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2

2.1 List of formulae

Abbr.	Designation	Measuring unit	Formula
$\varphi^{(\bullet)}$	Lead angle Self-locking during shutdown*: 2,4° < φ < 4,5° (Self-locking out of actuation: φ < 2,4°) Not self-locking: φ > 4,5°	°	$\varphi=\arctan[P_h/(d_2*\pi)]$
η_{Anl}	Lifting system efficiency rating		
η_{HE}	Worm gear screw jack efficiency rating		
a	Acceleration	m/s^2	a =v / (60*t)
As	Number of load cycles		
C	Dynamic load rating	kN	
C_o	Static load rating	kN	
d_2	Pitch diameter	mm	
ED	Duty ratio	%/hr	ED = [lift*As/(60*v)]*100%
F_{dyn}	Dynamic axial force (= lifting force)	kN	
F_{stat}	Static axial force (= retention force)	kN	
HU	Lift per rotation	mm	HU= P_h / i
i	Transmission ratio		
L_h	Service life	h	$Lh=(C/F_{dyn})^3*10^6/(n_2*60)$
n_1	Input speed	min^{-1}	
n_2	Output speed	min^{-2}	n_2 = n1 / i
P	Power rating	kW	$P= F_{dyn} * v / (60*\eta)$
Ph	Screw lead	mm	
pv-value	Surface pressure x sliding speed	N/mm^2 * m/min	
p_{zul}	Permitted surface pressure	N/mm^2	
t	Time	s	
T_1	Drive torque	Nm	T_1 = P*9550 / n_1
T_2	Output torque (= screw torque)	Nm	
T_A	Starting torque	Nm	T_A ~ T_1 * 1,3
v	Lifting speed	m/min	v = n_1 * Ph / i

$^{(\bullet)}$ Vibrations and optimized sliding properties may affect the self-locking system. If in doubt, use a motor brake.

Index

HE _____ Worm gear screw jack

Anl _____ Lifting system

Ku _____ Ball screw

Tr _____ Trapezoidal screw

zul _____ Permissible

Configuration conforming to EN 1570, EN 280, EN-1756, EN 1493 (VBG 14)

Lead angle:

2,4°< φ < 4,5° ⇨ Motor with single braking torque

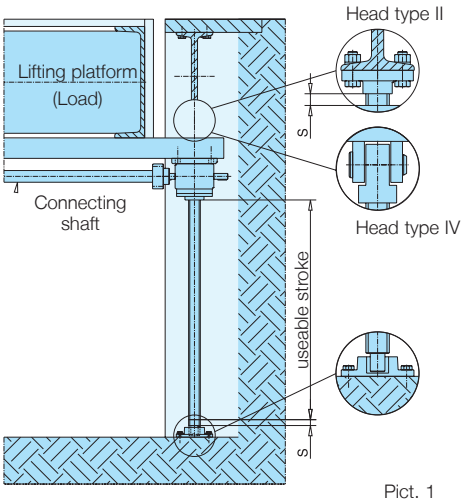
φ > 4,5° ⇨ Two independent braking systems

Standards for theatre stages and broadcasting studios BGV C1 (VBG 70)

Similar to configuration conforming to VBG 14, although self-locking screw is not an absolute requirement if all torque transmitting components are designed to withstand twice the rated load.

2.2 Suggestions for installation

2.2.1 Vertical installation

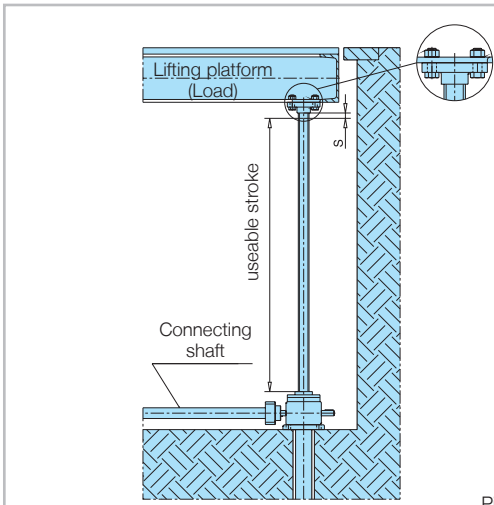


Pict. 1

Recommended arrangement for large lifting capacities and long screws

Tensile load

Design: Configuration type 1
With climbing screw jacks (without protection tube)

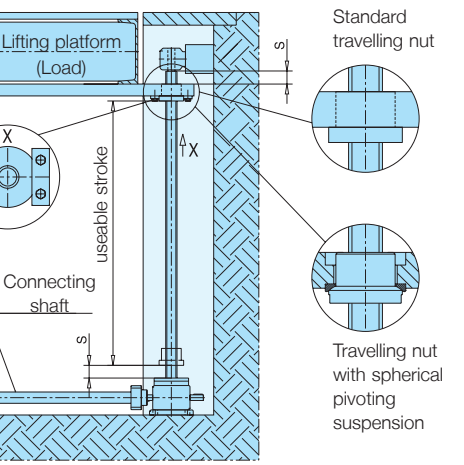


Pict. 2

Compression-loaded screws without lateral guides

Dimensioning of screw according to Euler's case I

Design: Configuration type 1
With lifting screw and protection tube

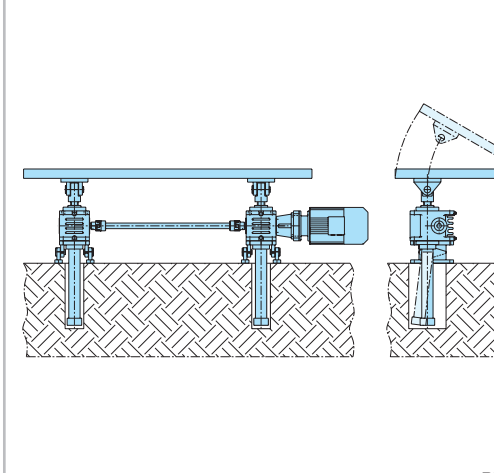


Pict. 3

Arrangement with compression-loaded screw, possible with or without additional guides

Dimensioning of screw according to Euler's case III and critical screw speed

Design: Configuration type 2
With rotating screw and travelling nut



Pict. 4

Swivelling movements require articulated mounting

Dimensioning of screw according to Euler's case II

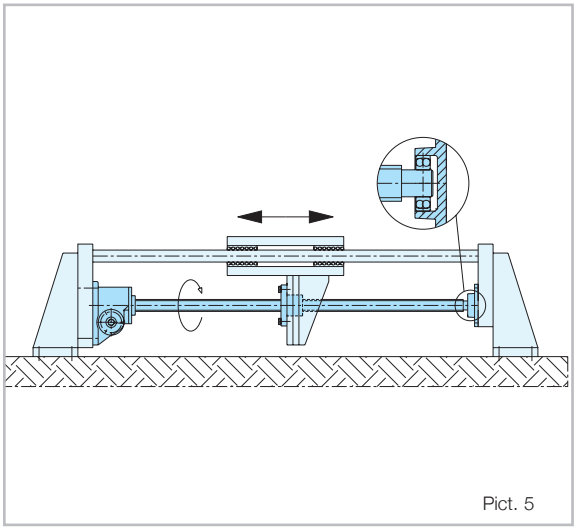
Design: Configuration type 1
With lifting screw, two guide rings and protection tube

S = safety clearance
See chapter 7 "Accessories" for details of all required add-on items (connecting flanges, swivel mounting bases etc.).

2

2.2 Suggestions for installation

2.2.2 Horizontal installation



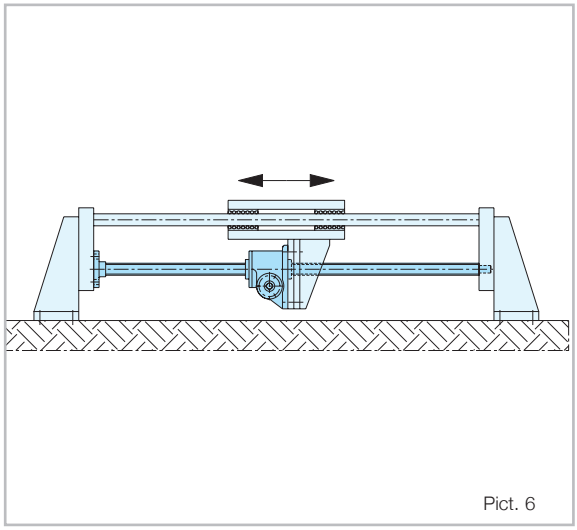
Pict. 5

Arrangement with compression- and tension-force-loaded screw
With guides supplied on site

Dimensioning of screw according to Euler's case III and critical screw speed

With screws pre-adjusted to tensile load ⇨
Dimensioning according to critical speed only

Design: Configuration type 2
With rotating screw and travelling nut

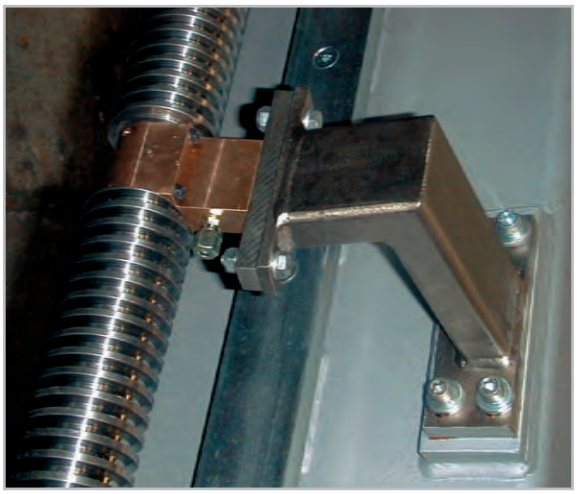


Pict. 6

Arrangement with compression- and tension-force-loaded screw
With guides supplied on site

Dimensioning of screw according to Euler's case II, if screw retaining force is insufficient. Otherwise, apply Euler's case III

Design: Configuration type 1
With clamped screw and linear traversing drive axis.



Intermediate bearing-support of a 12 m screw

Pict. 7

Standard once-piece screws can be made in lengths of up to 6 m (3 m for screws made of rust-free material). Longer screws are supplied in sections to make installation on site easier.

Special travelling nut

Pict. 8

If critical screw speed is exceeded (only applies to configuration type 2 = rotating screw), the screws must be adequately supported. This requires the use of our specially-supplied intermediate bearings and travelling nuts (see photos).

2.3 Service life L_h

The design and construction of Pfaff-silberblau worm gear screw and quick-lifting jacks are based on our long years of experience in the field and they have a long service life if the instructions in the operating manuals are observed.

Screw		Gearing layout	Bearing layout
Tr and S screw	**Ku ball screw**	**N or L**	**Thrust and radial bearings**
• These values are for guidance only, as exact calculation is not possible • Decisive layout factors are surface pressure and sliding speed (pv-value, p_{zul}) • Guaranteed relubrication • Ideal installation	• Calculation: $L_h=(C/F_{dyn})^{3*}10^6/(n_2*60)$	**Worm-drive gearing:** • SHE standard worm screw jack and MERKUR: approximate values according to DIN3996-D • In the case of HSE high performance worm gear screw jack, according to DIN 3996-C **Bevel gear tooth system:** • SHG quick-lifting screw jacks, L_h = fatigue endurable	• Calculations according to DIN or data supplied by the bearing supplier

The maximum load values given in the catalogue data (tables of settings) are based on a service life of minimum 500 operating hours.

2.4 Guidelines for use

2.4.1 Dirt protection

- Leakproofing of all ranges by means of rotary lip seals fitted to drive shafts is standard
- Enclosed housing configuration on HSE und SHG ranges using additional seals
- Screw protection tube for type 1

Optional lifting screw protective covers:
- Flexible protection boots made of various materials to prevent entry of dirt and for outdoor use (water-proof)
- Spiral spring cover for use in extreme environment (flying swarf, welding sparks)

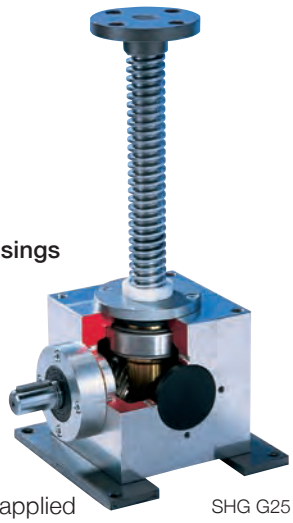
Special configurations:
Special configurations, e. g. for use under water or at high temperatures, are available on request

2.4.2 Corrosion protection

Corrosion protected aluminium housings fitted to the following ranges:

SHE	Size 0.5 and 1.1
MERKUR	Size M0, M1 and M2
HSE	Size 32 and 36.1
SHG	Size G25

Surface coating for all other sizes:
- SHE and HSE housings with series-applied prime coat
- MERKUR and SHG with phosphate coated housings



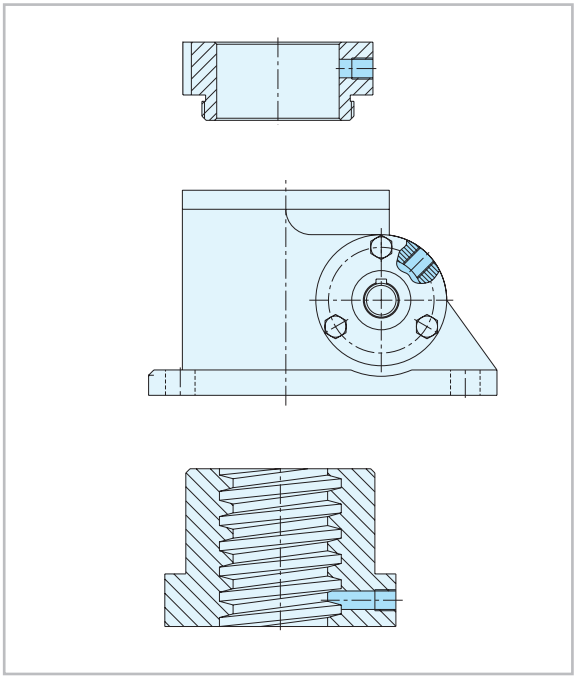
SHG G25 (aluminium housing)

Optional corrosion protection for special configurations:
Available for all ranges:
- Special coatings
- Screws and screw heads made of material 1.4305, 1.4301, 1.4571
- Worm-drive shafts made of rust-free material
- SHE range in completely rust-free material configuration

Corrosion protection provided by surface coatings:
Available for all ranges:
- Tenifer treated (salt-bath nitrided)
- Hard-chrome plated drive shafts

2

2.4 Guidelines for use



2.4.3 Items requiring regular lubrication

If access to the screw itself or the lubrication points on the housing is difficult, we recommend the use of a central lubrication system or automatic lubricant dispenser (see chapter 7.8). Our components can be supplied with the necessary screw-in connections for this purpose.

SHE and MERKUR range

Configuration	Lubrication point
Type 1	guide ring, protection tube, housing (gearing layout)
Type 2	travelling nut, housing (gearing layout)

HSE and SHG range

Configuration	Lubrication point
Type 1	guide ring, protection tube
Type 2	travelling nut

2.5 Ambient temperatures

Standard
- 10 °C + 40 °C

T < - 10 °C
- Special lubricants, max. - 30 °C
- Special materials (on request)

Note:
Please take our reduced performance or ED-(duty ratio) values into consideration if temperatures deviate from the standards given.

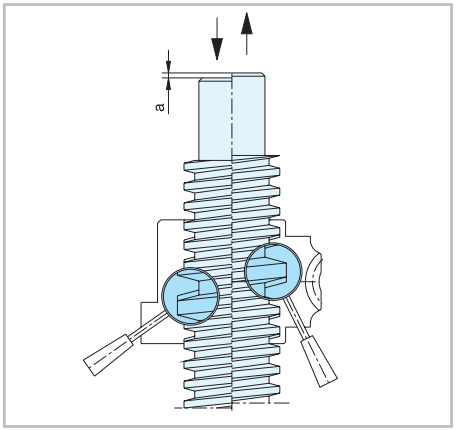
+ 40 °C < T ≤ 80 °C
- Special lubricants, max. + 80 °C
- Special measures T > 80 °C (on request)

2.6 Precision ratings

2.6.1 Axial play „a”

Axial play has no influence on positioning accuracy in the case of one-side load, as the flanks of the screw thread provide support.

Trapezoidal or buttress-thread screw	Ball screw
Standard 0,1 mm ≤ a ≤ 0,3 mm, depending on size	Single flange nut a ≤ 0,05 mm
Modified configuration: Axial play can be readjusted	Initial tension depending on size of ball 0,01 mm ≤ a ≤ 0,03 mm Pre-stressed double nut a ≤ 0,01 mm



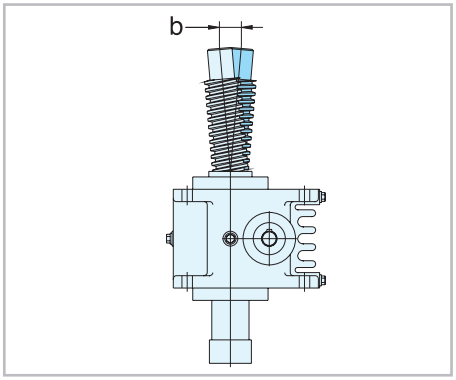
2.6.2 Lateral play „b”

Standard

Lateral play „b” occurs only in the case of type 1, as a result of play between the guide ring and the outer diameter of the screw. It comes up to about 0,2 mm and effects a linear calculative deviation „b“ depending on stroke length. The amount of play „b” can be reduced by means of a second guide ring.

Special configuration

2nd guide ring with reduced play and additionally ground screw material.



2.6.3 Tooth profile play

Worm gear
tooth configuration

The tooth profile play (when new) of 0,1 – 0,3 mm varies, depending on the size of the unit resp. centre distance of shaft to wheel, with the rate of wear.

Bevel gear
tooth configuration

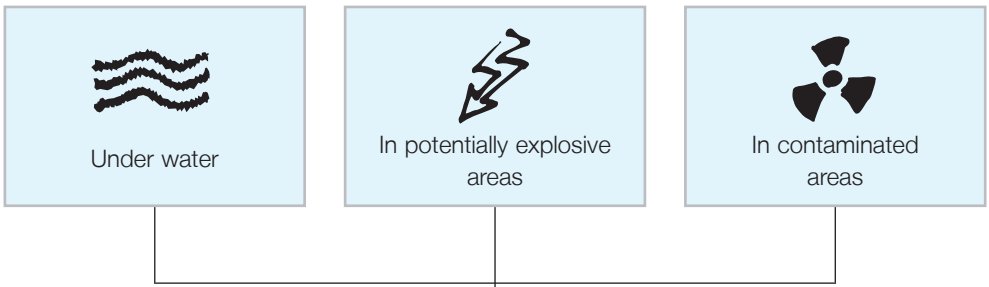
Tooth profile play of 0,05 – 0,1 mm kept constant throughout service life of unit.

2.6.4 Screw lead error

Trapezoidal screw thread conforming to DIN 103 T1; Buttress screw thread conforming to DIN 513		Ball screw thread conforming to DIN 69051T3
Whirled screw (standard) ± 0,05 mm		**Whirled screw (standard)** Tolerance classification T7; P300 = 0,052 mm
Rolled screw ± 0,1 mm		Ground screw; tolerance classification T1 - 5; P300 = 0,006 - 0,023 mm
		Rolled screw; tolerance classification T9; P300 = 0,1 mm

2

2.7 Special operating areas of application



Worm gear screw jacks and lifting systems in **special configuration**

- Special sealing with non-toxic lubricants
- Corrosion protection (rust-free materials)
- Travelling nuts made of self-lubricating material

- Worm gear screw jacks according to EC Directive 94/9/EC ATEX in equipment group II - Zone 1/21 (2/22) with c/k/b protection and temperature class T_1 and T_4
- Use of approved electrical components, such as motors, limit switches, pressure-resistant sealed brake units conforming to the corresponding type of protection and temperature class

e. g. use of approved materials with inspection certificate pursuant to DIN EN 10204 2.2-3.1 B-3.1 C

- Greasing with radiation resistant lubricants
- Earthquake proof configuration

We have many years of experience in the area of special applications for linear actuator technology, and can offer the following services:

- Project planning
- Design support
- Material testing and certification
- Supervision of installation procedures and initial start-up
- Project-related documentation

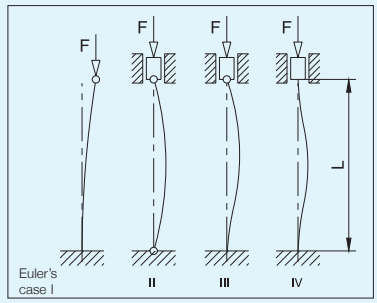
2.8 Dimensioning of worm gear screw jacks

2.8.1 Flow diagram

Axial force [kN]
F_{dyn} dynamic force
F_{stat} static force (retention force)
Lifting speed v [m/min]
Stroke [mm]
Determine configuration
(type 1 or type 2)

Dimensioning of screw according to load direction

Compression load



Screw diameter as displayed in chapter 3.4.2
Note: A reinforced screw diameter can be used for type 2 jacks (rotating screws)

Tensile load

Determine duty ratio ED [%/h]; determine power rating P [kW] (see formulae collection in chapter 2.1)

Technical information
See chapter 3

For example:
Efficiency ratings and performance tables

Pre-selection depends on performance limits of screw jack and diameter of screw.
Tables of settings, chapter 3.4.1

Are additional conditions to be observed?

- Extraordinary operating conditions
- Shocks/Strokes
- Lateral loads
- Duty ratio > 20 %/h
- Standards to be observed, e. g. VBG14 (elevating platforms), BGV C1 (theatre stages and broadcasting studios)

Yes

Check
according to chapter
2 Project planning
3.1 Construction support

or consult our screw jack specialists

Hotline:
Phone +49 / 8233 / 2121-4100
antriebstechnik@cmco.eu

No

Selected gear size can be applied

2.8 Dimensioning of worm gear screw jacks

2.8.2 Example

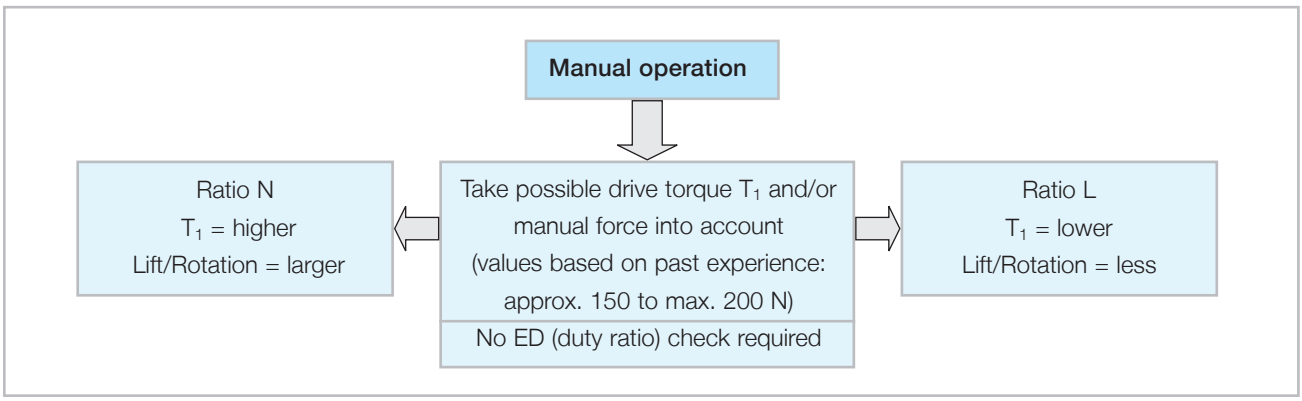
Single drive unit with motor

Required axial force F_{dyn} ____ 20 kN
Required lifting speed v ____ 1,9 m/min
Required lift ____ 1200 mm
Selected configuration ____ See chapter 3.2

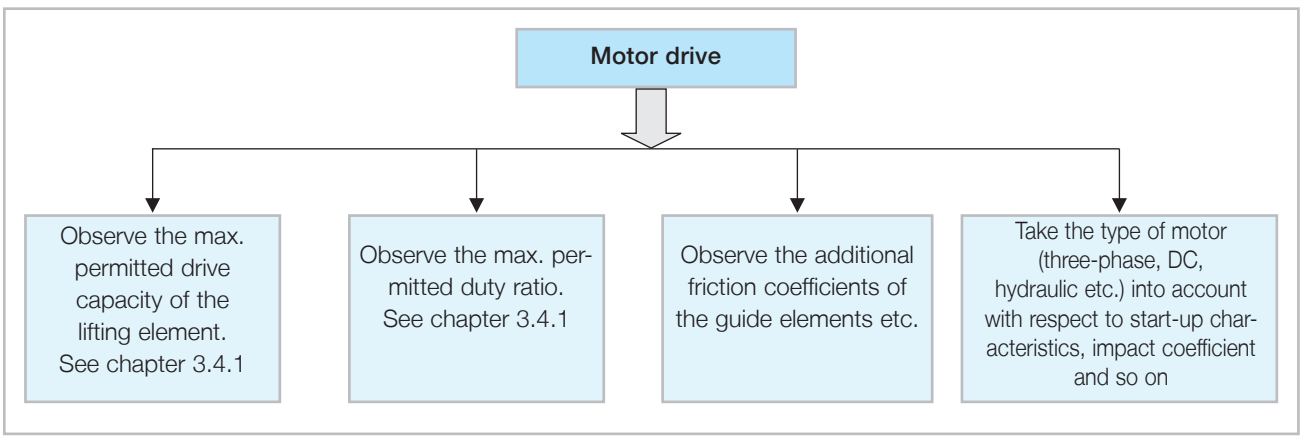
Guides fitted on site ____ Yes ⇨
Euler's case III
Load cycles/hour ____ 10
Travel per load cycle ____ 1200 mm
Configuration type 1 (lifting screw)

Screw	From buckling diagram	Tr 50x9	
Pre-selection of worm gear screw jack	Chapter 3.4.1	HSE 63.1	
Required drive performance	2,0 kW	Performance limit according to table of settings, chapt. 3.4.1	Perf < p_{zul} = 2,3 kW
Duty ratio	11%/h	For formula, see chapt. 2.1	ED_{vorh} < ED_{zul} = 20%/h
Selected motor	2,2 kW, 1500 min^{-1}		
Selected size HSE 63.1 is ok			

2.8.3 Manual operation for lifting elements



2.8.4 Motor drive for lifting elements



Motor designs:

Required starting torque	**T_A ~ 1,3 x T_N**
High lifting speeds, e. g. servo drive system	⇨ Inertial mass and acceleration time are decisive factors for configuration

2.8 Dimensioning of worm gear screw jacks

2.8.5 Adjustment and stopping accuracy

The level of adjustment accuracy depends mainly on the precision of the screw (see chapter 2.6). Positioning accuracy is influenced, in the case of motor-actuated units, by the electrical control and regulating system, the control system of the brake, and by the adjustment precision of the limit switches.

IMPORTANT: DO NOT allow motor-actuated components to collide with fixed end-limit stops!

2.9 Permitted operating settings

2.9.1 General

Lateral force on screw
F_s

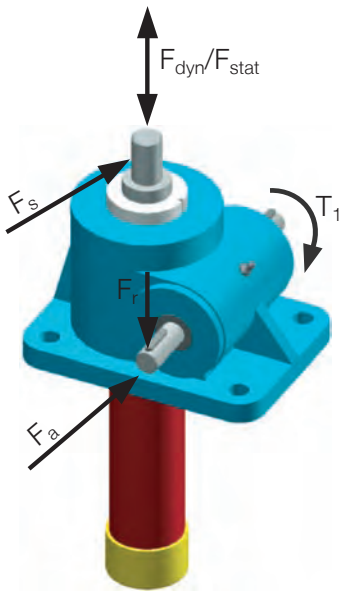
For details of permitted values, see diagrams in chapter 3.4.8

Drive capacity
$P_{HE} < p_{zul}$

$P_{HE} = F_{dyn} * v/(60 * \eta_{HE})$
For calculation details, see chapter 2.1
Standard layout at 20 % ED/hour and 20 °C, or 10 % ED/hour and 20 °C

Drive torque
$T_1 < T_{zul}$

$T_1 = P_{HE} * 9550/n_1$
For calculation details, see chapter 2.1



Dynamic and static compression/tensile load
F_{dyn}/F_{stat}

Configuration according to table of settings chapter 3.4.1 and/or buckling diagrams in chapter 3.4.2

Axial load on drive shaft
F_a

No axial loads permitted
(This should also be taken into account when fitting couplings and connecting shafts)

Radial load on drive shaft
F_r

For details of permitted values, see chapter 3.4.9

2.9 Permitted operating settings

2.9.2 Operating factors

Standard worm gear screw jacks SHE and MERKUR

Reduction of ED relative to ambient temperature

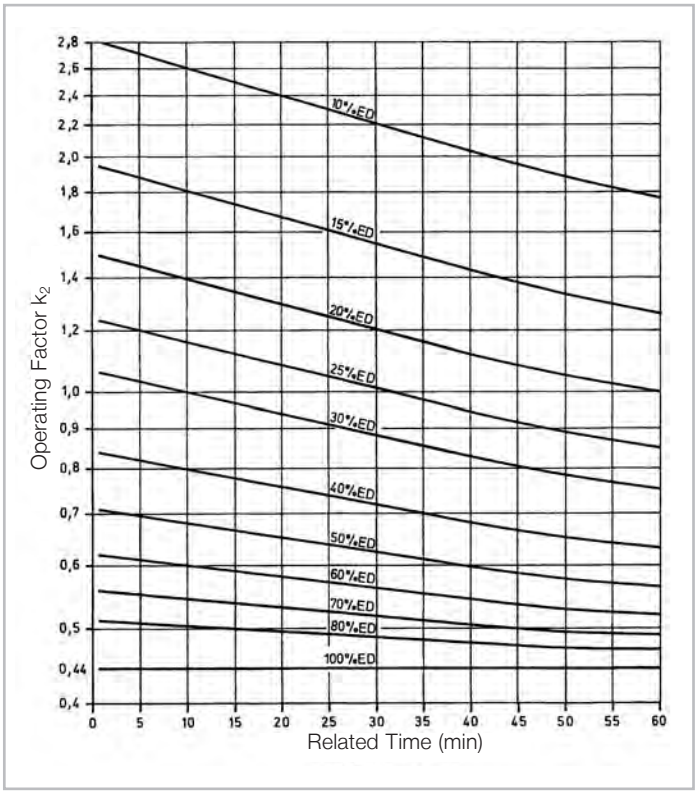
2

Ambient temperature [°C]		50 °	60 °	70 °	80 °
in the case of screw jacks SHE and MERKUR					
Maximum permitted duty ratio	%/h	18	15	10	5
	%/10 min	36	30	20	10
CAUTION: Maximum operating temperature HE = 80 °C					

High performance worm gear screw jack HSE

Size HSE	32	36.1	50.1	63.1	80.1
Power factor k_1 [kW]	0,40	0,64	1,0	1,62	2,43

Size HSE	100.1	125.1	200.1
Power factor k_1 [kW]	3,30	5,41	13,30



Power factor k_1

Power factor k_1 is the lost energy (quantity of heat) that can be dissipated at ED 20 %/h and 20 °C ambient temperature of HSE without an outside cooling system. The steady-state temperature in this case is 80 °C.

$$p_{zul} = k_1 * k_2 * k_3 / (1 - \eta_{HE})$$

Duty factor k_2

The duty factor k_2 is the correction value used to increase or decrease the permitted drive capacity p_{zul} with a deviation of 20 % ED/h. At 20 % ED/h or 30 % ED/10 min is $k_2 = 1$.

If the duty ratio deviates from the established settings, k_2 can be determined using the diagram shown here.

Temperature factor k_3

At normal temperatures of 20 °C, this factor is 1.

In the event of fluctuating ambient temperatures (= ϑ), this factor is calculated as follows:

$$k_3 = \frac{80 - \vartheta}{60}$$

Power factors k_1, k_2 and k_3 apply specifically to HSE high performance worm gear screw jacks. They must not be applied to standard worm gear screw jacks, Merkur systems or quick-lifting screw jacks.

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2.10 Dimensioning of lifting systems

2.10.1 Flow diagram

Overall force [F_{ges}] of the system [kN]
Lifting speed
Select schematic drive-system layout (chapter 2.11)
Number and arrangement of screw jacks, type of motor, connecting shafts, bevel gear boxes, couplings

$$P_{Anl} = \frac{Fges^{*}\ v}{60^{*}\eta_{HE}{}^{*}\eta_{Anl}}$$

$$T_{Anl} = \frac{P_{Anl}{}^{*}\ 9550}{n_1}$$

η_{Anl} ~ 0,8
η_{HE} as shown in chapter 3.4.1 or 3.4.5

$$P_{HE} = \frac{P_{Anl}{}^{*}\ 1,3}{\text{Number of screw jacks}}$$

Check screw jack as show in capter 2.9

*Factor for unequal load distribution = 1,3
Observe the maximum drive torque on drive shaft of screw jack

Determine type of motor according to P_{Anl}, turning speed, with/without brake, torque T_A

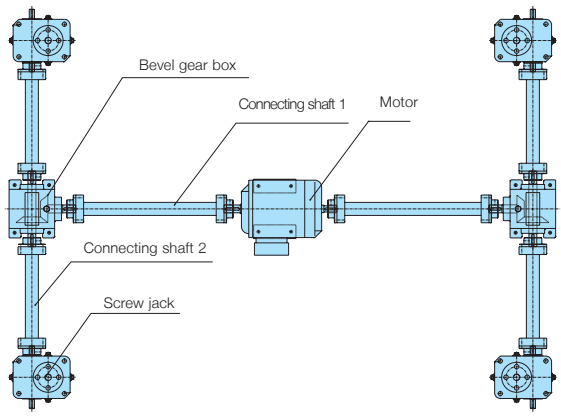
If non-self-locking lifting systems are in operation, fit the motor with a spring-actuated safety brake.

Configure bevel gear boxes, couplings, connecting shafts (according to torque and turning speed)

T_{Anl} = minimum nominal torque of motor
starting torque
T_A ~ $T_{Anl}{}^{*}$ 1,3

2.10.2 Example

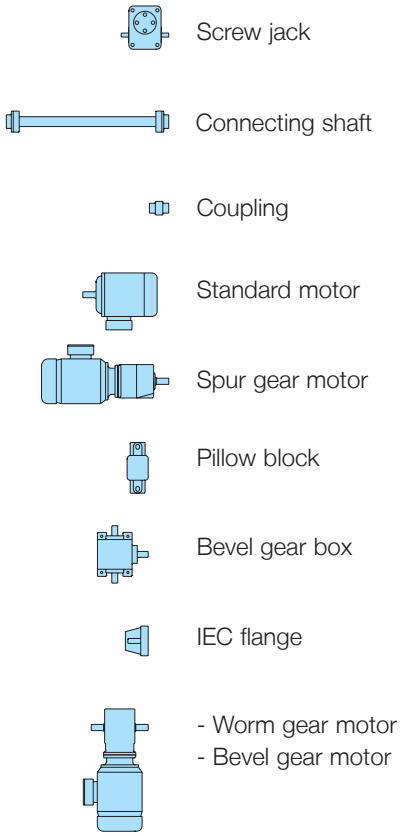
Technical specifications:
F_{ges} = 60 kN (dyn. and stat.)
v = 1,9 m/min
ED = 20 %/h
Schematic view 4.1
Three-phase motor
Bevel gear box i = 1:1



F_{HE} = 60 kN/4*1.3 F_{HE} = 19,5 kN	Pre-selection of screw jack according to chapter 2.8	⇨ HSE 63.1, Tr50x9, η_{HE} = 0,311; P_{HE} = 2,0 kW, η_{Anl} ~ 0,8
P_{Anl} = 7,63 kW	⇨ motor selection 7,5 kW, n_1 = 1500 min^{-1}	⇨ motor 132 M/4
T_{Anl} = 49 Nm	⇨ T_{Keg} = 25 Nm, i = 1:1 (chapter 4)	⇨ bevel gear box K 11.13
	T_{GW1} = 25 Nm, n_1 = 1500 min^{-1}; observe max. length according to n_{krit} (chapter 6)	⇨ connecting shaft ZR 28/38
	T_{GW2} = 12,5 Nm, n_1 = 1500 min^{-1}; observe max. length according to n_{krit} (chapter 6)	⇨ connecting shaft ZR 24/28

2.11 Schematic drive system layout

Symboles



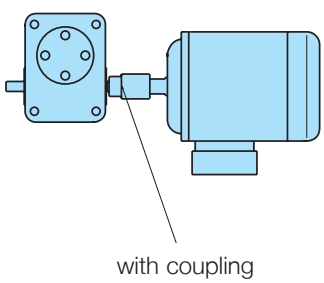
Pfaff-silberblau worm gear screw jacks and quick-lifting screw jacks can be used as either single drive units (see chapter 2.11.1) or multi-screw lifting systems (see chapter 2.11.2). Multi-screw lifting systems with mechanical synchronization are driven by a single motor, which makes them impervious to unequal load distribution and its negative effects on the synchronization of the screw jacks. Multi-screw lifting systems with electrical synchronization are distinguished by their low requirements in terms of mechanical connecting elements (and therefore lack of running noise), but they do require more sophisticated controls. Precise configuration of the drive motors, in conjunction with a master-slave layout, produces the corresponding exact synchronization of the drive systems.
Once you have decided on the best layout for your needs, you can establish which bevel gear boxes, couplings and connecting shafts are to be fitted. The fitting of pillow blocks can multiply the speed-dependent length of the connecting shafts.

Note:
If quick-lifting screw jacks are in use, correct configuration can eliminate the need for bevel gear boxes.

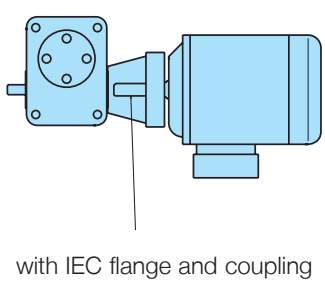
2.11.1 Single drive unit

Worm gear screw jack – coupling – motor in configuration B3 (base-mounted)

Schematic view 1.1



Worm gear screw jack – coupling – IEC flange in configuration B14 or B5 (IEC flange-mounting)



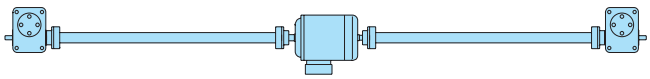
2.11 Schematic drive system layout

2.11.2 Multi-screw lifting system

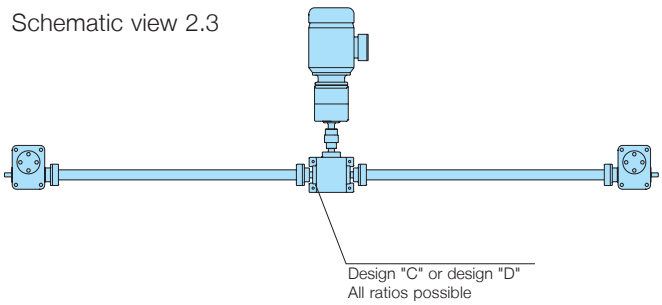
2.11.2.1 Mechanically synchronized

Schematic view 2.1

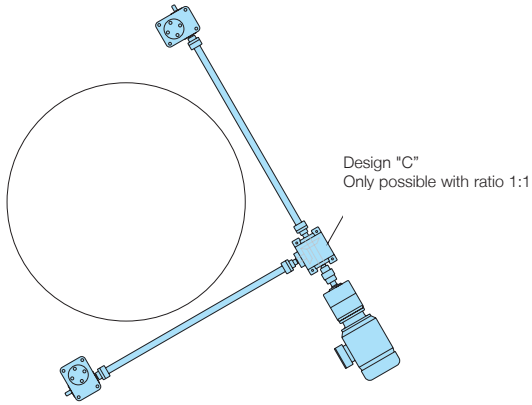
Schematic view 2.2



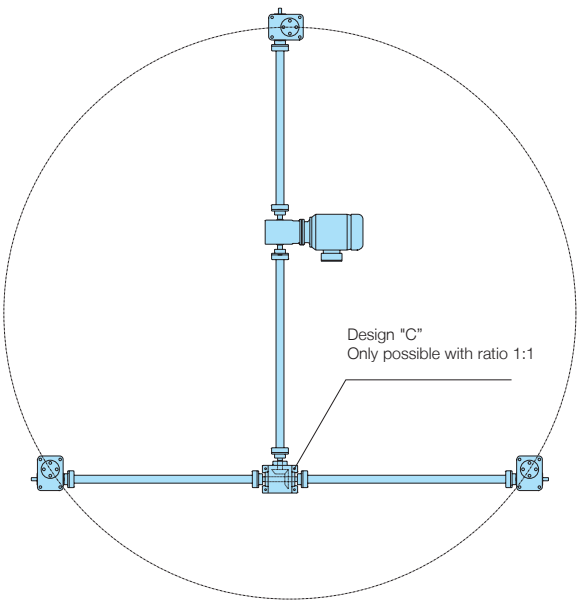
Schematic view 2.3



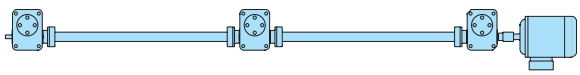
Schematic view 2.4



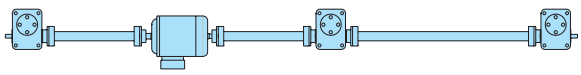
Schematic view 3.1



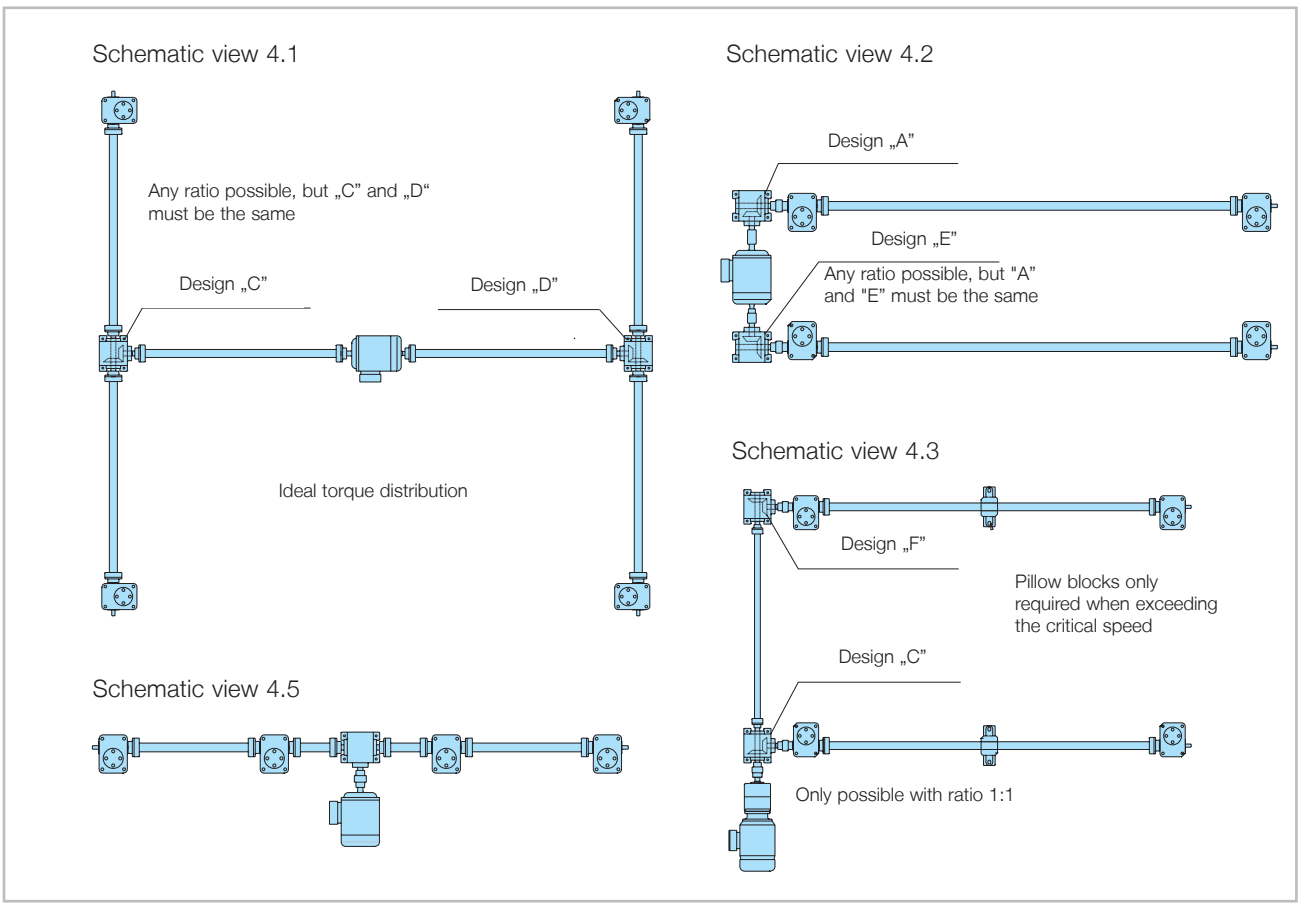
Schematic view 3.2



Schematic view 3.3



2.11 Schematic drive system layout



2.11.2.2 Electrically synchronized