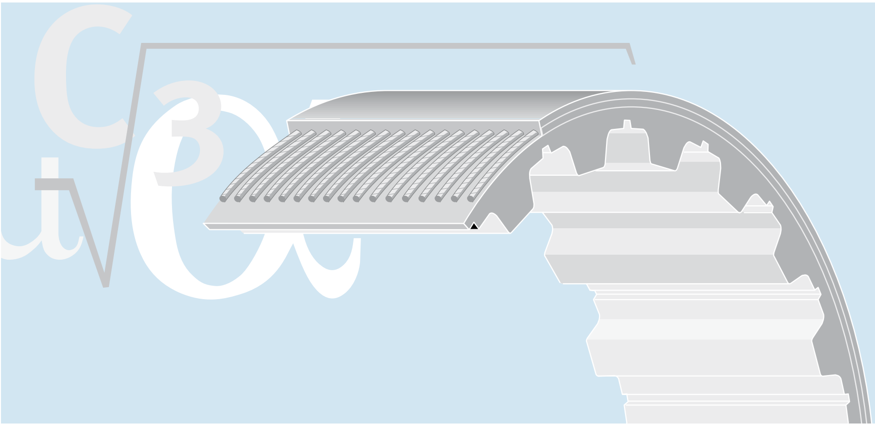
siegling proposition
timing belts

Calculation methods



You can find detailed information on Siegling Proposition high quality timing belts in the overview of the range (ref. no. 245).

Contents

Siegling – total belting solutions

MOVEMENT SYSTEMS

Formulae

1. Forces

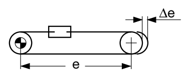
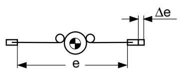
Symbol	Designation	Unit	Calculation/Remarks
Effective pull to be transmitted	F_U	N	$F_U = \frac{2 \cdot 10^3 \cdot T}{d_0} = \frac{19.1 \cdot 10^6 \cdot P}{n \cdot d_0} = \frac{10^3 \cdot P}{v}$ [N] $F_U = F_A + F_H + F_R$ ... [N]
Accelerating force	F_A	N	$F_A = m \cdot a$ [N]
Lifting power	F_H	N	$F_H = m \cdot g \cdot \sin \alpha$ [N] (sin α for inclined conveying)
Frictional force (μ values table 4)	F_R	N	$F_R = m \cdot \mu \cdot g$ [N] ($g = 9.81$ m/s²)
Maximum effective pull	$F_{U\,max}$	N	$F_{U\,max} = F_U \cdot (c_2 + c_3)$ [N]
Specific effective pull required	$F'_{U\,req}$	N	$F'_{U\,req} = F_{U\,max}/c_1$ [N]
Specific effective pull	F'_U	N	from calculation sheet
Pretensioning force	F_V	N	$F_V \geq 0.5 \cdot F_{U\,max}$ [N] (2-pulley drives) $F_V \geq F_{U\,max}$ [N] (linear drives)
Force determining belt selection	F_B	N	$F_B = F_{U\,max} + F_V$ [N]
Permissible tension member load	F_{per}	N	Table value from calculation sheet
External force	F	N	
Static shaft load	F_{WS}	N	$F_{WS} = 2 \cdot F_V$ [N] (2-pulley drives)

2. Masses

Symbol	Designation	Unit	Calculation/Remarks
Mass to be moved	m	kg	$m = m_R + m_L + m_{Z\,red} + m_{S\,red}$ [kg]
Mass of belt	m_R	kg	$m_R = m'_R \cdot l/1000$ [kg];
Belt weight per metre	m'_R	kg/m	Table value from calculation sheet
Mass of linear slide	m_L	kg	
Mass of timing belt pulley	m_Z	kg	$m_Z = \frac{(d_k^2 - d^2) \cdot \pi \cdot b \cdot \rho}{4 \cdot 10^6}$ [kg]
Reduced mass of timing belt pulley	$m_{Z\,red}$	kg	$m_{Zred} = \frac{m_Z}{2} \cdot \left[1 + \frac{d^2}{d_k^2}\right]$ [kg]
Mass of take-up pulley	m_S	kg	$m_S = \frac{(d_S^2 - d^2) \cdot \pi \cdot b \cdot \rho}{4 \cdot 10^6}$ [kg]
Reduced mass of take-up pulley	$m_{S\,red}$	kg	$m_{Sred} = \frac{m_S}{2} \cdot \left[1 + \frac{d^2}{d_S^2}\right]$ [kg]

MOVEMENT SYSTEMS

3. Measurements

Symbol	Designation	Unit	Calculation/Remarks
Bore diameter	d	mm	
Pitch diameter	d_0	mm	$d_0 = z \cdot t/\pi$ [mm], catalogue value
Outside diameter	d_k	mm	Catalogue value of timing belt pulley supplier
Take-up pulley diameter	d_s	mm	
Width of timing belt pulley, take-up pulley	b	mm	
Belt width	b_0	mm	
Belt length untensioned for 2-shaft drives	l	mm	for $i = 1$: $l = 2 \cdot e + \pi \cdot d_0 = 2 \cdot e + z \cdot t$ [mm] for $i \neq 1$: $l = \frac{t \cdot (z_2 + z_1)}{2} + 2e + \frac{1}{4e}\left[\frac{t \cdot (z_2 - z_1)}{\pi}\right]^2$
Belt length general		mm	$l = z \cdot t$ [mm]
Clamping length per belt end	l_k	mm	for AdV 07
Centre distance (exact)	e	mm	is calculated from l
Centre distance (exact)	Δe	mm	Rotating 2-pulley drives and 2-pulley linear drives (AdV 07clamped): $\Delta e = \frac{F_V \cdot l}{2 \cdot c_{spec}}$ [mm]  Clamped belt (AdV 07)  $\Delta e = \frac{F_V \cdot l}{c_{spec}}$ [mm]
Positioning deviation under influence of external forces	Δs	mm	$\Delta s = \frac{F}{c}$ [mm]; $\Delta s_{min} = \frac{F}{c_{max}}$ [mm]
Belt pitch	t	mm	Centre distance of adjacent teeth

4. Constants and Coefficients

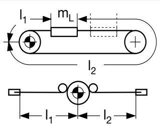
Symbol	Designation	Unit	Calculation/Remarks
Density	ρ	kg/dm^3	e.g. pulley material
Friction coefficient	μ		Depends on friction pairing; see table 4
Teeth in mesh factor; number of teeth involved in power flux	c_1		$i = 1$; $c_1 = z/2$ $i \neq 1$; $c_1 = \frac{z_1}{180} \cdot \arccos \frac{(z_2 - z_1) \cdot t}{2 \cdot \pi \cdot e}$ Note $c_{1\,max}$ table 1!
Operational factor	c_2		Table 2
Acceleration factor	c_3		Table 3

Formulae

5. Quantities of Motion

Symbol	Designation	Unit	Calculation/Remarks
Speed (RPM)	n	min^{-1}	$n = \frac{v \cdot 19{,}1 \cdot 10^3}{d_0}$ $[min^{-1}]$
Belt speed	v	m/s	$v = \frac{d_0 \cdot n}{19.1 \cdot 10^3} = \sqrt{\frac{2 \cdot s_a \cdot a}{1000}}$ [m/s]
Acceleration	a	m/s^2	
Acceleration due to gravity	g	m/s^2	$g = 9.81$ $[m/s^2]$
Travel total	s_v	mm	$sv = s_a + s'_a + s_c$ [mm]
Accelerating (braking) distance	s_a (s'_a)	mm	$s_a (s_a') = \frac{a \cdot t_a^2 \cdot 10^3}{2} = \frac{v^2 \cdot 10^3}{2 \cdot a}$ [mm]
Travel where v = constant	s_c	mm	$s_c = v \cdot t_c \cdot 10^3$ [mm]
Accelerating (braking) time	t_a (t'_a)	s	$t_a (t_a') = \frac{v}{a} = \sqrt{\frac{2 \cdot s_a}{a \cdot 1000}}$ [s]
Travel time where v = constant	t_c	s	$t_c = \frac{s_c}{v \cdot 10^3}$ [s]
Travel time total	t_v	s	$t_v = t_a + t_a' + t_c$ [s]
Gear ratio	i		

6. Other Values/Abbreviations

Symbol	Designation	Unit	Calculation/Remarks
Angle of incline	α	°	for inclined conveying
Specific spring rate	c_{spec}	N	Table value from calculation sheet
Spring rate of a belt Spring rate of a linear drive	c	N/mm	generally: $c = \frac{c_{spec}}{l}$ [N/mm] $c = \frac{l}{l_1 \cdot l_2} \cdot c_{spec}$ [N/mm]
Determine from extreme positions of linear drive c_{min} for $l_1 = l_2$	c_{min}/c_{max}	N/mm	 $l = l_1 + l_2$ [mm] $c_{min} = \frac{4 \cdot c_{spec}}{l}$ [N/mm]
Natural frequency	f_e	s^{-1}	$f_e = \frac{1}{2\pi} \cdot \sqrt{\frac{c \cdot 1000}{m_L}}$ $[s^{-1}]$
Exciter frequency	f_0	s^{-1}	$f_0 = \frac{n}{60}$ $[s^{-1}]$
Tooth base service factor	S_{tooth}		$S_{tooth} = F'_U/F'_{U\,req}$
Tension member service factor	S_{tm}		$S_{tm} = F_{per}/F_B$
Number of teeth	z		where i = 1
Number of teeth on small pulley	z_1		where i ≠ 1
Number of teeth on large pulley	z_2		where i ≠ 1
Minimum number of teeth	z_{min}		Table value from calculation sheet
Minimum take-up pulley diameter	$d_{s\,min}$	mm	Table value from calculation sheet
Power to be transmitted	P	kW	$P = \frac{F_U \cdot n \cdot d_0}{19.1 \cdot 10^6} = \frac{F_U \cdot v}{10^3}$ [kW]
Torque to be transmitted	T	Nm	$T = \frac{F_U \cdot d_0}{2 \cdot 10^3}$ [Nm]
Timing belt open	AdV 07		
Timing belt welded endless	AdV 09		

Calculation method for B 92 timing belts

$$F_U = \frac{2 \cdot 10^3 \cdot T}{d_0} = \frac{19.1 \cdot 10^6 \cdot P}{n \cdot d_0} = \frac{10^3 \cdot P}{v} \quad [N]$$

and $v = \frac{d_0 \cdot n}{19.1 \cdot 10^3}$ [m/s] with $d_0 = \frac{z \cdot t}{\pi}$ [mm]

or: Sum of all forces $F_U = F_R + F_H + F_A \ldots$ [N]

in which: $F_R = m \cdot \mu \cdot g$ [N] frictional force

$F_H = m \cdot g$ or $m \cdot g \cdot \sin \alpha$ [N] lifting power

$F_A = m \cdot a$ [N] accelerating force

Effective pull F_U [N] to be transmitted **1**

Operational and acceleration factor c_2 and c_3 take from tables 2 and 3

$F_{U\,max} = F_U \cdot (c_2 + c_3)$ [N]

Maximum effective pull $F_{U\,max}$ [N] **2**

$c_1 = z/2$ for $i = 1$

$$c_1 = \frac{z_1}{180} \cdot \arccos \frac{(z_2 - z_1) \cdot t}{2 \cdot \pi \cdot e} \quad \text{for } i \neq 1$$

Always round down calculated values for c_1 to the smaller round figure.
Note maximum values in table 1!
Estimate number of teeth if not given and determine n.

Teeth in mesh factor c_1 for the driving (smaller) pulley **3**

$$F'_{U\,req} = \frac{F_{U\,max}}{c_1} \quad [N]$$

Specific effective pull required $F'_{U\,req}$ [N] **4**

Find $F'_{U\,req}$ in the belt overview graph and move horizontally to the right to the point of intersection with the speed in question. All belt pitches which lie above this point can be used in principle.

Belt selection from graphs

Select belt type and find point of intersection on the calculation sheet for that particular type. The curve above the point of intersection gives the belt width b_0 [mm]. The point where speed and width curve intersect gives the transmittable effective pull F'_U [N].

F'_U [N] of selected belt type

$l = 2 \cdot e + z \cdot t = 2 \cdot e + \pi \cdot d_0$ [mm] for $i = 1$

$$l = \frac{t \cdot (z_2 - z_1)}{2} + 2e + \frac{1}{4e}\left[\frac{t \cdot (z_2 - z_1)}{\pi}\right]^2 \quad [mm] \quad \text{for } i \neq 1$$

l must always be an integral multiple of the belt pitch t in mm. Equations are valid for rotating 2-pulley drives. Calculate other designs according to their geometry.

$m_R = m'_R \cdot l/1000$ [kg]; $m_{R'}$ from calculation sheet
For calculation see formulae.
Timing belt pulley measurements from catalogue.

Belt length l [mm] **5**

Belt mass m_R [kg]

Reduced mass of timing belt pulley and take-up pulleys $m_{Z\,red}$, $m_{S\,red}$ [kg].

Calculation method for B 92 timing belts

6 Check F_U with F_A

including m_R, $m_{Z\,red}$ and $m_{S\,red}$

Repeat steps 1 – 4 if the influence of the belt mass must not be neglected; e.g. on linear drives with high acceleration.

7 Determining tooth base

$$S_{tooth} = \frac{F'_U \cdot c_1}{F_{U\,max}} = \frac{F'_U}{F_{U\,req}}$$

Demand: $S_{tooth} > 1$

8 Pretensioning force [N]

$F_V > 0.5 \cdot F_{U\,max}$ [N] for 2-pulley drives

$F_V > F_{U\,max}$ [N] for linear drives

Force determining belt selection F_B [N]

$F_B = F_{U\,max} + F_V$ [N]

Determining tension member service factor S_{tm}

$$S_{tm} = \frac{F_{per}}{F_B}$$

Demand: $s_{tm} > 1$

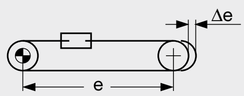
F_{per} from calculation sheet

9 Take-up range Δe [mm]

(For endless belts:
Elongation at fitting
ε approx. 0.1 %
For open material:
Elongation at fitting
ε approx. 0.2 %)

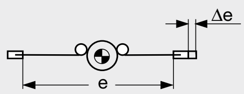
Rotating 2-pulley drives and 2-pulley linear drive (AdV 07 clamped)

$$\Delta e = \frac{F_V \cdot l}{2 \cdot c_{spec}} \text{ [mm]}$$



Clamped belt (AdV 07)

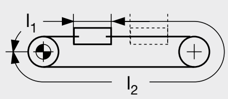
$$\Delta e = \frac{F_V \cdot l}{c_{spec}} \text{ [mm]}$$



Steps 10 – 12 of calculation method only for linear drives as a rule!

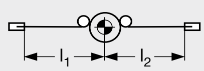
10 Spring rate of entire system c [N/mm] and c_{min} [N/mm]

$$c = \frac{l}{l_1 \cdot l_2} \cdot c_{spec} \text{ [N/mm]; } l = l_1 + l_2$$



c_{min} and c_{max} as per extreme right and left positions of slide.

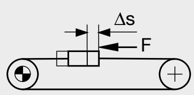
$$c_{min} = \frac{4 \cdot c_{spec}}{l} \text{ [N/mm] for } l_1 = l_2$$



11 Positioning deviation under influence of external force Δs [mm]

$$\Delta s = \frac{F}{c} \text{ [mm]}$$

$$\Delta s_{max} = \frac{F}{c_{min}} \text{ [mm]}$$



12 Resonance behaviour: Natural frequency: f_e [s^{-1}]

$$f_e = \frac{1}{2\pi} \cdot \sqrt{\frac{c \cdot 1000}{m}} \text{ [s}^{-1}\text{]}$$

$f_e \neq f_0$
There is then no danger of resonance.

Exciter frequency: f_0 [s^{-1}]

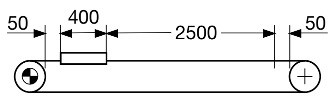
$$f_0 = \frac{n}{60} \text{ [s}^{-1}\text{]}$$

Linear drive for moving assembly carriers

Travel	S_V = 2500 mm
Speed	v = 3 m/s = const.; i = 1
Acceleration	a = 15 m/s^2
Mass of slide	m_L = 25 kg
	incl. assembly carrier + goods being carried
Frictional force of guide rails	F_R = 80 N
Slide length	l_L = 400 mm
d_0	approx. 100 mm

Required: Belt type and width b_0, RPM, timing belt pulley data, pretensioning force and take-up range, effective pull, positioning accuracy

Diagram



Effective pull F_U [N] 1

$F_U = F_A + F_R$ [N]
F_A = 25 kg · 15 m/s^2 = 375 N
F_U = 375 N + 80 N = 455 N
Mass of timing belt pulley and belt neglected.

Effective pull F_U [N] to be transmitted – approximate.

Operational and acceleration c_2 and c_3 2

c_2 = 1.4 because of high acceleration
c_3 = 0 as i = 1
455 N · 1.4 = $F_{U\,max}$ = 637 N

$F_{U\,max}$ – approximate.

Teeth in mesh factor c_1 3

Selected: c_1 = 12 for open material
Where $d_0 \approx$ 100 mm and c_1 = 12 Z_{min} = 24;
i.e. 14 und 20 mm pitches ruled out due to d_0!

$F'_{U\,req}$ 4

$$F'_{U\,req} = \frac{F_{U\,max}}{c_1} = 53.08\ \text{N}$$

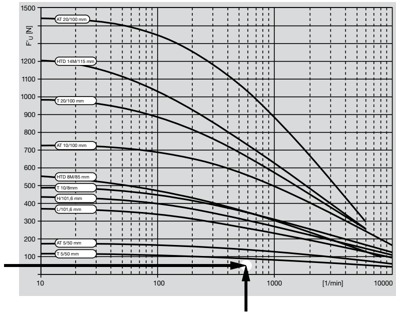
$$n = \frac{v \cdot 19.1 \cdot 10^3}{d_0} = 573\ \text{min}^{-1}$$

n from given values d_0 and v

Linear drive for moving assembly carriers

Belt selection

For linear drives preferably use AT and HTD!
Possible types:
AT 5, AT 10, HTD 8M.

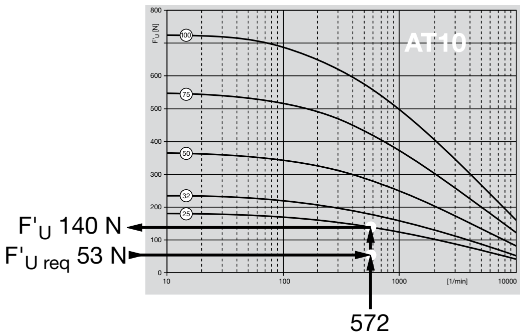


Overview graph

F'$_U$ of selected belt type

Selected:
AT 10 because of high spring resistance; t = 10 mm.

F'$_U$ = 140 N



AT 10 graph

5 Selecting timing belt pulley

$d_0 = 100$ mm
=> $100 \cdot \pi = 314 / t = 31.4$ teeth
Selected: Z = 32; standard pulley
Material aluminium; $\rho = 2.7$ kg/dm^3
$d_0 = 32 \cdot t/\pi = 101.86$ mm
therefore:

$$n = \frac{v \cdot 19.1 \cdot 10^3}{101.86} = 562 \text{ min}^{-1}$$

Mass of timing belt pulley

$d_K = 100$ mm; d = 24 mm; b = 32 mm

$$\Rightarrow m_Z = \frac{(100^2 - 24^2) \cdot \pi \cdot 32 \cdot 2.7}{4 \cdot 10^6} = 0.64 \text{ kg}$$

Reduced mass of timing belt pulley

$$m_{Z\,red} = \frac{0.64}{2} \cdot \left[1 + \frac{24^2}{100^2}\right] = 0.34 \text{ kg}$$

Calculate belt length

from diagram and d_0; clamping length l_K per belt end = 80 mm.

$l = 2 \cdot (2500 + 400 + 100 + d_0) - (400 - 2 \cdot 80) + z \cdot t$
$l = 6283.7$ mm => $l = 6290$ mm

Determining belt mass

$m'_R = 0.064$ kg/m $\cdot$ 2.5 cm = 0.16 kg/m
$m_R = 1.00$ kg

$F_A = (25\ kg + 1\ kg + 2 \cdot 0.34\ kg) \cdot a$
$F_A = 400.2\ N$
$F_U = 400.2 + 80 = 480\ N$
$F_{U\ max} = 480 \cdot 1.4 = 675\ N$
$F'_{U\ req} = 56.02\ N$

$F_{U\ max}$ exact including m_R and $m_{Z\ red}$ 6

$$S_{tooth} = \frac{F'_U}{F'_{Ureq}} = \frac{140}{56.02} = 2.5 \quad >1$$ Demand fulfilled

Tooth base service factor S_{tooth} 7

$F_V \geq F_{U\ max}$ for linear drives!
F_V selected $= 1.5\ F_{U\ max} = 1000\ N$

$F_B = F_V + F_{U\ max} = 1675\ N$

$$S_{tm} = \frac{F_{per}}{F_B} = \frac{3750}{1675} = 2.24 \quad >1$$ Demand fulfilled

Force determining belt selection F_B 8

Pretensioning force F_V

Tension member service factor S_{tm}

F_{per} from calculation sheet for AT 10

$$\Delta e = \frac{F_V \cdot l}{2 \cdot c_{spec}} = \frac{1000\ N \cdot 6290\ mm}{2 \cdot 10^6\ N} = 3.14\ mm$$

Take-up range Δe [mm]
c_{spec} from calculation sheet for AT 10 9

$$c_{min} = \frac{l}{l_1 \cdot l_2} \cdot c_{spec} = \frac{6290 - 2 \cdot 80}{2684 \cdot 3446} \cdot c_{spec} = 662.77\ N/mm$$

$$c_{max} = \frac{l}{l_1 \cdot l_2} \cdot c_{spec} = \frac{6290 - 2 \cdot 80}{184 \cdot 5946} \cdot c_{spec} = 5602.96\ N/mm$$

Spring rate of system c_{min}; c_{max} 10

l_1 and l_2 from diagram!

External force here: $F_R = 80\ N$

$$\Delta s_{min} = \frac{F_R}{c_{max}} = 0.014\ mm$$

$$\Delta s_{max} = \frac{F_R}{c_{min}} = 0.122\ mm$$

Positioning accuracy due to external force 11

$$f_e = \frac{1}{2\pi} \cdot \sqrt{\frac{c_{min} \cdot 1000}{m_L}} = 25.7\ s^{-1}$$

$$f_0 = \frac{n}{60} = \frac{562}{60} = 9{,}4\ s^{-1}$$ i.e. no danger of resonance

Natural frequency of system 12

Exciter frequency

Timing belt 25 AT 10, 6290 mm long
Timing belt pulley with Z = 32 für 25 mm belt
Take-up range to generate F_V $\Delta e = 3.14\ mm$
$n = 562\ min^{-1}$
$\Delta s_{max} = 0.122\ mm$

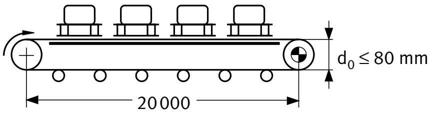
Result

If Δs_{max} has to be smaller,
$b_0 = 32\ mm$ would be selected.
No danger of resonance.

Calculation example 2

Drag band conveyor for workpiece tray

Diagram



Speed	v = 0.5 m/s
Mass of tray incl. load	m = 1.8 kg
Maximum loading	20 trays
Belt support tight side	Plastic rails
Belt support slack side	Rollers
Centre distance	e = 20000 mm
Start	Without load
Operation	continuous operation, purely conveying
Pulley diameter	$d_0 \leq 80$ mm

Required: Belt type, length, take-up range, timing belt pulley data

1 Effective pull F_U [N]

Effective pull F_U [N] to be transmitted without belt mass.

F_U here = F_R, as acceleration negligible.
$F_U = F_R = m \cdot \mu \cdot g$
μ selected approx. 0.25 from table 4
$m = 20 \cdot 1.8$ kg = 36 kg
$F_U = F_R = 36 \cdot 9.81 \cdot 0.25 = 88.3$ N

2 Operational and acceleration factor

$c_3 = 0$, as $i = 1$
$c_2 = 1.2$ selected (20 % reserve)
$F_{U\,max} = 1.2 \cdot 8.3$ N = 106 N for 2 belts
$F_{U\,max} = 53$ N per belt

3 Teeth in mesh factor

c_1 selected = $c_{1\,max} = 6$ for AdV 09
Belt rotates and has been welded endless.

4 Specific effective pull required $F'_{U\,req}$

$$F'_{U\,req} = \frac{F_{U\,max}}{c_1} = 8.8 \text{ N}$$

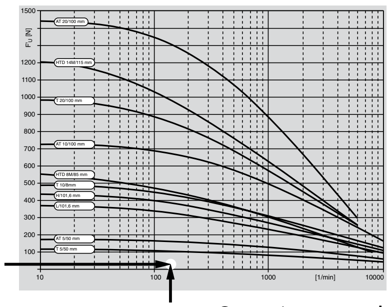
Speed

where $d_0 = 75$ mm

$$n = \frac{v \cdot 19.1 \cdot 10^3}{75} = 127 \text{ min}^{-1}$$

Belt selection

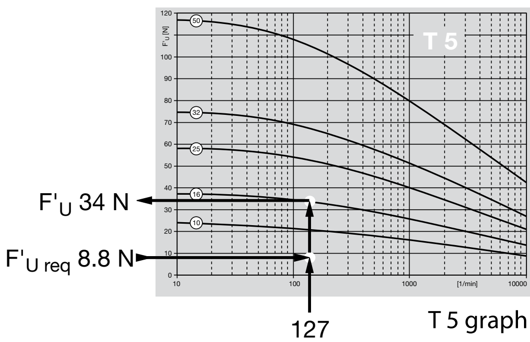
The narrowest belt is already sufficient.
Selected: 2 pieces 16 T 5.
16 mm width to provide greater support for tray.



Overview graph

F'_U [N] of selected belt type

$F'_U = 34$ N



T 5 graph

Selecting timing belt pulley 5

$$\frac{d_0 \cdot \pi}{t} = Z = 47.1 \quad \text{teeth}$$

Selected: Z = 48 teeth; standard pulley

Belt length

$$l = Z \cdot t + 2 \cdot e = 40240 \text{ mm}$$

Belt mass

$$m_R = l \cdot m'_R = 0.038 \text{ kg/m} \cdot 40.24 \text{ m} = 1.53 \text{ kg}$$

$F_{U\,max}$ including m_R of tight side 6

$F_{U\,max} = F_R \cdot 1.2$
$F_R = (20 \cdot 1.8 \text{ kg} + 2 \cdot 1.53 \text{ kg}) \cdot 9.81 \cdot 0.25 = 95.8 \text{ N}$
$F_{U\,max} = 115 \text{ N} = 57.5 \text{ N/belt}$
If increase is negligible, further calculation unnecessary

Tooth base service factor 7

$$S_{tooth} = \frac{F'_U \cdot c_1}{F'_{U\,max}} = \frac{34 \cdot 6}{57.5} = 3.69 \quad >1$$

Demand fulfilled

Pretensioning force F_V 8

$F_V \geq 0.5 \cdot F_{U\,max}$
Selected: $F_V = 40 \text{ N}$

Force determining belt selection F_B

$$F_B = F_V + F_{U\,max} = 40 + 57.5 = 97.5 \text{ N}$$

Tension member service factor S_{tm}

$$S_{tm} = \frac{F_{per}}{F_B} = \frac{270 \text{ N}}{97.5 \text{ N}} = 2.8 \quad >1$$

Demand fulfilled

F_{per} from calculation sheet for 16 T5 Adv 09

Take-up range Δe 9

$$\Delta e = \frac{F_V \cdot l}{2 \cdot c_{spec}}$$

with $c_{spec} = 0.12 \cdot 10^6$ from calculation sheet

$$\Delta e = \frac{40 \cdot 40240}{2 \cdot 0.12 \cdot 10^6} = 6.7 \text{ mm}$$

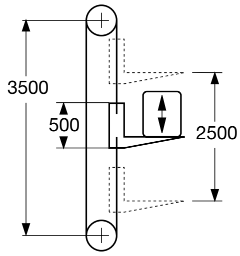
Result

2 pieces timing belt type 16 T 5, 40240 mm long, AdV 09
Timing belt pulley with Z = 48 teeth for 16 mm belt
Take-up range to generate F_V $\Delta e = 6.7 \text{ mm}$

Calculation example 3

Lifting device

Diagram



Travel	2500 mm
Speed	2 m/s
Medium acceleration/deceleration	4 m/s²
Max. deceleration (emergency shutdown)	10 m/s²
Slide mass with load	75 kg
No. of belts	2 pieces
Frictional force of guide rails	$F_R = 120$ N
d_0	maximum 150 mm

Required: Belt type and length, pretensioning force, take-up range, speed.
Rough operating conditions!

1 Effective pull F_U [N]

Effective pull F_U [N] to be transmitted.

$F_U = F_A + F_H + F_R + \ldots$

$F_R = 120$ N

$F_A = 75 \text{ kg} \cdot 4 \text{ m/s}^2 = 300$ N

$F_{A\,max} = 75 \text{ kg} \cdot 10 \text{ m/s}^2 = 750$ N (emergency shutdown)

$F_H = 75 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 736$ N

$F_U = 120 \text{ N} + 736 \text{ N} + 750$ N (emergency braking during descent)

$F_U = 1606$ N

2 Operational factor c_2 Acceleration factor c_3

$c_3 = 0$ as $i = 1$

$c_2 = 2.0$ because of rough operating conditions

$F_{U\,max} = 1606 \cdot 2 = 3212$ N distributed between 2 belts

$F_{U\,max} = 1606$ N pro belt

3 Teeth in mesh factor c_1

Open material: $c_1 = 12 = c_{1\,max}$ for AdV 07 selected

=> $Z_{min} = 24$; t = 20 ruled out because of $d_{0\,max}$

4 Specific effective pull required $F'_{U\,req}$

$$F'_{U\,req} = \frac{F_{U\,max}}{12} = 133 \text{ N}$$ per belt!

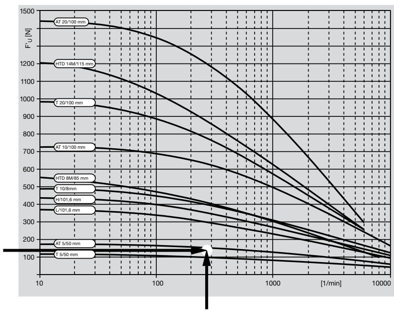
Speed

Where $d_0 = 140$ mm

$$n = \frac{v \cdot 19.1 \cdot 10^3}{d_0} = 273 \text{ min}^{-1}$$

Belt selection

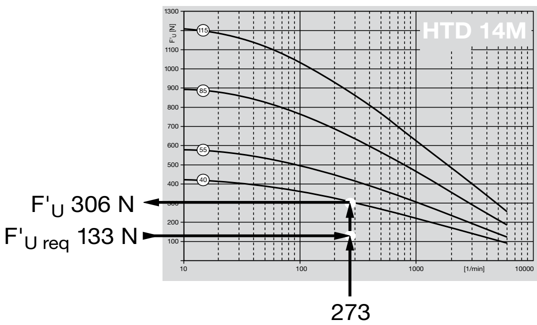
All types between L and HTD 14M are possible.
Selected: HTD 14M because of large reserves.
Designation: 40 HTD 14M



Overview graph

F'_U [N] of selected belt type

$F'_U = 306$ N



HTD 14M graph

Pulley selected 5

$$Z = \frac{d_0 \cdot \pi}{t} = \frac{140 \cdot \pi}{14} = 31.4$$

Selected: Z = 32; standard pulley => $n = 268\ min^{-1}$

Belt length

$l = 3500 \cdot 2 + Z \cdot t - 500 + 2 \cdot 114$

$l = 7176\ mm \triangleq 512.6$ teeth

l selected: 512 teeth $\triangleq$ 7168 mm

Belt mass

$m'_R \cdot l = 0.44\ kg/m \cdot 7.168\ m = 3.155\ kg/belt$

Timing belt pulley data

$m_Z = 6.17\ kg$ (catalogue values)

$d_K = 139.9\ mm$ (catalogue values)

$d = 24.0\ mm$ (catalogue values)

Reduced mass of timing belt pulley

$$m_{Z\ red} = \frac{m_Z}{2} \cdot \left[1 + \frac{d^2}{d_K^2}\right] = 3.18\ kg$$

gives in total: $4 \cdot 3.18 = 12.7\ kg$

F_U with belt and pulley mass considered 6

$F_U = F_A + F_H + F_R$

$F_H = 736\ N$

$F_R = 120\ N$

$F_A = (75\ kg + 12.7\ kg + 2 \cdot 3.155\ kg) \cdot 10\ m/s^2 = 940\ N$

$F_U = 940 + 120 + 736 = 1800\ N$

$F_{U\ max} = c_2 \cdot F_U = 3600\ N$; distributed between 2 belts

=> $F_{U\ max} = 1800\ N/belt$

$$F'_{U\ req} = \frac{1800}{12} = 150\ N$$

Tooth base service factor S_{tooth} 7

$$S_{tooth} = \frac{F'_U}{F'_{U\ req}} = \frac{310}{150} = 2.07 \quad >1$$

Demand fulfilled

Lifting device

8 Selecting pretensioning force

$F_V \geq F_{U\,max} = 1800$

Selected: 2000 N = F_V

Force determining belt selection F_B

$F_B = F_{U\,max} + F_V = 3800$ N

Permissible force on each strand

$F_{per} = 8500$ N

Tension member service factor S_{tm}

$S_{tm} = \frac{F_{per}}{F_B} = \frac{8500}{3800} = 2.24 \quad >1 \quad$ Demand fulfilled

9 Take-up range Δe

$c_{spec} = 2.12 \cdot 10^6$ N

$$\Delta e = \frac{F_V \cdot l}{2 \cdot c_{spec}} = \frac{7168 \cdot 2000}{2 \cdot 2.12 \cdot 10^6} = 3.38 \text{ mm}$$

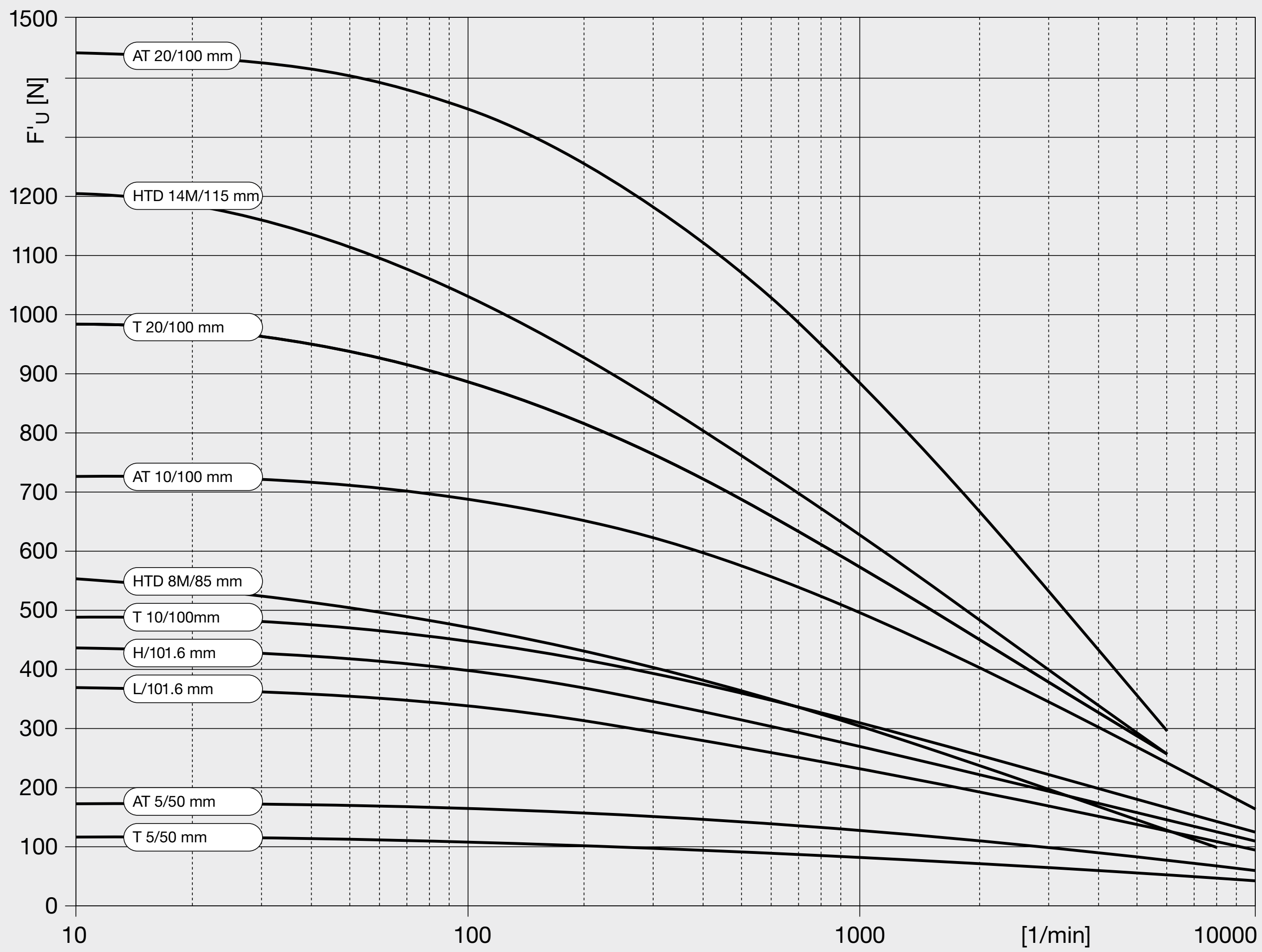
Result

Timing belt type 40 HTD 14M
7168 mm long = 512 teeth
Timing belt pulleys à 32 teeth for 40 mm wide belt
Take-up range to generate force F_V $\quad \Delta e = 3.38$ mm

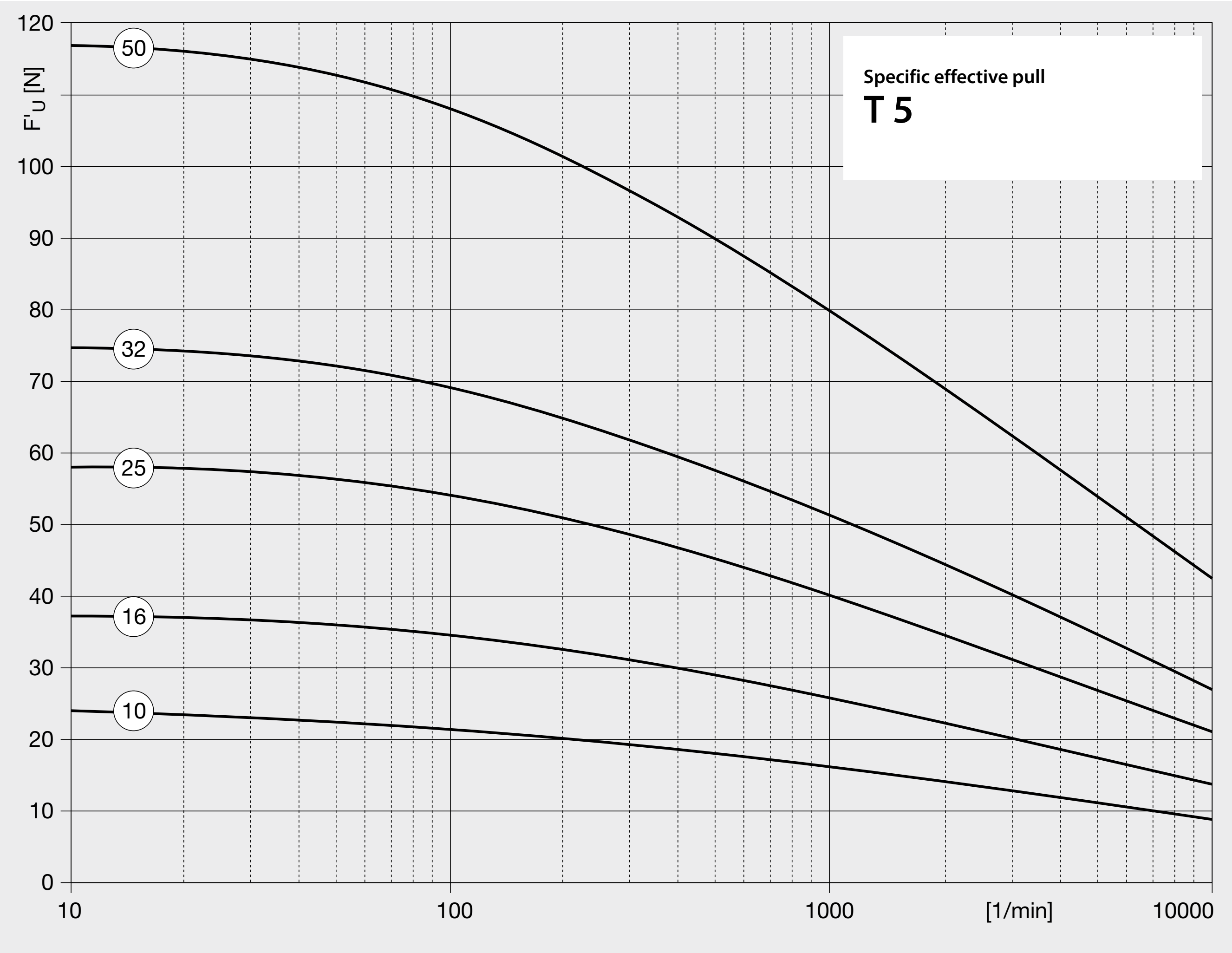
Safety note

In the case of lifting devices the regulations of professional/trade associations should be observed. If necessary, safety from breakage must be proven from the breaking load of the belt.
With open material AdV 07 this is approximately 4 times the permissible force on each strand F_{per}.
Exact values on request.

Overview graph



Timing belt type T 5



Characteristic values: Type T 5 (steel tension member)*

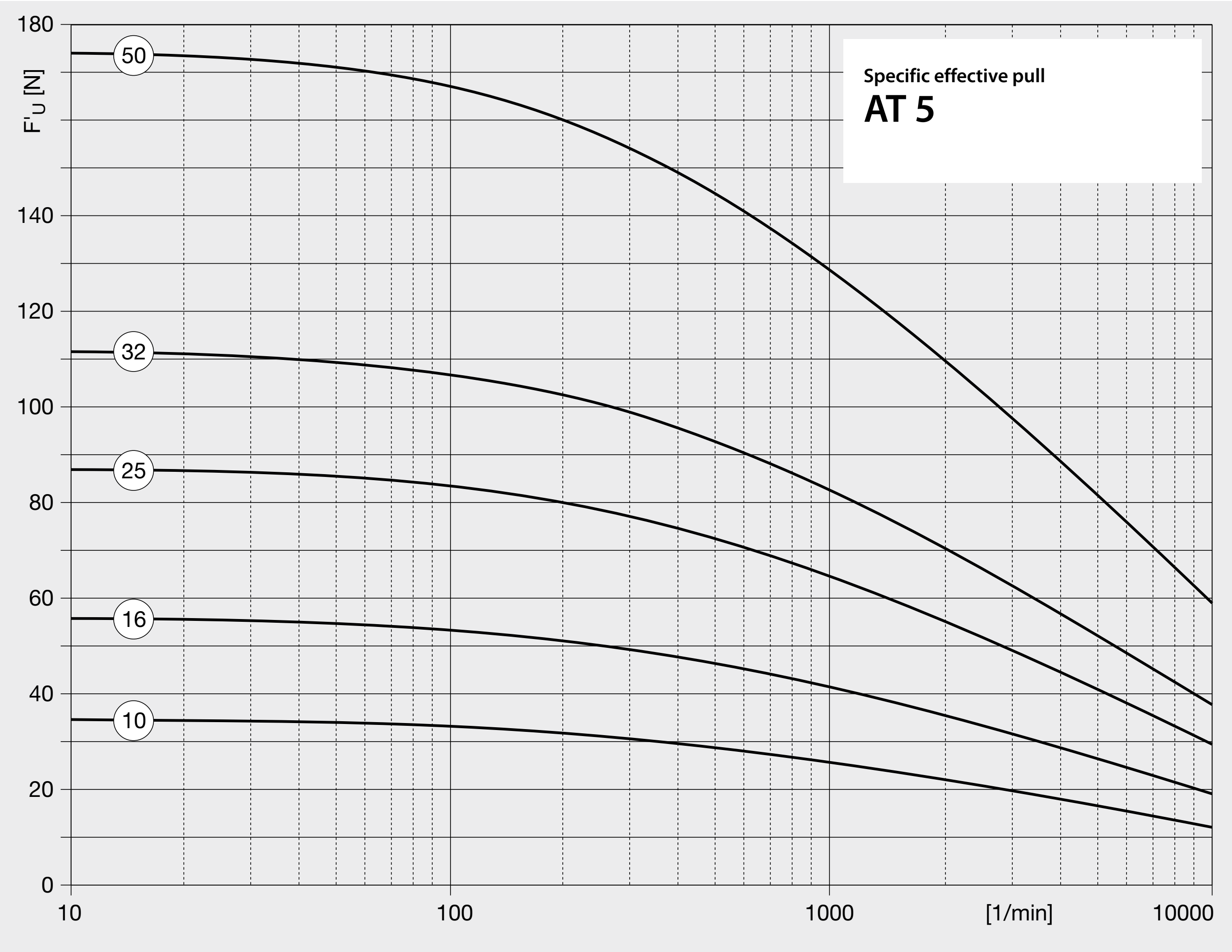
Value	b_0 [mm]	10	16	25	32	50
F_{per} [N] AdV 09		150	230	410	460	830
F_{per} [N] AdV 07		310	460	830	930	1660
C_{spec} [N] · 10^6		0.08	0.12	0.19	0.24	0.38
m'_R [kg/m]		0.024	0.038	0.06	0.077	0.12

Characteristic values: Type T 5 (Kevlar tension member)*

Value	b_0 [mm]	10	16	25	32	50
F_{per} [N] AdV 09		210	300	490	600	900
F_{per} [N] AdV 07		430	610	980	1200	1800
C_{spec} [N] · 10^6		0.06	0.09	0.14	0.18	0.29
m'_R [kg/m]		0.020	0.032	0.050	0.064	0.10

* The specifications stated are empirical. Nevertheless, our specifications do not cover all applications on the market. It is the OEM's responsibility to check whether Forbo Siegling products are suitable for particular applications. The data provided is based on our in-house experience and does not necessarily correspond to product behaviour in industrial applications. Forbo Siegling cannot assume any liability for the suitability and reliability in different processes of its products. Furthermore, we accept no liability for the results produced in processes, damage or consequential damage in conjunction with the usage of our products.

Timing belt type AT 5



Characteristic values: Type AT 5 (steel tension member)*

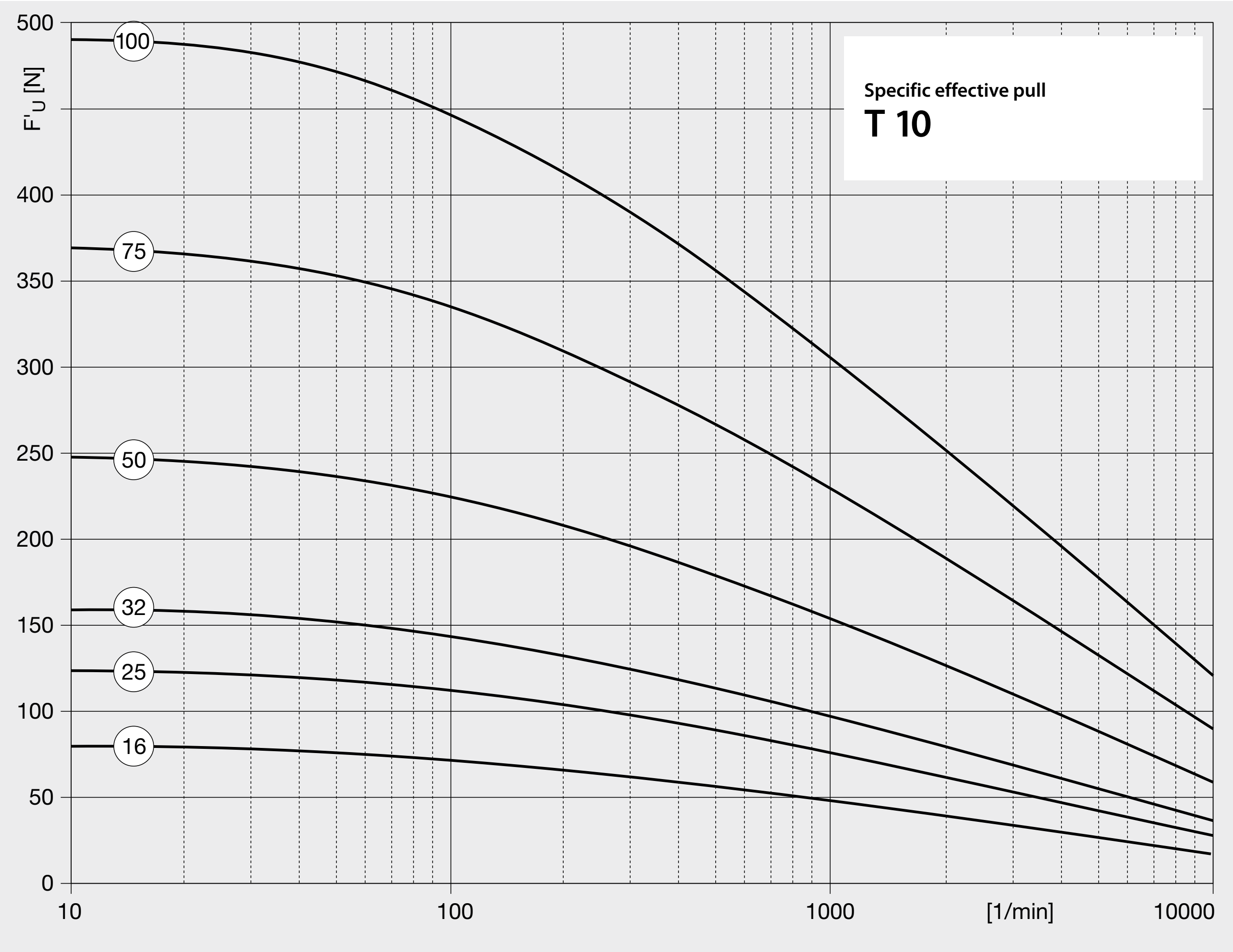
Value	b_0 [mm]	10	16	25	32	50
F_{per} [N] AdV 09		320	560	920	1120	1840
F_{per} [N] AdV 07		640	1120	1840	2240	3680
C_{spec} [N] · 10^6		0.17	0.27	0.42	0.54	0.84
m'_R [kg/m]		0.03	0.048	0.075	0.096	0.15

Characteristic values: Type AT 5 (Kevlar tension member)*

Value	b_0 [mm]	10	16	25	32	50
F_{per} [N] AdV 09		341	568	908	1172	1851
F_{per} [N] AdV 07		455	757	1210	1562	2468
C_{spec} [N] · 10^6		0.13	0.20	0.32	0.41	0.63
m'_R [kg/m]		0.027	0.043	0.068	0.086	0.135

* See comment on page 16

Timing belt type T 10



Characteristic values: Type T 10 (steel tension member)*

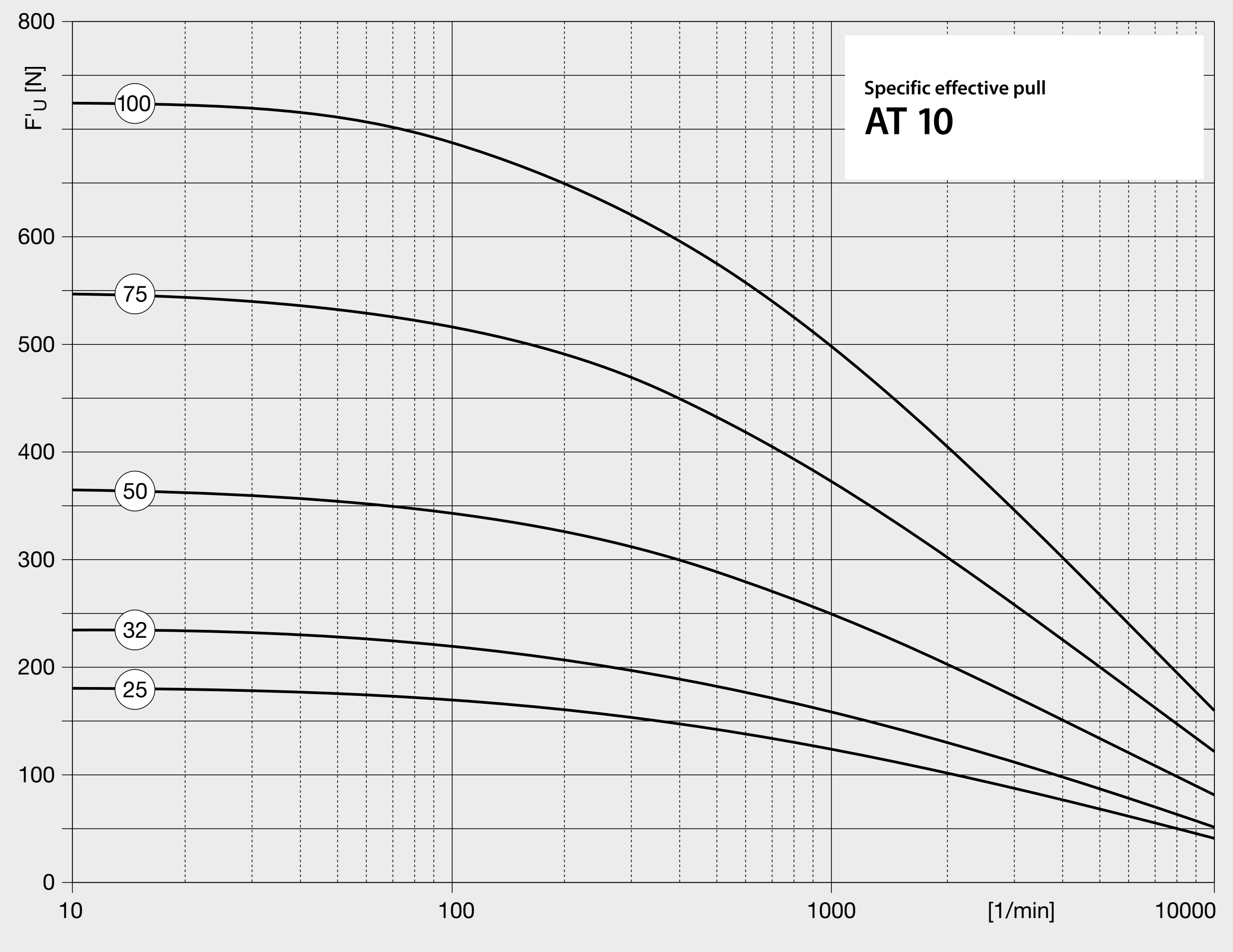
Value	b_0 [mm]	16	25	32	50	75	100
F_{per} [N] AdV 09		650	1100	1300	2200	3300	4400
F_{per} [N] AdV 07		1300	2200	2600	4400	6600	8800
C_{spec} [N] · 10^6		0.32	0.5	0.64	1.0	1.5	2.0
m'_R [kg/m]		0.077	0.12	0.154	0.24	0.36	0.48

Characteristic values: Type T 10 (Kevlar tension member)*

Value	b_0 [mm]	16	25	32	50	75	100
F_{per} [N] AdV 09		500	870	1170	1980	2450	3350
F_{per} [N] AdV 07		1000	1750	2350	3970	4900	6700
C_{spec} [N] · 10^6		0.24	0.38	0.48	0.75	1.13	1.5
m'_R [kg/m]		0.064	0.10	0.128	0.20	0.30	0.40

* See comment on page 16

Timing belt type AT 10



Characteristic values: Type AT 10 (steel tension member)*

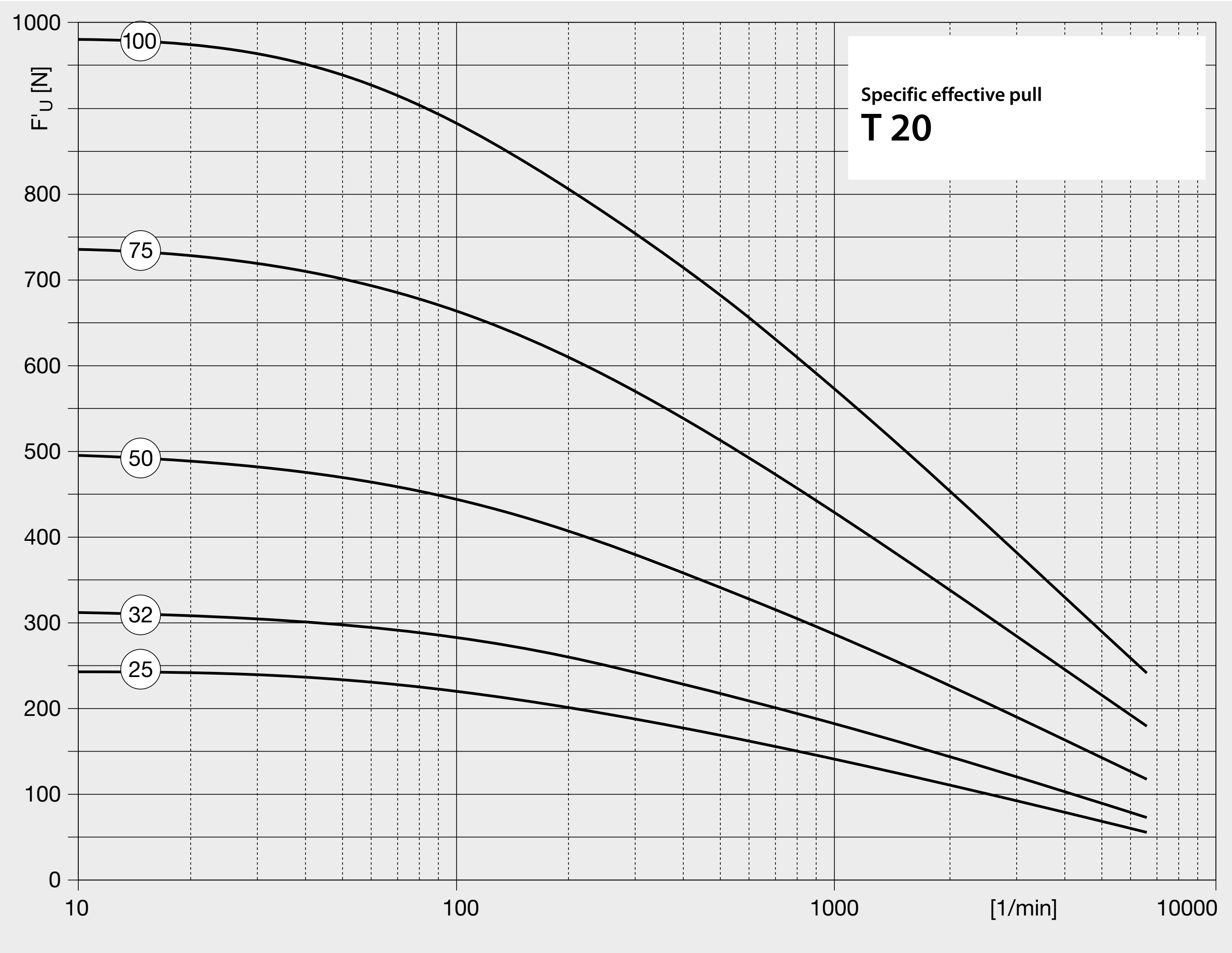
Value	b_0 [mm]	25	32	50	75	100
F_{per} [N] AdV 09		1920	2280	3840	5760	7680
F_{per} [N] AdV 07		3840	4560	7680	11520	15360
C_{spec} [N] · 10^6		1.0	1.28	2.0	3.0	4.0
m'_R [kg/m]		0.16	0.205	0.32	0.48	0.64

Characteristic values: Type AT 10 (Kevlar tension member)*

Value	b_0 [mm]	25	32	50	75	100
F_{per} [N] AdV 09		1313	1705	2713	4113	5513
F_{per} [N] AdV 07		1750	2273	3617	5483	7350
C_{spec} [N] · 10^6		0.75	0.96	1.5	2.25	3.0
m'_R [kg/m]		0.105	0.134	0.210	0.315	0.420

* See comment on page 16

Timing belt type T 20



Characteristic values: Type T 20 (steel tension member)*

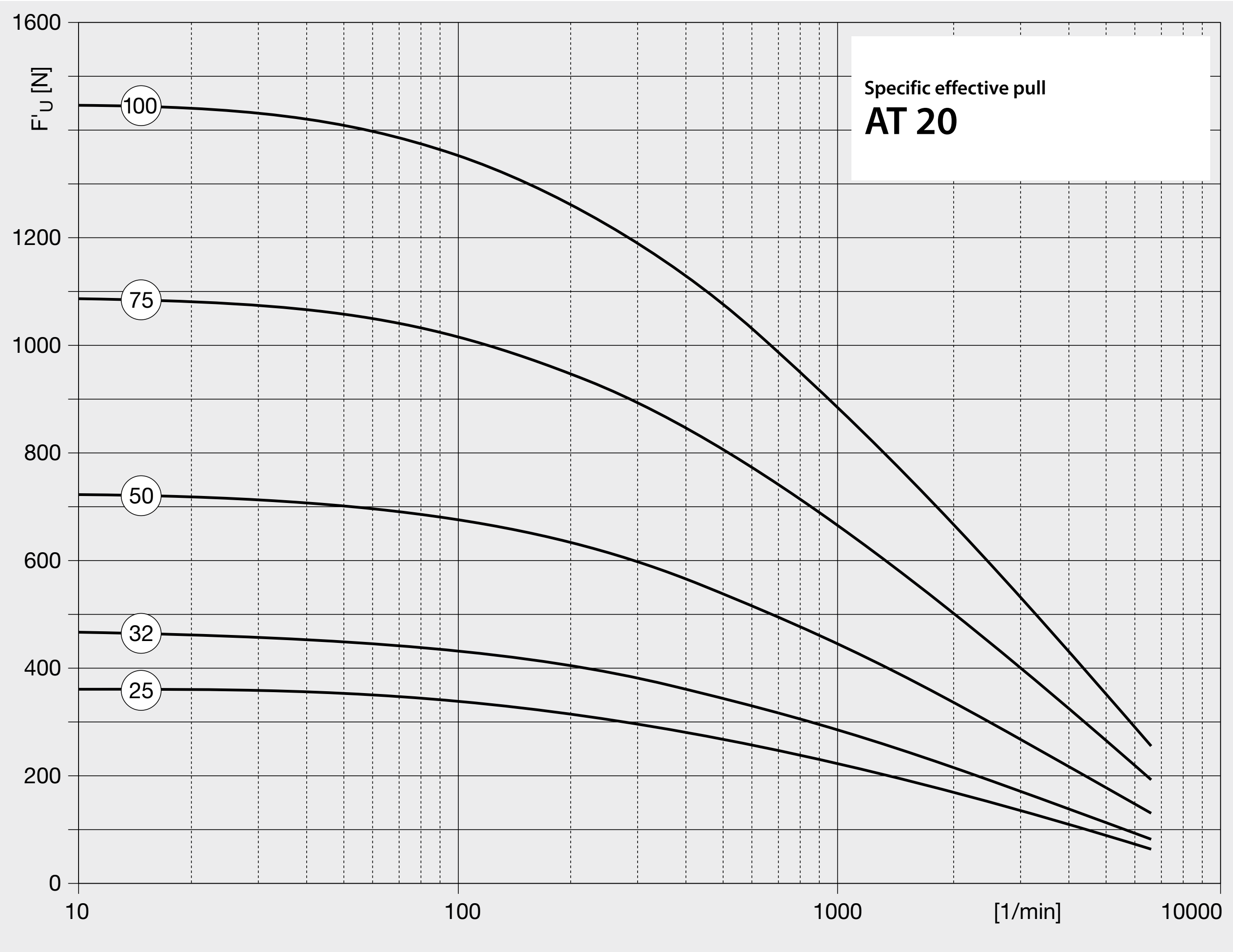
Value	b_0 [mm]	25	32	50	75	100
F_{per} [N] AdV 09		1680	2160	3360	5040	6720
F_{per} [N] AdV 07		3360	4320	6720	10080	13440
C_{spec} [N] $\cdot 10^6$		0.88	1.32	1.75	2.63	3.5
m'_R [kg/m]		0.193	0.246	0.385	0.578	0.77

Characteristic values: Type T 20 (Kevlar tension member)*

Value	b_0 [mm]	25	32	50	75	100
F_{per} [N] AdV 09		1450	1870	2850	4200	5500
F_{per} [N] AdV 07		2900	3750	5700	8400	11000
C_{spec} [N] $\cdot 10^6$		0.66	0.99	1.31	1.97	2.63
m'_R [kg/m]		0.16	0.205	0.32	0.48	0.64

* See comment on page 16

Timing belt type AT 20



Characteristic values: Type AT 20 (steel tension member)*

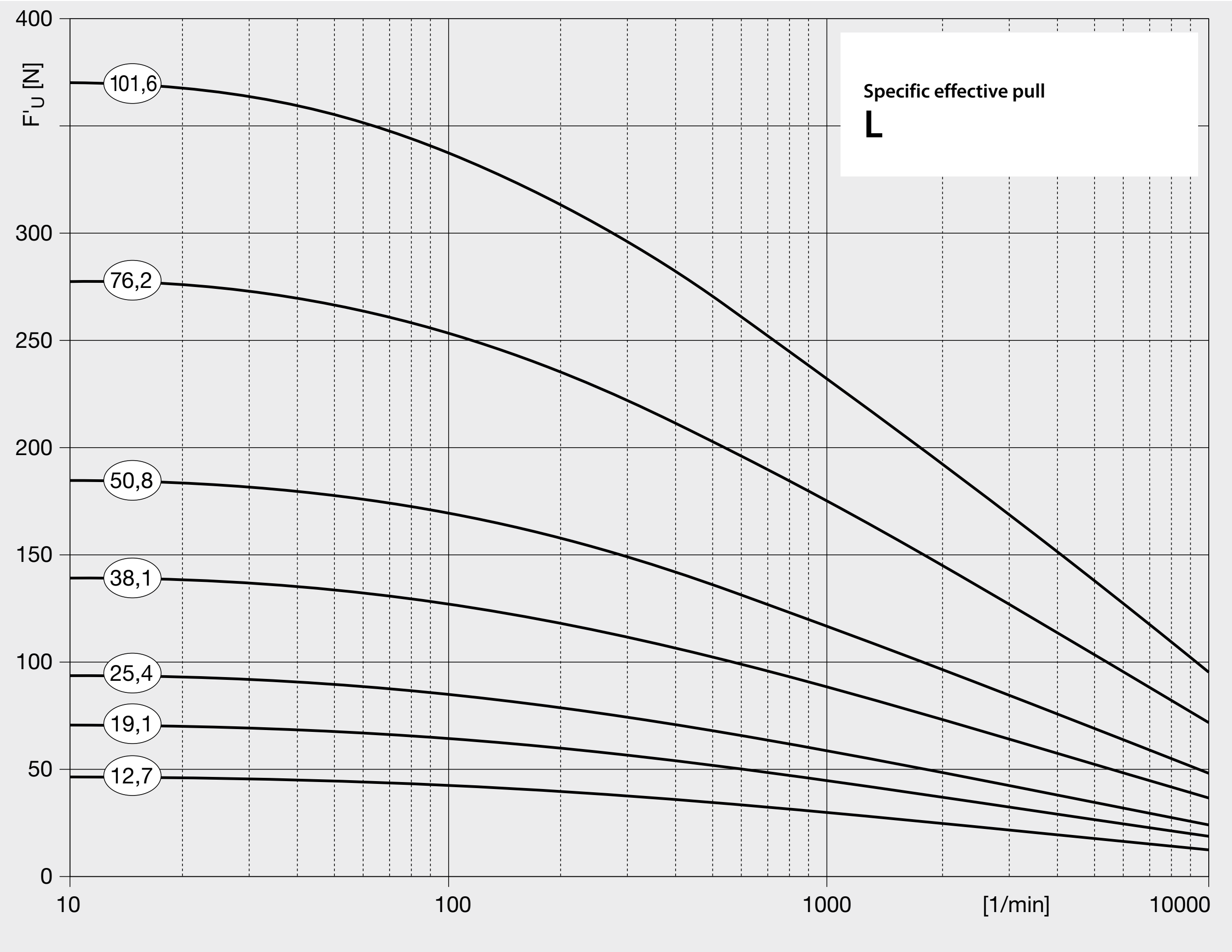
Value	b_0 [mm]	25	32	50	75	100
F_{per} [N] AdV 09		3300	4400	6600	9900	13200
F_{per} [N] AdV 07		6600	8800	13200	19800	26400
C_{spec} [N] · 10^6		1.56	2.00	3.13	4.69	6.25
m'_R [kg/m]		0.25	0.32	0.50	0.75	1.0

Characteristic values: Type AT 20 (Kevlar tension member)*

Value	b_0 [mm]	25	32	50	75	100
F_{per} [N] AdV 09		1313	1706	2719	4125	5531
F_{per} [N] AdV 07		1750	2275	3625	5500	7375
C_{spec} [N] · 10^6		1.17	1.5	2.35	3.52	4.69
m'_R [kg/m]		0.183	0.234	0.365	0.548	0.730

* See comment on page 16

Timing belt type L = 3/8" ≙ t = 9.525 mm



Characteristic values: Type L = 3/8" (steel tension member)*

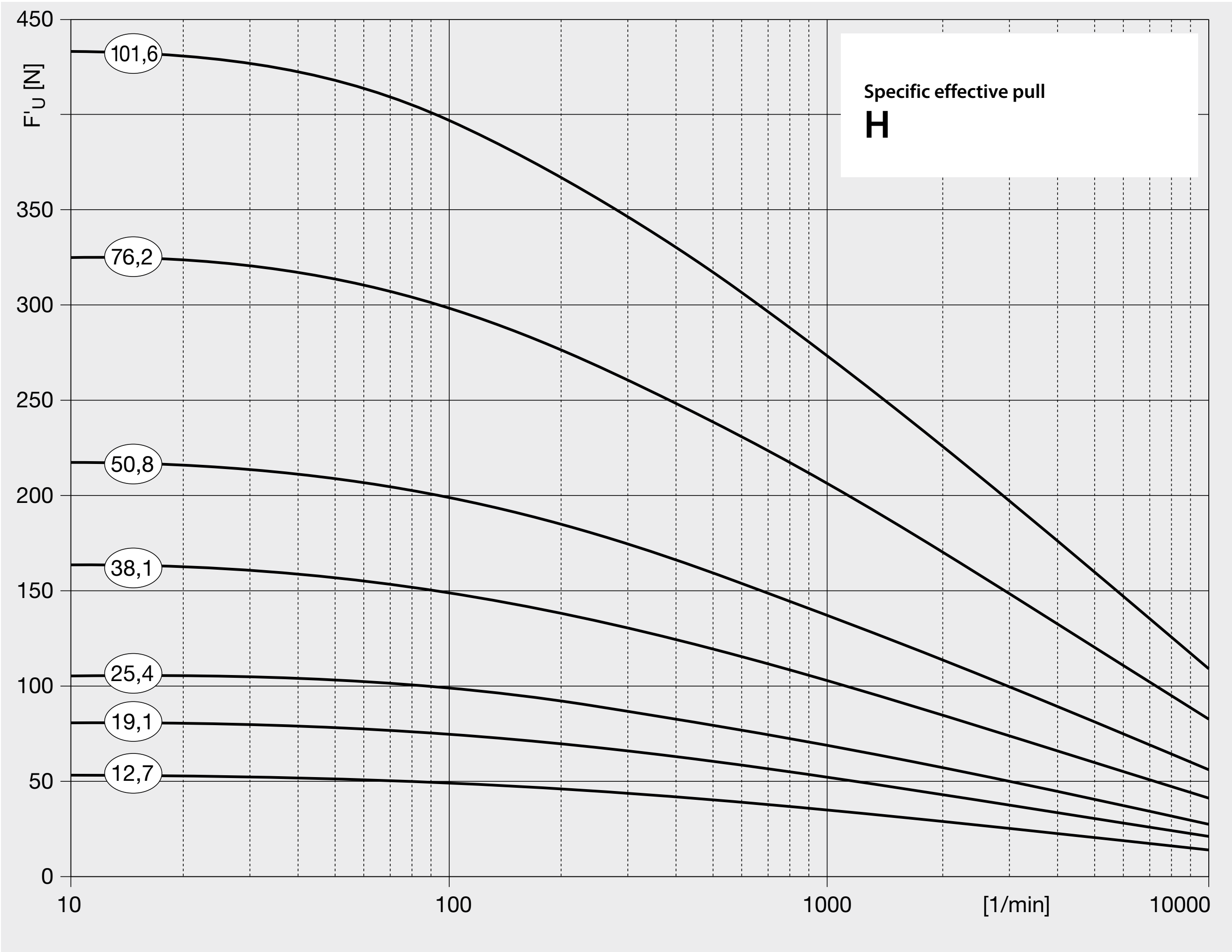
Value	b_0 [mm]	12.7	19.1	25.4	38.1	50.8	76.2	101.6
F_{per} [N] AdV 09		550	800	1100	1600	2200	3300	4400
F_{per} [N] AdV 07		1100	1600	2200	3200	4400	6600	8800
C_{spec} [N] · 10^6		0.25	0.38	0.5	0.75	1.0	1.5	2.0
m'_R [kg/m]		0.05	0.074	0.099	0.149	0.198	0.297	0.396

Characteristic values: Type L = 3/8" (Kevlar tension member)*

Value	b_0 [mm]	12.7	19.1	25.4	38.1	50.8	76.2	101.6
F_{per} [N] AdV 09		410	620	830	1240	1660	2480	3320
F_{per} [N] AdV 07		830	1250	1600	2480	3320	4960	6640
C_{spec} [N] · 10^6		0.19	0.29	0.38	0.56	0.75	1.13	1.5
m'_R [kg/m]		0.041	0.061	0.081	0.122	0.163	0.244	0.325

* See comment on page 16

Timing belt type H = 1/2" ≙ t = 12.7 mm



Characteristic values: Type H = 1/2" (steel tension member)*

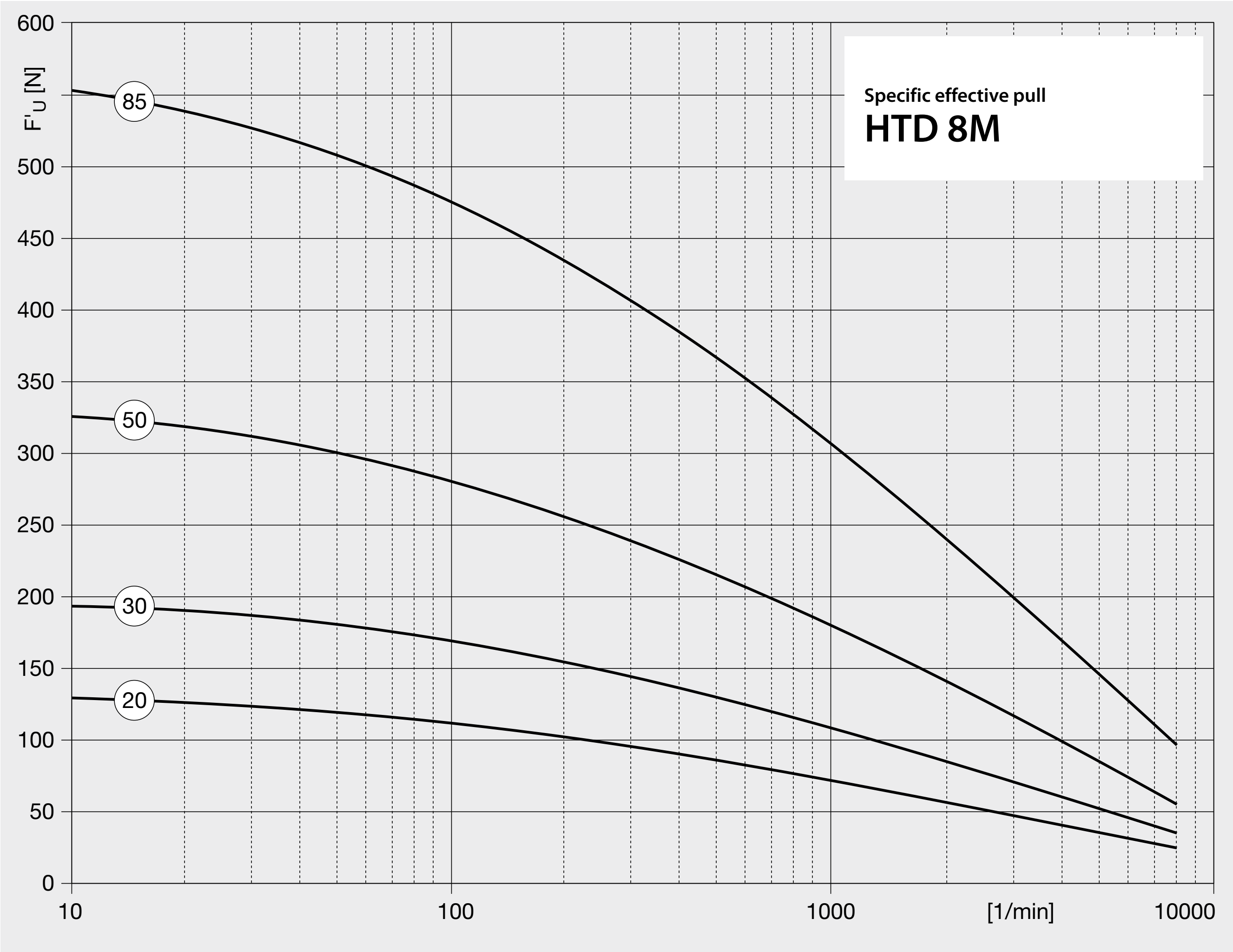
Value	b_0 [mm]	12.7	19.1	25.4	38.1	50.8	76.2	101.6
F_{per} [N] AdV 09		500	800	1100	1600	2200	3300	4400
F_{per} [N] AdV 07		1000	1600	2200	3200	4400	6600	8800
C_{spec} [N] · 10^6		0.25	0.38	0.5	0.75	1.0	1.5	2.0
m'_R [kg/m]		0.057	0.086	0.114	0.171	0.229	0.343	0.457

Characteristic values: Type H = 1/2" (Kevlar tension member)*

Value	b_0 [mm]	12.7	19.1	25.4	38.1	50.8	76.2	101.6
F_{per} [N] AdV 09		410	620	830	1240	1660	2450	3150
F_{per} [N] AdV 07		830	1250	1660	2480	3320	4900	6300
C_{spec} [N] · 10^6		0.19	0.29	0.38	0.56	0.75	1.13	1.5
m'_R [kg/m]		0.044	0.067	0.089	0.133	0.178	0.267	0.356

* See comment on page 16

Timing belt type HTD 8M



Characteristic values: Type HTD 8M (steel tension member)*

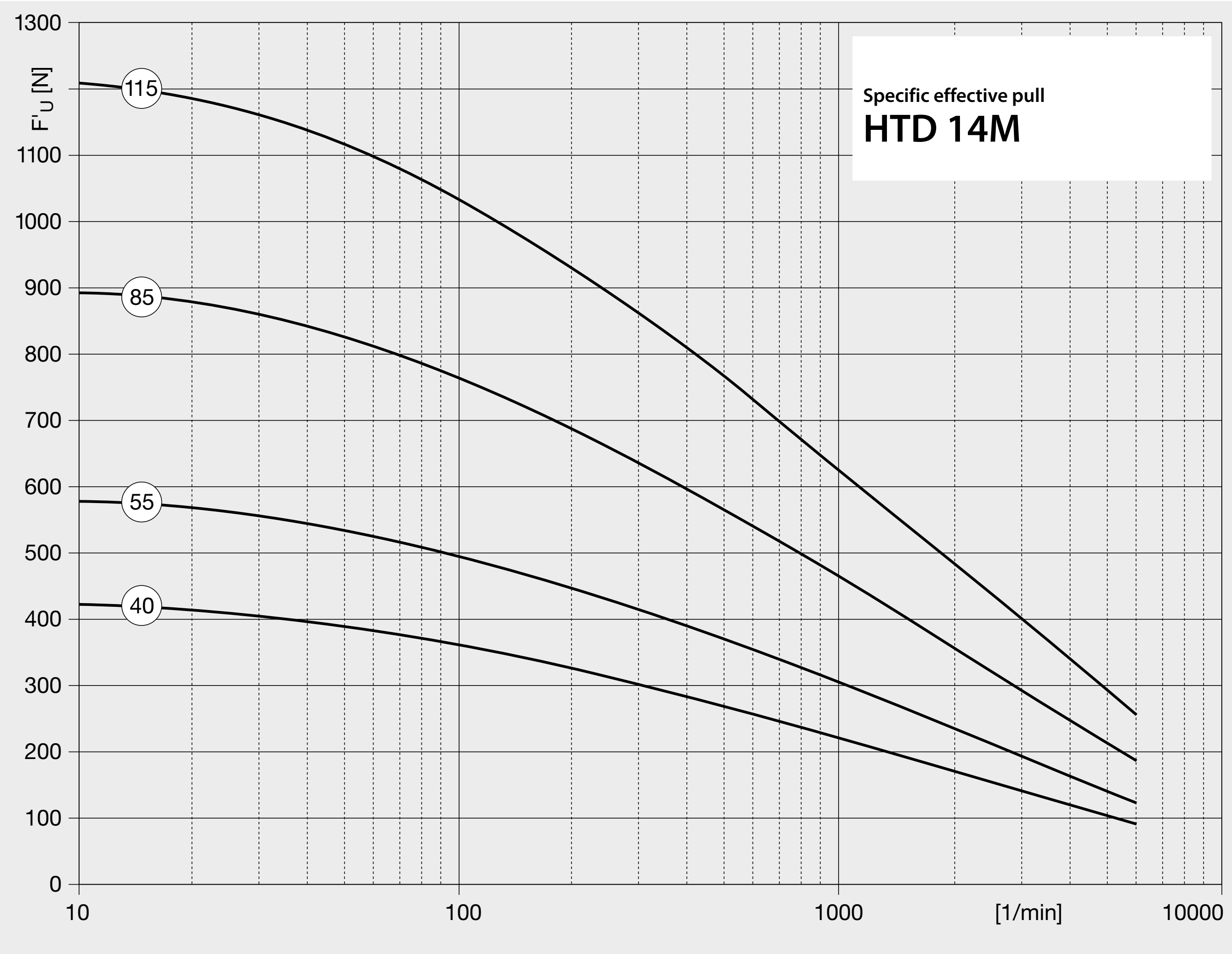
Value	b_0 [mm]	20	30	50	85
F_{per} [N] AdV 09		1440	2400	3840	7320
F_{per} [N] AdV 07		2880	4800	7680	14640
C_{spec} [N] · 10^6		0.7	1.05	1.75	2.98
m'_R [kg/m]		0.138	0.207	0.345	0.587

Characteristic values: Type HTD 8M (Kevlar tension member)*

Value	b_0 [mm]	20	30	50	85
F_{per} [N] AdV 09		1033	1593	2713	4673
F_{per} [N] AdV 07		1377	2123	3617	6230
C_{spec} [N] · 10^6		0.53	0.79	1.31	2.24
m'_R [kg/m]		0.094	0.142	0.236	0.400

* See comment on page 16

Timing belt type HTD 14M



Characteristic values: Type HTD 14M (steel tension member)*

Value	b_0 [mm]	40	55	85	115
F_{per} [N] AdV 09		5500	7970	12650	17600
F_{per} [N] AdV 07		11000	15950	25300	35200
C_{spec} [N] · 10^6		2.12	2.92	4.51	5.83
m'_R [kg/m]		0.44	0.605	0.935	1.265

Characteristic values: Type HTD 14M (Kevlar tension member)*

Value	b_0 [mm]	40	55	85	115
F_{per} [N] AdV 09		1874	2612	4087	5562
F_{per} [N] AdV 07		2499	3482	5449	7416
C_{spec} [N] · 10^6		1.59	2.19	3.38	4.37
m'_R [kg/m]		0.336	0.462	0.714	0.966

* See comment on page 16

Tables

Table 1
Teeth in mesh factor c_1

Application	c_1 max
Welded belts AdV 09	6
Open belts AdV 07	12
Linear drives with higher positioning accuracy	4

c_1 = Number of teeth involved in power flux

Table 2
Operational factor c_2

Smooth operating conditions	$c_2 = 1.0$
Short-term overload < 35 %	$c_2 = 1.10 – 1.35$
Short-term overload < 70 %	$c_2 = 1.40 – 1.70$
Short-term overload < 100 %	$c_2 = 1.75 – 2.00$

Table 3
Acceleration factor c_3

Transmission ratio i	c_3
i > 1 to 1.5	0.1
i > 1.5 to 2.5	0.2
i > 2.5 to 3.5	0.3
i > 3.5	0.4

Table 4
Friction coefficients of timing belts

µ	PU	PAZ	PAR
Bed/rail	0.5	0.2 – 0.3	0.2 – 0.3
Plastic support rail	0.2 – 0.3	0.2 – 0.25	0.2 – 0.25
Accumulation	0.5	0.2 – 0.3	0.2 – 0.3

All values are guidelines
PU = polyurethane
PAZ = polyamide fabric on toothed side
PAR = polyamide fabric on back of belt

Resistances

Chemical	Resistance
Acetic acid 20 %	❍
Acetone	❍
Aluminium chloride, aqueous 5 %	●
Ammonia 10 %	●
Aniline	–
ASTM oil 1	●
ASTM oil 2	●
ASTM oil 3	❍
Benzol	❍
Butyl acetate	–
Butyl alcohol	❍
Carbon tetrachloride	–
Common salt solution, conc.	●
Cyclohexanol	❍
Diesel oil	●
Dimethyl formamide	–
Ethyl acetate	–
Ethyl alcohol	❍
Ethyl ether	●
Hydrochloric acid 20 %	❍
Iron chloride, aqueous 5 %	❍
Isopropyl alcohol	❍
Kerosine	●

Chemical	Resistance
Lubricating grease (sodium soap fat)	●
Methyl alcohol	❍
Methyl alcohol/Benzine 15-85	●
Methyl ethyl ketone	❍
Methylene chloride	–
Mineral oil	●
n-Heptane	●
n-Methyl-2-pyrrolidone	–
Nitric acid 20 %	–
Petrol, regular	●
Petrol, super	●
Potash lye 1 N	❍
Sea water	●
Soda lye 1 N	❍
Sodium chloride solution, conc.	●
Sodium soap fat	●
Sodium soap fat + 20 % water	❍
Sulphuric acid 20%	❍
Tetrahydrofurane	–
Toluene	–
Trichloroethylene	–
Water	●

Table 5
Chemical resistance at room temperature

Symbols

● = good resistance

❍ = limited resistance; slight weight and dimensional changes after a certain period of time

– = no resistance

Siegling – total belting solutions

Because our products are used in so many applications and because of the individual factors involved, our operating instructions, details and information on the suitability and use of the products are only general guidelines and do not absolve the ordering party from carrying out checks and tests themselves. When we provide technical support on the application, the ordering party bears the risk of the machinery functioning properly.

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