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Continuous mechanical handling equipment — Belt conveyors with carrying idlers — Calculation of operating power and tensile forces

Engins de manutention continue — Transporteurs à courroie munis de rouleaux porteurs — Calcul de la puissance d'entraînement et des efforts de tension

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 5048 was prepared by Technical Committee ISO/TC 101, *Continuous mechanical handling.*

This second edition cancels and replaces the first edition (ISO 5048 : 1979), clause 2, subclauses 4.1.2 and 4.3.4, clause 5 and figures 3, 4 and 5 of which have been technically revised, and figure 6 and table 4 deleted. A new clause 2 (definitions) has been added.

Introduction

In the design of belt conveyors, it is advisable first to calculate the required driving force on the driving pulley and the belt tensile stresses resulting therefrom, since these values will effectively determine the choice of driving system and the construction of the belt.

The operating power requirements are derived from the driving force on the driving pulley and from the speed of the belt.

The necessary belt width is calculated on the basis of the maximum capacity of the belt and, possibly, of the particle size of the material to be handled.

Attention is drawn to the many varied factors which influence the driving force on the driving pulley and which make it extremely difficult to predict the power requirement exactly. This International Standard is intended to give a simple method of conveyor design calculation. Consequently it is limited in terms of precision but is sufficient in the majority of cases. Many factors are not taken into account in the formulae but details are provided on their nature and their effect.

In simple cases, which are the most frequent, it is possible to progress easily from the calculation of power requirements to those of the necessary and the real tensions in the belt, which are critical in the selection of the belt and in the design of the mechanical equipment.

However, certain conveyors present more complicated problems, for example those with multiple drives, or with an undulating profile in vertical elevation. For these calculations, which are not covered in this International Standard, it is advisable to consult a competent expert.

Continuous mechanical handling equipment — Belt conveyors with carrying idlers — Calculation of operating power and tensile forces

1 Scope

This International Standard specifies methods for the calculation of the operating power requirements on the driving pulley of a belt conveyor, and of the tensile forces exerted on the belt. It applies to belt conveyors with carrying idlers.

2 Definitions

For the purposes of this International Standard, the following definitions apply.

2.1 surcharge angle (of the material handled), θ : Angle formed with the horizontal by the tangent to the material cross-section at the intersecting point with the belt in motion (see figure 3). The surcharge angle is expressed in degrees.

2.2 angle of repose, α : Angle formed with the horizontal by the surface of a conical heap of material falling slowly and regularly from a small height onto a horizontal stationary surface. The angle of repose is expressed in degrees.

3 Symbols and units

Table 1 — Symbols and units

Symbol	Description	Unit
a_o	Idler spacing on the carrying side of the conveyor	m
a_u	Idler spacing on the reverse side of the conveyor	m
A	Contact area between the belt and the belt cleaner	m^2
b	Material-carrying belt width (i.e. width of the belt actually filled with or bearing material); usable width of the belt	m
b_1	Width between skirtplates	m
B	Belt width	m
C	Coefficient (secondary resistances)	–
C_ε	Trough factor	–
d	Belt thickness	m
d_o	Shaft diameter of inside bearing	m
D	Pulley diameter	m
e	Base of natural logarithms	–
f	Artificial friction coefficient	–
F	Average belt tension at the pulley	N
F_1	Tight-side tension at the pulley (see figure 2)	N
F_2	Slack-side tension at the pulley (see figure 2)	N
F_H	Main resistances	N
F_{max}	Maximum belt tension	N
F_{min}	Minimum belt tension	N
F_N	Secondary resistances	N
F_S	Special resistances	N
F_{S1}	Special main resistances	N
F_{S2}	Special secondary resistances	N
F_{St}	Resistance due to slope	N
F_T	Vectorial sum of the two belt tensions acting on the pulley and of the forces due to the mass of the revolving parts of the pulley	N
F_U	Required peripheral driving force on the driving pulley(s)	N
g	Acceleration due to gravity	m/s^2
$(h/a)_{adm}$	Allowable belt sag between idlers	–
H	Lift of the conveyor between the dumping area and the loading area	m
I_V	Capacity	m^3/s
k	Slope factor	–
k_a	Scraping factor	N/m
l	Length of the installation equipped with skirtplates	m
l_3	Length of centre idler (three-roller trough)	m
l_b	Acceleration length	m
L	Conveyor length (centre-to-centre distance)	m
L_o	Additional length of the conveyor	m
L_ε	Length of the installation equipped with tilted idlers	m
p	Pressure between the belt cleaner and the belt	N/m^2
P_A	Operating power requirement on the driving pulley(s)	W
P_M	Operating power requirement on the driving motor(s)	W
q_B	Mass per metre of the belt along the carrying side and along the return side	kg/m
q_G	Mass per metre of the material handled	kg/m
q_{RO}	Mass per metre of the revolving idler parts along the carrying side of the conveyor	kg/m
q_{RU}	Mass per metre of the revolving idler parts along the return side of the conveyor	kg/m
S	Cross-sectional area of the material on the belt	m^2
v	Belt speed	m/s
v_o	Velocity component of the conveying speed of material handled in the direction of belt movement	m/s

Table 1 *(concluded)*

Symbol	Description	Unit
α	Angle of repose	degrees
δ	Slope angle of the installation in the direction of movement	degrees
ϵ	Tilt angle of the idler axis with respect to the plane perpendicular to the longitudinal axis of the belt	degrees
η	Efficiency	–
θ	Surcharge angle (of the material handled)	degrees
λ	Angle between the side axis of the troughed carrying idlers and the horizontal	degrees
μ	Friction coefficient between the driving pulley(s) and the belt	–
μ_0	Friction coefficient between the carrying idlers and the belt	–
μ_1	Friction coefficient between the material and the belt	–
μ_2	Friction coefficient between the material and the skirtplates	–
μ_3	Friction coefficient between the belt and the belt cleaner	–
ξ	Acceleration coefficient	–
ϱ	Loose bulk density of the material handled	kg/m^3
φ	Angle of the belt wrap on the driving pulley(s)	radians

4 Resistances to motion of belt conveyor

4.1 General

The overall resistance to motion of a belt conveyor comprises various resistances, which can be classified into the following five groups :

- main resistances, F_H (see 4.2);
- secondary resistances, F_N (see 4.3);
- special main resistances, F_{S1} (see 4.4);
- special secondary resistances, F_{S2} (see 4.5);
- slope resistance, F_{St} (see 4.6).

These five groups include all the resistance which a belt conveyor driving system has to overcome to counter friction and the route slope, and also to accelerate the conveyed material up to belt speed at the loading point.

The main and secondary resistances, F_H and F_N, occur on all belt conveyors, whereas special resistances, $F_S = F_{S1} + F_{S2}$, are only present in certain installations. The main resistances, F_H and F_{S1}, occur continuously along the belt conveyor, whereas secondary resistances, F_N and F_{S2}, are only present locally.

The slope resistance, F_{St}, may have positive, zero or negative values, depending on the gradient of the conveyor. Furthermore, it can occur in a continuous manner all along the conveyor or only arise on some sections of the length.

4.2 Main resistances, F_H

Main resistances, F_H, comprise the following :

a) rotational resistance of the carrying and return strands of idlers due to friction in the idler bearings and seals [see equations (3) and (4)];

b) belt advancement resistance due to the pressing down of the idlers into the belt, and the recurrent flexing of the belt and of the material.

4.3 Secondary resistances, F_N

Secondary resistances, F_N, comprise the following :

a) inertial and frictional resistances due to the acceleration of the material at the loading area;

b) resistance due to the friction on the side walls of the chute at the loading area;

c) pulley bearing resistance with the exception of the driving pulley bearings;

d) resistance due to the wrapping of the belt on the pulleys.

4.4 Special main resistances, F_{S1}

Special main resistances, F_{S1}, comprise the following :

a) drag resistance due to forward tilt of the idler in the direction of belt movement;

b) resistance due to friction against chute flaps or skirtplates, if these are present over the full length of the belt.

4.5 Special secondary resistances, F_{S2}

Special secondary resistances, F_{S2}, comprise the following :

a) resistance due to friction with belt and pulley cleaners;

b) resistance due to friction with the chute flaps or skirtplates, if these are present over only part of the length of the belt;

c) resistance due to inversion of the return strand of the belt;

d) resistances due to discharge ploughs;

e) resistance due to trippers.

4.6 Slope resistance, F_{St}

Slope resistance, F_{St}, is resistance due to the lifting or lowering of the material on inclined conveyors.

Contrary to certain other resistances, the slope resistance can be precisely determined using the following equation :

$$F_{St} = q_G H g \qquad \text{...(1)}$$

The elevation height, H, is taken as positive for ascending installations and negative for descending installations.

5 Driving force and power requirements

5.1 Peripheral force required on the driving pulley(s)

5.1.1 General calculation formulae

The peripheral driving force, F_U, required on the driving pulley(s) of a belt conveyor is obtained by adding up all the resistances as follows :

$$F_U = F_H + F_N + F_{S1} + F_{S2} + F_{St} \qquad \text{...(2)}$$

The main resistance, F_H, can be calculated in a simplified manner by using an artificial friction coefficient, f. By applying Coulomb's friction law the main resistance is equal to the product of the artificial coefficient, f, the conveyor length, L, and the sum of the vertical forces per linear metre resulting from all the moving masses; therefore, by substituting F_H in equation (2), the following equation is obtained :

$$F_U = f L g [q_{RO} + q_{RU} + (2 q_B + q_G) \cos \delta] + F_N + F_{S1} + F_{S2} + F_{St} \qquad \text{...(3)}$$

Since a conveyor slope of the order of 18° generally represents an upper limit for smooth-surfaced belt conveyors, the angle of slope, δ, may be disregarded in equation (3) and vertical loads equal to the conveyor loads may be used for calculation ($\cos \delta = 1$).

If the conveyor slope exceeds 18° (made possible by use of ribbed or herringbone belts), the conveyor loads q_B and q_G shall be multiplied by $\cos \delta$.

The conveyor load, q_G, resulting from the mass of the conveyed material, can be calculated, in, for example, kilograms per metre, using the following equation :

$$q_G = \frac{I_V \varrho}{v} \qquad \text{...(4)}$$

where

I_V is the capacity, in, for example, cubic metres per second;

ϱ is the loose bulk density, in, for example, kilograms per cubic metre;

v is the belt speed in, for example, metres per second.

Equation (3) is valid for all installation lengths.

For long centre-belt conveyors (for example over 80 m), the secondary resistances are clearly less than the main installation resistances and can be calculated in a simplified manner without risk of too serious an error. For this purpose, a coefficient C is introduced as main resistance factor dependent on the length of the belt conveyor; therefore, the following equation is obtained :

$$F_U = C f L g [q_{RO} + q_{RU} + (2 q_B + q_G)] + q_G H g + F_{S1} + F_{S2} \qquad \text{...(5)}$$

If the conveyor slope exceeds 18° (made possible by use of ribbed or herringbone belts), the conveyor loads, q_B and q_G shall be multiplied by $\cos \delta$.

5.1.2 Coefficient C

Coefficient C corresponds to the quotient given by the following equation :

$$C = \frac{\text{Total resistance without slope resistances and without special resistances}}{\text{Main resistances}}$$

$$= \frac{F_H + F_N}{F_H} \qquad \text{...(6)}$$

Coefficient C is a function of the length of the installation because the majority of the secondary resistances, F_N, in equation (6) are independent of conveyor length and only occur locally.

Figure 1 indicates coefficient C as a function of the length L of the belt conveyor, the values plotted being derived from tests carried out on a variety of installations — particularly for the longer centre installations. The diagram in figure 1 shows that, when applying coefficient C in calculations, reliable values for the peripheral force as the driving pulley can only be obtained for conveyor lengths over 80 m.

If the conveyor length, L, is over 80 m, coefficient C can be calculated using the following equation :

$$C = \frac{L + L_o}{L} \qquad \text{...(7)}$$

where the additional length, L_o, is, in general, between 70 m and 100 m.

Coefficient C shall be equal to or greater than 1,02.

For centre-to-centre distances, L, of less than 80 m, the value of coefficient C becomes unsure, as is shown by the hatched area in figure 1. The unreliable area of coefficient C for short centre conveyors is explained by the predominance of the secondary resistances of such installations. The broken lines for coefficient C in this short centre zone do not represent boundary curves but merely draw the attention to a growing uncertainty of the C value.

In most cases C will be located in the hatched area. It is, however, also possible to have smaller values, especially for conveyors with unit loads with small secondary resistances, or much greater values, especially for short high-speed feed conveyors of large capacity.

For more precise calculation of the driving power of belt conveyors with a centre-to-centre distance, L, of less than 80 m, it is consequently recommended that equation (3) be used.

5.1.3 Artificial friction coefficient, f

The artificial friction coefficient, f, comprises the rolling resistance of the carrying idlers and the belt advancement resistance, and has been calculated at 0,02 as a basic value for a moving belt, based on the results of a broad series of tests.

For fixed and properly aligned installations, with easily rolling idlers and also for low internal friction materials, this value can be lower by about 20 %, dropping to 0,016, whereas for poorly aligned belt conveyors with badly rolling idlers and high internal friction materials, values exceeding the basic value by about 50 %, ranging up to 0,03, may result.

The basic value indicated for the artificial friction coefficient applies only to normally aligned belt conveyors. Strictly speaking, it is furthermore only applicable to an installation

- used at around 70 % to 110 % of its nominal capacity;
- conveying products with an average internal friction coefficient;
- equipped with three-roll carrying idlers for the upper side of the belt;
- with a 30° side troughing angle;
- operating at belt speeds of about 5 m/s;
- operating at ambient temperatures of about 20 °C;
- with 108 mm to 159 mm diameter carrying idlers with labyrinth grease seals, together with idler spacing of 1 m to 1,5 m for the upper strand (or carrying side) of the belt and of around 3 m for the lower strand (or return side) of the belt.

The value of f may, for instance, increase above the basic value 0,02 and range up to 0,03 in the following cases :

a) for handled materials with a high internal friction coefficient;

b) for troughing angles of over 30°;

c) for belt speeds of over 5 m/s;

d) for carrying idler diameters lower than those mentioned above;

e) for ambient temperatures of less than 20 °C;

f) for a decrease in belt tension;

g) for flexible carcass belts and those with thick and flexible covers;

h) for poorly aligned installations;

i) when operating conditions are dusty and wet and/or sticky;

j) for idler spacing of markedly more than 1,5 m for the upper strand (or carrying side) of the belt and 3 m for the lower strand (or return side) of the belt.

The artificial friction coefficient, f, may decrease under the basic value of 0,02 if the influences listed above in a) to j) are reversed.

If the installation is running under no-load conditions, the value of f can be either lower or higher than under full-load operating conditions, depending on the mass of the moving parts and on the tension of the conveyor belt.

After account has been taken of the influences listed above in a) to j), the value of $f = 0{,}02$ may be confirmed. However, the optimum choice and assessment of the exact value of f should be left to the manufacturer because of the many and diverse influences in connection with it. In general, sufficiently accurate results are reached with respect to the driving force at the pulley of a belt conveyor if the basic value of the factor $f = 0{,}02$ is inserted into equation (3) or (5).

Downhill conveyors which require to be braked by brake-motor, shall, as a safety measure, be calculated with a value lower by 40 % than that used for the calculation of driven belt conveyors : the result of this is a basic value of $f = 0{,}012$.

5.1.4 Secondary and special resistances

For a more precise calculation of the driving force on the driving pulley and the operating power requirements of belt conveyors using equation (3), the secondary and special resistances, F_N, F_{S1} and F_{S2}, shall be known.

The calculation formulae for these resistances are given in tables 2 and 3, and values can be determined on the basis of the known characteristics of the belt conveyor.

Table 2 gives the secondary resistances, F_N, which occur on all belt conveyors, whereas table 3 gives the special resistances, F_S, which do not always occur.

It is possible to simplify the calculation by disregarding minor secondary and special resistances, i.e. by account only being taken of the inertial and frictional resistance at the loading area and the friction of the conveyed material on the side walls of the chute in the acceleration area, together with the frictional resistance due to the belt cleaners and forward tilt of carrying idler sets.

Table 2 — Formulae for calculating secondary resistances, F_N

Symbol	Type of resistance	Unit
F_{bA}	Inertial and frictional resistance at the loading point and in the acceleration area between the material handled and the belt : $F_{bA} = I_V \varrho (v - v_o)$	N
F_f	Frictional resistance between handled material and the skirtplates in the acceleration area : $F_f = \dfrac{\mu_2 I_V^2 \varrho g l_b}{\left(\dfrac{v + v_o}{2}\right)^2 b_1^2}$ where $\mu_2 = 0,5$ to $0,7$ and $l_{b,min} = \dfrac{v^2 - v_o^2}{2 g \mu_1}$ where $\mu_1 = 0,5$ to $0,7$	N
F_1	Wrap resistance between belt and pulleys — for fabric carcass belts : $F_1 = 9 B \left(140 + 0,01 \dfrac{F}{B}\right) \dfrac{d}{D}$ — for metal carcass belts : $F_1 = 12 B \left(200 + 0,01 \dfrac{F}{B}\right) \dfrac{d}{D}$	N
F_t	Pulley bearing resistance (not to be calculated for the driving pulleys) : $F_t = 0,005 \dfrac{d_o}{D} F_T$	N

Table 3 — Formulae for calculating special resistances, F_S

Symbol	Type of resistance	Unit
F_ϵ	Resistance due to idler tilting — for carrying idlers equipped with three equal length rollers : $F_\epsilon = C_\epsilon \mu_0 L_\epsilon (q_B + q_G) g \cos\delta \sin\epsilon$ where $C_\epsilon = 0,4$ for 30° trough $= 0,5$ for 45° trough $\mu_0 = 0,3$ to $0,4$ — for return idlers equipped with two rollers : $F_\epsilon = \mu_o L_\epsilon q_B g \cos\lambda \cos\delta \sin\epsilon$ where $\mu_0 = 0,3$ to $0,4$	N
F_{gL}	Resistance due to friction between material handled and skirtplates : $F_{gL} = \dfrac{\mu_2 I_V^2 \varrho g l}{v^2 b_1^2}$ where $\mu_2 = 0,5$ to $0,7$	N
F_r	Friction resistance due to the belt cleaners : $F_r = A p \mu_3$ where p is normally between 3×10^4 and 10×10^4 N/m²	N
F_a	Resistance due to friction at a discharge plough : $F_a = B k_a$ where k_a is normally 1 500 N/m	N

5.1.5 Applicability of formulae

The formulae for calculating the peripheral force at the driving pulley are only suitable for uniformly and continuously loaded installations.

For belt conveyors running over rough ground with slope changes or only sloping in a downhill direction, for which partial loading of the belt is frequently the case, the calculation of the peripheral force shall be carried out under, for example, the following different operating conditions :

a) empty conveyor;

b) fully loaded throughout;

c) loaded on some sections of the conveyor with a rising, level or slightly descending run where each section requires positive force to move it, and empty on the remaining sections which would be regenerative if loaded;

d) loaded on regenerative sections, and empty on sections with a rising, level or slightly descending run.

The highest peripheral force on the driving pulley found in this way is used for the design of the driving system.

Should one or more of the loading conditions indicate negative force at the driving pulley, the system thus becoming regenerative, it is necessary to introduce into this calculation a basic value lower than that used for the drive calculation, as given in 5.1.3. In such cases, the highest positive driving force and the greatest negative braking force shall then both be taken into account for the design of the driving and braking systems.

5.2 Operating power requirements for the belt conveyor

The operating power required on the driving pulley(s) of the belt conveyor P_A, in, for example, kilowatts, is derived from the peripheral driving force, F_U; the value of P_A is calculated from the following equation :

$$P_A = F_U v \quad \text{...(8)}$$

where

F_U is the peripheral driving force, in, for example, kilonewtons;

v is the belt speed, in, for example, metres per second.

The respective operating power required on the driving motor(s) is obtained from equation (9a) or (9b), in which account is taken of the efficiency of transmission equipment, as appropriate :

— for belt conveyors requiring positive power

$$P_M = \frac{P_A}{\eta_1} \qquad \text{...(9a)}$$

— for regenerative installations

$$P_M = P_A \eta_2 \qquad \text{...(9b)}$$

where

η_1 is generally chosen between 0,85 and 0,95;

η_2 is generally chosen between 0,95 and 1.

5.3 Belt forces

5.3.1 General

The tensile forces exerted on the belt vary along the whole length of the belt; their magnitude depends on

— the path of the belt conveyor;

— the number and arrangement of driving pulleys;

— the characteristics of the driving and braking systems;

— the type and arrangement of the belt-tensioning devices;

— the load case of the installation : starting, nominal rating, braking, stopped, either at no load or completely or partially loaded.

Considering the stress of the belt and the other parts in the installations submitted to forces produced in the belt, the tensile forces applied to the belt shall be as low as possible.

However, for the correct operation of the installation it is indispensable that the tensile forces in the belt fulfil the following two conditions :

a) the tensile forces exerted on the belt shall be such that, at any rating, the peripheral forces applied to all the driving pulleys are transmitted to the belt by friction without the belt slipping;

b) the tensile force exerted on the belt shall be sufficient for there not to be too much belt sag between two sets of carrying idlers.

5.3.2 Transmission of the peripheral force at the driving pulley(s)

For the transmission of a peripheral force, F_U, from a driving pulley to the belt, as shown in figure 2, it is necessary to maintain a tensile force, F_2, on the return belt, which can be calculated using the following formula :

$$F_{2,min} > F_{U,max} \frac{1}{e^{\mu\varphi} - 1} \qquad \text{...(10)}$$

where

$F_{U,max}$ is the maximum peripheral force which most often occurs when starting up or when braking the completely loaded conveyor;

μ is the friction coefficient between the driving pulley and the belt, which can be determined using table 4;

φ is the angle of wrap of a driving pulley, which is, according to the geometrical conditions, approximately between 2,8 and 4,2 (160° and 240°).

Table 4 — Friction coefficient, μ, between driving pulleys and rubber belting

Operating conditions	Friction coefficient, μ, as a function of pulley lagging			
	Smooth bare rim steel pulley	Rubber lagging with herringbone-patterned grooves	Polyurethane lagging with herringbone-patterned grooves	Ceramic lagging with herringbone-patterned grooves
Operation in dry conditions	0,35 to 0,4	0,4 to 0,45	0,35 to 0,4	0,4 to 0,45
Operation in clean and wet conditions (water)	0,1	0,35	0,35	0,35 to 0,4
Operation in wet and dirty conditions (clay or loam)	0,05 to 0,1	0,25 to 0,3	0,2	0,35

5.3.3 Limitation due to belt sag

The minimum tensile force, F_{min}, which shall be exerted on the belt in order to limit belt sag between two sets of carrying idlers is obtained from formulae (11a) or (11b), as appropriate :

— for the upper strand (carrying side)

$$F_{min} > \frac{a_o (q_B + q_G) g}{8 (h/a)_{adm}} \qquad \text{...(11a)}$$

— for the lower strand (return side)

$$F_{min} > \frac{a_u q_B g}{8 (h/a)_{adm}} \qquad \text{...(11b)}$$

Values lower than these shall never be reached at any point on the installation. The maximum allowable belt sag, $(h/a)_{adm}$, is generally fixed at between 0,005 and 0,02.

5.3.4 Variation of the tensile forces and maximum tensile force on the belt

The necessary tensile force and its alteration along the conveying length shall be determined for each load case as a function of the number, the arrangement and characteristics of the driving and braking devices, and according to the type and location of the tensioning devices, by suitably adding to or subtracting from the minimum forces exerted on the belt the resistances to motion, the forces due to the weight of the belt and the materials conveyed, and the peripheral forces applied to all the driving pulleys.

The minimum necessary tensile force is fixed either by the ability to transmit the peripheral force at a driving pulley or by the limitation of belt sag. This highest value of the necessary tensile force for a given load case is generally maintained with all the other load cases, even if they do not require it, as, normally, it is neither reasonable nor practicable to produce different take-up forces with different load cases.

The maximum tensile force, F_{max}, exerted on the belt which shall be used for the choice and dimensioning of the belt cannot be indicated by a formula which is universally valid.

It is only in the simple cases, which, however, occur relatively often, i.e.

— in the case of horizontal conveying or with a small gradient,

— and if there is a single driving pulley,

— and if low braking forces for stopping the plant are required,

— and if the minimum belt tension required is not determined by any other layout or operating conditions (for example by belt sag),

that the maximum tensile force applied to the belt can be calculated, approximately, by using the following formula (see figure 2):

$$F_{max} \approx F_1 \approx F_U \xi \left(\frac{1}{e^{\mu\varphi} - 1} + 1 \right) \qquad \text{...(12)}$$

The coefficient ξ takes into account the fact that the peripheral force shall be higher when starting the plant up than when at its nominal rating. According to the drive characteristics, the value of coefficient ξ lies between 1,3 and 2.

In all complicated cases, the variation of the tensile forces applied to the belt shall be carefully calculated by a specialist.

6 Capacity and cross-section of a conveyor with a smooth patternless belt

The maximum capacity of the belt conveyor, q_V, in, for example, cubic metres per second, is calculated using the following equation :

$$I_V = Svk \qquad \text{...(13)}$$

where

S is the maximum cross-sectional area of the material on the belt, in, for example, square metres;

v is the belt speed, in, for example, metres per second;

k is the slope factor of the installation.

The maximum cross-sectional area of material on the belt depends on

a) the usable width of the belt, b, in metres, which is a function of the belt width, B, in metres;

b) the shape of the trough, i.e. the number and dimensions of the idlers (length of the centre idler, l_3), and their arrangement (angle between the side axis of the troughed carrying idlers and the horizontal, λ);

c) the shape of the load stream on the belt (as understood in this International Standard) limited by a curve of parabolic shape characterized by the surcharge angle, θ (see 2.1).

The usable width of the belt, b, in metres, is determined generally using the following equations :

— for $B < 2$ m

$$b = 0{,}9\,B - 0{,}05 \qquad \text{...(14a)}$$

— for $B > 2$ m

$$b = B - 0{,}25 \qquad \text{...(14b)}$$

For horizontally running belts and one-, two- or three-idler sets, the total cross-sectional area of material on the belt, S, can be determined by using the surcharge angle θ and adding the (upper) section S_1 and the (lower) section S_2 (see figure 3) as expressed in the following equations :

$$S_1 = \left[l_3 + (b - l_3) \cos\lambda \right]^2 \frac{\operatorname{tg}\theta}{6} \qquad \text{...(15a)}$$

$$S_2 = \left[l_3 + \frac{(b - l_3)}{2} \cos\lambda \right] \left[\frac{(b - l_3)}{2} \sin\lambda \right] \qquad \text{...(15b)}$$

$$S = S_1 + S_2 \qquad \text{...(15c)}$$

In the case of one- or two-idler sets, the length of the centre idler has to be taken as zero.

The surcharge angle, θ, is dependent on the material and on the conveying conditions (for example speed, belt sag, etc.). If the surcharge angle, θ, is not known, an approximate value can be calculated using the angle of repose (see 2.2), by taking a value of $\theta = 0,75\,\alpha$. If, however, the material has unusual flow properties, i.e. it is sticky or very free-flowing, the value of θ may vary significantly from this approximation.

The slope factor, k, is determined by taking into account the decrease of the section S_1 when the material is fed on to an inclined part of the belt, as expressed in the following equation :

$$k = 1 - \frac{S_1}{S}(1 - k_1) \qquad \text{...(16)}$$

where k_1 is the reduction factor of the surcharge portion.

If an idealized running of conveyors handling virtually sized material with a middle lump size is considered, it can be assumed that k_1 is given by the following equation :

$$k_1 = \sqrt{\frac{\cos^2\delta - \cos^2\theta}{1 - \cos^2\theta}} \qquad \text{...(17)}$$

where

δ is the slope angle of the conveyor;

θ is the surcharge angle of the material handled.

Using equations (15) to (17), it is noticeable that, where the slope angle of a conveyor, δ, is equal to the surcharge angle of the material handled, θ, the upper section S_1 becomes non-existent and only the lower section S_2 can be used for handling purposes.

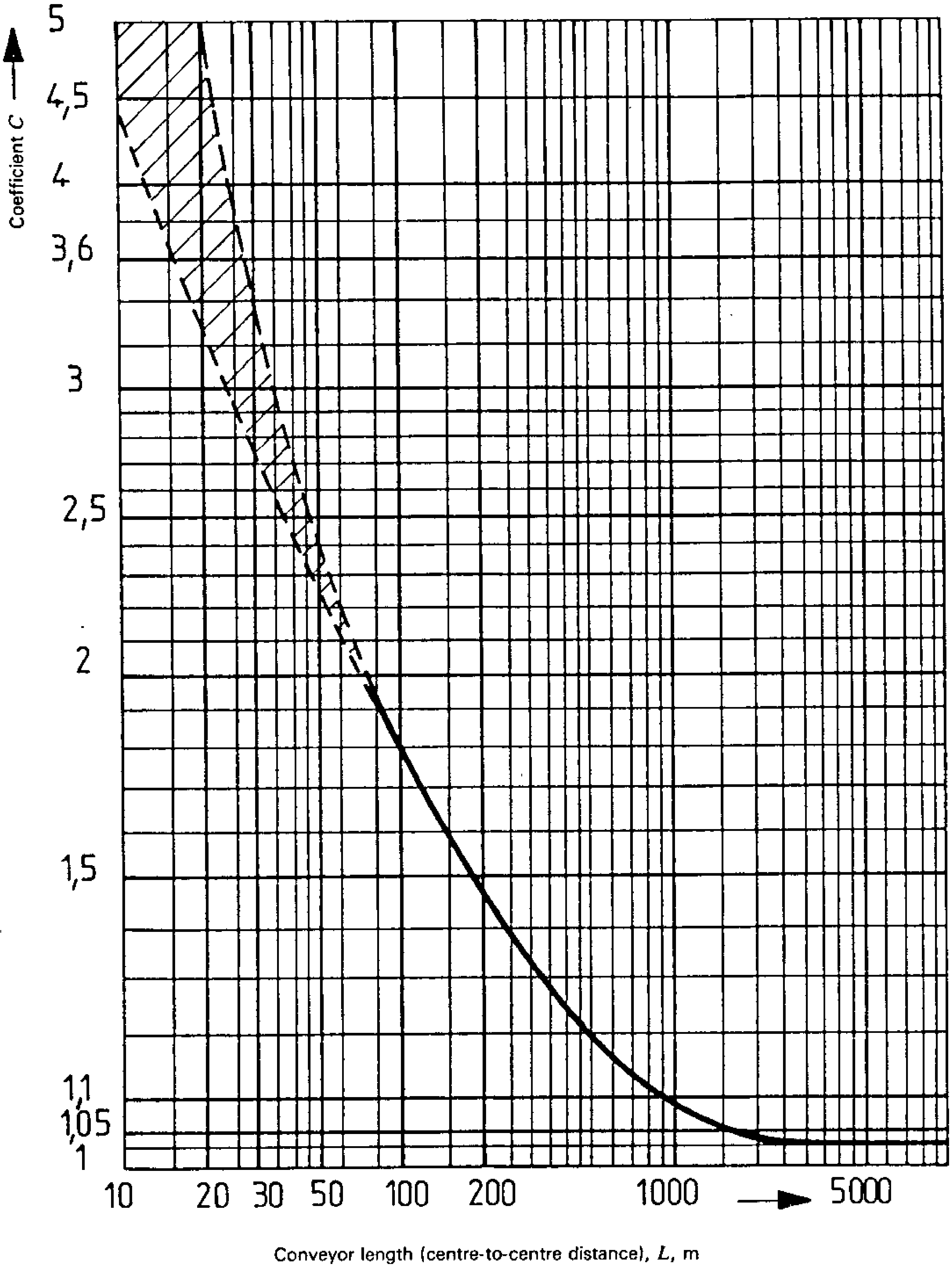


Figure 1 — Coefficient C as a function of L

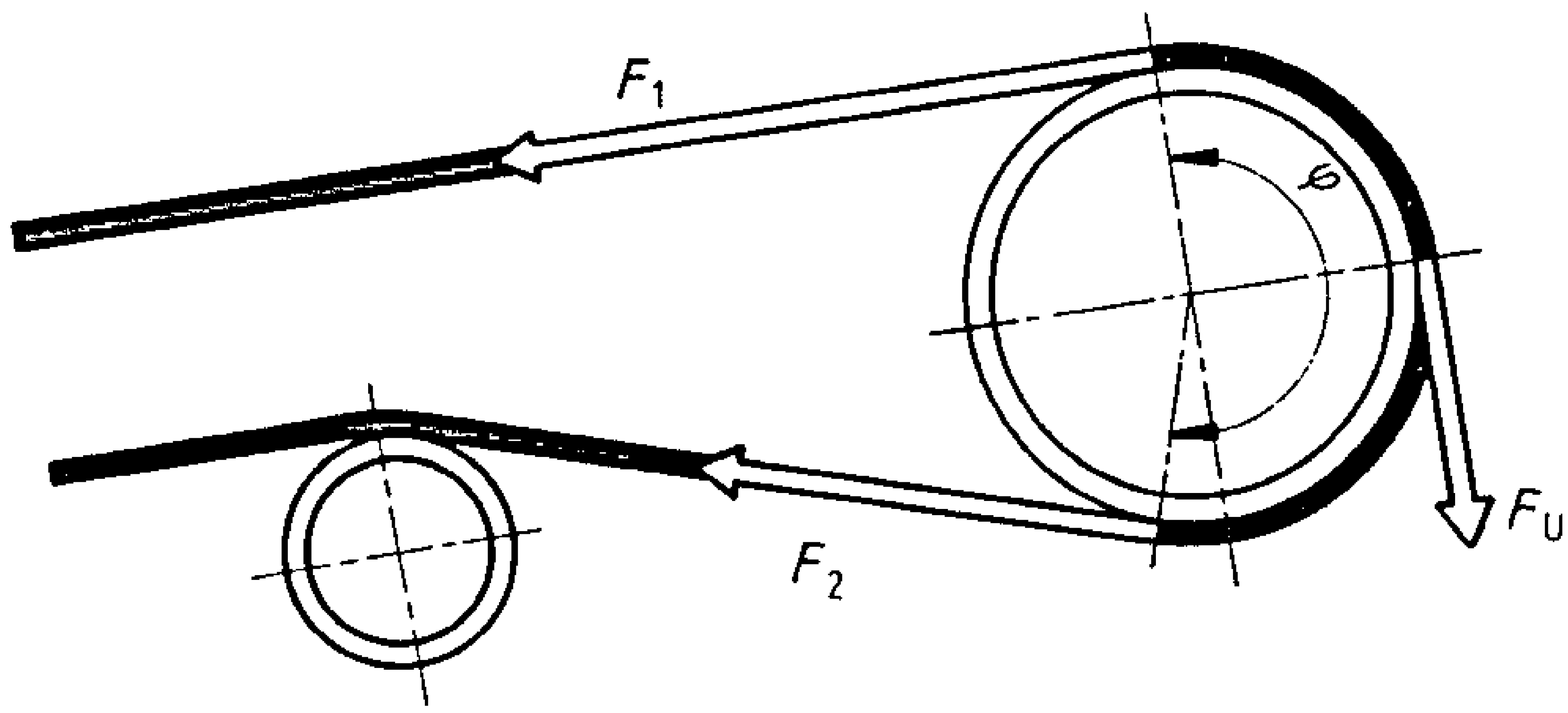
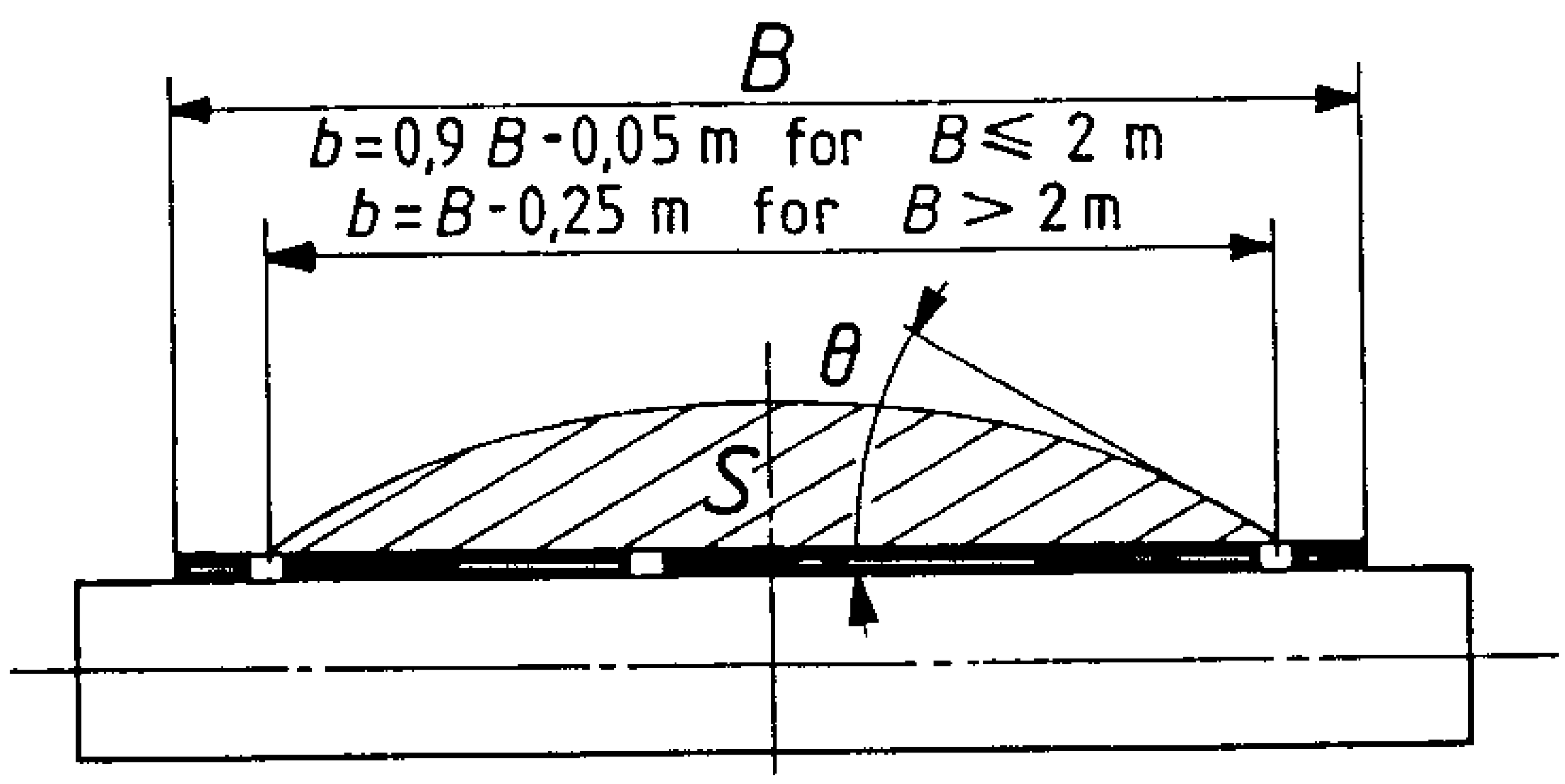
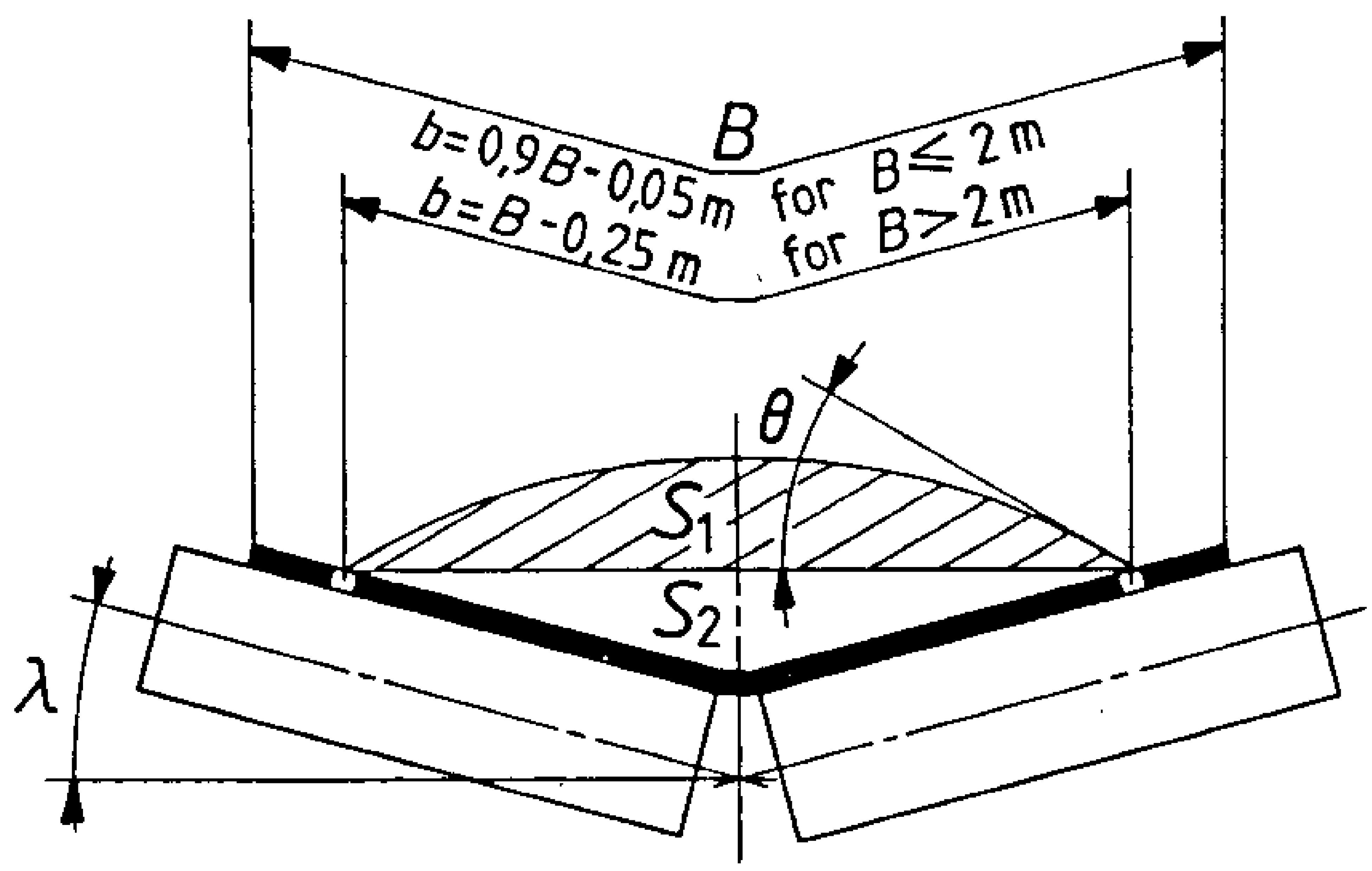


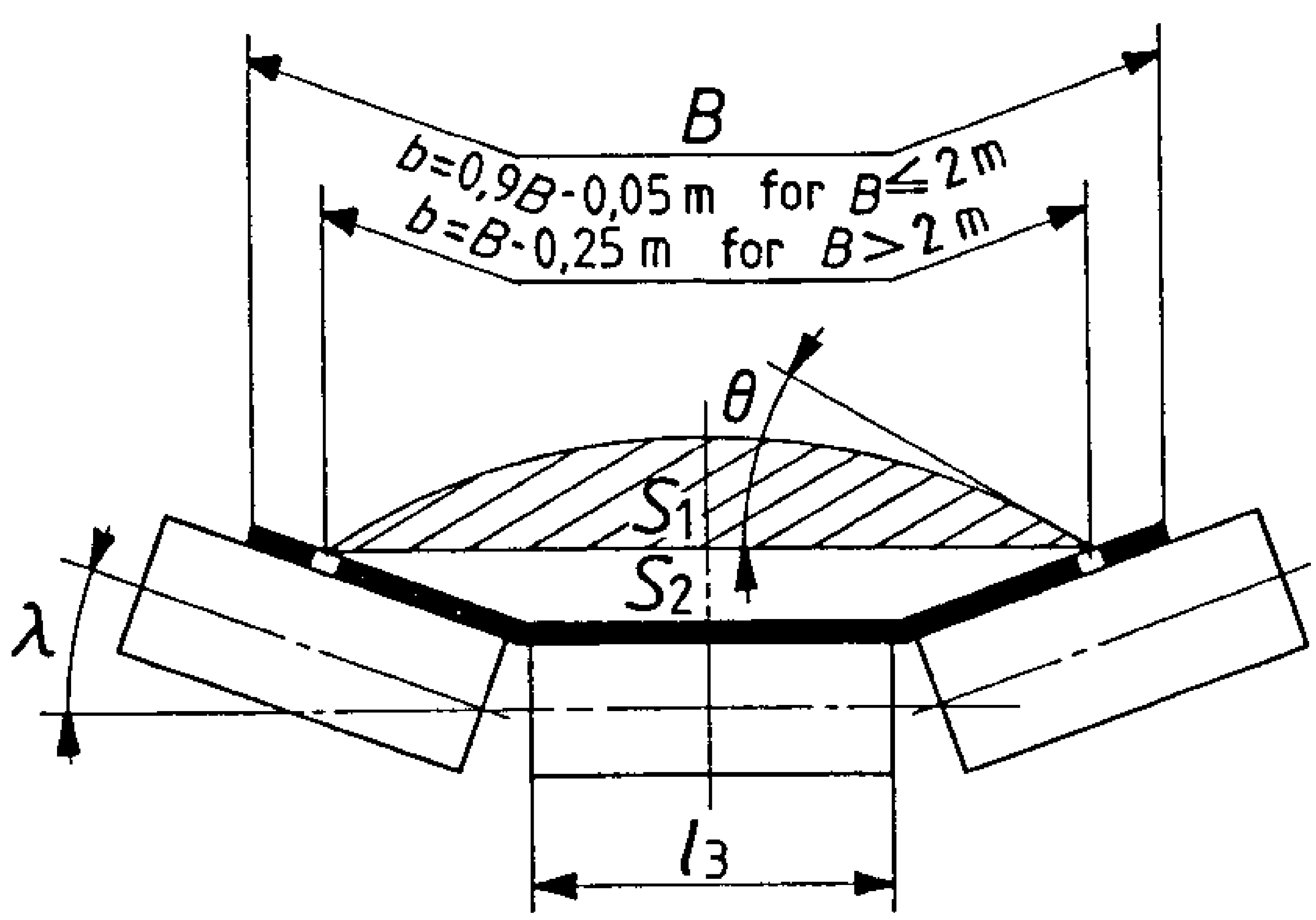
Figure 2 — Tensile forces exerted on the belt



a) With one carrying idler



b) With two carrying idlers



c) With three carrying idlers

Figure 3 — Trough cross-sections

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Descriptors : handling equipment, continuous handling, conveyors, belt conveyors, rules of calculation, power, tension.

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