250	322	31,0
–	–	160	90	342 001 012 1	70	120	65	140	200	31	65	280	345	33,6
200[4]	110[4]	–	–	371 200 012 1	100	180	80	160	250	39	80	324	394	65,0
–	–	200	110	371 160 012 1	80	175	85	140	215	39	62	250	322	31,0

Bemerkungen:

Die Lagerböcke sind zum Anbau bei Befestigungsart MP5, MT4 und am Gelenkkopf geeignet.
Lagerböcke werden immer paarweise geliefert.

2) = Für Befestigungsart MP5 und MT4
3) = Für Gelenkkopf
4) = Nur für Befestigungsart MT4
5) = Masse pro Paar

Notes:

The mounting blocks are suitable for use with mounting types MP5, MT4 and self-aligning clevis.
Mounting blocks are always supplied as pairs.

2) = For mounting types MP5 and MT4
3) = For self-aligning clevis
4) = Only for mounting type MT4
5) = Weight per pair

Remarques:

Les consoles sont désignées pour montage avec types de fixation MP5, MT4 et tenon à rotule.
Les consoles sont toujours livrées par paires.

2) = Pour types de fixation MP5 et MT4
3) = Pour tenon à rotule
4) = Seulement pour type de fixation MT4
5) = Masse par paires

CERAMAX / CERAMAX / CERAMAX

CERAMAX ist eine homogene, nichtleitende, undurchlässige, schwarze Keramikbeschichtung auf Kolben-stangen. Sie ist hart, jedoch in ausreichendem Maße elastisch, um sich mit der Kolbenstange des Zylinders zu biegen. Die mechanischen Eigenschaften von CERAMAX, wie Schlag-, Biegefestigkeit und die Haltfestigkeit auf dem Grundmaterial, sind ausreichend gegen Schläge und Belastungen innerhalb der mechanischen Grenzen des Kolbenstangenmaterials.

Technische Daten:

Rauhtiefe:	Ra 0,10 bis 0,30 μ
Oberflächenhärte:	900 bis 1000 Hv
Schichtdicke:	200 bis 300 μ
Schlagfestigkeit:	7 bis 15 Nm
Elastizitätsmodul:	360 bis 410 GPa
Ausdehnungskoeffizient:	7,5 • 10⁶/°C

CERAMAX is a homogeneous, non conductive, impermeable, black ceramic coating for piston rods. It is hard, yet sufficiently flexible to bend together with the piston rod of the cylinder. The mechanical properties of CERAMAX such as resistance to impact, bending strength and adhesion on the basic material are sufficient against impact and stress within the mechanical limits of the piston rod material.

Technical data:

Surface roughness:	Ra 0.10 to 0.30 μ
Surface hardness:	900 to 1000 Hv
Coat thickness:	200 to 300 μ
Impact resistance:	7 to 15 Nm
Modulus of elasticity:	360 to 410 GPa
Expansion coefficient:	7.5 • 10⁶/°C

Le CERAMAX est un revêtement céramique noir, pour tiges de vérin, homogène, isolant et imperméable. Il est dur mais suffisamment souple pour accepter un flambage de la tige. Les caractéristiques mécaniques du CERAMAX telles que la résistance aux chocs, au flambage et l'adhérence sur le matériau de base sont suffisantes pour résister aux chocs et aux charges comprises dans les limites mécaniques du matériau de la tige.

Données techniques:

Rugosité:	Ra 0,10 à 0,30 μ
Dureté de surface:	900 à 1000 Hv
Epaisseur de la couche:	200 à 300 μ
Résistance au choc:	7 à 15 Nm
Module d'élasticité:	360 à 410 GPa
Coefficient de dilatation:	7,5 • 10⁶/°C

Wegmeßsystem / Position measuring system / Système de détection de position

CIMS MK II (CERAMAX-INTEGRIERTES-MESS-SYSTEM) ist ein Wegmeßsystem für den Einbau in Hydrozylinder. Der im Zylinderkopf eingebaute CIMS-Sensor tastet Rillen ab, die sich unter der CERAMAX-Beschichtung im Grundmaterial der Kolbenstange befinden. Die Form der Rillen bewirkt eine Änderung des Magnetfeldes. Diese Magnetfeldänderungen werden vom Sensor aufgenommen und in der Sensorelektronik in Zählimpulse gewandelt. Die Wegerfassung erfolgt also über die Anzahl der gezählten Impulse.

Technische Daten:

Meßlänge: wie Hublänge

Spannungsversorgung:
24 VDC ± 20 %, max. 250 mA

Digitalausgang:
Inkrementaler Geber 1024 • (A+B)
Impulse pro 10 mm

Ausgangstreiber:
RS 422A Differentialausgang
(SN65176B)

Linearität: < 1 mm

Temperaturkoeffizient: ± 0,025 mm/°C

Hysterese: ± 0,05 mm

Schutzart: IP 68 bis 10 bar

Betriebstemperatur: – 25 °C bis + 60 °C

Datenübertragung:
bis 400 m möglich

Einbaumaß wird um 85 mm länger.

Weitere Informationen, Zeichnungen und Maße auf Anfrage.

CIMS MK II (CERAMAX INTEGRATED MEASURING SYSTEM) is a position measuring system for installation into the hydraulic cylinder. The CIMS sensor, which is integrated into the cylinder head, senses grooves under the CERAMAX coating in the basic material of the piston rod. The form of these grooves causes a change in the magnetic field. These changes in the magnetic field are detected by the sensor and converted into counting pulses in sensor electronics. Thus, position measuring is carried out via the number of the counted pulses.

Technical data:

Measuring lengths: equals stroke

Voltage supply:
24 VDC ± 20 %, max. 250 mA

Digital output:
Incremental encoder 1024 • (A+B)
Pulses per 10 mm

Output driver:
RS 422A differential output
(SN65176B)

Linearity: < 1 mm

Temperature coefficient: ± 0.025 mm/°C

Hysteresis: ± 0,05 mm

Type of protection: IP 68 up to 10 bar

Operating temperature: – 25 °C to + 60 °C

Data transmission:
possible up to 400 m

The installation dimension becomes 85 mm longer.

Further information, drawings and dimensions on enquiry.

Le CIMS MK II (système de mesure intégré) est un système de détection de position pour montage dans un vérin hydraulique. Le capteur CIMS intégré dans la tête du vérin analyse les rainures qui se trouvent sous le revêtement CERAMAX, dans le matériau de base de la tige. La forme des rainures entraîne un changement dans le champ magnétique. Ces changements du champ magnétique sont détectés par le capteur et convertis en impulsions de comptage par l'électronique du capteur. Donc, la détection de la position s'effectue par le nombre d'impulsions comptées.

Données techniques:

Longueur de mesure: identique à la course

Alimentation en courant:
24 VDC ± 20 %, maxi 250 mA

Sortie numérique:
Capteur incrémental 1024 • (A+B)
impulsions par 10 mm

Protocole de sortie:
RS 422A sortie différentielle
(SN65176B)

Linéarité: < 1 mm

Coefficient de température: ± 0,025 mm/°C

Hystérésis: ± 0,05 mm

Type de protection: IP 68 jusqu'à 10 bar

Température de service: – 25 °C à + 60 °C

Transfert de données:
possible jusqu'à 400 m

L'encombrement devient de 85 mm plus long.

Autres Informations, schémas et dimensions sur demande.

Knickung / Buckling / Flambage

Die Berechnung auf Knickung wird mit den folgenden Formeln durchgeführt:

1. Berechnung nach Euler

$$F = \frac{\pi^2 \bullet E \bullet I}{\nu \bullet L_K^2} \text{ wenn } \lambda > \lambda g$$

2. Berechnung nach Tetmajer

$$F = \frac{d^2 \bullet \pi (335 - 0{,}62 \bullet \lambda)}{4 \bullet \nu} \text{ wenn } \lambda \le \lambda g$$

Erläuterung:

E = Elastizitätsmodul in N/mm²
= 2,1 x 10^5 für Stahl

I = Flächenträgheitsmoment in mm⁴ für Kreisquerschnitt
$= \frac{d^4 \bullet \pi}{64} = 0{,}0491 \bullet d^4$

ν = 3,5 (Sicherheitsfaktor)

L_K = freie Knicklänge in mm (abhängig von der Befestigungsart siehe die Skizzen A, B, C Seite 36).

d = Kolbenstangen-Ø in mm

λ = Schlankheitsgrad
$= \frac{4 \bullet L_K}{d} \quad \lambda g = \pi \sqrt{\frac{E}{0{,}8 \bullet R_e}}$

R_e = Streckgrenze des Kolbenstangenmaterials

Beispiel:

Gesucht wird ein Differentialzylinder der Baureihe CDL1..., beidseitig mit Gelenklager für eine Druckkraft F von 100 kN (10200 kp) bei einem Betriebsdruck von 120 bar. Die Hublänge soll 900 mm betragen.

Die erste Schätzung der freien Knicklänge L_K ergibt:

$L_K = L = 2$ x Hublänge = 1800 mm (siehe Seite 36 Abb. B)

Aus dem Diagramm (Seite 36) ist ersichtlich, daß ein Kolbenstangen-Ø von 70 mm ausreichend ist.

Über die Berechnung der erforderlichen Fläche $A_{1\,erf}$ ergibt sich aus der Auswahltabelle auf Seite 6 der zugehörige Kolben-Ø von 125 mm.

$A_{1\,erf.} = F/p$ = 10200 kp/120 bar

$A_{1\,erf}$ = 85 cm² (Bedingung: $A_{1\,erf} < A_1$)

Die tatsächliche freie Knicklänge kann nun aus den Maßtabellen auf Seite 14 (Befestigungsart MP5) und Seite 30 (Gelenkkopf 371 120 002 1) wie folgt ermittelt werden:

$L_K = L$, also der Abstand zwischen den beiden Lagerpunkten bei ausgefahrener Kolbenstange.

L_K = XO + Hublänge + Hublänge + CH
L_K = 259 + 900 + 900 + 140
L_K = 2199 mm.

Das Diagramm auf Seite 36 zeigt, daß der ausgewählte Kolbenstangen-Ø von 70 mm ausreichend ist und die erforderliche Druckkraft aufgebracht werden kann.

Calculations for buckling are carried out using the following formulas:

1. Calculation according to Euler

$$F = \frac{\pi^2 \bullet E \bullet I}{\nu \bullet L_K^2} \text{ if } \lambda > \lambda g$$

2. Calculation according to Tetmajer

$$F = \frac{d^2 \bullet \pi (335 - 0.62 \bullet \lambda)}{4 \bullet \nu} \text{ if } \lambda \le \lambda g$$

Explanation:

E = Modulus of elasticity in N/mm²
= 2.1 x 10^5 for steel

I = Moment of inertia in mm⁴ for circular cross-sectional area
$= \frac{d^4 \bullet \pi}{64} = 0.0491 \bullet d^4$

ν = 3.5 (safety factor)

L_K = Free buckling length in mm (depending on mounting type, see sketches A, B, C on page 36).

d = Piston rod Ø in mm

λ = Slenderness ratio
$= \frac{4 \bullet L_K}{d} \quad \lambda g = \pi \sqrt{\frac{E}{0.8 \bullet R_e}}$

R_e = Yield strength of the piston rod material

Example:

A differential cylinder of series CDL1... is to be calculated with plain bearings on both ends for a pushing force F of 100 kN (10200 kp) at an operating pressure of 120 bar. The stroke length is to be 900 mm.

A first estimation of the free buckling length L_K provides:

$L_K = L = 2$ x stroke length = 1800 mm (see page 36, fig. B)

The diagram (page 36) shows that a piston rod Ø of 70 mm is sufficient.

On the basis of the required area $A_{1\,req}$, the selection table on page 6 indicates an associated piston Ø of 125 mm.

$A_{1\,req} = F/p$ = 10200 kp/120 bar

$A_{1\,req}$ = 85 cm² (condition: $A_{1\,req} < A_1$)

The actual free buckling length can now be determined from the dimension tables on page 14 (mounting type MP5) and page 30 (self-aligning clevis 371 120 002 1) as follows:

$L_K = L$, i.e. the distance between the bearings with the piston rod being extended.

L_K = XO + stroke length + stroke length + CH
L_K = 259 + 900 + 900 + 140
L_K = 2199 mm.

The diagram on page 36 shows that the selected piston rod Ø of 70 mm is sufficient and that the required pushing force can be provided.

Le calcul de flambage se fait à l'aide des formules suivantes:

1. Calcul selon Euler

$$F = \frac{\pi^2 \bullet E \bullet I}{\nu \bullet L_K^2} \text{ si } \lambda > \lambda g$$

2. Calcul selon Tetmajer

$$F = \frac{d^2 \bullet \pi (335 - 0{,}62 \bullet \lambda)}{4 \bullet \nu} \text{ si } \lambda \le \lambda g$$

Explication:

E = Module d'élasticité en N/mm²
= 2,1 x 10^5 pour l'acier

I = Moment d'inertie géométrique en mm⁴ pour une section circulaire
$= \frac{d^4 \bullet \pi}{64} = 0{,}0491 \bullet d^4$

ν = 3,5 (coefficient de sécurité)

L_K = Longueur libre de flambage en mm (en fonction du mode de fixation, voir les figures A, B, C page 36).

d = Ø de la tige en mm

λ = Degré d'élancement
$= \frac{4 \bullet L_K}{d} \quad \lambda g = \pi \sqrt{\frac{E}{0{,}8 \bullet R_e}}$

R_e = Limite d'élasticité du matériau de la tige

Exemple:

On cherche un vérin différentiel de la série CDL1..., avec palier à rotule aux deux extrémités pour une poussée F de 100 kN (10200 kp) à une pression de service de 120 bar. La course doit être de 900 mm.

La première estimation de la longueur libre de flambage L_K est:

$L_K = L = 2$ x course = 1800 mm (voir page 36 Fig. B)

Le diagramme (page 36) montre qu'un Ø de 70 mm pour la tige du piston suffit.

Par le calcul de la section requise $A_{1\,req}$, le tableau de sélection page 6 donne un Ø de piston de 125 mm.

$A_{1\,req} = F/p$ = 10200 kp/120 bar

$A_{1\,req}$ = 85 cm² (condition: $A_{1\,req} < A_1$)

La longueur libre de flambage réelle peut alors être déterminée à partir des tableaux de cotes page 14 (type de fixation MP5) et page 30 (tenon à rotule 371 120 002 1) comme suit:

$L_K = L$, c.-à-d. la distance entre les deux paliers, la tige étant sortie.

L_K = XO + course + course + CH
L_K = 259 + 900 + 900 + 140
L_K = 2199 mm.

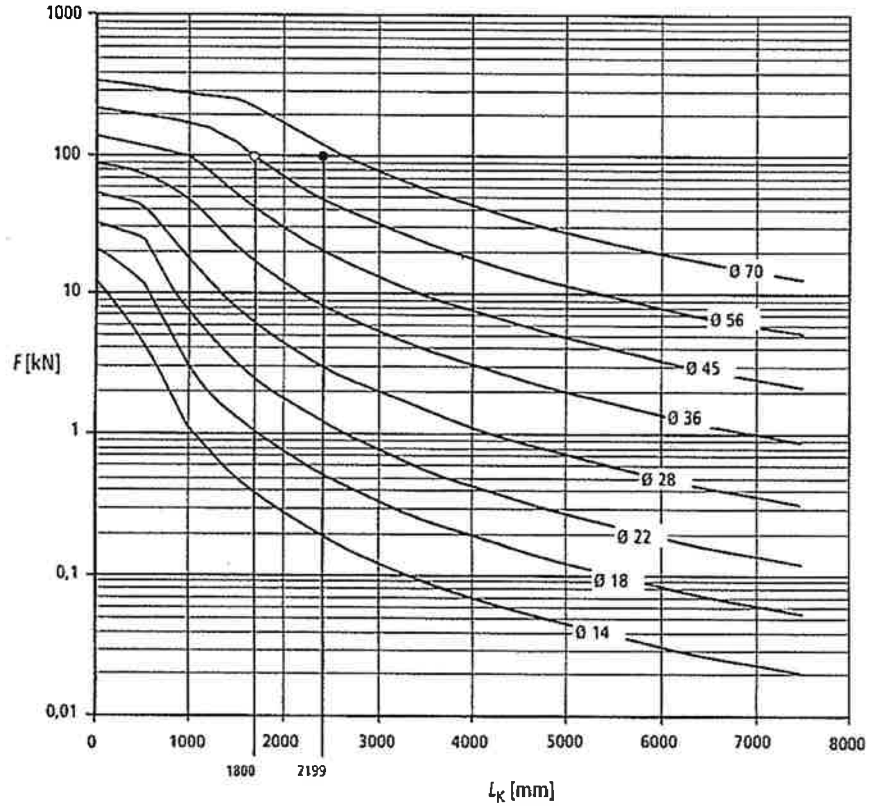
Le diagramme de la page 36 montre que le Ø de 70 mm selectionné pour la tige de piston suffit et que le vérin peut fournir la poussée requise.

Knickung, Diagramm / Buckling, diagram / Flambage, diagramme

Auslegungsdiagramm:
Kolbenstangen-Ø: 14 bis 70 mm
Sicherheitsfaktor = 3,5
Kolbenstange ohne Querkraftbelastung

Dimensioning diagram:
Piston rod Ø: 14 to 70 mm
Safety factor = 3.5
Piston rod without radial loading

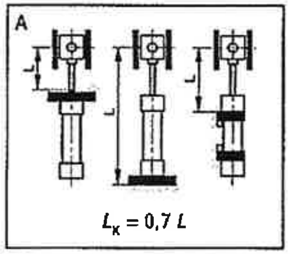
Diagramme de dimensionnement:
Ø de la tige: 14 à 70 mm
Coefficient de sécurité = 3,5
Tige sans charge radiale

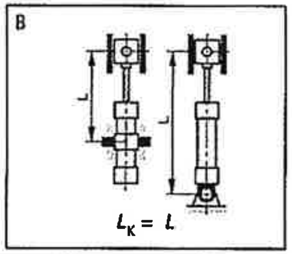


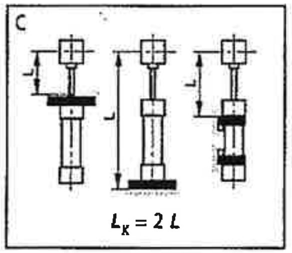
Einfluß der Befestigungsart auf die Knicklänge:

Influence of the mounting type on the buckling length:

Influence du mode de fixation sur la longueur de flambage:





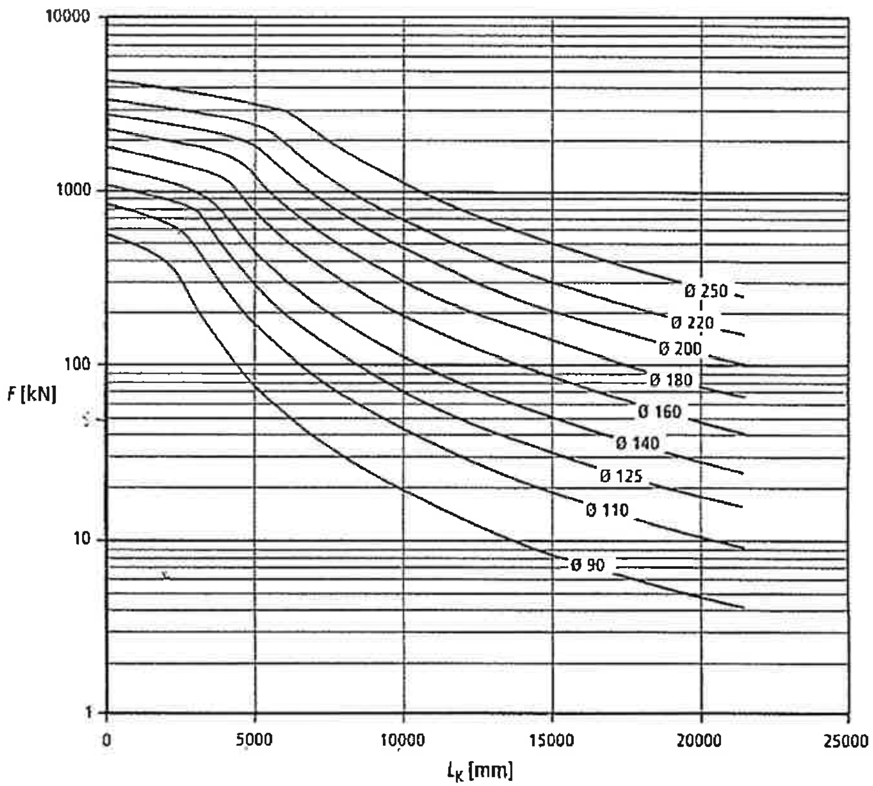


Knickung, Diagramm / Buckling, diagram / Flambage, diagramme

Auslegungsdiagramm:
Kolbenstangen-Ø: 90 bis 250 mm
Sicherheitsfaktor = 3,5
Kolbenstange ohne Querkraftbelastung

Dimensioning diagram:
Piston rod Ø: 90 to 250 mm
Safety factor = 3.5
Piston rod without radial loading

Diagramme de dimensionnement:
Ø de la tige: 90 à 250 mm
Coefficient de sécurité = 3,5
Tige sans charge radiale



Bemerkungen

Die beiden Diagramme stellen die zulässige Druckkraft F als eine Funktion der freien Knicklänge L_K für die Kolbenstangen-Ø dieser Baureihe dar.

Die Diagramme sind nur für vertikale Einbaufälle gültig. Horizontale Einbaufälle auf Anfrage.

Notes

The two diagrams represent the permissible pushing force F as a function of the free buckling length L_K for the piston rod Ø of this series.

These diagrams only refer to vertical installation. For horizontal installation, please consult us.

Remarques

Les deux diagrammes représentent la poussée F admissible en fonction de la longueur libre de flambage L_K pour les Ø des tiges de cette série.

Les diagrammes ne sont valables que pour un montage vertical. Pour un montage horizontal, veuillez nous consulter.

MANNESMANN REXROTH

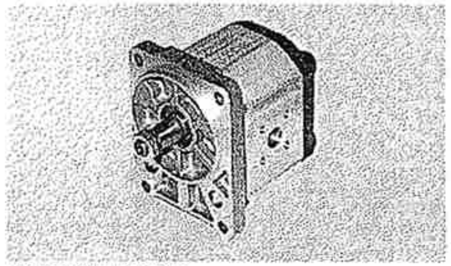
Zahnradpumpe Typ G2, Serie 4X

RD 10 030/05.98

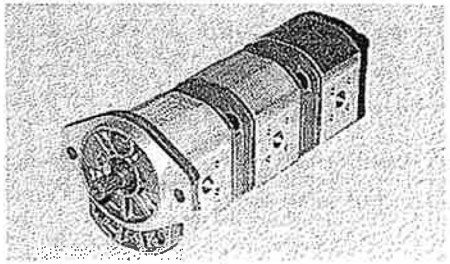
Ersetzt: 01.97

NG 4 bis 22	bis 250 bar	bis 22,4 cm³

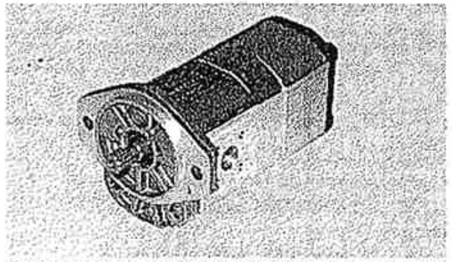
- neues Prinzip für die Gehäuseabdichtung, dadurch sehr hohe Gehäuselebensdauer
- lange Lebensdauer der Dichtungen auch bei Maximaltemperatur
- Gleitlager für hohe Belastungen
- Einblock-Lager
- einfache und robuste Bauweise
- neues Prinzip für den hydrostatischen Spielausgleich
- gemeinsamer Sauganschluß für Doppelpumpe, auf Anfrage
- auf Anfrage, Möglichkeit von Mehrfachpumpen-Aufbau mit Zugankern und Monoblock-Zwischenflansch



1PF2G2-4X/011RC20MB



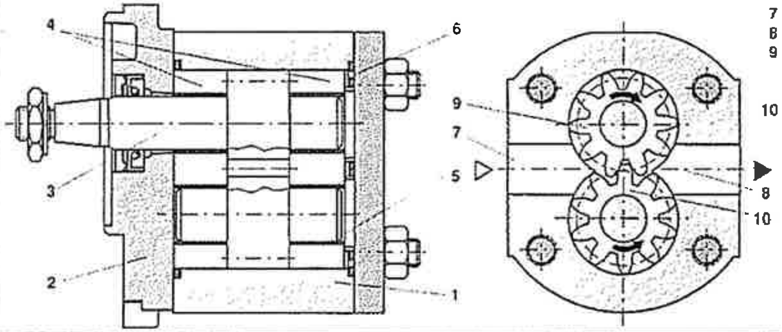
1PFG2-4X/011RR20MRK +
1PFG2-4X/011LN20MDN +
1 PFG2-4X/00 LN20MD



Sonderausführung (S107) mit gemeinsamem Sauganschluß auf Anfrage

Funktionsbeschreibung, Schnitt

Hydropumpen des Typs G2 sind selbstansaugende Zahnradpumpen mit Außenverzahnung. Ihre Aufgabe ist es, einen konstanten Volumenstrom zu erzeugen und diesem gleichzeitig nach Bedarf die erforderlichen Kräfte zu erteilen.
Sie bestehen im wesentlichen aus Gehäuse (1), Befestigungsflansch (2), Antriebswelle (3), 2 Lagerblöcke (4), Lagerbuchse (5) und Scheiben (6) für hydrostatischen Spielausgleich.
Die bei der Drehbewegung auseinander laufenden Zähne, lassen die Zahnkammern freiwerden. Der dadurch entstehende Unterdruck, sowie der atmosphärische Druck auf dem Druckflüssigkeitsspiegel im Behälter bewirken, daß der Pumpe aus dem Behälter Druckflüssigkeit zuläuft. Diese Druckflüssigkeit füllt die Zahnkammern und wird in Pfeilrichtung (Schnittzeichnung) von der Saug- zur Druckseite befördert.
Hier greifen die Zähne wieder ineinander, verdrängen die Druckflüssigkeit aus den Zahnkammern und verhindern ein Rückströmen zum Saugraum.
Um einen harten und stoßweisen Lauf der Pumpe zu vermeiden, sind seitlich Entlastungsnuten in den Lagerblöcken (4) angeordnet. Damit wird die "Quetschflüssigkeit" in den Druckraum geleitet.



7 Saugseite
8 Druckseite
9 treibendes Zahnrad (rechtsdrehend)
10 getriebenes Zahnrad

Materialgaben

1PF2G2 – 4X / ☐ ☐ ☐ ☐ ☐ * ☐

Serie 40 bis 49 (40 bis 49: unveränderte Einbau- und Anschlußmaße)		= 4X
(Nennvolumen)	NG	
4 cm³	4	= 004
5,5 cm³	5	= 005
8,2 cm³	8	= 008
11 cm³	11	= 011
14,1 cm³	14	= 014 ¹)
16,2 cm³	16	= 016
19 cm³	19	= 019 ¹)
22,4 cm³	22	= 022
rechtsdrehend		= R
linksdrehend		= L
Konische Welle 1:5 Ø 17 mm		= C
Vielkeilwelle SAE-A 5/8", 9 Zähne		= R
Welle mit Klauenkupplung für Einzelpumpe, mittlere/hintere Pumpe		= N
Konische Welle 1:5 Ø 20 mm für Vorsatzlager		= S
Zylindrische Welle ISO Ø 18 (mit 01 Anschlüßen)		= A

weitere Angaben im Klartext

ohne Bez. =	Einzelpumpe
K =	vordere Pumpe für Kombination
L =	hintere Pumpe für Kombination
N =	mittlere Pumpe für Kombination
B =	Rechteckflansch Ø 80 mm
P =	2-Lochbefestigung Ø 50 mm
R =	SAE-A-2-Lochflansch Ø 82,5 mm
M =	2-Lochbefestigung Ø 52 mm
A =	Vorsatzlager Ø 80 mm
D =	Kombiflansch für G2 (hintere und mittlere Pumpe)
H =	Kombiflansch für G3, G4
M =	NBR-Dichtung bis 80 °C
K =	Wellendichtring in FKM übrige Dichtungen in NBR (Anbau an Dieselmotoren)
20 =	Saug- und Druckanschluß quadratischer Flansch, metrisches Befestigungsgewinde
01 =	Rohrgewinde nach ISO 228/1 (mit zylindrischer Welle A)

¹) Nenngröße 14 und 19 nicht lieferbar mit zylindrischer Welle A

Bestellbeispiele für Einzelpumpen:
1PF2G2-4X/005RC20MB Material-Nr. 363013
1PF2G2-4X/016RC20MBK Material-Nr. 363115
(nur vordere Pumpe)
1PF2G2-4X/008LN20MDL Material-Nr. 363126
(nur hintere Pumpe)

Hinweis: Es sind nur die im Katalogblatt angegebenen, mit Materialnummern versehenen Pumpentypen lieferbar.
Andere Ausführungen auf Anfrage.
Flanschverschraubungen für Leitungsanschlüsse (siehe Seite 12) sind gesondert zu bestellen.

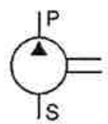
Bestellbeispiele für Mehrfachpumpen
1PF2G2-4X/008RC20MBK Material-Nr. 363109
1PF2G2-4X/004LN20MDL Material-Nr. 363122
Kombinationsteile G2/008 + G2/004

Mehrfachpumpen werden komplett montiert ausgeliefert. Die Kombinationsteile sind jedoch als Materialposition separat aufzuführen (siehe Bestellbeispiel).
Bei der Auftragsbearbeitung wird die Materialnummer der Kombinationsteile vom Sachbearbeiter eingesetzt.
Es besteht die Möglichkeit, die Kombinationsteile auch allein als Satz zu bestellen. Bestellangaben siehe Beispiel Mehrfachpumpen. Der Satz besteht aus 2 Zugankern, 2 Muttern. Das Kupplungsstück ist im Lieferumfang der hinteren bzw. mittleren Pumpe enthalten.

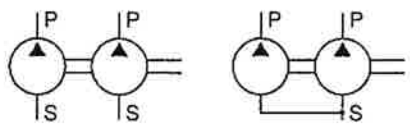
1PF2G2-4X/022RC20MBK Material-Nr. 363119
1PF2G2-4X/011LN20MDN Material-Nr. 363296
1PF2G2-4X/005LN20MDL Material-Nr. 363124
Kombinationsteile G2/022 + G2/011 + G2/005

Symbole

Einzelpumpe



Doppelpumpe



Auf Anfrage

Kenngrößen (Bei Ge[…]einsatz außerhalb der Kenngröße bitte anfragen!)

Druckflüssigkeit: Mineralöl nach Katalogblatt RD 07 075 für den Betrieb mit HFC-, HFD-, HETG-, HEPG- und HEES-Flüssigkeiten siehe RD 10 025-S.

Druckflüssigkeits-Temperaturbereich: – 15 bis + 80 °C bei höheren Temperaturen bitte anfragen

Umgebungs-Temperaturbereich: – 15 bis + 60 °C

Viskositätsbereich: 10 bis 300 mm²/s (empfohlener Viskositätsbereich), 1000 mm²/s (zulässige Startviskosität)

Maximal zulässiger Verschmutzungsgrad der Druckflüssigkeit nach NAS 1638, Klasse 10. Dafür empfehlen wir ein Filter mit einer Mindestrückhalterate $\beta_{20} \geq 100$. Zur Sicherung einer hohen Lebensdauer empfehlen wir Klasse 9, NAS 1638; erreichbar mit Filter-Rückhalterate $\beta_{10} \geq 100$.

Antriebsart: elastische Kupplung, bei anderer Antriebsart bitte Rückfrage

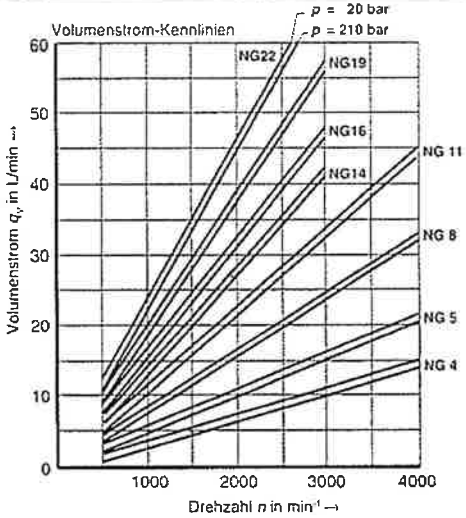
Einbaulage: beliebig

Drehrichtung: Die Pumpe darf nur in der angegebenen Drehrichtung betrieben werden

Masse: siehe Tabelle der einzelnen Pumpentypen

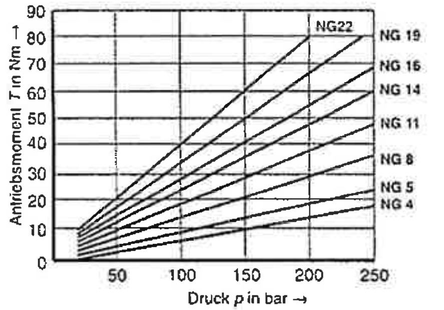
Nenngröße	NG	4	5	8	11	14	16	19	22
Nennvolumen	cm³	4	5,5	8,2	11	14,1	16,2	19	22,4
Betriebsdruck, Eingang: absoluter Druck	bar	$p_{abs\,min}$ 0,7 $p_{abs\,max}$ 3,0							
max. Dauerdruck $p1$	bar	250	250	250	250	250	250	240	210
Spitzendruck $p2$ (bei 10⁵ Einschaltdruckspitzen)	bar	275	275	275	275	275	275	270	230
max. Drehzahl bei Dauerdruck $p1$	min⁻¹	5000	4000	4000	4000	3500	3000	3000	2500
min. Drehzahl bei p = 180 bar	min⁻¹	1000	1000	700	500	500	500	500	500
min. Drehzahl bei $p1$	min⁻¹	1200	1200	1000	700	700	700	700	700

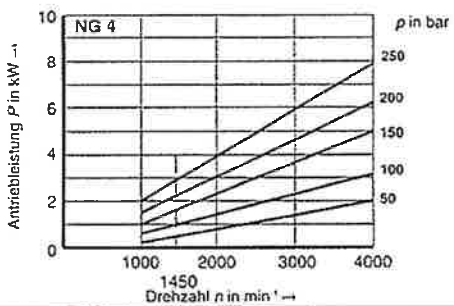
Kennlinien (gemessen bei ν = 41 mm²/s und ϑ = 50 °C)

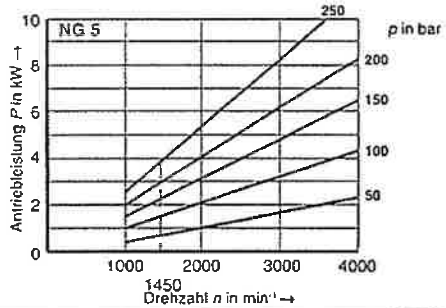


zulässige Drehmomente am Wellenende

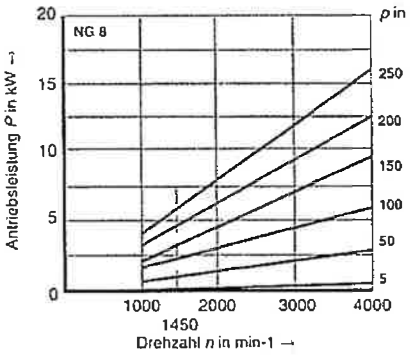
A =	Zylindrische Welle Ø 18 mm	T_{max} =	70 Nm
C =	Konische Welle 1: 5 Ø 17 mm	T_{max} =	150 Nm
R =	Vielkeilwelle SAE-A 5/8"	T_{max} =	110 Nm
N =	Welle mit Klauenkupplung	T_{max} =	70 Nm
S =	Konische Welle 1: 5 Ø 20 mm für Vorsatzlager	T_{max} =	70 Nm

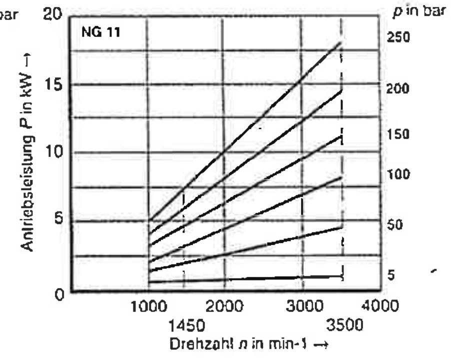


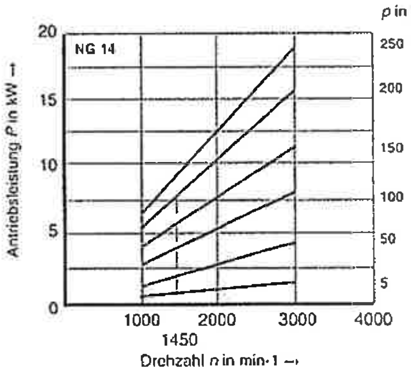


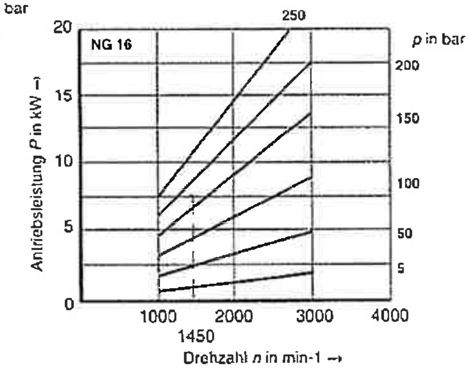


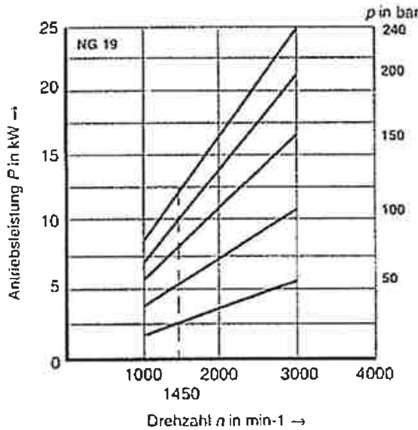
Kennlinien (gemessen bei $\nu = 41$ mm²/s und $\vartheta = 50$ °C)

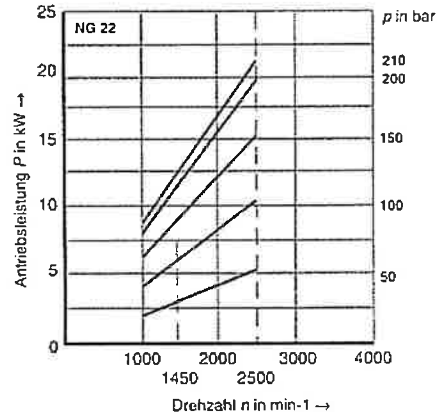












Schalldruckpegel ~essen bei $n = 1450$ min⁻¹, $\nu = 41$ mm²/s und $\vartheta = 50$ °C)

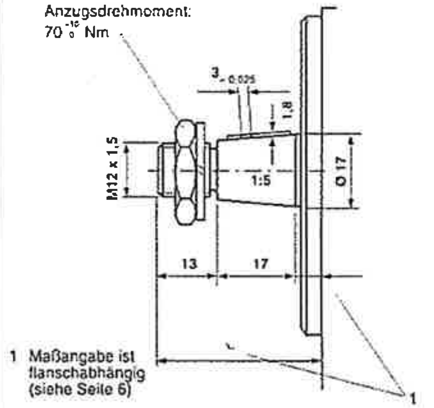
p in bar \ NG	4	5	8	11	14	16	19	22
5	57	59	59	59	62	62	62,5	62
50	58,5	60	60	60	64	66,5	67	66
100	59	61	61	62	65,5	68	69,5	67
150	60	62	62	64,5	66,5	69	70,5	68,5
200	61	63	63,5	66	68	69,5	70	69
250	61,5	64,5	65	68	69,5	70,5	71	–

gemessen im Schallmeßraum nach DIN 45 635 Teil 26 in dB(A)
Meßabstand Schallaufnehmer – Pumpe = 1 m

Wellenende (Maßangaben in mm)

C

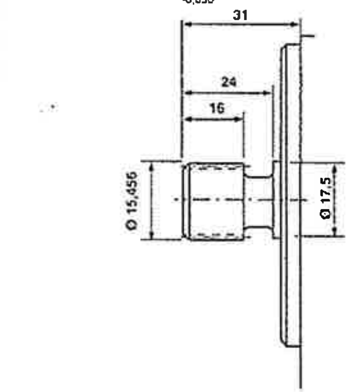
Konische Welle 1: 5, Ø 17 mm



1 Maßangabe ist flanschabhängig (siehe Seite 6)

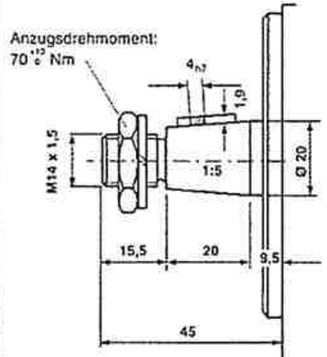
R

Vielkeilwelle SAE-A 5/8", 9T 16/32 DP und Zahndicke $t = 2{,}357_{-0{,}030}$



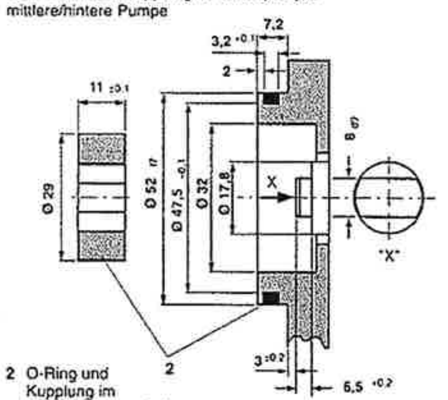
S

Konische Welle 1: 5, Ø 20 mm für Vorsatzlager



N

Welle mit Klauenkupplung für Einzelpumpe, mittlere/hintere Pumpe



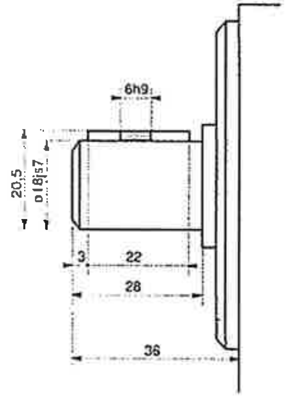
2 O-Ring und Kupplung im Lieferumfang enthalten

Wellenende

(Ma.... gaben in mm)

A

Zylindrische Welle ISO Ø 18 mm



Geräteabmessungen, Bestellangaben (Maßangaben in mm, A = vorzugsweise lieferbar)

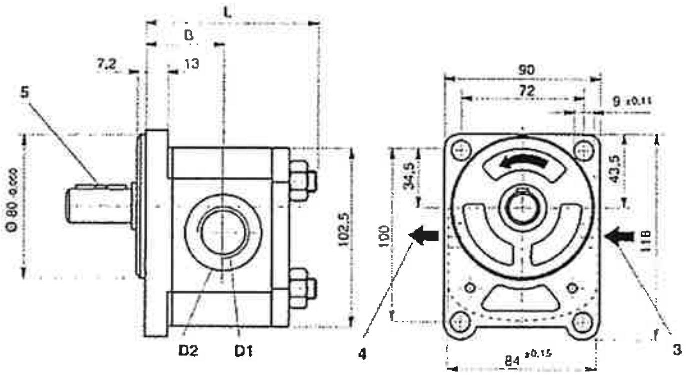
1PF2G2-4X/... R/L A01MB

Nenngröße (siehe Tabelle)

Drehrichtung:
rechtsdrehend = R
linksdrehend = L

Zylindrische Welle Ø 18 mm

Nenngröße	Maßangaben				Materialnummer		Masse
	L	B	D1	D2	rechtsdrehend	linksdrehend	in kg
004	88	42,25	G 1/2	34	530566A	530567	2,7
005	93	41,5	G 1/2	34	530568A	530569	2,7
008	93	45,25	G 1/2	34	530570A	530571	2,8
011	98	47,25	G 3/4	42	530572A	530573	3,0
016	108	49	G 3/4	42	530574A	530575	3,0
022	113	55,5	G 3/4	42	530576A	530577	3,5



Drehrichtung: linksdrehend (Ausführung "L") auf das Wellenende gesehen
Bei rechtsdrehender Ausführung "R" sind Saug- und Druckanschluß vertauscht!

3 Saugseite
4 Druckseite
5 Zylindrische Welle Ø 18

Geräteabmessur..., Bestellangaben (Maßangaben in mm, A = vorzugsweise lieferbar)

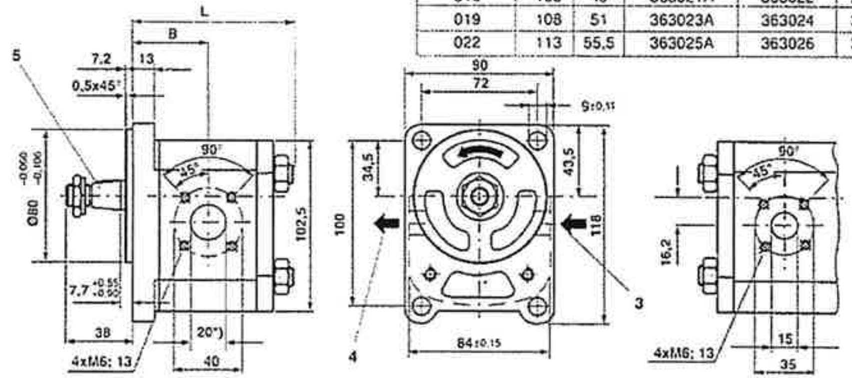
1PF2G2-4X/... R/L C20MB

Nenngröße (siehe Tabelle)

Drehrichtung:
rechtsdrehend = R
linksdrehend = L

Konische Welle 1: 5; Ø 17 mm

Nenngröße	Maßangaben		Materialnummer		Masse
	L	B	rechtsdrehend	linksdrehend	in kg
004	88	42,25	363011A	363012	2,4
005	93	41,5	363013A	363014	2,5
008	93	45,25	363015A	363016	2,6
011	98	47,25	363017A	363018	2,7
014	103	49,5	363019	363020	2,8
016	108	49	363021A	363022	2,9
019	108	51	363023A	363024	3,1
022	113	55,5	363025A	363026	3,3



*) Ø15 bei Nenngröße 4 und 5
Drehrichtung: linksdrehend (Ausführung "L") auf das Wellenende gesehen
Bei rechtsdrehender Ausführung "R" sind Saug- und Druckanschluß vertauscht!

3 Saugseite
4 Druckseite
5 Kegel 1 : 5; Ø 17 mm (siehe Seite 5)

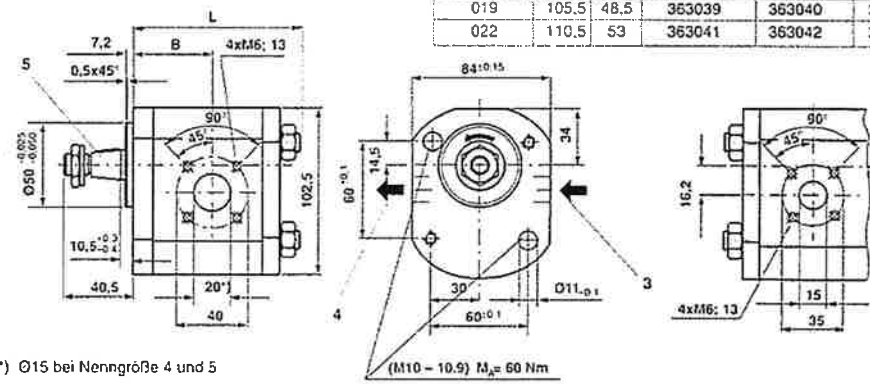
1PF2G2-4X/... R/L C20KP

Nenngröße (siehe Tabelle)

Drehrichtung:
rechtsdrehend = R
linksdrehend = L

Konische Welle 1: 5; Ø 17 mm

Nenngröße	Maßangaben		Materialnummer		Masse
	L	B	rechtsdrehend	linksdrehend	in kg
004	85,5	39,75	363027	363028	2,7
005	90,5	39	363029	363030	2,7
008	90,5	42,75	363031	363032	2,8
011	95,5	45	363033	363034	3,0
014	100,5	47	auf Anfrage		3,0
016	105,5	46,5	363037	363038	3,0
019	105,5	48,5	363039	363040	3,2
022	110,5	53	363041	363042	3,5



*) Ø15 bei Nenngröße 4 und 5

Drehrichtung: linksdrehend (Ausführung "L") auf das Wellenende gesehen
Bei rechtsdrehender Ausführung "R" sind Saug- und Druckanschluß vertauscht!

3 Saugseite
4 Druckseite
5 Kegel 1 : 5; Ø 17 mm (siehe Seite 5)

Geräteabmessungen, Bestellangaben (Maßangaben in mm, A = vorzugsw‹ › lieferbar)

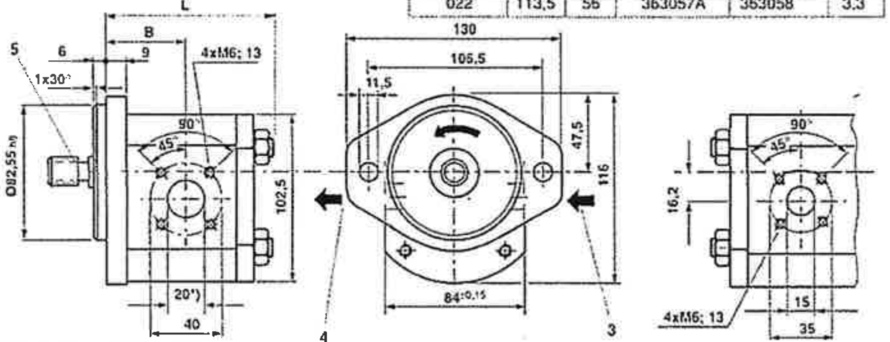
1PF2G2-4X/... R/L R20MR

Nenngröße (siehe Tabelle)

Drehrichtung:
rechtsdrehend = R
linksdrehend = L

Vielkeilwelle SAE-A 5/8" 9 Zähne

Nenngröße	Maßangaben L	Maßangaben B	Materialnummer rechtsdrehend	Materialnummer linksdrehend	Masse in kg
004	88,5	42,75	363043A	363044	2,6
005	93,5	42	363045	363046	2,6
008	93,5	45,75	363047A	363048	2,8
011	98,5	47,75	363049A	363050	2,9
014	103,5	50	363051	363052	3,0
016	108,5	49,5	363053A	363054	3,1
019	108,5	51,5	363055A	363056	3,2
022	113,5	56	363057A	363058	3,3



*) Ø 15 bei Nenngröße 4 und 5

Drehrichtung: linksdrehend (Ausführung "L") auf das Wellenende gesehen
Bei rechtsdrehender Ausführung "R" sind Saug- und Druckanschluß vertauscht!

3 Saugseite
4 Druckseite
5 Vielkeilwelle (siehe Seite 5)

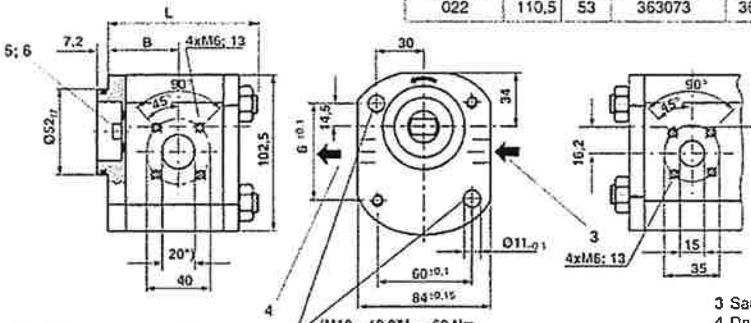
1PF2G2-4X/... R/L N20MM

Nenngröße (siehe Tabelle)

Drehrichtung:
rechtsdrehend = R
linksdrehend = L

Welle mit Klauenkupplung

Nenngröße	Maßangaben L	Maßangaben B	Materialnummer rechtsdrehend	Materialnummer linksdrehend	Masse in kg
004	85,5	39,75	363059	363060	2,6
005	90,5	39	363061	363062	2,6
008	90,5	42,75	363063	363064	2,7
011	95,5	45	363065	363066	3,0
014	100,5	47	auf Anfrage		3,0
016	105,5	46,5	363069	363070	3,0
019	105,5	48,5	363071	363072	3,0
022	110,5	53	363073	363074	3,5



*) Ø 15 bei Nenngröße 4 und 5

Drehrichtung: linksdrehend (Ausführung "L") auf das Wellenende gesehen
Bei rechtsdrehender Ausführung "R" sind Saug- und Druckanschluß vertauscht!
Achtung: Bei NG 19 und 22 Druckeinschränkung wegen zulässiger Drehmomente (siehe Seite 3).

3 Saugseite
4 Druckseite
5 Welle mit Klauenkupplung (siehe Seite 5)
6 Pumpe ohne Wellendichtring

Geräteabmessur‹ ›ı, Bestellangaben (Maßangaben in mm)

1PF2G2-4X/... R/L S20MA

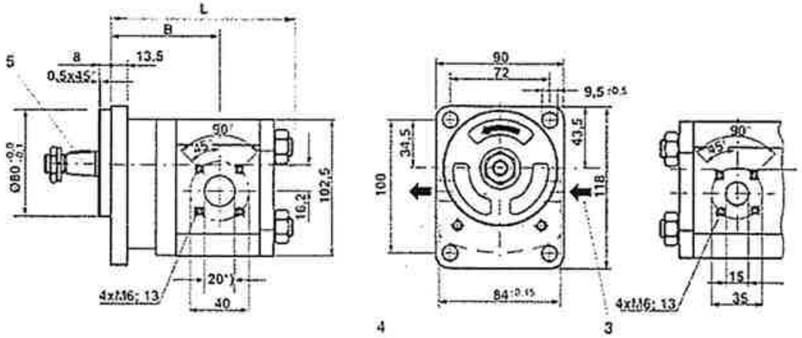
Nenngröße (siehe Tabelle)

Drehrichtung:
rechtsdrehend = R
linksdrehend = L

Konische Welle 1:5; Ø 20 mm

Pumpe mit Vorsatzlager zur Aufnahme radialer und axialer Kräfte (siehe unten)

Nenngröße	Maßangaben L	Maßangaben B	Materialnummer rechtsdrehend	Materialnummer linksdrehend	Masse in kg
004	117,5	71,5	363075	363076	3,4
005	122,5	71	363077	363078	3,4
008	122,5	74,75	363079	363080	3,5
011	127,5	77	363081	363082	3,8
014	132,5	79	auf Anfrage		3,8
016	137,5	78,5	363085	363086	3,8
019	142,5	80,5	363087	363088	3,8
022	147,5	85	363089	363090	4,3

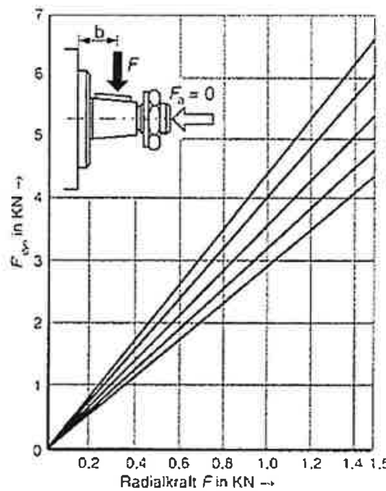


*) Ø 15 bei Nenngröße 4 und 5

Drehrichtung: linksdrehend (Ausführung "L") auf das Wellenende gesehen
Bei rechtsdrehender Ausführung "R" sind Saug- und Druckanschluß vertauscht!
Achtung: Bei NG 19 und 22 Druckeinschränkung wegen zulässiger Drehmomente am Vorsatzlager (siehe Seite 3).

3 Saugseite
4 Druckseite
5 Kegel 1 : 5; Ø 20 mm (siehe Seite 5)

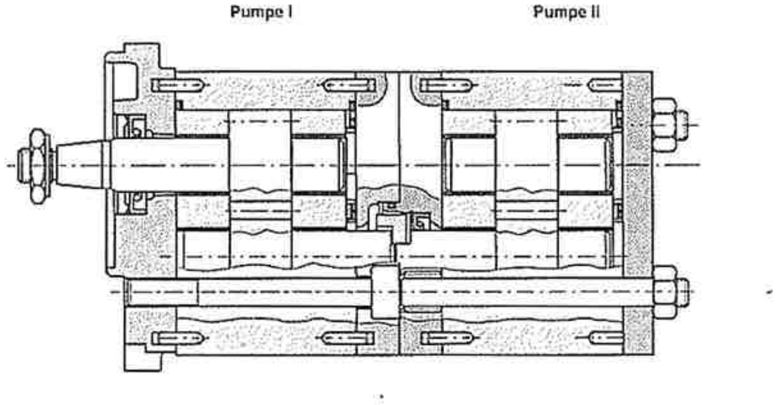
Vorsatzlager, theoretische Lagerlebensdauer



$$L_h = \frac{10^6}{n \cdot 60} \left(\frac{C_{dyn}}{F'_{dyn}}\right)^3$$

n = Drehzahl in min⁻¹
L_h = theoretische Lagerlebensdauer in h
F'_{dyn} = dynamische äquivalente Belastung
C_{dyn} = dynamische Tragzahl 21.2 kN

Mehrfachzahnradpumpen Typ G2, Serie 4X



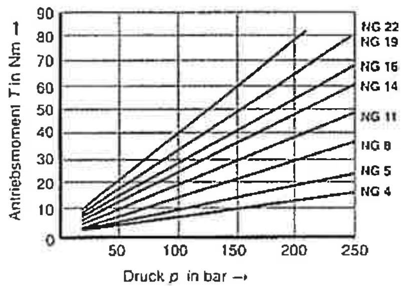
Kenngrößen (Bei Geräteeinsatz außerhalb der Kenngrößen bitte anfragen)

- Es gelten die gleichen allgemeinen Kenngrößen wie bei den Einzelpumpen (siehe Seite 3)

Masse: siehe Tabelle der einzelnen Pumpentypen Kombiteile – plus 0,4 kg

Bei Mehrfachpumpen ist besonders zu beachten:

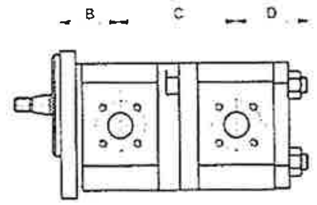
- Die Nenngröße 4 kann als Pumpe I nicht eingesetzt werden.
- Die Pumpe I sollte höher belastet sein (Druck x Volumenstrom) als die Pumpe II.
- Die einzelnen Pumpen sind durch einen Wellendichtring saugseitig getrennt (Pumpen können aus verschiedenen Behältern ansaugen).
- Die Antriebswellen und das Kupplungsstück zwischen den Pumpen sind im übertragbaren Drehmoment begrenzt (siehe unten).
- Bei der Auslegung von Mehrfachpumpen muß darauf geachtet werden, daß die Summe der Drehmomente die zulässigen Werte nicht übersteigt.

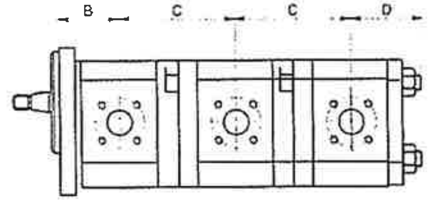


zulässige Drehmomente am Wellenende:

A = Zylindrische Welle Ø 18 mm	T_{max} = 70 Nm
C = Konische Welle 1: 5; Ø 17 mm	T_{max} = 150 Nm
R = Vielkeilwelle SAE-A 5/8"	T_{max} = 110 Nm
Kupplung zwischen Pumpe I und Pumpe II	T_{max} = 70 Nm

Mehrfachpumpen (Maßangaben in mm, A = vorzugsweise lieferbar)





1PF2G2-4X/ ... RC 20 MBK

1PF2G2-4X/ ... LN 20 MDN

1PF2G2-4X/ ... LN 20 MDL

- Nenngröße (siehe Tabelle)
- Drehrichtung: rechtsdrehend = R, linksdrehend = L
- Anschlüße (01, 20)
- Wellenende (A, C, N, R)

Maß C und D

		vordere Pumpen Maß C							Maß D
		005	008	011	014	016	019	022	
hintere Pumpen	004	84.75	84.5	86.5	88.75	92.25	94.25	94.75	46.0
	005	84	83.75	85.75	88	91.5	93.5	94	51.5
	008		87.5	89.5	91.75	95.25	97.25	97.75	48.0
	011			91.5	93.75	97.25	99.25	99.75	51.0
	014				96	99.5	101.5	99.75	53.5
	016					99	101	101.5	59.0
	019						103	103.5	57.0
	022							108	57.5

Maß B: siehe Einfachpumpe

Materialnummern für vordere, mittlere und hintere Pumpen

		004	005	008	011	014	016	019	022
vordere	RC20MBK	NL	363107A	363109A	363111A	363113	363115 A	363117	363119A
	RR20MRK	NL	363151	363153A	363155A	363157	363159 A	363161	363163A
	RC20KPK	NL	363137	363139	363141	363143	363145	363147	363149
	RA01MBK	NL	530581	530583	530585	NL	530587	NL	530589
hintere / mittlere	LN20MDN	NL	363286	363294	363296	363298	363300	363302	363304
	LN01MDN	NL	530601	530602	530603	NL	530604	NL	530605
hintere	LN20MDL	363122A	363124A	363126A	363128A	363130	363132A	363134	363136
	LN01MDL	530611	530612	530613	530614	NL	530615	NL	530616

		004	005	008	011	014	016	019	022
vordere	LC20MBK	NL	363108	363110	363112	363114	363116	363118	363120
	LR20MRK	NL	363152	363154	363156	363158	363160	363162	363164
	LC20KPK	NL	363138	363140	363142	363144	363146	363148	363150
	LA01MBK	NL	530582	530584	530586	NL	530588	NL	530590
hintere / mittlere	RN20MDN	NL	363291	363293	363297	363295	363301	363299	363303
	RN01MDN	NL	530606	530607	530608	NL	530609	NL	530610
hintere	RN20MDL	363121	363123	363125	363127	363129	363131	363133	363135
	RN01MDL	530617	530618	530619	530620	NL	530621	NL	530622

NL: nicht lieferbar

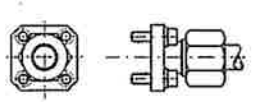
Dichtungssätze (NBR)

Pumpentyp (alle Nenngrößen)	Dichtungssatz Material-Nr.	Wellendichtung Material-Nr.
1PF2G2-4X/...C20MB	309401	001855
1PF2G2-4X/...C20KP	309402	013133 (FKM)
1PF2G2-4X/...R20MR	309401	001855
1PF2G2-4X/...S20MA	309403	005721
1PF2G2-4X/...N20MM	309401	-

Pumpentyp (alle Nenngrößen)	Dichtungssatz Material-Nr.	Wellendichtung Material-Nr.
1PF2G2-4X/...C20MBK	309401	001855
1PF2G2-4X/...C20KPK	309402	013133 (FKM)
1PF2G2-4X/...R20MRK	309401	001855
1PF2G2-4X/...N20MDL	309401	001855
1PF2G2-4X/...N20MDN	309401	001855

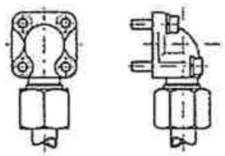
Flanschverschraubungen für Leitungsanschlüsse

Gerade-Flanschverschraubung



Saugseite		Druckseite	
Rohr-Ø	Material-Nr.	Rohr-Ø	Material-Nr.
15	321433	10	321436
18	321434	12	321437
22	321435	15	321438
28	323237	16	323235

Winkel-Flanschverschraubung



Saugseite		Druckseite	
Rohr-Ø	Material-Nr.	Rohr-Ø	Material-Nr.
-	-	10	321444
15	321440	12	321445
18	321441	15	321446
22	321442	16	321447
28	321443	20	321448

Technische Daten siehe RN 205.21

Alle Verschraubungen werden komplett mit Schrauben, O-Ring, Schneidring und Überwurfmutter geliefert

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Project : Mallamocco Navigation Lock

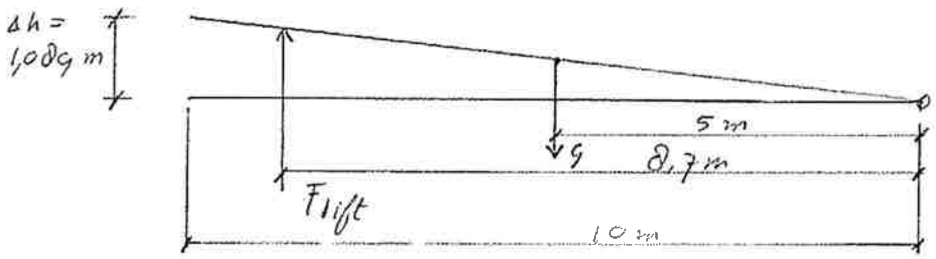
Onderdeel : Road ramp

Hydraulic cilinders

See drawing MV036-PEMAD 4310 and 4313

The cilinders are integrated in the hydraulic system of the levelling sluices, see MV036-PEMPK5103 P&ID Hydraulic control philosophy.

weight of ramp $G_r = 128$ kN



$F_{lift} = 128 \cdot \frac{5}{8,7} = 73,6$ kN

Cilinder 100/56:

$A_1 = 78,54 \text{ cm}^2$

$p = F / A_1$

$\Rightarrow p = 93,8$ bar

maximum pressure cilinder: 120 bar

$\Rightarrow F_{max} = 94,2$ kN

Speeds and pressures of the cilinder are obtained from the flow and pressures given by the hydraulic system mentioned above

$Q = 4,6$ l/min at $p = 120$ bar

$V_{cil} = A_1 \cdot \Delta h = 8,55$ l

$t = \frac{V_{cil}}{Q} = 1,86$ min. (112 s.)

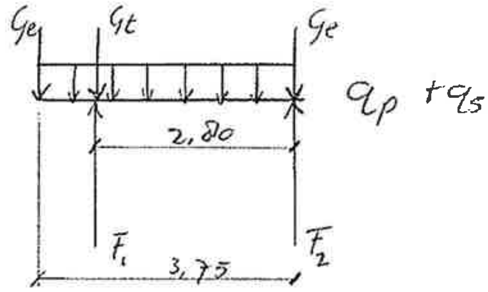
Opgesteld : A. T. Datum : 23-4-'04 Bladnummer : 1. Rev. :

Project : Mallamocco Navigation Lock

Onderdeel : Roadramp

loads on locking pins on Locking beams

1) weight of people $q_p = 4\ kN/m^2$, $\gamma = 1{,}5$
2) weight of steel structure $G_s = 128\ kN$, $\gamma = 1{,}35$
3) weight of endsupport and barrier $G_e = 4{,}9\ kN$, $\gamma = 1{,}35$
4) weight of traffic $G_t = 50\ kN$; $\gamma = 2{,}1$



F_1 and F_2 are reactionforces of pin 1 and 2

$F_1 > F_2$, so only pin 1 is regarded

Project : Mallamocco Navigation Lock

Onderdeel : Roodramp

load 1

$$F_p = \frac{\frac{1}{2}a}{b}\left(q_p \cdot c \cdot \frac{1/2\,c}{d}\right) \cdot a \cdot \gamma = \frac{a^2 c^2}{4bd}\, q_p \cdot \gamma$$

with:

$a = 3{,}75$ m $q_p = 4$ kN/m²

$b = 2{,}80$ m $\gamma = 1{,}5$

$c = 10$ m $\Rightarrow F_p = 87$ kN

$d = 0{,}7$ m

load 2

$$F_s = \frac{\frac{1}{2}a}{b}\left(G_s \cdot \frac{1/2\,c}{d}\right) \cdot \gamma = \frac{a \cdot c}{4bd} \cdot G_s\, \gamma$$

with

$a = 3{,}75$ m $G_s = 128$ kN

$b = 2{,}80$ m $\gamma = 1{,}35$

$c = 10$ m

$d = 0{,}7$ m $\Rightarrow F_s = 67$ kN

Opgesteld : A.T. Datum : 23-4-04 Bladnummer : 3 Rev. :

Project : Mallamocco Navigation Lock

Onderdeel : Road ramp

load 3 :

$F_e = \frac{a}{b} \cdot G_e \cdot \gamma$

with:

$a = 3{,}75\ m$

$b = 2{,}80\ m$

$G_e = 4{,}9\ kN$

$\gamma = 1{,}35$

$\Rightarrow F_e = 8{,}9\ kN$

load 4 :

$F_t = G_t\ \gamma$

with:

$G_t = 50\ kN$

$\gamma = 2{,}1\ kN$

$\Rightarrow F_t = 105\ kN$

Total load on pin 1

$F_1 = F_p + F_s + F_e + F_t$

$= 87 + 67 + 8{,}9 + 105 = 268\ kN$

Opgesteld : A.T. Datum : 23-4-'04 Bladnummer : 4 Rev. :

Project :

Onderdeel : Roadramp

$F_1 = 268$ kN

pin ϕ 70 mm

$\sigma_a = 235$ N/mm²

$$\sigma = \frac{F}{b \cdot d} = \frac{268 \cdot 10^3}{20 \cdot 70} = 191 \text{ N/mm}^2$$

$$u.c = \frac{\sigma}{\sigma_a} = 0{,}81 \quad \text{O.k.}$$

$$Bm = \tfrac{1}{4} PL = \tfrac{1}{4} \cdot 268 \cdot 10^3 \cdot 70$$

$$Bm = 4{,}69 \cdot 10^6 \text{ Nmm}$$

$$W_b = \frac{\pi}{32} d^3 = 0{,}1 \cdot 70^3 = 34{,}3 \cdot 10^3 \text{ mm}^3$$

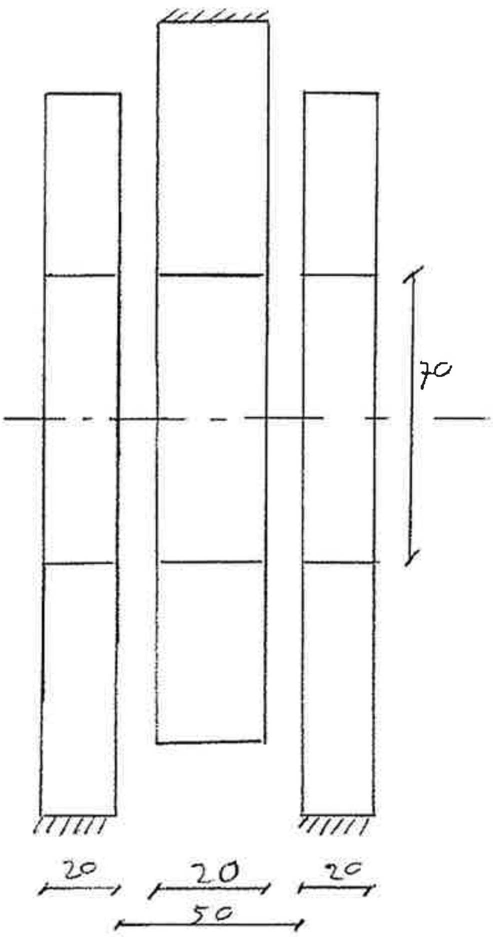
$$\sigma_b = \frac{Bm}{W_b} = \frac{4{,}69 \cdot 10^6}{34{,}3 \cdot 10^3} = 137 \text{ N/mm}^2$$

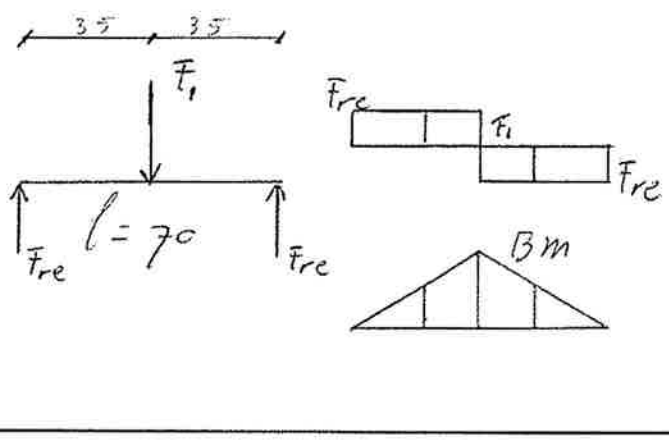
$$\tau = \frac{4}{3} \cdot \frac{268 \cdot 10^3}{2 \cdot \frac{\pi}{4} \cdot 70^2} = 46 \text{ N/mm}^2$$

$$\sigma_{id} = \sqrt{\sigma^2 + 3\tau^2} = 159 \text{ N/mm}^2$$

$$u.c. = \frac{\sigma_{id}}{\sigma_a} = 0{,}68$$

O.k.



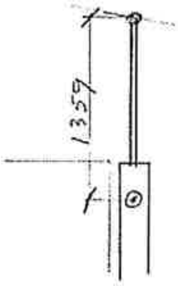


Opgesteld : A.T. Datum : 23-4-'04 Bladnummer : 5 Rev. :

Project : Mallanocco Navigation Lock

Onderdeel : Road ramp

Check on buckling of cilinder



Cilinder 100/56

buckling length in ultimate position:

$L_k = 1359$ mm

piston rod $\phi = 56$ mm

from buckling diagram Rexroth Hydraulics:

$F_{allowed} = 150$ kN at $L_k = 1359$ mm

$F_{lift} = 73{,}6$ kN

$F_{max} = 125{,}6$ kN

$\Rightarrow F_{lift} < F_{allowed}$ and

$F_{max} < F_{allowed}$

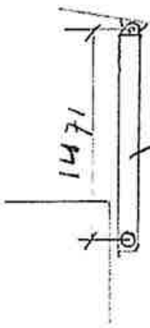
O.K.

Opgesteld : A.T. Datum : 23-4-'04 Bladnummer : 5 Rev. :

Project : Mallamocco Navigation Lock

Onderdeel : Roadramp

Check on buckling of locking beam 1



buckling length $L_k = 1471$ mm

$F_1 = 268$ kN

Area profile $A = 150^2 - 137{,}5^2 = 3594\ mm^2$

$$\sigma_1 = \frac{F_1}{A_1} = 74{,}6\ N/mm^2$$

$I = 1{,}738 \cdot 10^7\ mm^4$ (150x150x10)

$i = \sqrt{I/A_1} = 70$

slenderness ratio $\lambda = \frac{L_k}{i}$

$\Rightarrow \omega = 1{,}11$ (FEM 1.001 T.A. 3.3.2)

critical stress:

$$\sigma_{cr} = \frac{\omega \cdot F_1}{A_1} = \frac{1{,}11 \cdot 268 \cdot 10^3}{3594} = 83\ N/mm^2$$

allowed stress:

$\sigma_a = 240\ N/mm^2$ (T.3.2.1.1)

$\Rightarrow \sigma_{cr} < \sigma_a$

O.k.

Opgesteld : A.T. Datum : 23-4-'04 Bladnummer : 6 Rev. :

ALLEGATO C

Sistema dell'hydrofoot

C1 Pompe di alimentazione dell'acqua

C2 Pompe di spinta

C3 Cuscinetto reggispinta, incluso lo sviluppo di calore per attrito

C4 Cuscinetti in gomma

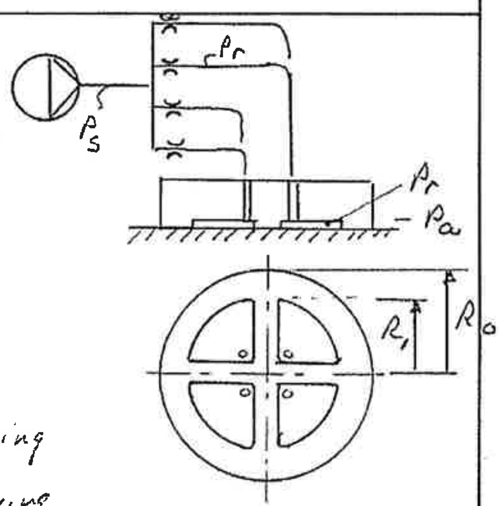
C5 Sviluppo di calore dai supporti scorrevoli orizzontali

Project : Malamocco Navigation Lock

Onderdeel : Hydro static Thrust Bearing.

Hydro foot

Water pressures and required flow



P_s = pressure at pump

P_r = pressure after orifice

P_a = pressure of environment

R_1 = 420 mm inner diameter of bearing

R_o = 585 mm outer diameter of bearing.

$R_1/R_o = 420/585 = 0,718$

$$A_e = \frac{\pi}{2} \frac{R_1^2 - R_o^2}{\ln R_1/R_o} \times 10^{-6} = 0,786\ m^2$$

Hydro foot at maximum load F = 1350 kN

$F = A_e(P_r - P_a)$ with $P_a = 0,14$ MPa is outside water pressure

$F = 1350 = 0,786 \times (P_r - 0,14) \times 10^{+3} \longrightarrow P_r - 0,14 = \frac{1350}{0,786 \times 10^3} = 1,72$ MPa

$P_r = 1,72 + 0,14 = 1,86$ MPa

Flow : $Q = \frac{h^3}{\eta}(P_r - P_a) \times \frac{-\pi}{6 \ln R_1/R_o}$ with: h = 0,1 mm, dyn. visc: η = 0,001 Pa/s à 20 °C

$$Q = \frac{0,1^3}{0,001} \times 1,72 \times \frac{-\pi}{6 \ln 0,718} = 2,72\ l/s \triangleq 9,78\ m^3/hr$$

Power demand with: Sterling MSVA (7 stages) 05007 9AA BK3 4R PO
2950 1/m, 50 Hz

P ≈ 24 kW required; Installed 30 kW

Opgesteld : W. Loch | Datum : 26-04-04 | Bladnummer : 1 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Hydrostatic Thrust Bearing

Orifice

$Q = C_D A \sqrt{\frac{2(P_s - P_r)}{\rho}}$ with $P_s = 30 bar = 3 MPa$

$Q = 2,72 \times 10^{-3} = 0,65 A \sqrt{\frac{2(3-1,86) \times 10^6}{1000}}$ $C_D = 0,65$

$Q = 2,72$ l/s

gives $A = 87,637 \times 10^{-6}$ m^2

$A = 87,637$ mm^2 in total

per line $\frac{A}{4} = 21,91$ mm^2 $\rightarrow A = \frac{\pi}{4} D^2 \rightarrow D = 5,28$ mm

Max load to be lifted when the bearing surface is in complete contact

$A = \pi R^2 - dl = \pi \times 420^2 - 60 \times \{2 \times 420 + 2 \times (420 - 30)\} = 457 \times 10^3$ mm^2

$p = 3,1 MPa = 3,1 N/mm^2$

$F = A \times p = 457 \times 10^3 \times 3,1 \times 10^{-3} = 1415$ kN

Opgesteld : W. Loch Datum : 26-04-04 Bladnummer : 2 Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Hydrostatic Thrust Bearing

Hydrofoot with minimum load F=100 kN
(water height 17 m)

$F = Ae\,(P_r - P_a) = 0{,}786 \times (P_r - 0{,}17) \times 10^3 = 100\ kN$

$P_r - 0{,}17 = 0{,}1272\ MPa$

$P_r = 0{,}2972\ MPa$

With $P_s = 2{,}8\ MPa$ @ $14\ m^3/h$ and $A_{orifice} = 87{,}637\ mm^2$

$Q = C_D \cdot A \sqrt{\frac{2(P_s - P_r)}{\rho}} = 0{,}65 \times 87{,}637 \sqrt{\frac{2 \times (2{,}8 - 0{,}2972)}{1000} \times 10^6} \times 10^{-6}$

$Q = 4{,}03 \times 10^{-3}\ m^3/s = 4{,}03\ l/s = 14{,}5\ m^3/hr$

Lifting height bearing

$Q = \frac{h^3}{\eta}(P_r - P_a) \times \frac{-\pi}{6 \ln R_i/R_o} = \frac{h^3}{0{,}001} \times 0{,}1272 \times \frac{-\pi}{6 \ln 0{,}710} = 4{,}03\ l/s$

$h^3 = 0{,}02\ mm^3 \rightarrow h = 0{,}272\ mm$

Stiffness of water film

$F = 1350\ kN \quad \delta = 0{,}1\ mm$

$F = 100\ kN \quad \delta = 0{,}272\ mm$

$S = \frac{\Delta F}{\Delta \delta} = \frac{1250}{0{,}172} = 7267\ kN/mm$

Opgesteld : W. Loch   Datum : 26-04-04   Bladnummer : 3   Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of bearing stiffnes

Bearing stiffnes

$\beta = \frac{P_r - P_a}{P_s - P_a} = \frac{1,72}{2,86} = 0,6$ at load 1350 kN

$A_e/A = \frac{0,786}{20 \times 0,585^2} = 0,7311$

From table 13.14 $S^* = 0,55$

$\frac{S \cdot h}{A_e(P_s - P_a)} = S^* = 0,55$

mm², MPa = N/mm²

$S = \frac{0,55 \cdot A_e(P_s - P_a)}{h} = 0,55 \frac{\times 0,785 \times 10^6 \times 2,86}{0,1} = 12,35 \times 10^6$ N/mm

mm

$= 12350$ kN/mm

Rubber stiffnes

At 1350 kN 12 mm compression $C = \frac{1350}{12} = 112$ kN/mm

6000 kN 28 mm " $C = \frac{6000}{28} = 214$ kN/mm

Load 100 kN:

$\beta = \frac{P_1 - P_a}{P_s - P_a} = \frac{0,1272}{2,63} = 0,0484$

$A_e/A = 0,7311 \longrightarrow S^* \approx 0,1$

$S = \frac{0,1 \cdot A_e(P_s - P_a)}{h} = \frac{0,1 \times 0,785 \times 10^6 \times 2,63}{0,272} = 0,76 \times 10^6$ N/mm

760 kN/mm

Rubber stiffnes $\frac{100}{3} = 33$ kN/mm

At 100 kN 3 mm compression

Opgesteld : W. Loch

Datum : 20/7 2004

Bladnummer : 4

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Hydrostatic Thrust Bearing.

Hydro foot

Pressure on UHMWPE ($\sigma_{yield} = 22\ N/mm^2$)

Door resting on hydrofoot without waterflow.

Contact area :

$A = \frac{\pi}{4}(D_0^2 - D_1^2) + D_1 \times b + (D_1 - b) \times b$

$A = \frac{\pi}{4}(1170^2 - 840^2) + 840 \times 60 + (840 - 60) \times 60 =$

$A = 520.955 + 50.400 + 46800$

$A = 618\ 155\ mm^2$

Normal maximum $F = 1350\ kN \rightarrow \sigma = \frac{F}{A} = 2,18\ N/mm^2$

Extreme maximum $F = 6000\ kN \rightarrow \sigma = \frac{F}{A} = 9,71\ N/mm^2$

Allowable $\sigma = 10\ N/mm^2$

Opgesteld : W. Loch

Datum : 26-04-04

Bladnummer : 5

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Hydro static Thrus Bearing

Rubber bearing

F_{vert} max = 1350 kN $M = 88$ kNm at $\alpha = 0{,}006$ rad

(F_{vert} extreme = 6000 kN)

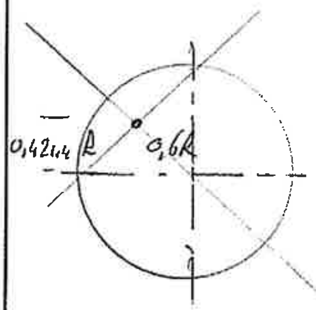
Displacements of bearing.

Axial displacement : $F_{vert} = 1350$ kN → $\Delta = 12$ mm
$F_{vert} = 6000$ kN → $\Delta = 28$ mm

Horizontal displacement is zero due to foot construction

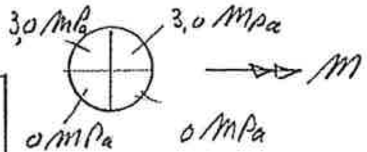
Rotation is $\alpha = 0{,}006$ rad due to movement of the door and out of plane of the construction.
(of rubber bearing)

Rotation of hydro bearing is 0,0002 rad. ($h = 0{,}1$ mm, $R = 0{,}585$ m)



Maximum moment on hydro foot due to rotation of rubber bearing.

situation A



$M = 2 \times 0{,}4244 \times \bar{R} \times p \times A$
with
$p = 3 - 0{,}14 = 2{,}86$ MPa

$A_e = \frac{1}{4} \times 0{,}786$ m²

$\bar{R} = \frac{420 + 585}{2} = 502{,}5$ mm

$M_{max} = 240 \times 10^3$ Nm

$M_{normal} \approx \frac{1}{3} M_{max} \approx 80 \times 10^3$ Nm

$F = 2 \times \frac{A_e}{4} p = 1124$ kN

From: The hydro-Support An Elasto-Hydrostatic Thrust Bearing with mixed Lubrication by R. van Ostayen

$$\frac{M}{\alpha} = \frac{\bar{M}}{\bar{\alpha}} \cdot \frac{W \frac{A}{2}}{\frac{h_0}{R/2}} = \frac{0{,}105}{1{,}0} \cdot \frac{1350 \times 10^3}{0{,}0001} \times 0{,}585^2 =$$

↑ for four reces bearing.

$\frac{M}{\alpha} = 4{,}85 \times 10^6$ Nm

$\alpha = \frac{0{,}0001}{0{,}583} = 0{,}0002$ rad → $M = 83$ kNm

Opgesteld : W. Lock

Datum : 26-04-04

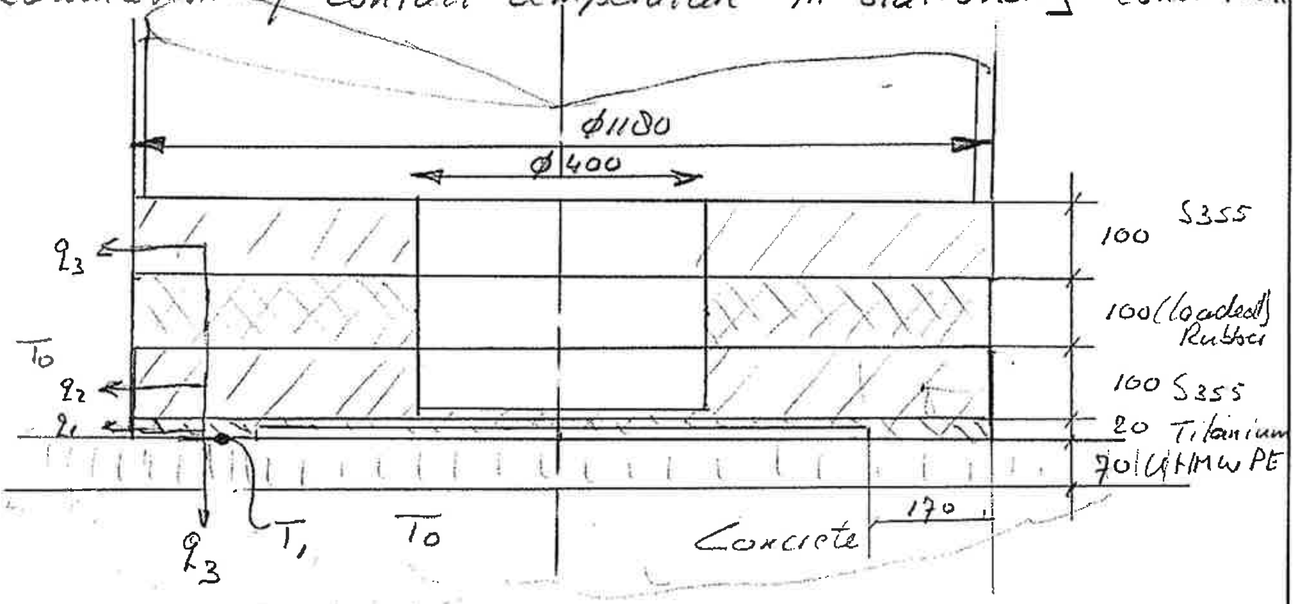
Bladnummer : 6

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

Calculation of contact temperature in stationary condition.

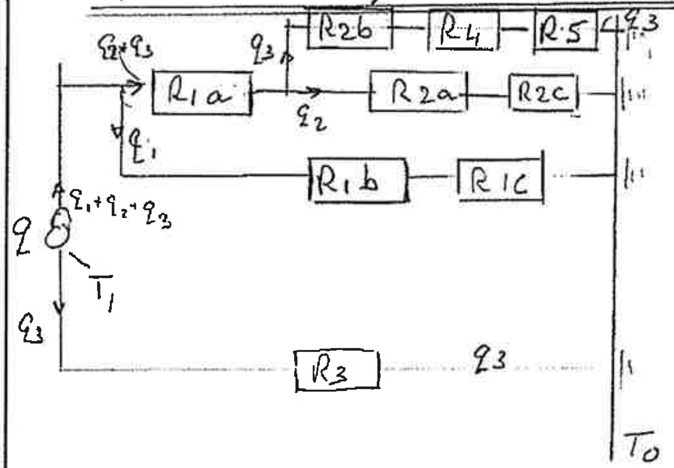


Speed 0,06 m/s

Load 900 kN

friction titanium/UHMWPE $\mu = 0,15$ take $\mu = 0,17$ for calculation

$T_1 - T_0 = \Delta T = \mu\ F.\ v.\ R. = 0,17 \times 900 \times 10^3 \times 0,06 \times R = 9180\ R$ [Kelvin]



R_1 = resistance of Titanium

R_2 = " of Steel S355

R_3 = " of UHMWPE

R_4 = " of Rubber

R_5 = " of Steel S355

$R_{i,C}$ = " heat transfer to sea water

Opgesteld : W. Loch

Datum : 20/7/04

Bladnummer : 7

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

Calculation of resistances

$$R_{1a} = \frac{L}{K.A} = \frac{0{,}02}{16 \times 0{,}618} = 0{,}002 \left[\frac{K}{W}\right]$$

contact area UHMWPE/Titanium ≈ conductive area Titanium/Steel

L = length [m]

K = coeficient of thermal conductivity $\left[\frac{W}{mK}\right]$

A = conductive area. [m^2]

$$R_{1b} = \frac{L}{K.A} = \frac{170/2 \times 10^{-3}}{16 \times \pi \times 1{,}18 \times 0{,}02} = 0{,}0717 \left[\frac{K}{W}\right]$$

L = mean length between contact area UHMWPE/Titanium to contact area Titanium/Sea water

A = conductive area Titanium/Sea water

$$R_{2a} = \frac{L}{K.A} = \frac{(50+85) \times 10^{-3}}{65 \times \pi \times 1{,}18 \times 0{,}1} = 0{,}0056 \left[\frac{K}{W}\right]$$

L = mean length between contact area Titanium/Steel to contact area Steel/Sea water

A = conductive area Steel/Sea water

$$R_{2b} = \frac{L}{KA} = \frac{0{,}1}{65 \cdot \frac{\pi}{4}(1{,}18^2 - 0{,}4^2)} = 0{,}0016 \left[\frac{K}{W}\right]$$

L = thickness steel

A = conductive area Steel/Rubber

Opgesteld : W. Loch

Datum : 20/7/04

Bladnummer : 8

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

$$R_3 = \frac{L_3}{K_3 A_3} = \frac{0,07}{0,42 \times 0,618} = 0,2697 \left[\frac{K}{W}\right]$$

L_3 = thickness of UHMWPE

A_3 = conductive area Titanium / UHMWPE.

$$R_4 = \frac{L_4}{K_4 A_4} = \frac{0,100}{0,42 \cdot \frac{\pi}{4}(1,18^2 - 0,4^2)} = 0,2460 \left[\frac{K}{W}\right]$$

L_4 = thickness of Rubber

A_4 = conductive area Steel / Rubber

$$R_5 = \frac{L_5}{K_5 \cdot A_5} = \frac{\frac{1180-400}{4} \times 10^{-3}}{65 \times \pi \times 1,18 \times 0,1} = 0,0081 \left[\frac{K}{W}\right]$$

L_5 = mean length between contact area Steel/Rubber to contact area Steel / Seawater

A = conductive area Steel / Seawater

$$R_{1C} = \frac{A_{1C}}{\alpha}$$

A_{1C} = Conductive area titanium / sea water

α = heat transfer coëfficient = 200 $\left[\frac{W}{m^2 K}\right]$

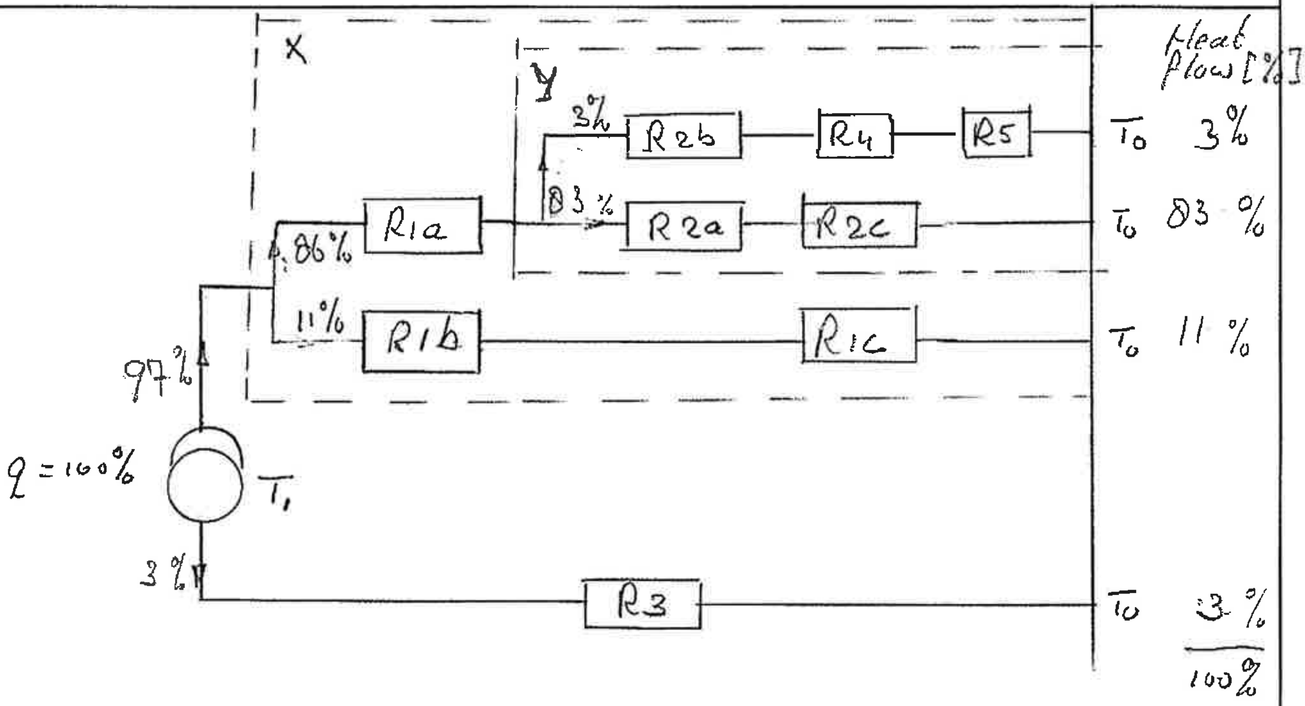
$$R_{1C} = \frac{\pi \times 1,18 \times 0,02}{200} = 0,0004 \left[\frac{K}{W}\right]$$

$$R_{2C} = \frac{A_{2C}}{\alpha} = \frac{\pi \times 1,18 \times 0,1}{200} = 0,0019 \left[\frac{K}{W}\right]$$

Opgesteld : W. Loch | Datum : 2017/04 | Bladnummer : 9 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature



R_y : $\frac{1}{R_y} = \frac{1}{R_{2a}+R_{2c}} + \frac{1}{R_{2b}+R_4+R_5} = \frac{1}{0{,}0056+0{,}0019} + \frac{1}{0{,}0016+0{,}2460+0{,}0081}$

$\frac{1}{R_y} = \frac{1}{0{,}0075} + \frac{1}{0{,}2557} = 137{,}24$

$R_y = 0{,}0073$

R_x : $\frac{1}{R_x} = \frac{1}{R_{1b}+R_{1c}} + \frac{1}{R_{1a}+R_y} = \frac{1}{0{,}0717+0{,}0004} + \frac{1}{0{,}002+0{,}0073} = 121$

$R_x = 0{,}0082$

R : $\frac{1}{R} = \frac{1}{R_3} + \frac{1}{R_x} = \frac{1}{0{,}2697} + \frac{1}{0{,}0082} = 125 \rightarrow R = 0{,}0080$

Opgesteld : W. Loch | Datum : 20/7/04 | Bladnummer : 10 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

Contact temperature in stationary condition with
$F = 900\,kN$, $\mu = 0{,}17$ and $v = 0{,}06\ m/s$

$T_1 - T_0 = \mu F v R = 9180 \times 0{,}0080 = 73\ [K]$

with $T_0 = 15°C$ gives $T_1 = T_{max} = 88°C$ = contact temp.

Allowable for UHMWPE

$T_{melt} = 135°C$

$T_{max}(1h) = 90°C$ $T_{max}(5000h) = 80/90°C$

End temperature in stationary condition with
$F = 750\,kN$, $\mu = 0{,}15$ and $v = 0{,}05\ m/s$

$T_1 - T_0 = \mu F v R = 0{,}15 \times 750 \times 10^3 \times 0{,}05 \times 0{,}0080 = 45\ [K]$

with $T_0 = 15°C$ gives $T_1 = 60°C$

These temperatures will not be reached as the time to move the gate ($t = 900$ sec) is too short to obtain a stationary condition

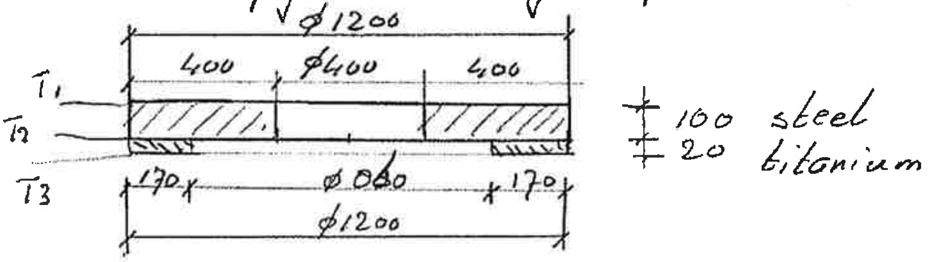
Opgesteld :	Datum :	Bladnummer :	Rev. :
W. Loch	23/7	10a	

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

Contact temperature in non stationary (heating-up) condition.

Simplify the hydrofoot to:



Heat added to the system (during 900 sec)

$Q = W \times t = \mu F_v \times t = 0{,}17 \times 900 \times 10^3 \times 0{,}06 \times 900 =$

$Q = 8{,}26 \times 10^6$ [J]

Heat capacity of titanium disc.:

mass of disc : $m = \frac{\pi}{4}(1{,}2^2 - 0{,}86^2) \times 0{,}02 \times 4540$

$m = 50$ kg

heat cap. $= m \times c_{tit}$ $50 \times 520 = 26000$ $\left[\frac{J}{K}\right]$

Heat capacity of steel disc

mass of disc $m = \frac{\pi}{4}(1{,}2^2 - 0{,}4^2) \times 0{,}1 \times 7850$

$m = 789$ kg

heat cap. $= m \times c_{steel} =$ $789 \times 469 = 370120$ $\left[\frac{J}{K}\right]$

Opgesteld : W. Lock   Datum : 23/7   Bladnummer : 10b   Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

Simplify the system further:

1) All heat (100%) passes through the titanium disc and heats the steel disc.
2) No heat exchange from steel disc to the surrounding water and rubber disc.

The temperature difference over the titanium disc will be:

$\Delta T = T_3 - T_2$ from

$$\Phi = \lambda \times \Delta T \times \frac{A}{L} = 16 \times \Delta T \times \frac{\frac{\pi}{4}(1{,}2^2 - 0{,}86^2)}{0{,}02} = \mu F v = 9180 \left[\frac{J}{s}\right]$$

$\Delta T = 21\,^\circ C.$

The mean temperature rise of the steel disc:

$$\Delta T = \frac{\mu F v \times t}{m \times c_{steel}} = \frac{8{,}26 \times 10^6}{370120} = 22{,}3\,^\circ C.$$

Time (t) required for the heat to penetrate the steel disc is obtained from $\sqrt{\pi a t} = d$.

with $a = \frac{\lambda}{\rho c} = \frac{65}{7850 \times 469} = 1{,}765 \times 10^{-5}$

d = height of disc = 0,1 m

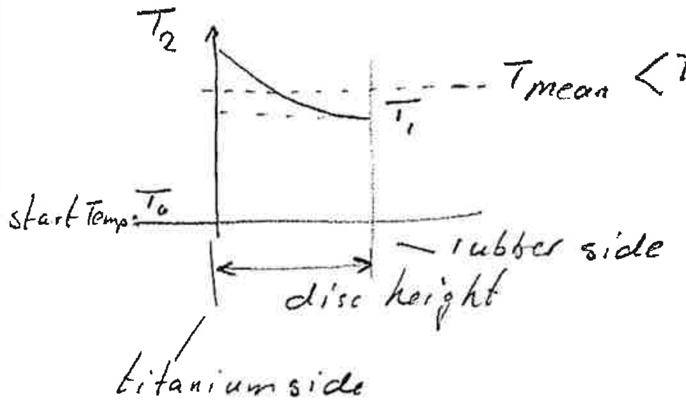
$\Big\}\ t = 180$ sec.

Opgesteld : W. Lock Datum : 23/7 Bladnummer : 10C Rev. :

Project : Malamocco Navigation Lock

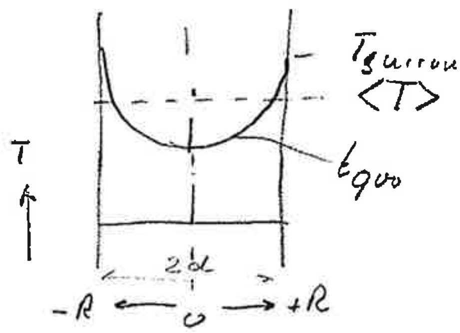
Onderdeel : Calculation of contact temperature

The shape of the temperature distribution will be:



with $T_{mean} = T_0 +$ mean temp rise
$= 15^\circ + 22{,}3^\circ = 37{,}3^\circ C$

This is to compare with a flat plate heated from both sides (basic heat transport condition)



Take for the thickness of the flat plate two times the thicknes of the steel disc.

$$F_0 = \frac{a t}{(2d)^2} = \frac{\lambda}{\rho c} \times \frac{t}{(2d)^2} = \frac{65}{7850 \times 469} \times \frac{900}{(0{,}2)^2} = 0{,}3972$$

This gives $$\frac{T_{surr.} - \langle T_{mean} \rangle}{T_{surr.} - T_{start\,cond.}} = 0{,}015$$

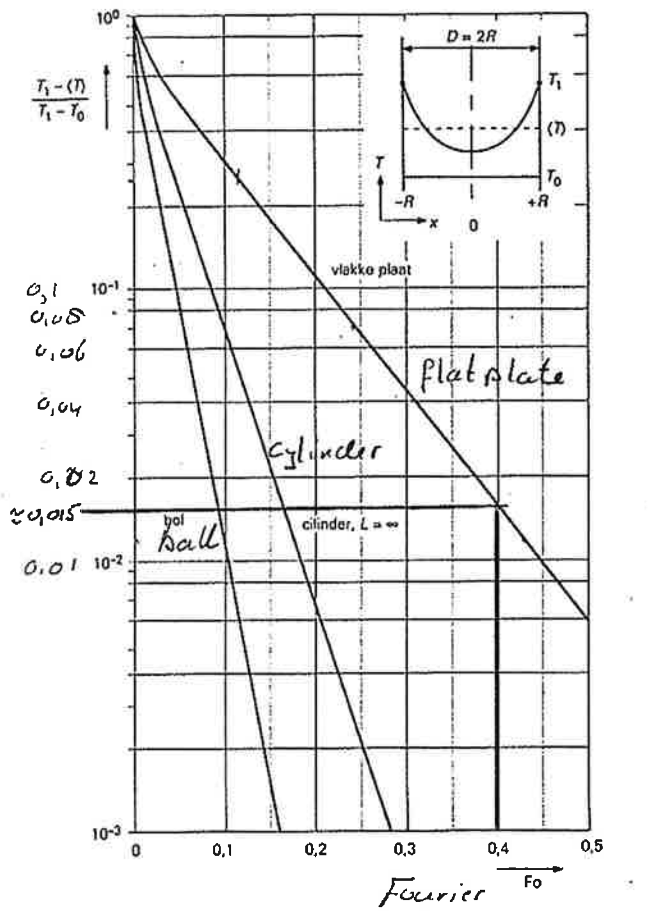
see figure on next page.

Opgesteld : W Loch
Datum : 23/7
Bladnummer : 10 d
Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact temperature

3. Warmtetransport 119



$T_{surr} = T_{titanium}$

$T_{start} = 15\,^\circ C$

$T_{mean} = 15 + 22{,}3 = 37{,}3\ ^\circ C$

$$\frac{T_{surr} - 37{,}3}{T_{surr} - 15} = 0{,}015$$

$$0{,}985\, T_{surr} = 37{,}3 - 15 \times 0{,}015$$

$$T_{surr} = \frac{37{,}3 - 0{,}225}{0{,}985}$$

$$T_{surr} = 37{,}64\ ^\circ C = T_2$$

The temperature of the titanium disc at the contact area with the UHMWPE plate will be: $T_3 = T_2 + \Delta T_{titanium}$

$$T_3 = 37{,}64 + 21 = 59\ ^\circ C$$

Due to all simplifications this is an unfavourable (high) temperature. The real temperature will be lower.

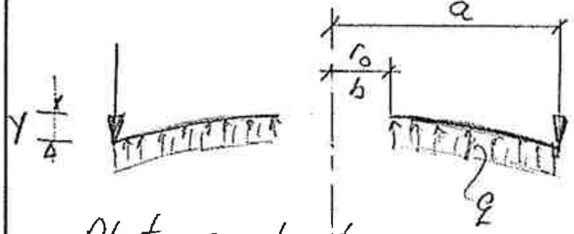
Opgesteld :	Datum :	Bladnummer :	Rev. :
W Loch	23/7	10 e	

Project : Malamocco Navigation Lock

Onderdeel : Calculation of foot plate

$t = 100$ mm
Material S355 J.R.

Calculation of foot plate.



Roark's Formulas for Stress & Strain
Chap 10 table 24, case 2a
Flat circular plates, outer edge simply supported, inner edge free.

Plate constant

$D = Et^3 / 12(1-\nu^2)$

q = load per unit area,
Q = total load = 1350 kN
a = 600 mm

$r_0 = 200$ mm = b

$b/a = 0,33$

$y = K_y \frac{qa^4}{D}$ with $K_y = 0,0761$

$\theta = K_\theta \frac{qa^3}{D}$ $K_{\theta_b} = 0,1079$, $K_{\theta_a} = 0,1120$

$M = K_M qa^2$ $K_M = 0,3272$

$q = \frac{1350 \times 10^3}{\pi(600^2 - 200^2)} = 1,3429$ N/mm².

$$y = \frac{0,0761 \times 1,3429 \times 600^4}{\frac{2,1 \times 10^5 \times 100^3}{12(1-0,3^2)}} = \frac{13,244 \times 10^9}{19,23 \times 10^9} = 0,69 \text{ mm}$$

$$\theta_a = \frac{0,1120 \times 1,3429 \times 600^3}{19,23 \times 10^9} = 0,0017 \text{ rad resp } \theta_b = 0,0016 \text{ rad}$$

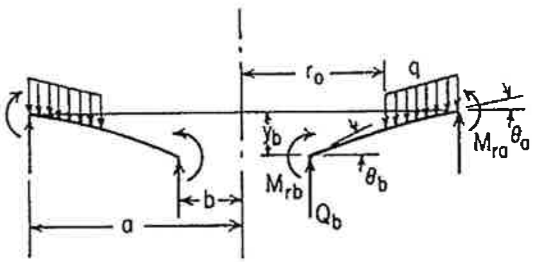
$$M = 0,3272 \times 1,3429 \times 600^2 = 158\,148 \text{ Nmm}$$

$$\sigma = \frac{6M}{t^2} = \frac{6 \times 158\,148}{100^2} = 95 \text{ N/mm}^2 < \bar{\sigma} = \frac{310}{1,5} = 207 \text{ N/mm}^2$$

In case of ship collision, Q = 6000 kN, deformation might occur. Inspection necessary after extreme loading.

Opgesteld : W. Loch
Datum : 20/7/04
Bladnummer : 11
Rev. :

Case 2. Annular plate with a uniformly distributed pressure q over the portion from r_o to a



General expressions for deformations, moments, and shears:

$$y = y_b + \theta_b r F_1 + M_{rb}\frac{r^2}{D}F_2 + Q_b\frac{r^3}{D}F_3 - q\frac{r^4}{D}G_{11}$$

$$\theta = \theta_b F_4 + M_{rb}\frac{r}{D}F_5 + Q_b\frac{r^2}{D}F_6 - q\frac{r^3}{D}G_{14}$$

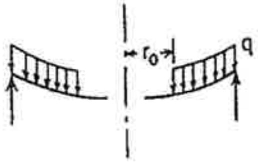
$$M_r = \theta_b\frac{D}{r}F_7 + M_{rb}F_8 + Q_b r F_9 - qr^2G_{17}$$

$$M_t = \frac{\theta D(1-\nu^2)}{r} + \nu M_r$$

$$Q = Q_b\frac{b}{r} - \frac{q}{2r}(r^2 - r_o^2)\langle r - r_o\rangle^0$$

For the numerical data given below, $\nu = 0.3$

$$y = K_y\frac{qa^4}{D} \qquad \theta = K_\theta\frac{qa^3}{D} \qquad M = K_M qa^2 \qquad Q = K_Q qa$$

Case no., edge restraints	Boundary values	Special cases
2a. Outer edge simply supported, inner edge free 	$M_{rb} = 0 \quad Q_b = 0 \quad y_a = 0 \quad M_{ra} = 0$ $y_b = \frac{-qa^4}{D}\left(\frac{C_1L_{17}}{C_7} - L_{11}\right)$ $\theta_b = \frac{qa^3}{DC_7}L_{17}$ $\theta_a = \frac{qa^3}{D}\left(\frac{C_4L_{17}}{C_7} - L_{14}\right)$ $Q_a = \frac{-q}{2a}(a^2 - r_o^2)$	Max $y = y_b$ Max $M = M_{tb}$ If $r_o = b$ (uniform load over entire plate),

b/a	0.1	0.3	0.5	0.7	0.9
K_{y_b}	−0.0687	−0.0761	−0.0624	−0.0325	−0.0048
K_{θ_a}	0.0986	0.1120	0.1201	0.1041	0.0477
K_{θ_b}	0.0436	0.1079	0.1321	0.1130	0.0491
$K_{M_{tb}}$	0.3965	0.3272	0.2404	0.1469	0.0497

Project : Malamocco Navigation Lock

Onderdeel : Calculation of footplate

Friction forces on hydrofoot

- Normal working condition with water film

$$F_{fr} = \tau . A = \eta \frac{u}{h} \{ \pi (R_1^2 - R_0^2) + d (2 \times R_1 + 2(R_1 - d) \}$$

$u = 0,35$ m/s $h = 0,1 \times 10^{-3}$ m $\mu = 0,001$ Pa.s

$R_1 = 585 \times 10^{-3}$ m $R_0 = 420 \times 10^{-3}$ m $d = 60 \times 10^{-3}$ m

$F_{fr} = 2,15$ N $\rightarrow \mu = \frac{2,15}{1350 \times 10^3} = 1,6 \times 10^{-6}$

- Friction force on hydrofoot at malfunction of foot

$F_{foot} = 1350$ kN $\mu = 0,15 - 0,25$ $\left(\underset{dry}{0,23 \text{ m/s}}, 2 \text{ MPa} \right)$

conditions are : $v = 0,06$ m/s 2,18 MPa, wet
$\mu = 0,17 - 0,2$ Take safety factor $S = 1,25$
calculate with maximum
$\mu = 1,25 \times 0,2 = 0,25$
$F_{fr_{max}} = 0,25 \times 1350 = 337$ kN

Calculation of bolts 16 x M20 8.8

BM: $337 \times 200 = 67400$ Nm

$F_{bolt} \approx \frac{67400}{3 \times 0,45} = 49926$ N $\rightarrow \approx 50$ kN

M20 8.8 $\bar{F}_{allow} = 88$ kN

Opgesteld : W. Loch Datum : 20/7/04 Bladnummer : 13 Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of foot plate

Bush in lower part hydrofoot (S355JR)

Load : BM= 67400 Nm F= 337kN

D_{in} = 306 mm

D_{out} = 400 mm

$$\sigma_B = \frac{67400}{\frac{\frac{\pi}{64}(400^4 - 306^4)}{\frac{400}{2}}} \times 10^3 = 16\ N/mm^2$$

mat: S355JR

$\bar{\sigma} \approx 300\ N/mm^2$

$$\tau = \frac{F}{A_{SHEAR}} = \frac{337 \times 10^3}{\frac{\pi}{4}(400^2 - 306^2) \times 45} = 13\ N/mm^2 \rightarrow \sqrt{\sigma^2 + 3\tau^2} = 27\ N/mm^2$$

Bearing on bush. (ORKOT-TLM-marine)

(ϕ395; h_{net} = 20 mm

$F_{Hor} = F_{fr_{max}}$ = 337 kN

$$\sigma = \frac{337 \times 10^3}{395 \times 30} = 29\ N/mm^2$$

$\bar{\sigma}_{comp}$ = 346 N/mm²

Required tolerances according manufacturer of bearing material.

Opgesteld : WLoch
Datum : 2017/04
Bladnummer : 14
Rev. :

STERLING

Customer :

Sterling Fluid Systems (Netherlands) B.V.
Havenstraat 22-28
1948 NP Beverwijk
Netherlands

Project :
Item : 1
Quote No. : NL-132-3
Your Ref. :

Contact :
Phone : Fax :
Date : donderdag 27 mei 2004

Pump Model: MSVA 050 7 Stages
Pump Op. Speed: 2950 RPM, 50 Hz Electric

Stages	Trim Status	Imp. Dia. (mm)
—	Full	170
7	w	168

Impeller No.: A

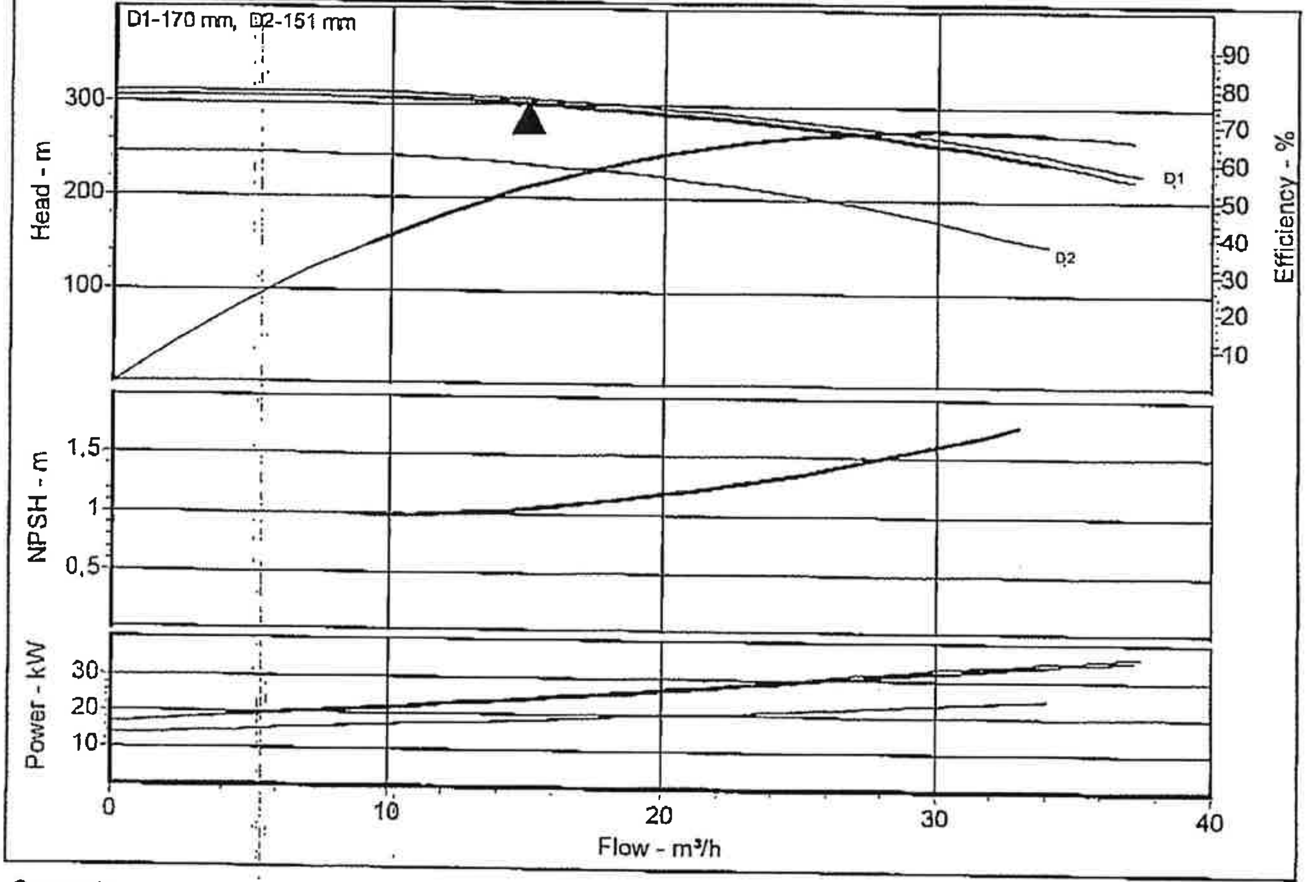
Material Spec. Group: [4R] Stainless steel, shaft from Duplex

Fluid: Water

Temperature: 20 °C
Viscosity: 1,01 mm²/s
Density: 998,2 kg/m³

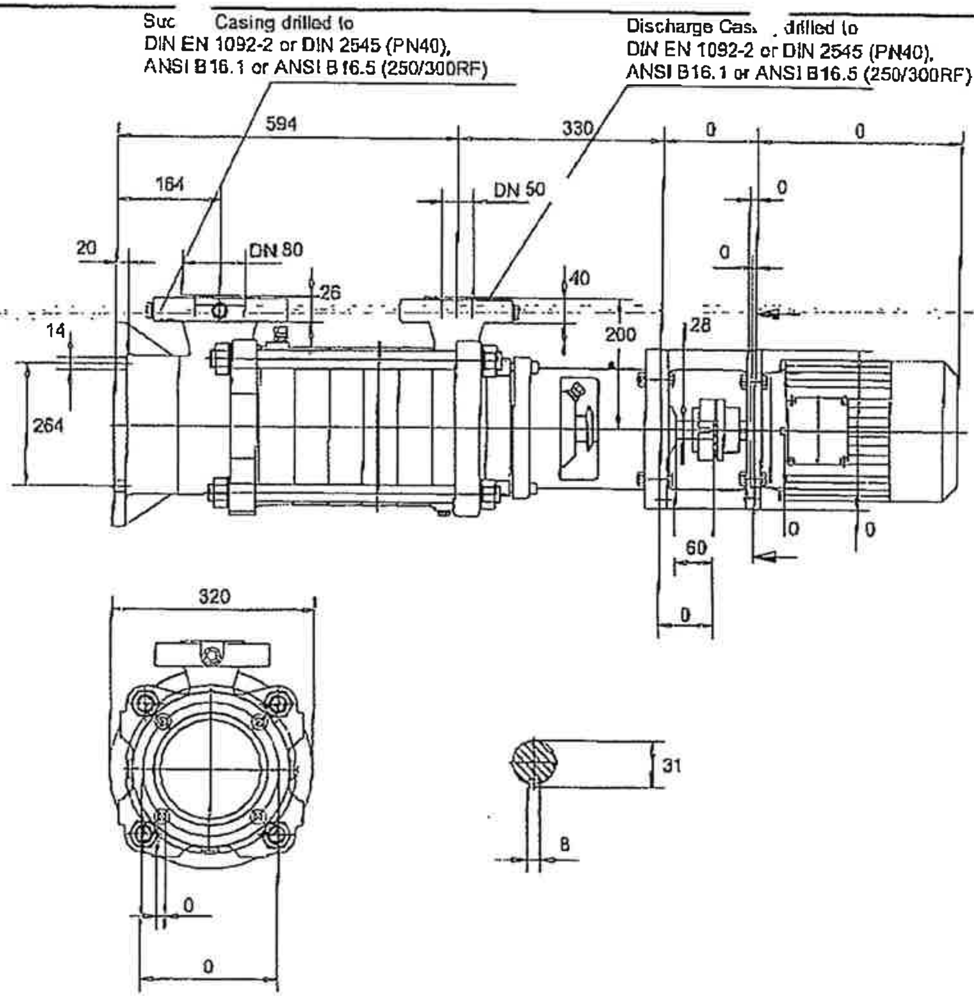
Flow rate Q:	15	m³/h
Differential Head H:	300	m
Efficiency	53	%
Power Required	23,9	kW
NPSH Required	1,05	m

Performance curve according to ISO 9906 Grade 2



Comments
NPSHR - for guaranteed NPSHR values, add 0.5 m safety margin on the values read from the curves.

STERLING SIHI | STERLING HALBERG | STERLING SAT | STERLING SERVICE

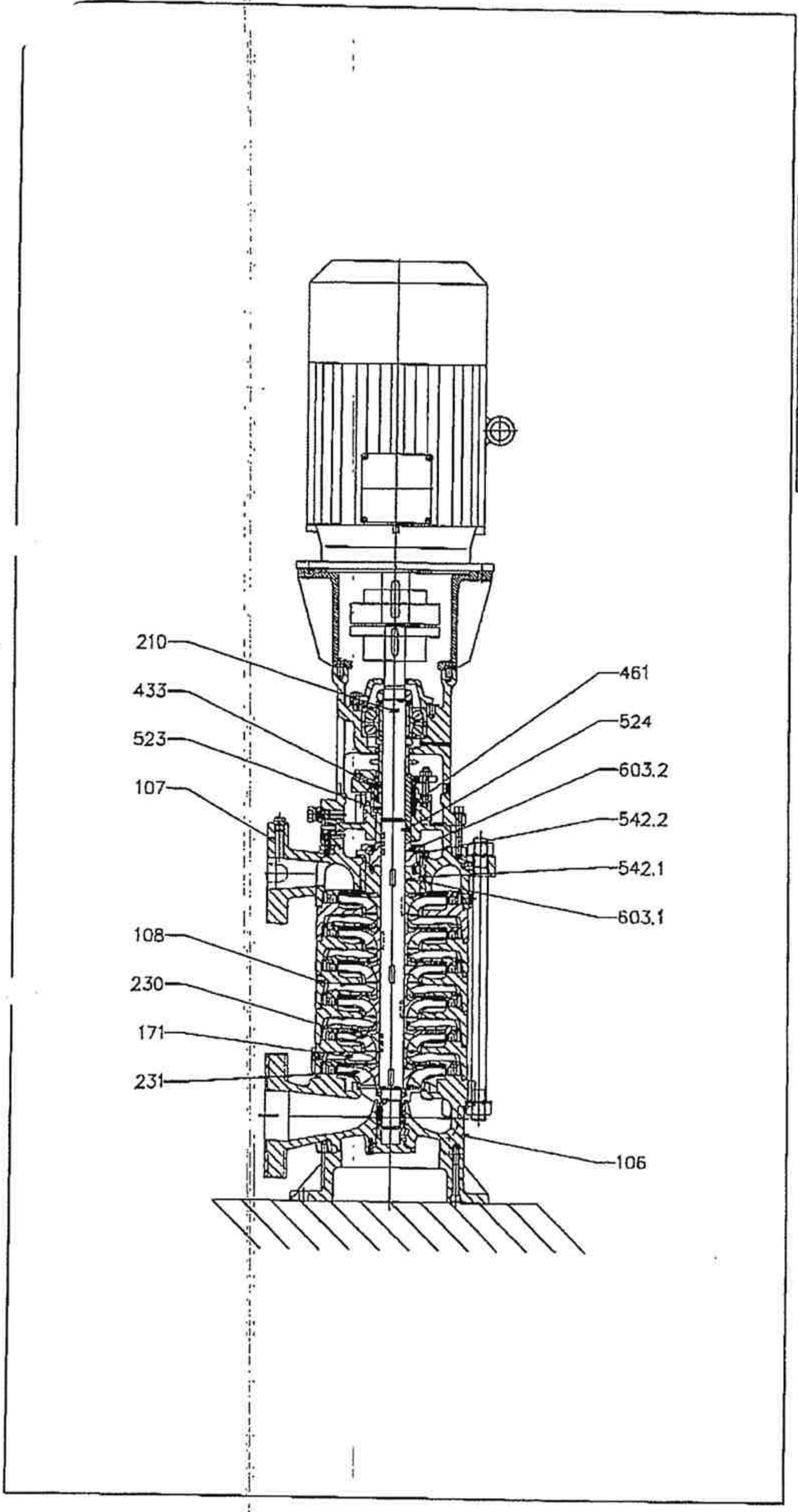


Dimensions in (mm)

Our Ref.:	NL-132-3	Model	MSVA 050 7 Stages		
Liquid	Water	Flow	15 (m^3/h)	Head	300 (m)
Speed	2950 (RPM)	Motor		Impeller Dia.	168 (mm)
Your Ref.:		Weight	181 kg	Item No.	1

Sterling Fluid Systems (Netherlands) B.V.
Havenstraat 22-28
1948 NP Beverwijk
Netherlands

Date donderdag 27 mei 2004



STERLING

Sterling Fluid Systems (Netherlands) B.V.

Havenstraat 22-28
1948 NP Beverwijk
Netherlands

Our Ref.:	NL-132-3	Model	MSVA 050 7 Stages		
Liquid	Water	Flow	15 (m^3/h)	Head	300 (m)
Speed	2950 (RPM)	Motor		Impeller Dia.	168 (mm)
Your Ref.:		Weight	181 kg	Item No.	1

Date donderdag 27 mei 2004

STERLING

Your Reference:	Our Reference:	Company Name:	Date:
	NL-132-3		27-5-2004

SIHI *Multi* vertical, multistage pump, that meets to the requirements of ISO 5199/EN 25199

Pos.: *1* - Quantity: *1* - Type: MSVA 050 07 09 A A BK3 4R P 0

Operating Conditions:

Fluid	: Water
Temperature	: 20 °C
Density	: 998,2 kg/m³
Viscosity	: 1,01 mm²/s
Flow	: 15 m³/h
Head	: 300 m
Speed	: 2950 RPM
Required Power	: 23,9 kW
NPSHR (Required)	: 1,05 m (NPSHA≥ NPSHR + 0.5 m)

Materials:

Casing (106, 107,)	: Stainless Steel
Suction Impeller (231)	: Stainless Steel
Impeller (230)	: Stainless Steel
Diffuser (171)	: Stainless Steel
Shaft (210)	: Duplex
Shaft Protection Sleeve (524)	: Duplex
Shaft Sleeve (523)	: Stainless Steel
Balance Drum System (603.1, 603)	: Duplex
Throttle Bushes (542.1)	: Duplex
Mechanical Bearing ()	:
Throttle Bushes (542.2)	: Ni-Resist

Construction:

Hydraulic	: A
Number of Stages	: 7
Impeller configuration	: Cut Impeller
Impeller diameter	: 168 mm
Orientation nozzles	: [0] Suction nozzle DIN PN 16 discharge nozzle DIN PN 40, discharge nozzle 180° to suction nozzle
Suction nozzle	: DN PN 16 - EN 1092-2
Discharge nozzle	: DN PN 40 - EN 1092-2
Bearing and Lubrication	: [A] Grease lubricated roller bearing at discharge side, medium lubricated plain bearing at suction side
Shaft Seal	: [BK3] Uncooled mech. seal Burgmann MG1, AQ1EGG
Casing Seal	: [P] O-rings from perbunan
Direction of rotation	: Counter-clockwise, when viewed from discharge side.

Scope of Delivery:

Pump mounted including motor.

TRELLEBORG
ENGINEERED SYSTEMS

Rapport	: TB ED 2004-068	Onderwerp	: Berekenings resultaten
Datum	: 02-07-2004	Produkt	: Hydrovoet
Revisie	: 1	Project	: Venetië
Datum	: 05 Juli 2004	Klant	: Iv-Bouw & Industrie
File	: \ED2004\2004-068.DOC	Klant On.	:
Artikelnr.	: 60.00.00	TB On.	:
Door	: D.J.D. van Waardhuizen	Aan	: Dhr W. Lock, Iv

1] Inleidding

Voor de Oranjesluizen heeft Trelleborg Bakker in het verleden (1993) de rubber delen van de zogenaamde Hydrovoeten ontwikkeld en geproduceerd.
Op dit moment wordt een sluis ontworpen, lokatie in de buurt van Venetië. Hier wil men hetzelfde concept toepassen echter met aanzienlijk hogere belastingen.
Gevraagd :

- Afmetingen rubber deel
- Terugstelmoment bij rotatie om horizontale as
- Torsie bij rotatie on verticale as
- Haalbaarheid

2] Gegevens

Belasting / Vervorming	Waarden	Eenheden
Extreme belasting F_{ex} =	6000	kN
Nominale belasting F_{nom} =	1350	kN
Minimale belasting F_{min} =	100	kN
Maximale Rotatie $\Phi_{h,max}$ =	0,0060	RAD
Tosie Rotatie $\Phi_{v,max}$ =	0,0145	RAD

3] Berekeningen

Met behulp van de testwaarden van de hydrovoeten geproduceerd in 1993 zijn de beschikbare analytische berekeningsmethoden geijkt.
Hiermee zijn daarna de hydrovoeten voor Venetië doorgerekend.

4] Berekenings resultaten

Uitwendige afmetingen rubber deel : Ø1180 x Ø400 x 110 mm

Belast. / Verv.	Waarden	Eenheden	Berekende reactie	Waarden	Eenheden
F_{ex} =	6000	kN	Compressie c =	28	mm
F_{nom} =	1350	kN	Compressie c =	12	mm
F_{min} =	100	kN	Compressie c =	3	mm
$\Phi_{h,max}$ =	0,0060	RAD	Terugstelmoment M =	88	kN.m
$\Phi_{v,max}$ =	0,0145	RAD	Torsie moment M =	230	kN.m

Haalbaarheid : Bovenvermelde afmetingen zijn te produceren en te testen.

Project : Malamocco Nav. Lock

Onderdeel : slide supports (horizontal)

Sea - side:

* UHMWPE ~~[illegible]~~ slide beam
* steel slide block
* $A_{contact} = 2 * 120 * 1000 = 0.24\ m^2$
* A steel block → air cooling $= 4 m^2$

lagoon - side

* Stainless steel slide beam
* UHMWPE slide block
* $A_{contact} = 2 * 120 * 2000 = 0.48\ m^2$
* $A_{s.steel}$ slides (2* [profiles $l = 53$ m) $= 7 m^2$ (aircooling)

General:

Speed : $V = 0.35$ m/s

Contact-force : $\frac{1}{2} * \Delta h * \rho_{water} * A_{loaded}$

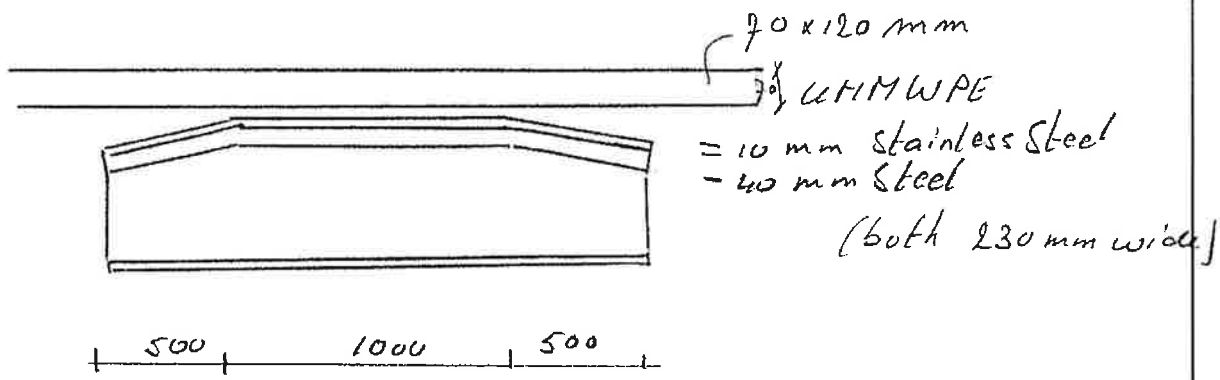
$= \frac{1}{2} * 0.1 * 10.3 * 14.2 * 53 = 400\ kN$

Opgesteld : Datum : Bladnummer : Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calc. temp contact area

Sea side.



Friction coëff. $\mu = 0,15$

Speed $v = 0,35$ m/s

Contact force $F = 400$ kN (divided over 2 strips)

$$p = \frac{400 \times 10^3}{2 \times 120 \times 1000} = 1,66 \text{ N/mm}^2$$

First assumption:

1e) 60% heat is consumed by the stainless steel and steel plate

Heat generated $\Phi = \mu F v = 0,15 \times \frac{400 \times 10^3}{2} \times 0,35 = 10500$ W

2) 60% transfer through stainless steel

$$\Phi = \lambda \times \Delta T \times \frac{A}{L} = 16 \times \Delta T \times \frac{(1,000 \times 0,12)}{0,01} = 10500 \times 0,60 \text{ [W]}$$

(contact area)

$$\Delta T = \frac{10500 \times 0,6}{16} \times \frac{0,01}{1,000 \times 0,12} = 33 \text{ °C}$$

Opgesteld : W. Loch

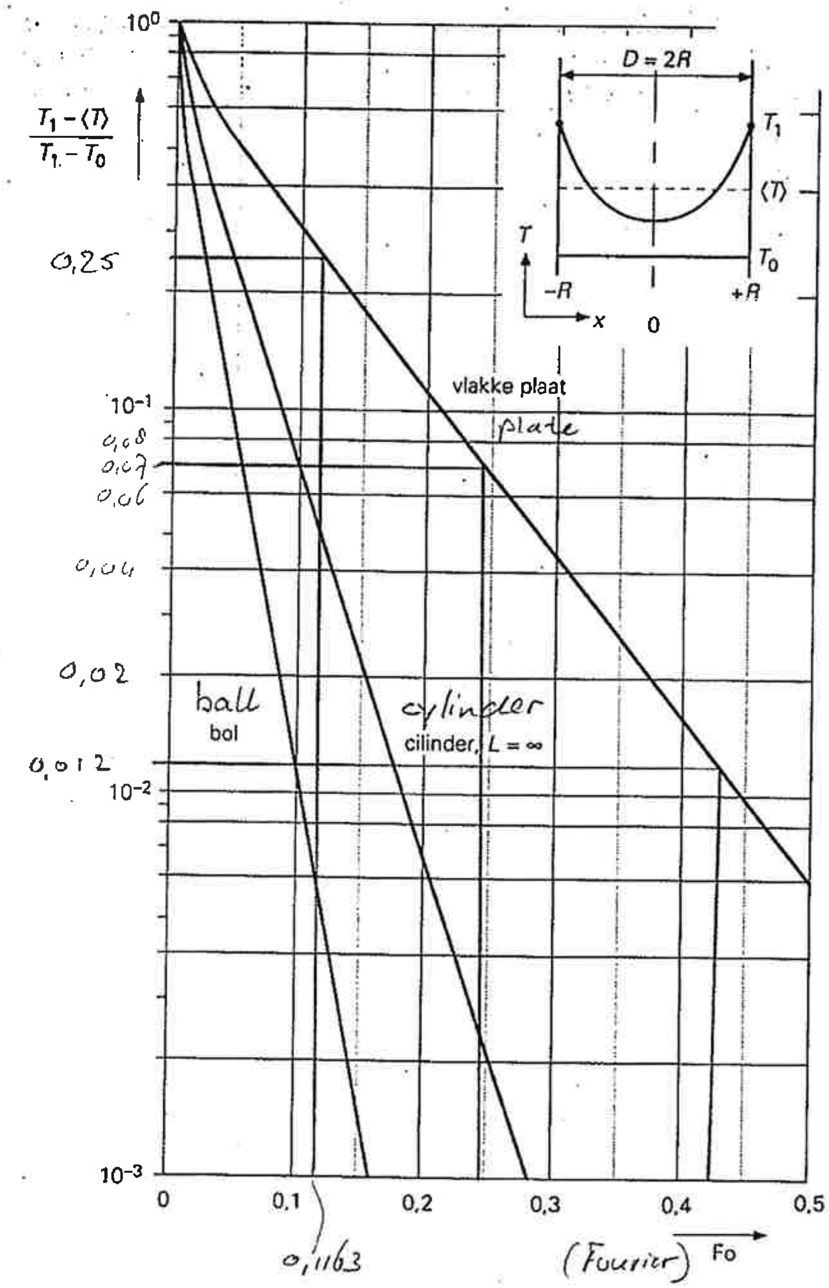
Datum : 2/8

Bladnummer : 1

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calculation of contact area temperature



$$Fo = \frac{a t}{D^2} = \frac{\lambda}{\rho . c} \times \frac{t}{D^2}$$

Opgesteld : W. Lock

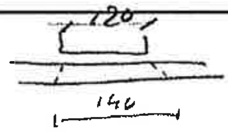
Datum : 2/8

Bladnummer : 1a

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calc temp contact area



Heat absorbed by S. Steel.

Contact time $t_s = \frac{S}{V} \; \frac{53{,}9}{0{,}35} = 154$ sec.

$Q = \Phi \times t = 0{,}6 \times 10500 \times 154 = 0{,}970 \times 10^6$ [J]

$c = 500 \left[\frac{J}{kg \times {}^\circ C}\right]$

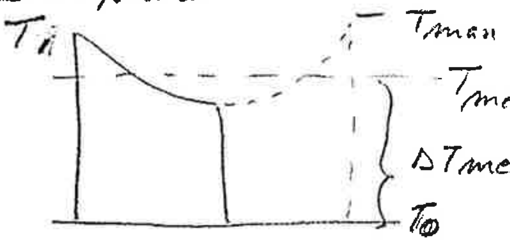
mean width

$m = 0{,}010 \times 1{,}000 \times 0{,}13 \times 8000 = 10{,}4$ kg

$Q = m \times c \times \Delta T = 10{,}4 \times 500 \times 50 = 260 \times 10^3$ [J].

(2nd assumption)

Steelplate



$\Delta T_{mean} = \frac{Q}{\text{Heatcap.}}$

$\Delta T_{mean} = \frac{0{,}60 \times 1{,}67 \times 10^6 - 0{,}26 \times 10^6}{469 \times 57} =$

$\boxed{\Delta T_{mean} = 26{,}6\,^\circ C}$

$m = 0{,}040 \times 1{,}00 \times 0{,}18 \times 7850 = 57$ kg

$c = 469 \left[\frac{J}{kg\, {}^\circ C}\right]$.

$F_0 = \frac{a t}{(2d)^2} = \frac{\lambda}{\rho c} \cdot \frac{t}{(2d)^2} = \frac{65}{7850 \times 469} \times \frac{154}{(2 \times 0{,}04)^2} = 0{,}4248$

$\boxed{T_0 = 30^\circ C}$

see page 10

$\frac{T_1 - \langle T \rangle}{T_1 - T_0} = 0{,}012$ $\qquad \frac{T_1 - 56{,}6}{T_1 - 30} = 0{,}012 \rightarrow T_1 = \frac{56{,}6 - 30 \times 0{,}012}{0{,}988}$

$T_1 = 57\,^\circ C$

$T_{contact\ area} = \overset{\Delta T_{ss} + T_1}{33 + 57} = 90\,^\circ C$

Opgesteld : W. Lock

Datum : 2/8

Bladnummer : 2

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calc temp contact area

Part of the heat is transferred into UHMWPE

contact time $t = \frac{1,00}{0,35} = 2,86$ sec

penetration depth $\sqrt{\pi a t_e} = \sqrt{\pi \frac{\lambda}{\rho c} . t_e}$

$\sqrt{\pi \times \frac{0,42}{940 \times 1842} \times 2,86} = 0,0015$ m $\hat{=}$ 1,5 mm

$Q'' = 2 \sqrt{\frac{\lambda \rho c}{\pi t}} \times t \times \Delta T$

$Q'' = 2 \times \sqrt{\frac{0,727 \times 10^6}{\pi \times 2,86}} \times 2,86 \times 60 = 97624 \frac{J}{m^2}$ (90−T_0)

$A = 0,12 \times (53,9 - 1) = 6,35 m^2 \rightarrow Q = 97624 \times 6,35 = 619912$ J.

$\Phi \times 6$

$Q_{tot} = 10500 \times 154 = 1617000$ J. ← | ≃ 38,5 % in UHMWPE |

So first assumption of heat division is ok.
second assumption of $\Delta T = 50$ is too high
$\Delta T = 90 - \frac{33}{2} - 30 = 43,5$ °C

Temperature rise of steel δ: 40 mm will be slightly higher

Opgesteld : W. Loch

Datum : 2/8

Bladnummer : 3

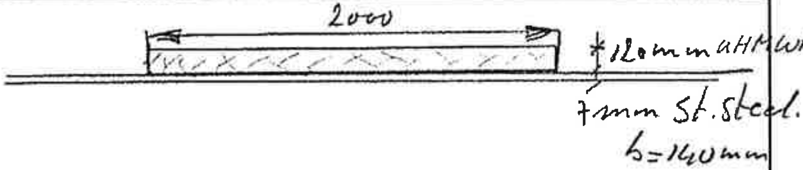
Rev. :

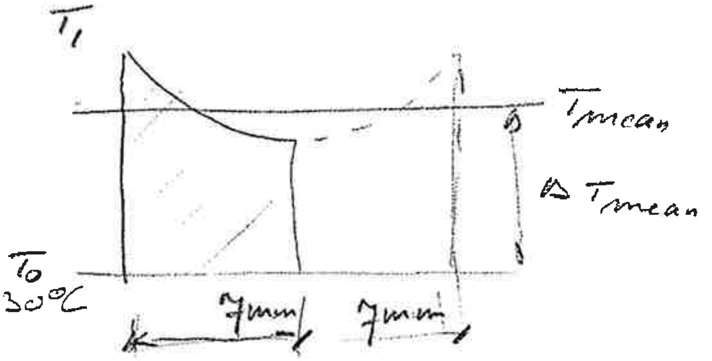
Project : Malamocco Navigation Lock

Onderdeel : Calc. temp. contact area Lagoonside.

$F = 2 \times 200 \times 10^3$ N.

$V = 0{,}35$ m/s





Temperature curve in stainless steel

Contact time $t = \frac{2000}{0{,}35} = 5{,}7$ sec.

Penetration depth

$$\sqrt{a \pi t_e} = \sqrt{\pi \frac{\lambda}{\rho c} \cdot t_e} = \sqrt{\pi \times \frac{16}{8000 \times 500} \times 5{,}7} = 0{,}0085 \text{ m}$$

$\delta = 0{,}007$ m

$$\Delta T_{mean} = \frac{Q}{\text{Heat cap}} = \frac{\mu F v \times 154}{c \times m} = \frac{0{,}15 \times 200 \times 10^3 \times 154 \times 0{,}35}{500 \times 52{,}9 \times 0{,}14 \times 0{,}007 \times 8000}$$

(t_{tot})

$\Delta T_{mean} = 8$ °C with $T_0 = 30$°C → $T_{mean} = 38$°C

$$F_0 = \frac{\lambda}{\rho c} \times \frac{t}{(2d)^2} = \frac{16}{8000 \times 500} \times \frac{5{,}7}{0{,}014^2} = 0{,}1163$$

→ see table page 1a

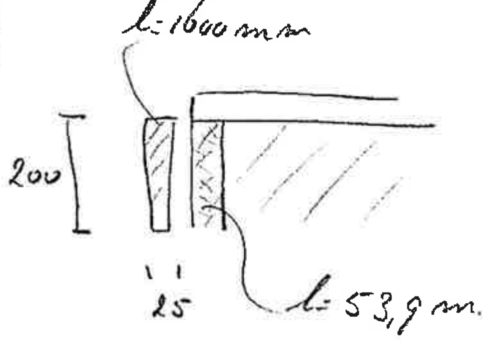
$$\frac{T_1 - \langle T \rangle}{T_1 - T_0} = 0{,}25 \qquad T_1 = \frac{38 - 0{,}25 \times 30}{0{,}75} = 40{,}7 \text{ °C}$$

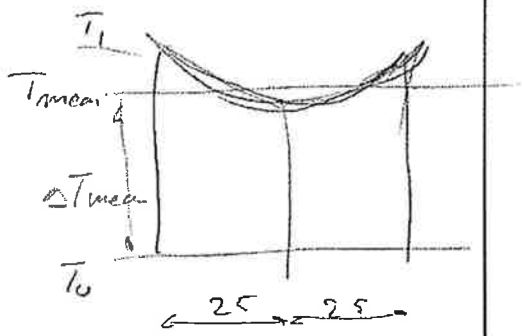
Opgesteld : W. Lock | Datum : 2/5 | Bladnummer : 4 | Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calc temp contact area

Bottom side of Lock-door. (door guidance)





Friction coeff $\mu = 0,15$

Speed $v = 0,35$ m/s → $t = 154$ sec.

Contact force $F = 400$ kN

First assumption

1) 60% of the heat is consumed by the stainless steel

Heat generated

$G = t \times \mu F v = 154 \times 0,15 \times 400 \times 10^3 \times 0,35 = 3,23 \times 10^6$ J.

$c = 500 \frac{J}{kg\,^\circ C}$ $m = 0,20 \times 1,6 \times 0,025 \times 8000 = 64$ kg.

$Q = m \times c \times \Delta t = 64 \times 500 \times \Delta t = 3,23 \times 10^6 \times 0,6$

Mean $\Delta t = 61°$

$T_0 = 15°C$ → mean $T = 76°C$.

Opgesteld : W. Lock

Datum : 2/8

Bladnummer : 5

Rev. :

Project : Malamocco Navigation Lock

Onderdeel : Calc temp contact area.

$$Fo = \frac{\lambda}{\rho c} \cdot \frac{t}{(2d)^2} = \frac{16}{8000 \times 500} \times \frac{154}{0{,}050^2} = 0{,}246$$

From figure: page 1a

$$\frac{T_1 - \langle T \rangle}{T_1 - T_0} = 0{,}07$$

$$T_1 = \frac{76 - 0{,}07 \times 15}{0{,}93} = 80{,}6 \ ^\circ C$$

Part of the heat is transferred in to UHMWPE

contact time $t = \frac{1{,}6}{0{,}35} = 4{,}6$ sec.

penetration depth $\sqrt{\pi a t_e} = \sqrt{\pi \frac{\lambda}{\rho c} \cdot t_e}$

$$\sqrt{\pi \times \frac{0{,}42}{940 \times 1842} \times 4{,}6} = 0{,}0019 \ \hat{=}\ 1{,}9 \text{ mm}$$

$$Q'' = 2\sqrt{\frac{\lambda \rho c}{\pi \cdot t}} \times t \times \Delta T$$

$$2 \times \sqrt{\frac{0{,}727 \times 10^6}{\pi \times 4{,}6}} \times 4{,}6 \times (80 - 15) = 134\,126 \left[\frac{J}{m^2}\right]$$

$A = 0{,}2 \times (53{,}9 - 1{,}6) = 10{,}46 \ m^2 \longrightarrow Q = 1{,}403 \times 10^6 \ J$

First assumption of heat division 60 - 40 % is ok — **43 %** of total.

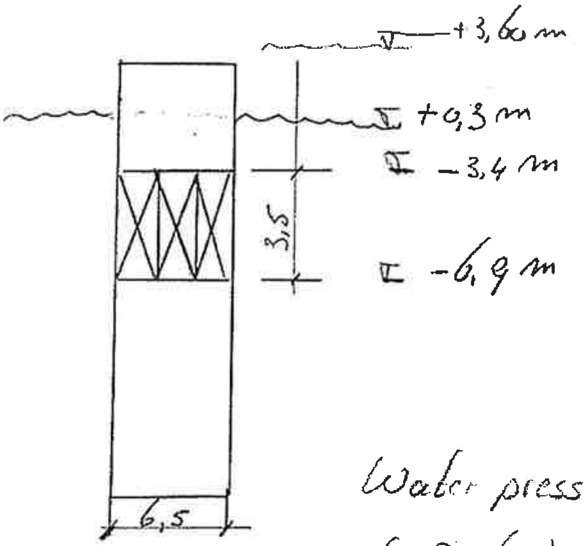
Opgesteld : W. Loch | Datum : 2/8 | Bladnummer : 6 | Rev. :

ALLEGATO D

Parti meccaniche delle camere di galleggiamento

Project : Mallamocco Navigation Lock

Onderdeel : BUOYANCY CHAMBER AIR COMP. SYSTEM



Dimensions L x W x H:

L = 54 m

W = (6,5 - 1,8) m

H = 3,5 m.

Water pressure at bottom level normal:

$\frac{(0,3 + 6,9)}{1000} \times 9,81 \times 1,03 = 0,0728$ MPa

Waterpressure at bottom level with highest level, within the waves

$\frac{(3,6 + 6,9)}{1000} \times 9,81 \times 1,03 = 0,1061$ MPa

Plates and stiffeners calculated at: $\underset{m}{\overset{\Delta h}{10,5}} \times \underset{kN/m^3}{\overset{s.w.}{10}} \times \overset{sf}{1,5} = 157,7\ kN/m^2 \doteq 0,16$ MPa

Time required to empty a tank of 160 m^3 is assumed to be 30 minutes → 320 m^3/h

Air compressor 320 m^3/h @ 0,2 MPa effective pressure over pressure ≙ 0,3 MPa abs.

equals $\frac{3 \times 320 \times 1000}{60 \times 60} = 266$ l/s @ 0,1 MPa abs.

Due to strength of buoyancy chambers set max overpressure at 0,13 MPa

Screw compressor Atlas Copco ZE-3 - 55 kW

Opgesteld :	Datum :	Bladnummer :	Rev. :
W Lock	19-01-04	1	

Low Pressure, Oil-free Air is Vital for your Process

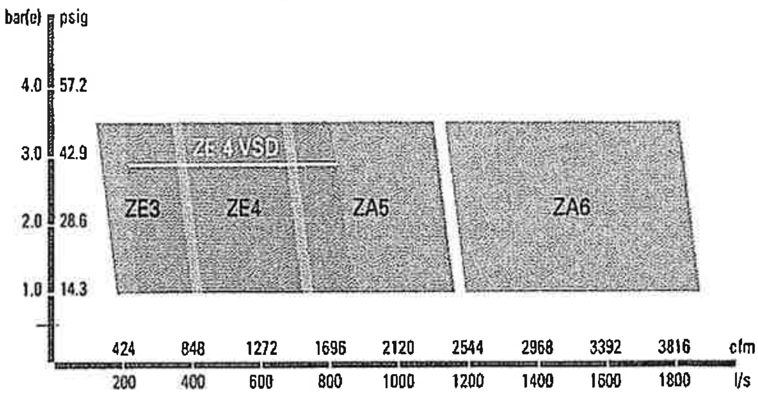
ISO 14001
Atlas Copco's Environmental Management System forms an integral part of each business process.

ISO 9001
From design to production and delivery, Atlas Copco compressors adhere to the ISO 9001 quality standard.

Low pressure compressed air is often a vital ingredient in your production process. It is a means to an end, yet so vital that you cannot run the risk of product contamination, disturbing pulsations, performance degradation, or even worse, a production standstill. Through interaction with customers just like you, Atlas Copco has made the ZE/ZA range the ideal compressor choice for low pressure applications such as powder and bulk handling, mixing of materials, aeration, air separation, fermentation, cooling and drying processes.

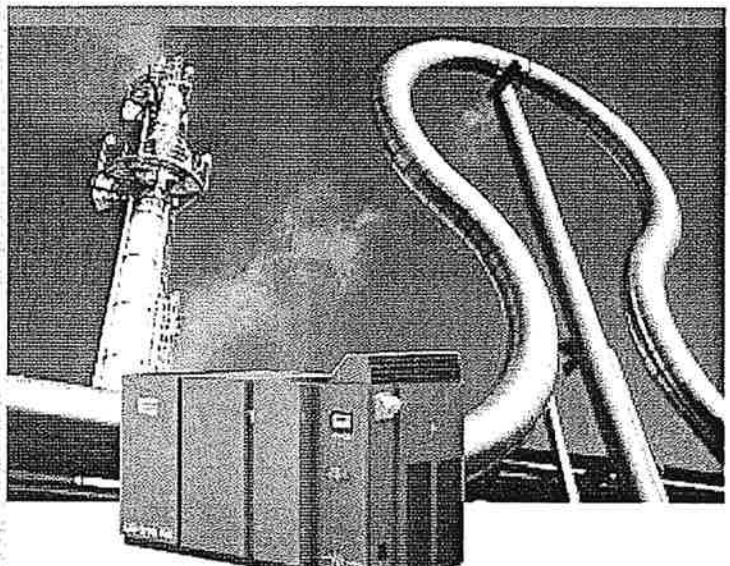
bar(e) = effective pressure

Operating range – ZE/ZA 3-6 / ZE 4 VSD – 50 Hz & 60 Hz



ZE: Aircooled / ZA: Watercooled
VSD: Variable Speed Drive
See data pages for range details.

ZE/ZA 3-6 Series – Any Pressure, Any Flow – In One Neat Package



ZE/ZA 3-6 – Facts

- ☐ Completely oil-free air – no risk of oil contamination
- ☐ Complete, ready-to-use package
- ☐ Water and aircooled versions
- ☐ Designed for easy integration of accessories
- ☐ Designed for easy integration into other systems using compressed air
- ☐ Wide range of pressure & capacity variants and gear ratios
- ☐ Guaranteed performance – ISO1217, Annex C, Ed. 3
- ☐ High efficiency, direct-driven IP55 motor
- ☐ Advanced control and monitoring – Elektronikon® regulation
- ☐ Variable Speed Drive (VSD) variant – optimal process stability
- ☐ Secure operation under all circumstances
- ☐ Durable quality components
- ☐ Low sensivity to dusty environments
- ☐ Proven, standard Atlas Copco product
- ☐ Backed by a global sales & service organisation

☑ The oil-free low pressure ZE/ZA3-6 compressor range gives you all this, and much more. The back-up of an organisation that truly understands what air compression is about. After all, we have over a century of learning behind us. Close interaction, innovation and commitment – the benchmarks that earned Atlas Copco the industry leadership and a high customer loyalty.

ZE 4 VSD

Variable Speed Drive variant for optimal process stability and the lowest cost compressed air.

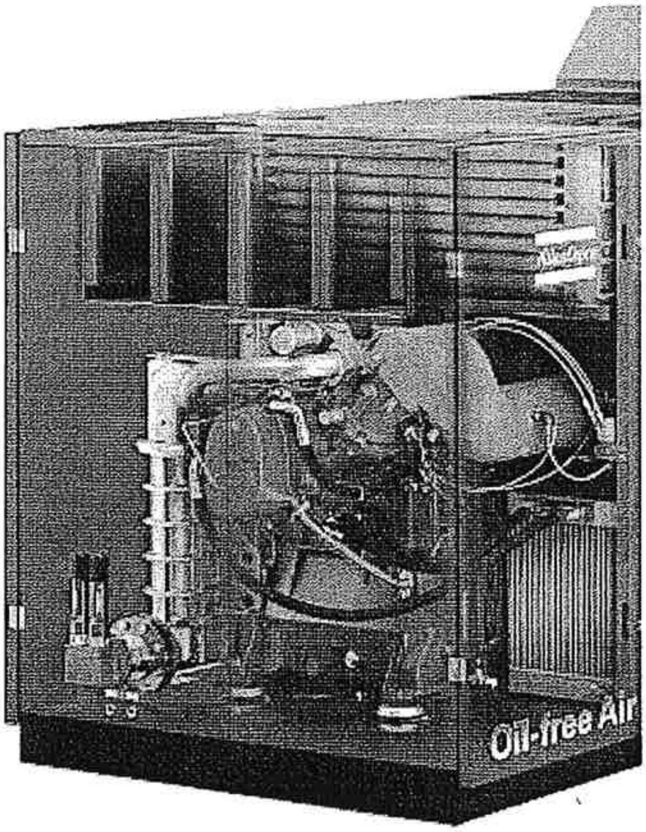
ZE/ZA – Complete Scope – No Costly Additions

As standard included

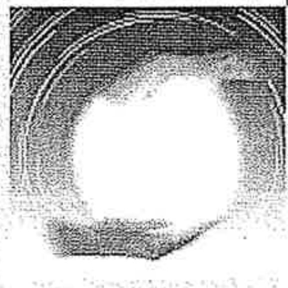
- ☑ Air intake filter and silencer
- ☑ Air intake flexible
- ☑ Outlet air silencer
- ☑ Discharge expansion joints
- ☑ Outlet air flange
- ☑ Complete water circuit
- ☑ Single point inlet and outlet connections
- ☑ Back-flush arrangement for cooler cleaning
- ☑ Check valve
- ☑ Safety valve
- ☑ IP55 water & dust proof motor
- ☑ Built-in starter
- ☑ Oil filled at delivery
- ☑ Complete oil circuit pre-piped
- ☑ Built-in oil breather system
- ☑ AGMA class 13 ; DIN class 5 gears
- ☑ Pre-mounted electric motor
- ☑ Pre-mounted electrical cubicle
- ☑ Silencing canopy (standard version)
- ☑ Skid with no need of foundations
- ☑ Vibration absorbing outlet
- ☑ Full load / no load regulator
- ☑ Integral blow off
- ☑ Coated rotors
- ☑ Elektronikon* control and monitoring system

Excellence by design

- ▸ Silenced units to work at any location
  - flexible, vibration-free compressor mounting
  - silencing canopy protects against noise emissions (beyond CE directives and US OSHA standards)
- ▸ Easy, low cost installation
  - no foundations, no bolting required
  - compact and complete unit – put in place and connect
- ▸ Designed for easy integration of additional components to suit particular application needs
- ▸ Advanced Elektronikon* control and monitoring system



ZE/ZA – A Ready-to-use Solution



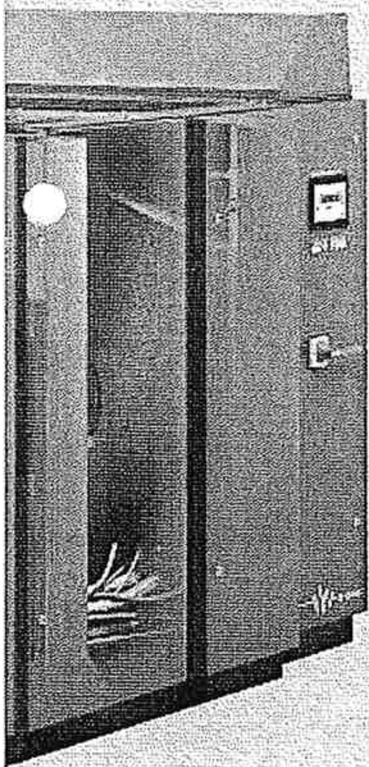
Global Presence

Local Service

- Service Worldwide
- Service friendly
  - Easy access for quick routine service
  - Due service predicted on Elektronikon® control panel

Caring for energy

- ZE 4VSD - Variable Speed Drive variant for the lowest cost compressed air
- Reduced internal pressure drops through integrated design
- Power saving cooling system
- Energy-less MD adsorption dryer



Standard Options

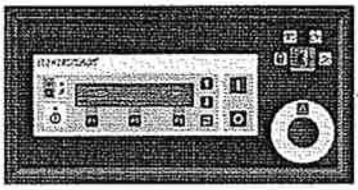
	ZE 3-4	ZA 5-6	ZE 4 VSD
Thermistors	•	•	n.r.
Anti-Condensation Heaters	•	•	•
PT100 Motor Thermal Protection	•	•	n.r.
Central Controller Communication Module COM1	•	•	st.
MODBUS Communication Module	•	•	st.
PROFIBUS Communication Module	•	•	•
Heavy-Duty Inlet Filter	n.a.	•	n.a.
ANSI Flanges	•	•	•
ASME Approval	n.r.	•	n.r.
DIR Approval	n.r.	•	n.r.
Automatic Water Shut-off	•	•	n.a.
Integrated Stainless Steel Aftercooler	•	•	st.
Separate Stainless Steel Aftercooler	•	n.a.	•
Watercooled Variant	•	st.	n.a.
Excluding Canopy	•	•	n.a.
Excluding Motor	•	•	n.a.
Excluding Full load / No load Regulator	•	•	n.a.
Canopy Extension for High Voltage Motor	n.a.	•	n.a.
Anchor Pads	•	•	•
Seaworthy Packaging	•	•	•
Witness Performance Test	•	•	•
Performance Test Certificate	•	•	•
SPM bearing monitoring	•	•	•

n.r.: not required
st.: standard
n.a.: not available

ZE/ZA – Proven Low Pressure Air Technology

Easy supervision and total reliable monitoring

Advanced Elektronikon® control and monitoring system with text display on the status of the entire system performance. It is designed for integration into processes with remote controls.

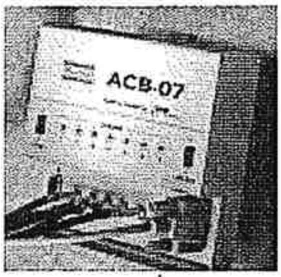


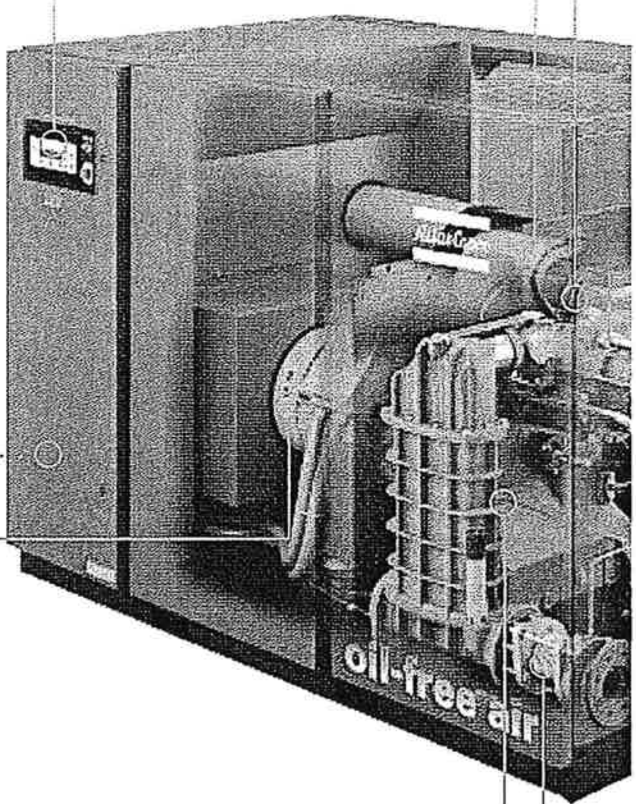
System integrity safeguarded

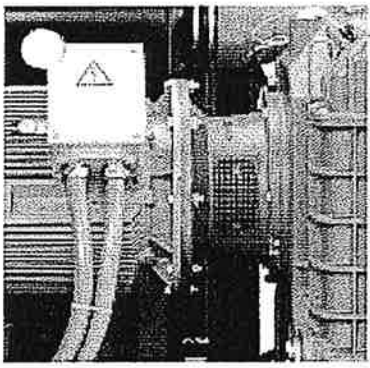
High efficiency air intake filters prevent dust damage and cut power consumption costs. Filter selection is based on internal compressor protection and reduction of pressure drop at the intake. Approved 99.5% for 1 micron particles.

Bearing condition monitoring

Motor and element bearing condition for pro-active service indications via the optional SPM monitoring box



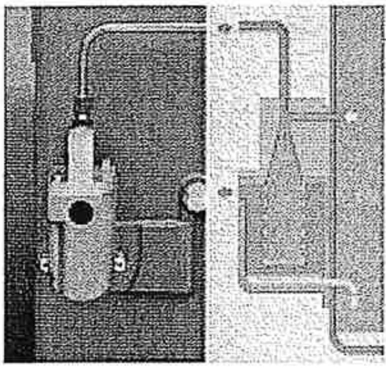




Ambient motor protection

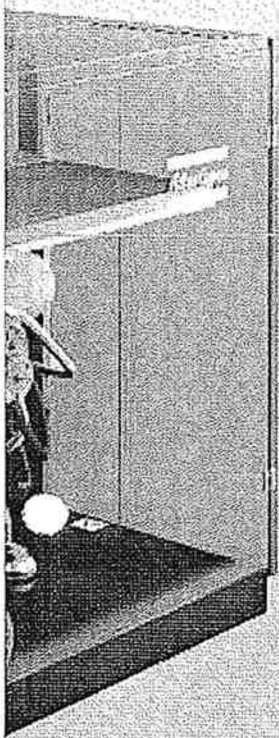
Direct drive efficiency

The IP55 high efficiency motor protects against dusty, humid ambients. It is directly coupled to the compression element for the best energy balance and permanent alignment.



Unique gearbox breathing system avoids compressor contamination

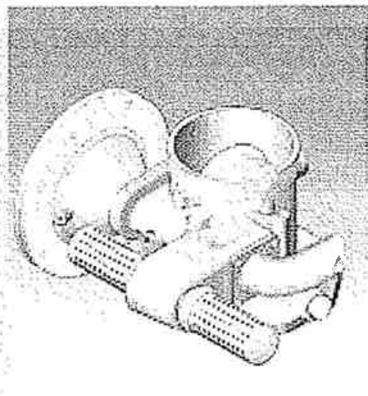
Oil and oil fumes remain where they belong: in the gearbox. Internal pressure build-up is prevented. Without any moving component, air and oil are separated mechanically.

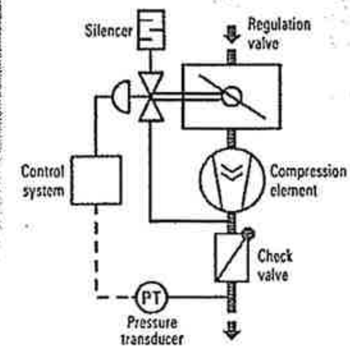


Designed to economically adapt to air demand

For processes with varying air demand, the full load / no load regulation system controls air production to best match air requirement.

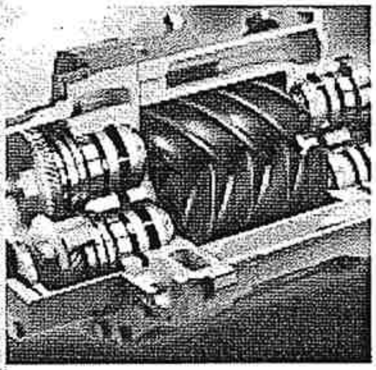
The regulator operates either at 100 % capacity (fully open) or 0 % capacity, using less power than a conventional blow-off system.

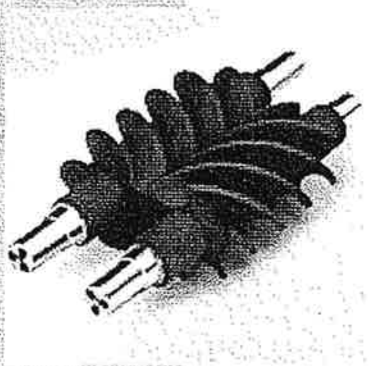




Liquid cooled compression elements for highest efficiency

Unlike aircooled elements, liquid cooling jackets ensure an even spread of heat over the compression elements, reducing material tension, maintaining clearance control and extending the bearing lifetime.





Secure compressor start under all circumstances

Atlas Copco rotor elements are coated with a unique carbon/Teflon mixture to eliminate corrosion or motor blocking after stand still. This allows for operation at 3.5 bar in high temperature conditions.

Stress absorbing, stainless steel air outlet connection for safe operation

Technical data ZE 3 series - 50 Hz

Aircooled low pressure oil-free air compressors

Pressure bar(e)			A	B	C	D	E	F	G	H	I	J	K	L	M
	Gear designation		A	B	C	D	E	F	G	H	I	J	K	L	M
	Unloaded power	kW	15	16	17	19	20	21	23	24	25	27	29	31	33
	Sound pressure level **														
	at max 2 bar	dB(A)		74	74	74	74	74	74	74	74	74	75	75	75
	at max 3.5 bar	dB(A)	76	76	76	76	76	76	76	76	76	76	77	77	
1.00	Free Air Delivery*	l/s		160	176	194	214	229	245	263	283	305	330	357	387
		cfm		340	374	412	454	486	520	558	601	648	701	758	822
	Outlet temperature	°C		102	103	104	105	106	107	107	108	109	110	112	114
	Shaft power	kW		26.0	28.2	30.6	33.5	35.6	38.0	40.7	43.8	47.2	51.1	55.6	60.8
	Motor size	kW		30	30	37	37	45	45	55	55	75	75	75	75
1.25	Free Air Delivery*	l/s		159	175	193	213	228	244	262	282	303	328	355	385
		cfm		338	372	410	452	484	518	556	599	643	696	754	817
	Outlet temperature	°C		114	115	115	116	117	118	118	119	119	120	121	123
	Shaft power	kW		26.9	29.1	31.6	34.5	36.7	39.2	41.9	45.0	48.5	52.4	57.0	62.2
	Motor size	kW		30	30	37	37	45	45	55	55	75	75	75	75
1.50	Free Air Delivery*	l/s		157	173	191	211	226	242	260	280	301	325	352	383
		cfm		333	367	406	448	480	514	552	594	639	690	747	813
	Outlet temperature	°C		128	128	128	128	128	129	130	130	130	131	132	134
	Shaft power	kW		28.4	30.7	33.3	36.3	38.6	41.2	44.1	47.3	50.9	55.0	59.7	65.1
	Motor size	kW		30	37	37	37	45	45	55	55	75	75	75	75
1.75	Free Air Delivery*	l/s		155	171	189	209	224	240	258	277	299	323	350	380
		cfm		329	363	401	444	476	510	548	588	635	686	743	807
	Outlet temperature	°C		141	140	140	139	138	138	138	139	139	141	142	142
	Shaft power	kW		30.3	32.7	35.5	38.8	41.2	43.9	46.9	50.3	54.1	58.5	63.4	69.1
	Motor size	kW		30	37	37	45	45	45	55	55	75	75	75	75
2.00	Free Air Delivery*	l/s		153	169	187	207	221	238	255	275	296	320	347	377
		cfm		325	359	397	439	469	505	541	584	628	679	737	800
	Outlet temperature	°C		154	153	152	152	151	151	150	149	149	150	152	155
	Shaft power	kW		32.5	35.2	38.2	41.6	44.2	47.1	50.3	53.9	58.0	62.6	67.8	73.9
	Motor size	kW		37	37	45	45	45	55	55	55	75	75	75	75
2.25	Free Air Delivery*	l/s	133	152	167	185	205	219	235	253	272	294	318	344	
		cfm	282	323	355	393	435	465	499	537	577	624	675	730	
	Outlet temperature	°C	168	165	164	162	161	161	161	161	162	162	164	166	
	Shaft power	kW	31.8	35.0	37.8	41.1	44.8	47.6	50.7	54.1	58.0	62.3	67.2	72.8	
	Motor size	kW	37	37	45	45	45	55	55	55	75	75	75	75	
2.50	Free Air Delivery*	l/s	132	150	166	183	203	218	234	251	270	292	315	342	
		cfm	280	318	352	389	431	463	497	533	573	620	669	726	
	Outlet temperature	°C	185	182	180	177	176	174	174	173	173	173	174	176	
	Shaft power	kW	34.1	37.6	40.7	44.1	48.1	51.1	54.4	58.1	62.2	66.9	72.1	78.1	
	Motor size	kW	37	45	45	45	55	55	55	75	75	75	75	90	
2.75	Free Air Delivery*	l/s	131	149	165	182	202	216	232	250	269	290	313	340	
		cfm	278	316	350	386	429	459	493	531	571	616	665	722	
	Outlet temperature	°C	195	192	190	189	187	186	185	184	184	183	184	186	
	Shaft power	kW	36.5	40.3	43.6	47.3	51.5	54.7	58.2	62.2	66.6	71.5	77.0	83.4	
	Motor size	kW	45	45	45	55	55	55	75	75	75	75	90	90	
3.00	Free Air Delivery*	l/s	130	148	164	181	201	215	231	248	267	288	312	338	
		cfm	276	314	348	384	427	456	490	527	567	611	662	718	
	Outlet temperature	°C	207	205	203	202	201	200	199	198	198	198	198	198	
	Shaft power	kW	38.9	42.9	46.3	50.3	54.8	58.1	61.9	66.0	70.7	75.9	81.7	88.4	
	Motor size	kW	45	45	55	55	55	75	75	75	75	90	90	90	
3.25	Free Air Delivery*	l/s	129	147	163	180	199	214	230	247	266	287	310	337	
		cfm	274	312	346	382	423	454	488	524	565	609	658	715	
	Outlet temperature	°C	221	218	216	214	212	211	210	208	208	208	208	208	
	Shaft power	kW	41.0	45.2	48.8	52.9	57.6	61.2	65.1	69.4	74.3	79.7	85.8	92.7	
	Motor size	kW	45	45	55	55	75	75	75	75	75	90	90	110	
3.50	Free Air Delivery*	l/s	128	146	161	179	198	213	228	246	265	286	309	335	
		cfm	272	310	342	380	420	452	484	522	563	607	656	711	
	Outlet temperature	°C	233	231	229	227	225	224	223	222	221	219	219	219	
	Shaft power	kW	42.6	47.0	50.8	55.0	59.9	63.6	67.6	72.1	77.0	82.6	88.9	96.0	
	Motor size	kW	45	55	55	75	75	75	75	75	90	90	90	110	

* Reference conditions
- Dry air
- Absolute intake pressure 1 bar (a)
- Cooling and intake air temperature 20 °C
- Capacity of the compressor package measured according to ISO1217, Third edition, Annex C

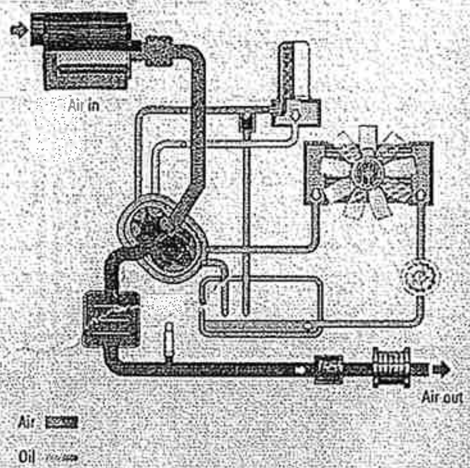
** ± 3 dB(A) according to Pneurop PN 8 NTC 2.2 test code measured at a distance of 1 m, excluding aftercooler

Dimensions mm	ZE
Length	2780
Width	1750
Height	1990

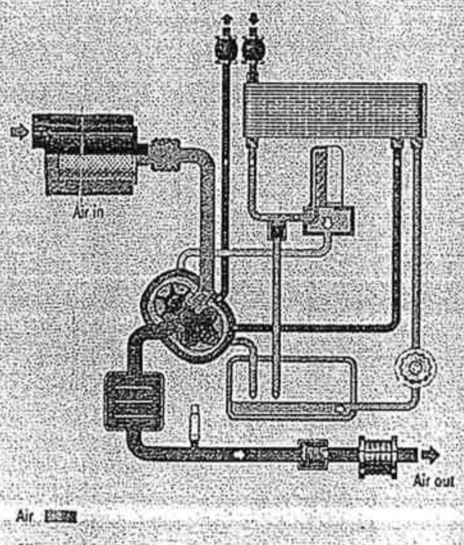
Air/oil/cooling flows

ZE/ZA – pre-engineered for full integration

Aircooled low pressure ZE compressor



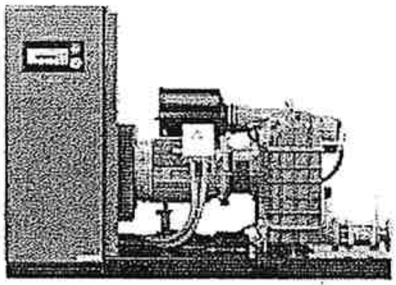
Watercooled low pressure ZA compressor



Variants for tailored applications

With the ZE-ZA range specific applications' needs are anticipated. The ability to add optional or remove standard equipment is incorporated.

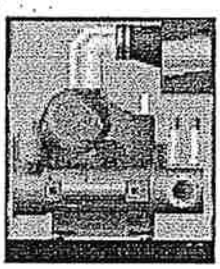
Full scope non-silenced version



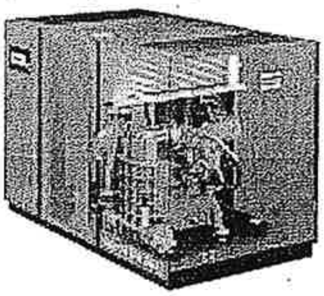
Non-silenced ZE3

- When noise levels are less critical
- A standard option

Designed to easily add an aftercooler



ZA5 with watercooled aftercooler incorporated



ZE3 with aircooled aftercooler incorporated

- Pre-engineered for cost-saving installation
- Pressure drop risks are avoided
- Time saving & adequate selection
- A standard option