International Standard ISO 7189

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Continuous mechancial handling equipment — Apron conveyors — Design rules

Engins de manutention continue — Transporteurs à tablier articulé — Règles pour le calcul

First edition — 1983-12-15

UDC 621.867.152.5

Ref. No. ISO 7189-1983 (E)

Descriptors : material handling equipment, continuous handling, apron conveyors, symbols, formulas (mathematics).

Price based on 7 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been authorized 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.

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.

International Standard ISO 7189 was developed by Technical Committee ISO/TC 101, *Continuous mechanical handling equipment*, and was circulated to the member bodies in February 1981.

It has been approved by the member bodies of the following countries:

Austria
Belgium
Brazil
Czechoslovakia
Egypt, Arab Rep. of
Finland
France
Korea, Dem. P. Rep. of
Korea, Rep. of
Netherlands
Norway
Poland
Romania
Sweden
United Kingdom
USSR

The member body of the following country expressed disapproval of the document on technical grounds:

Germany, F.R.

Printed in Switzerland

INTERNATIONAL STANDARD **ISO 7189-1983 (E)**

Continuous mechanical handling equipment — Apron conveyors — Design rules

1 Scope

This International Standard establishes design rules for apron conveyors.

2 Field of application

This International Standard is applicable to apron conveyors used for the transport of both loose bulk materials and unit loads.1)

It refers to the following appliances :

		Reference No. (ISO 2148)
a)	Apron conveyors	2.14.08
b)	Apron conveyors	2.14.081
c)	Pan conveyors	2.14.082
d)	Apron conveyors with closed pans	2.14.083
e)	Slat conveyors (metal or wood)	2.21.04 + 2.21.041 + 2.21.042
f)	Continuous (circular) plate conveyors (horizontal)	2.21.07

3 Reference

ISO 2148, *Continuous mechanical handling equipment — Nomenclature.*

---

1) The design rules remain valid if round link chains are used instead of flat link chains.

4 Symbols and units

Symbol	Designation	Unit
a	distance (pitch) between pans	m
a_{St}	average distance of unit loads	m
A	filling cross section	m^2
A_{th}	theoretical filling cross section	m^2
b	material carrying width	m
b_1	open space of chute	m
B	conveyor width	m
c	rolling friction coefficient (in flanged rollers)	—
e	rolling friction lever arm	mm
f	artificial friction coefficient	—
F_{dyn}	dynamic chain pull	N
F_{H}	main resistance	N
F_{K}	maximum chain pull	N
F_{K1}	maximum chain pull in nominal service	N
F_{K2}	maximum chain pull when starting	N
F_{N}	secondary resistance	N
F_{R}	resistance due to friction	N
F_{S}	special resistance	N
F_{St}	resistance due to the slope	N
F_{U}	driving wheels peripheral force	N
F_{V}	initial tension pull per strand	N
g	acceleration of gravity	m/s^2
h	filling height	m
h_1	height of the conveyed cross section	m
h_2	height of the adjoining pan partition	m
h_{B}	height of the trough or pan side partitions	m
H	conveyor lift (ascending positive, descending negative)	m
k	slope reduction factor	—
l	travel length between skirtplates	m
L	conveyor centre distance	m
L_1	loading length of conveyor	m

Symbol	Designation	Unit
m_{St}	average mass of unit loads	kg
N	number of teeth on the chain wheel	—
P_{A}	driving power applied to the chain wheel(s)	W
P_{Mot}	motor power	W
q_m	mass flow rate	kg/s
q_{St}	unit load flow rate	units/s
q_V	volume flow rate	m^3/s
r	pivot radius of carrying rollers, moving or fixed	mm
R	external radius of carrying rollers, moving or fixed	mm
t	chain pitch	m
v	conveying speed (chain speed)	m/s
V	filling volume of an individual pan	m^3
V_{th}	theoretical filling volume of a pan	m^3
β	maximum angle of repose of bulk material	—
β_{dyn}	dynamic angle of repose of bulk material	—
δ	conveyor slope angle	—
η_{ges}	efficiency between motor and chain wheel	—
μ_{W}	friction value between conveyed material and skirtplates	—
μ_{Z}	bearing friction coefficient	—
ϱ	density of conveyed bulk material	kg/m^3
$\varrho_{l\mathrm{G}}$	linear density of conveyed material (load per section)	kg/m
$\varrho_{l\mathrm{K}}$	linear density of conveyor chain (moving rollers included)	kg/m
$\varrho_{l\mathrm{Ro}}$	linear density of upper carrying rollers fixed to the structure	kg/m
$\varrho_{l\mathrm{Ru}}$	linear density of lower carrying rollers fixed to the structure	kg/m
φ	filling factor	—
ω	angular speed of the chain wheel	rad/s

5 Flow rate

5.1 Volume flow rate for continuous conveying of bulk material (for apron conveyors and pan conveyors)

The volume flow rate cap q_V is the product of the conveying speed v by the filling cross section A.

$$q_V = vA \qquad \dots (1)$$

5.2 Volume flow rate in pulsatory conveyance of bulk materials (apron conveyor with curved or flanged plates)

The volume flow rate q_V is the product of the filling volume V of each individual pan by the quotient of the conveying speed v by the distance a separating the pans :

$$q_V = V \frac{v}{a} \qquad \dots (2)$$

5.3 Unit load flow rate

The unit load flow rate q_{St} is equal to the quotient of the transport speed v by the average distance a_{St} separating the unit loads :

$$q_{\mathrm{St}} = \frac{v}{a_{\mathrm{St}}} \qquad \dots (3)$$

5.4 Mass flow rate

The mass flow rate q_m is the product of the volume flow rate q_V by the density ϱ or the unit loads flow rate by the weight of the unit loads :

$$q_m = q_V \varrho \quad \text{for the transport of bulk materials} \qquad \dots (4)$$

$$q_m = q_{\mathrm{St}}\, m_{\mathrm{St}} \quad \text{for the transport of unit loads} \qquad \dots (5)$$

5.5 Filling cross section and the filling volume for the conveyance of bulk materials

For horizontal conveyance, the theoretical filling cross sections A_{th} or the filling volumes V_{th} for the different constructional shapes, result from the geometrical dimensions of the carrying components and from the angle of repose of the bulk material.

However, in practice, these values are not reached permanently as in general one does not succeed in loading the conveyor completely and regularly in a permanent manner. The influence of an incomplete or irregular load is taken into consideration by the filling factor φ.

In the case of ascending or descending conveyors, the possible conveyor filling is reduced by the gradient. This slope influence is taken into account by the reducing factor k depending on the slope angle δ.

5.5.1 Flat apron plate conveyor filling cross section

The theoretical filling cross section is like an isosceles triangle (see figure 1) the base b of which (material carrying width) is a little smaller than the width B of the apron conveyor and the base angles of which are equal to the dynamic angle of repose β_{dyn} of the bulk material.

The conveyance of bulk material on the flat apron plate conveyors according to fig. 1 is limited to very rare cases.

$$\text{With } b = 0{,}9\,B - 0{,}05 \qquad \dots (6)$$

one has

$$A_{\mathrm{th}} = \frac{b^2}{4} \tan \beta_{\mathrm{dyn}} \qquad \dots (7)$$

$$\text{and } A = k\,\varphi\, \frac{b^2}{4} \tan \beta_{\mathrm{dyn}} \qquad \dots (8)$$

A_{th} and A are expressed in square metres.

The dynamic angle of repose may, in normal cases, be introduced for a value equal to half of the angle of repose β.

The flat apron plate conveyors which convey the bulk material along skirtplates as side partitions of the chutes (for example flat apron plate conveyors such as silo tapping plants) may reach considerably higher conveying cross sections, resulting from the open space of the chute b_1 and of the height h_1 of the conveying cross section (see figure 3)

$$A \approx k\,A_{\mathrm{th}} = k\, b_1\, h_1 \qquad \dots (9)$$

5.5.2 Filling cross section of a conveyor with curved apron plates with sides

The theoretical cross section is made of a rectangle with a width B and a filling height h, as well as of a triangle with a base B and base angles β_{dyn} (see figure 2).

$$\text{With : } h = h_{\mathrm{B}} - 0{,}05 \qquad \dots (10)$$

one has :

$$A_{\mathrm{th}} = B\,h + \frac{B^2}{4} \tan \beta_{\mathrm{dyn}} \qquad \dots (11)$$

$$\text{and } A = \varphi \left[h\,B + k\, \frac{B^2}{4} \tan \beta_{\mathrm{dyn}} \right] \qquad \dots (12)$$

A_{th} and A are expressed in square metres.

5.5.3 Filling cross section or filling volume for the conveyor with curved or flanged plates

If the gradient angle, δ, is smaller than the maximum angle of repose β, one can take the filling cross section into account as it results from the conveyor with curved apron plates with sides (for $\delta = \beta$, $k = 0$).

If the gradient angle δ is larger than the maximum angle of repose β, the filling volume of the pan (see figure 4) should be taken into account which results from :

$$V_{th} = B \left[a\, h_2 - \frac{a^2 \tan (\delta - \beta)}{2} \right] \qquad \dots (13)$$

and

$$V = \varphi\, B \left[a\, h_2 - \frac{a^2 \tan (\delta - \beta)}{2} \right] \qquad \dots (14)$$

5.5.4 Filling factor and reducing factor

The filling factor, φ, depends upon the properties of the bulk material considered and especially the feeding conditions of the apron conveyor.

Generally it is in the area of 0,5 to 1 and must, in the special case, be estimated.

Values for the reducing factor k are given in table 1.

5.6 Conveying speed

The conveying speed, v, is identical to the chain speed. It is recommended to not choose it too high so as to maintain the dynamic stresses, the rates of wear and the noise level which go with it, within acceptable limits.

For chain pitch lengths up to 200 mm and in the case of the number of teeth being more than 10 (see chapter 8, F_{dyn}), the upper maximum allowable limit of v will be :

$v \approx 0{,}6$ to $0{,}8$ m/s

for flat link chains and

$v \approx 1{,}2$ to $1{,}5$ m/s

for round link steel chains.

For normal apron conveyors, the working speeds are generally lower.

For conveying unit loads speeds do not usually exceed 0,4 m/s.

6 Resistances due to movement

The peripheral force, F_U, to be transmitted by the drive wheels on to the chain(s), is in equilibrium with the resistances due to friction and to the slope, F_R and F_{St}

$$F_U = F_R + F_{St} \qquad \dots (15)$$

6.1 Slope resistance

The resistance due to the slope, F_{St}, results from the conveying height H and the load per section ϱ_{lG} of the conveyed material, taking into account the acceleration of gravity g :

$$F_{St} = H\, \varrho_{lG}\, g \qquad \dots (16)$$

In the case of descending conveyance H and F_{St} become negative i.e. F_{St} acts in the opposite direction to F_R. In extreme cases F_U may also become negative, i.e. the conveyor does not need to be driven but braked.

The load per section ϱ_{lG} of the conveyed material is calculated from the mass capacity q_m and from the conveying speed v

$$\varrho_{lG} = \frac{q_m}{v} \qquad \dots (17)$$

so that the following also applies :

$$F_{St} = \frac{H\, q_m\, g}{v} \qquad \dots (18)$$

6.2 Friction resistances

The whole of the resistance due to friction F_R is made up of different partial resistances due to friction

$$F_R = F_H + F_N + F_S \qquad \dots (19)$$

6.2.1 Main resistance F_H

The main resistance, F_H, results from the operating movements of the upper and lower strand, on the to and fro haulage distance. It is calculated as a product of the whole of the efficient normal force and a corresponding artificial friction coefficient, f

$$F_H = f\, g \left[L\, (\varrho_{lRo} + \varrho_{lRu} + 2\, \varrho_{lK} \cos \delta) + L_1\, \varrho_{lG} \cos \delta \right] \qquad \dots (20)$$

The length L_1 of the loaded conveyor section may generally be introduced at a value equal to the centre distance L of the conveyor.

For $\delta < 15°$ one can assume that : $\cos \delta = 1$

The artificial friction coefficient, f, may be estimated according to the table 2 or calculated approximately by the rolling friction and the friction in the bearings, which is produced in the carrying rollers or in the wheels :

$$f = c \left(\frac{e + \mu_Z\, r}{R} \right) \qquad \dots (21)$$

The rolling friction lever arm, e, assuming steel on steel and a clean surface, is about : $e = 0{,}5$ mm.

Values for the friction coefficient in the bearings μ_Z are given in table 3.

The coefficient c takes into account the friction due to the guiding rail (on the wheels shoulders or flanges). It is always greater than 1 and is generally about $c = 1{,}1$ to $1{,}2$.

6.2.2 Secondary resistance F_N

The secondary resistance, F_N, is caused by the friction in the chain articulations as well as between the chains and the chain wheels while the chain passes through the chain wheels, in the chain wheels bearings and, should the occasion arise, by friction in the chain deflection devices. In the case of apron conveyors with moving rollers it is generally relatively small and may be taken into consideration in the form of an allowance :

$$F_N \approx 0{,}05\, F_H \text{ to } 0{,}1\, F_H \qquad \ldots (22)$$

In the case of apron conveyors with idlers fixed to the supporting structure, the friction within the chain becomes high and the resistance, F_N, may become high depending on the design and on the idler spacing and reach the same magnitude as the main resistance F_H.

6.2.3 Special resistance F_S

The special resistance, F_S, is produced when the conveyed material has to move along the skirtplates of the fixed chutes or the product guiding devices.

It can be calculated for the transport of loose bulk material :

$$F_S = \mu_W \frac{q_V^2 \varrho g l}{v^2 b_1^2} \qquad \ldots (23)$$

This formula is based on the following hypotheses :

- the cross section of the conveyed material is rectangular (see figure 3),
- the internal friction of the moving material is negligible.

The friction coefficient μ_W between the conveyed material and skirtplates depends upon the nature of the two materials. Usually it is in the order of $\mu_W \approx 0{,}5$ to $0{,}7$.

7 Required driving power

The driving power P_A on the chain wheel(s) is :

$$P_A = F_U v \qquad \ldots (24)$$

The motor power is :

$$P_{Mot} = \frac{P_A}{\eta_{ges}} \qquad \ldots (25)$$

The efficiency η_{ges} between the motor and chain wheel(s) depends upon the configuration of the drive assembly.

8 Chain pull

The chain pull is made up of the peripheral force F_U, of the descending force due to the chain's own weight, of the initial pull per strand F_V, necessary in some cases for operating reasons and of a superimposed dynamic chain pull F_{dyn} resulting from the polygonal effect of the chain's movement.

In nominal operation and at a maximal load the following applies :

$$F_{K1} = F_U + \varrho_{lK}\, g\, H + F_V \pm F_{dyn} \qquad \ldots (26)$$

The initial pull F_V maintains the chain taut and should be chosen so that the chain does not become slack when leaving the chain wheel, which could lead to trouble.

The dynamic chain pull results from the mass in movement and from the chain's maximal acceleration, i.e. :

$$F_{dyn} = \frac{\omega^2 t}{2} (2 L \varrho_{lK} + L_1 \varrho_{lG}) \qquad \ldots (27)$$

In order that the dynamic chain pull remains reduced, a small chain pitch t should be chosen and a small angular speed

$$\omega = \frac{2 \pi v}{t N} \text{ of the chain wheels} \qquad \ldots (28)$$

where

t is the chain pitch;

N is the number of teeth on the chain wheel.

When starting up the chain pull F_{K2} results from the motor starting torque and from the sum of all the masses to be accelerated. F_{K2} is larger than F_{K1} but is only produced for short periods.

According to the drive configuration, the starting force F_{K2} should be taken into account when choosing the chain. Its accurate calculation is superfluous in some cases.

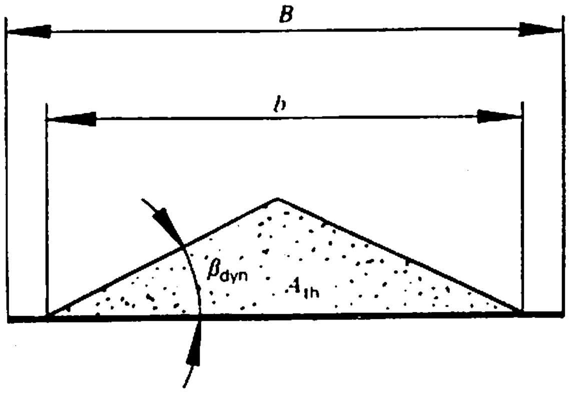

Figure 1

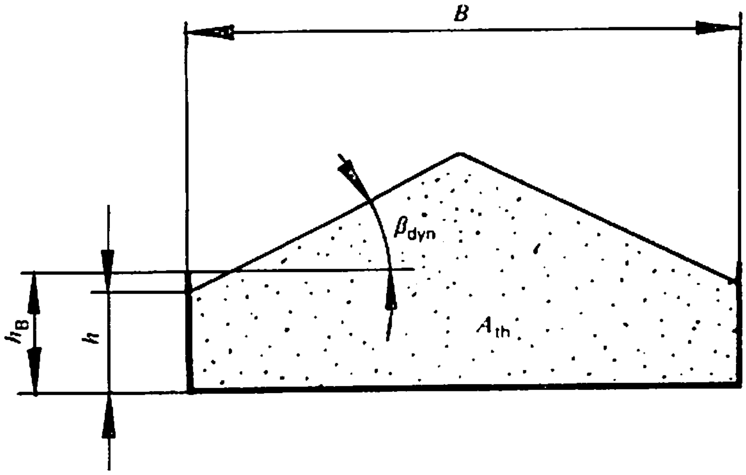

Figure 2

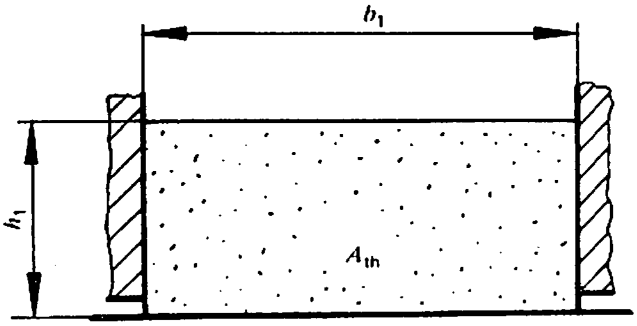

Figure 3

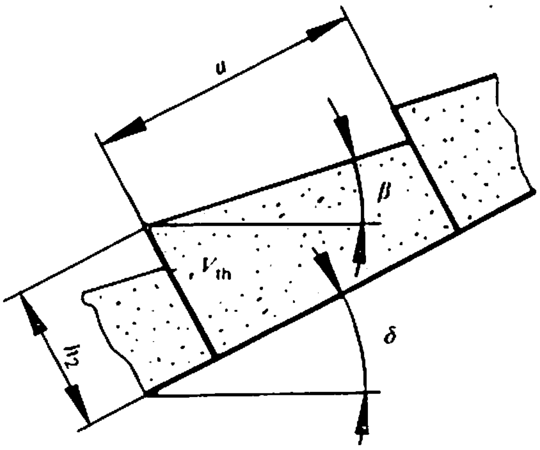

Figure 4

Table 1

Slope angle δ°	2	4	6	8	10	12	14	16	18	20	22	24
Reducing factor k	1,0	0,99	0,98	0,97	0,95	0,93	0,91	0,89	0,85	0,81	0,76	0,71

Table 2

Operating conditions	Artificial friction coefficient f	
	Carrying rollers or wheels with	
	plain bearings	rolling bearings
favourable	0,06 ... 0,08	0,02
normal	0,08 ... 0,10	0,03
unfavourable	0,10 ... 0,13	0,045

Table 3

Bearing and lubrication	Bearing friction coefficient μ_Z
plain bearings with regular lubrication	0,10 – 0,20
plain bearings with irregular lubrication	0,15 – 0,25
rolling bearings (including sealing) according to conditions of use	0,01 – 0,045