Mechanical Engineering Department
Carlos III University

BELT CONVEYORS

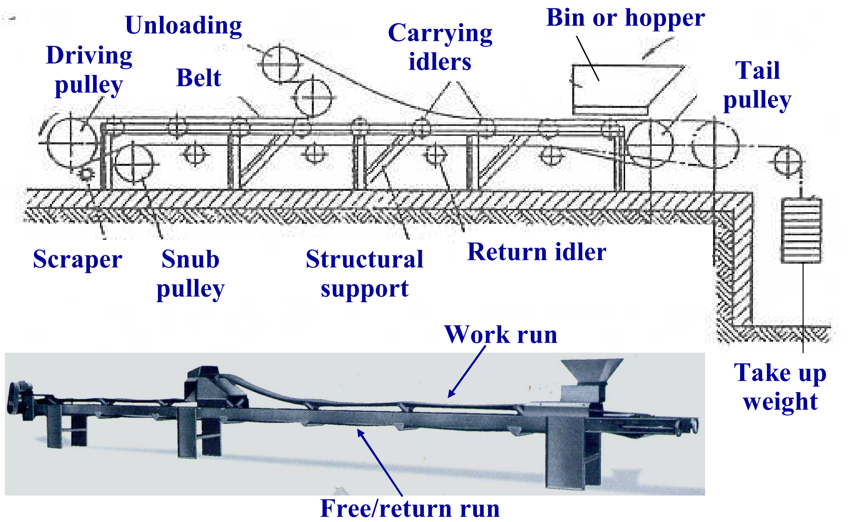
TRANSPORTATION

INTRODUCTION

A belt conveyor is rubber or textile structure with a belt shape closed ring, with a vulcanized or metallic joint, used for material transportation.

- **Belt conveyors are the most used for transport of solid objects and bulk materials at great speed, covering great distances (up to 30 km)**

COMPONENTS



BELT

Textile belts or smooth textiles

- **Definition (UNE 18 025):**
  - The width, expressed in mm.
  - The quality of the cover (standard UNE 18 052).
  - The number of plies.
  - The quality of the fabric (standard UNE 18 052).
  - The thickness of the top cover (tenths of mm).
  - The thickness of the bottom cover (tenths of mm).
  - The length of the belt (metres).

Highly resistant to abrasion Thickness of the top cover (tenth mm)

Width of the belt (mm) → 500 A - 4 L / 35 - 15 des 50 UNE 18025

Consists of 4 light plies (L type)

Length (m)

Thickness of the bottom cover (tenth mm)

BELT

Textile belts or smooth textiles

•Quality of the covers (UNE 18 052)

Quality of the cover	Tensile strength (g/mm^2)	Elongation at rupture (%)
A	2500	550
B	2000	500
C	1050	350

•Quality of the fabric (UNE 18 052)

Quality of the fabric	Warp		Weft
	Tensile strength (kgf/cm)	Elongation at rupture (%)	Tensile strength (kgf/cm)
L	60	20	25
LS	70	20	30
P	75	20	35

BELT

Textile belts or smooth textiles

- **Number of plies:**

$$z = \frac{S \cdot T_m}{100 \cdot B \cdot R_1}$$

- S: Safety factor
- T_m: Maximum stress work of the belt (kgf)
- B: Belt width (metres)
- R_1: Nominal tensile strength of each textile ply (kgf/m)

Regarding the maximum stress work of the belt:

- It depends on the time the belt finishes its travel, which depends on:
  - The number of flexures on the pulleys.
  - The load impacts.
- If time travel is above 5 *minutes* ⇒ - 2 plies

Safety Factors for textile Carcass Belts (DIN 22101 standard)			
Number of plies (z)	from 3to 5	from 6 to 9	More than 9
Safety factor (S)	11	12	13

BELT

Belt conveyors for vertical or inclined transport

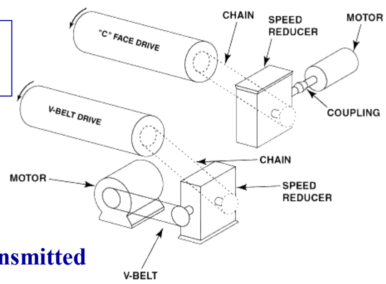
- **Drawback of smooth textile belt:**
  - **Grade limit : 18º - 20º**
- **Different solutions:**
  - **Profile belts:**
    - **Herringbone profile.**
    - **Nasta, Nappula, Ripa and Pyramid profile.**
    - **Grip Top profile.**
    - **Ripro profile.**
  - **U-cleats and V-cleats profiles.**
  - **Corrugated edge belt.**

BELT CONVEYORS II

PULLEYS

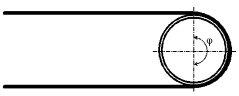
Driving pulley

Entrusted of transmitting movement by means of the motor-speed reducer.

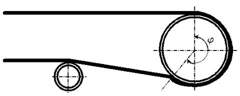


- **Guarantee maximum adherence ⇒ Low slip.**

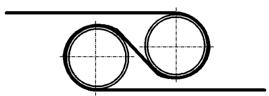
Bigger angle ⇒ **Bigger force transmitted**



Simple pulley
$\varphi = 180º$

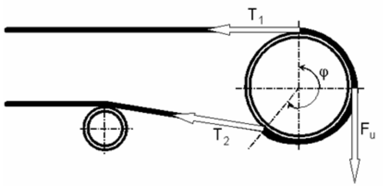


Simple plulley with snub pulley
$210º \leq \varphi \leq 230º$



Tandem motor
$350º \leq \varphi \leq 480º$

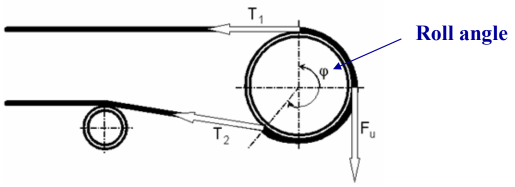
TENSION



- The tension varies along the belt length.
- Depends on:
  - Belt conveyor arrangement.
  - The number and arrangement of the drive pulleys.
  - The drive and brake features.
  - The type and tension devices arrangement.
  - Operation phase (start-up, normal operation, braking, etc.).

TENSION

One drive pulley



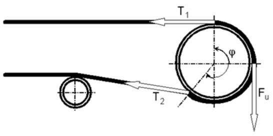
- Most common situation.
- Operation conditions:
  - Peripheral forces applied to the drive pulley have to be transmitted to the belt by friction without slippage.
  - The applied tension to the belt has to be adequate to avoid an important sag (between two pulleys).

TENSION

One drive pulley

• **Euler-Eytelwein (without slip) equation:**

$$\frac{T_1}{T_2} = e^{\mu \cdot \varphi}$$



$$T_1 = T_2 + F_u$$

$$\frac{T_1 - T_2}{T_2} = e^{\mu \cdot \varphi} - 1 \Rightarrow \frac{T_1 - T_2}{T_2} = \frac{F_u}{T_2} = e^{\mu \cdot \varphi} - 1 \Rightarrow$$

$$T_1 = \frac{e^{\mu \cdot \varphi}}{e^{\mu \cdot \varphi} - 1} \cdot F_u = C_{TS} \cdot F_u$$

$$T_2 = \frac{1}{(e^{\mu \cdot \varphi} - 1)} \cdot F_u = C_{T1} \cdot F_u$$

PULLEYS

Pulley diameter

$$D_{\min} = \frac{360 \cdot F}{p \cdot \pi \cdot \varphi \cdot B}$$

- $D_{\min}$: **Minimum driving pulley diameter proposed for fabric belts (m)**
- F: **Action force (kg)**
- B: **Belt width (m)**
- φ: **Angle contact (degrees)**
- p: **Transmission capacity pulley/belt: 1.600÷2.000 Kg/m²**
  In underground, up to 3.500 kg/m²

Standard pulley diameter s/DIN 22101												
200	250	320	400	500	630	800	1.000	1.250	1.400	1.600	1.800	2.000

$$D_{tail\ pulley} = D_{tensioning\ pulley} \cong 0.8 D_{driving\ pulley}$$

$$D_{snub\ pulley} \cong 0.65 D_{driving\ pulley}$$

MOBILE COMPONENT WEIGHT

Mobile component weight (kg):

$$M_T(kg) = M_B + M_R + M_B$$

Belt weight (kg): — Idler roller weight (kg): — Pulley weight (kg):

Mobile component weight per unit length (kg/m):

$$P_T = \frac{M_T}{L}$$

Belt length (m)

MOBILE COMPONENT WEIGHT

Belt width (mm)	Mobile component weight per unit length (kg/m)			
	Lightweight belt Rollers 102 mm	Moderate belt Rollers 127 mm	Heavy belt Rollers 152 mm	Steel cable belt Rollers 152 mm
450	23	25	33	
600	29	36	45	49
750	37	46	57	63
900	45	55	70	79
1050	52	64	82	94
1200	63	71	95	110
1350	70	82	107	127
1500		91	121	143
1650		100	132	160
1800			144	178
2100			168	205
2200			177	219

MOBILE COMPONENT WEIGHT PER UNIT LENGTH

Belt capacity (t/h)

$$q_G = \frac{Q}{3,6 \cdot v} = 0,278 \cdot \frac{Q}{v} \quad [\mathrm{kg/m}]$$

Belt speed (m/s)

RESISTANCE TO MOVEMENT

- **Classification (UNE 58-204-92):**
  1. **Principal resistances, F_H**
  2. **Secondary resistances, F_N**
  3. **Special principal resistances, F_{S1}**
  4. **Special secondary resistances, F_{S2}**
  5. **Resistances due to inclination, F_{St}**

$$F_u = F_H + F_N + F_{S1} + F_{S2} + F_{St}$$

In every installation (1) y (2)
In some installations (3) y (4)
Act in all the belt length (1) y (3)
Act in certain regions (2) y (4)

RESISTANCE TO MOVEMENT

Principal resistance

•**Turning resistance due to the load idlers rollers, due to friction in the bearings and joints in rollers.**

•**Belt friction resistance due to the rolling of the belt over the idlers rollers.**

$$F_H = f \cdot L \cdot g \cdot [q_{RO} + q_{RU} + (2 \cdot q_B + q_G) \cdot \cos\delta]$$

Friction coefficient (f)

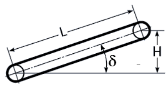
Return rollers weight per unit length (kg/m) (q_{RU})

Work run roller weight per unit length (kg/m) (q_{RO})

Belt weight per unit length (kg/m) (q_B)

Load weight per unit length (kg/m) (q_G)

Angle of the incline (δ)



Type of bearing	State	f
Roller Bearing	Favourable	0,018
	Normal	0,020
	Unfavourable	0,023 – 0,030
Friction		0,050

RESISTANCE TO MOVEMENT

Secondary resistances

•**Inertia resistance and friction due to material acceleration in the loading point:**

$$F_{ba} = I_v \cdot \rho \cdot (v - v_0)$$

Material flux (m³/s) (I_v)

Material density (kg/m³) (ρ)

Belt speed (m/s) (v)

Feed-in speed (m/s) (v_0)

•**Resistance due to material friction with feed-in chute sidewalls.**

RESISTANCE TO MOVEMENT

Secondary resistances

- **Resistance of pulley bearings safe drive pulleys:**
  - **For fabric belts:**

$$F_1 = 9 \cdot B \cdot (140 + 0.01 \cdot \frac{F}{B}) \cdot \frac{d}{D}$$

Belt width (m); **Mean belt stress (N)**; **Belt thickness (m)**

  - **For metallic belts:**

$$F_1 = 12 \cdot B \cdot (200 + 0.01 \cdot \frac{F}{B}) \cdot \frac{d}{D}$$

Pulley diameter (m)

- **Resistance due to rolling belt effect over the pulleys:**

$$F_t = 0.005 \cdot \frac{d_0}{D} \cdot F_T$$

Drive axle diameter (m); **Pulley applied forces (N)**

BELT CONVEYORS II

RESISTANCE TO MOVEMENT

Secondary resistances

- **When L > 80 m ⇒ $F_N < F_H$:**

$$F_H + F_N = f \cdot C_L \cdot L \cdot g \cdot [q_{RO} + q_{RU} + (2 \cdot q_B + q_G) \cdot \cos\delta] =$$
$$= f \cdot L_C \cdot g \cdot [q_{RO} + q_{RU} + (2 \cdot q_B + q_G) \cdot \cos\delta]$$

Incline angle

Friction coefficient

Corrected belt length (m)

Work run idler rollers weight per unit lenght (kg/m)

Return run idler rollers weight per unit length (kg/m)

Belt weight per unit length (kg/m)

Load weight per unit length (kg/m)

LENGTH CORRECTION FACTOR

Shorter belts need more power to overcome friction resistances than longer belt conveyors.

Corrected belt length (m):

Correction factor

$$L_c = C_L \cdot L$$

Belt length (m)	3	4	5	6	8	10	13	16	20	25	32	40
C_L	9	5.6	6.6	5.9	5.1	4.5	4	3.6	3.2	2.9	2.6	2.4

Belt length(m)	50	63	80	100	125	160	200	250	320	400	500
C_L	2.2	2	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.05

RESISTANCE TO MOVEMENT

Special principal resistance

•Toe resistance due to oblique belt position because of the loading rollers:

– **3 roller picking idler of the same length in the work run:**

Toe angle (degrees)

$$F_\in = C_\in \cdot \mu_o \cdot L_\in \cdot (q_B + q_G) \cdot g \cdot \cos\delta \cdot sen\in$$

Value:
- 0,4 for an angle of 30º
- 0,5 for an angle of 45º

Belt weight per unit length (kg/m)

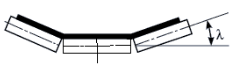
Load weight per unit length (kg/m)

Friction coefficient between the belt and the idler rollers : 0,3 – 0,4

Longitud de la instalación con rodillos portantes convergentes (m)

– **2 roller picking idler for the return run:**

$$F_\in = \mu_o \cdot L_\in \cdot q_B \cdot g \cdot \cos\lambda \cdot \cos\delta \cdot sen\in$$



RESISTANCE TO MOVEMENT

Special principal resistance

•Resistance due to friction with feed-in chute sidewalls, or with the longitudinal guide rails, when they take place along the total belt length:

$$F_{gL} = \frac{\mu_2 \cdot I_v^2 \cdot e \cdot g \cdot l}{v^2 \cdot b_1^2}$$

- Friction coefficient between the material and the guides: 0,5 – 0,7 (μ_2)
- Transported flux (m³/s) (I_v)
- Weight volume not tared (kg/m³) (e)
- Transport length between guide rails (m) (l)
- Belt width between guide rails (m) (b_1)

BELT CONVEYORS II

RESISTANCE TO MOVEMENT

Special secondary resistances

•Resistance due to friction between the cleaning systems and the belt:

$$F_r = A \cdot p \cdot \mu_3$$

- Contact surface between the belt and the cleaning system (m²) (A)
- Pressure between the cleaning system and the belt (N/m²) (p)
- Friction coefficient between the cleaning system and the belt (μ_3)

•Resistance due to the friction between the chute sidewalls or with guide rails when they only take place over a limited belt length :

$$F_a = B \cdot k_a$$

- Belt width (m) (B)
- Scraping factor = 1500 N/m (k_a)

RESISTANCE TO MOVEMENT

Resistance due to slopes

$$F_{St} = q_G \cdot H \cdot g$$

Load weight per unit lenght (kg/m)

Installation height (m)

POWER OF THE DRIVE PULLEY

$$P_A = F_u \cdot v$$

Force opposed to movement (N)

Belt speed (m/s)

Drive pulley power

- **For powered belts:**

$$P_m = \frac{P_A}{\eta_1}$$

TRANSPORT CAPACITY

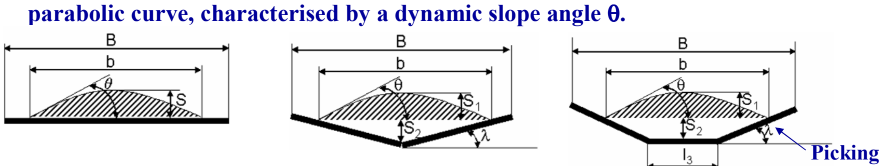
$$Q = 3600 \cdot v \cdot A \cdot \gamma \cdot k$$

- **Transport capacity (t/hora)**: Q
- **Speed (m/s)**: v
- **Cross section of material over the belt (m²)**: A
- **Material specific weight (t/m³)**: γ
- **Reduction capacity coefficient due to incline**: k

Incline (degrees)	2	4	6	8	10	12	14	16	18	20
k	1,0	0,99	0.,98	0,97	0,95	0,93	0,91	0,89	0,85	0,81

TRANSPORT CAPACITY

- **Cross section of the material over the belt depends on:**
  - **Effective width (b) of the belt is function of the real width B:**
    - $b = 0.9 \cdot B - 0.05$ for B ≤ 2 m
    - $b = B - 0.2$ for B > 2 m
  - **The number, arrangement and dimensions of the rollers.**
  - **The dynamic built-in shape of the material over the belt is limited by a parabolic curve, characterised by a dynamic slope angle θ.**



One roller — Two rollers — Three rollers

$$S = S_1 + S_2 \quad \begin{cases} S_1 = \left(l_3 + (b - l_3)\cdot \cos\lambda\right)^2 \cdot \dfrac{tg\theta}{6} \\ S_2 = \left(l_3 + \dfrac{(b-l_3)}{2}\cdot\dfrac{1}{\cos\lambda}\right)\cdot\left(\dfrac{(b-l_3)}{2}\cdot\sin\lambda\right) \end{cases}$$

Depends on: - material fluidity
- transport conditions

TRANSPORT CAPACITY

- **Uniform material size (cereals, granules or milled stones) do not influence belt width.**
- **Non classified materials (materials obtained in quarries or mines) influence on belt width:**
  - **Maximum material size.**
  - **Fine and coarse-grain percentage.**
- **It may occur that for little capacities the belt width is big ⇒ not economic**
- **Belt width as a function of the maximum grain size:**

Dynamic slope angle	10 % coarse, 90 % fines	100 % coarse
$\theta \leq 20º$	3	5
$20º \leq \theta \leq 30º$	6	10

TRANSPORT CAPACITY

- **The belt speed has to be as big as possible so that width is short.**
- **Speed depends on material properties:**
  - **Fluidity.** Dust risk.
  - **Abrasion.** Belt cut risk.
  - **Friable.** Material split risk.
  - **Size.** Great impacts on the belt take place for big sizes and heavy ones, thus weakening the belt.

Material	B (mm)	V (m/s)
Grains and other materials that have a good fluidity and are not abrasive	500 650 y 800 1000 y 1200 1400 y 2400	2,62 3,35 4,19 5,24
Coal, clay pan, soft minerals and soils, grinned stones of little size	500 650 a 1000 1200 a 1200 1400 a 2400	2,09 3,35 4,19 5,24
Non abrasive	Any width	1,05 – 1,68

Material	B (mm)	V (m/s)
Minerals with sharp edge, hard and heavy, grinned stones of little size	500 650 y 800 1000 a 2400	1,68 2,09 3,35
Prepared cast-iron sands or compacted	Any width	1,31 a 2,09
Discharge belts, flat or picking for fine non abrasive materials or medially abrasive	Any width	0,3 a 0,6

TRANSPORT CAPACITY

- **Standard speeds in m/s (DIN 22101)**

0,66	0,84	1,05	1,31	1,68	2,09	2,62	3,35	4,19	5,24

- **For horizontal belt conveyors:**

B\λ	0º	20º	25º	30º	35º	40º	45º
500	38 0,0105	74 0,0205	80 0,0222	87 0,0241	91 0,0252	95 0,0263	98 0,0272
650	69 0,0191	133 0,0369	144 0,0400	156 0,0433	164 0,0455	172 0,0477	176 0,0488
800	108 0,0300	208 0,0577	227 0,0630	244 0,0677	258 0,0716	269 0,0747	276 0,0766
1000	173 0,0480	336 0,0933	365 0,1013	394 0,1094	415 0,1152	434 0,1205	445 0,1236
1200	255 0,0710	494 0,1370	537 0,1491	580 0,1612	610 0,1705	638 0,1777	654 0,1828
1400	351 0,0980	680 0,1903	738 0,2071	798 0,2240	840 0,2368	878 0,2467	900 0,2536
1600	464 0,1294	898 0,2519	976 1055	1055 0,2965	1110 0,3134	1160 0,3264	1190 0,3355

Capacity in m^3/hour for v = 1 m/s

Cross section in m^2

TRANSPORT CAPACITY

EXAMPLE

Limestone
•Specific weight = 1,4 T/m^3
•Particle size:
•10% of coarse, maximum size: 250 mm
•Dynamic slope angle: 15º
•Not abrasive, friable but no reduction in price, due to a needed later grinding

Belt geometry:
- L = 805 m, vertical extent = 150 m, incline = 10,73º
- For the previous incline, the capacity reduction coefficient k = 0,95
- Picking angle = 35º

Capacity to be transported: 1500 T/hour

⇒ **¿Speed?**
¿Belt width?

TRANSPORT CAPACITY

EXAMPLE

Slope angle (degrees)	2	4	6	8	10	12	14	16	18	20
K	1,0	0,99	0.,98	0,97	0,95	0,93	0,91	0,89	0,85	0,81

θ=15º

Dynamic slope angle	10 % coarse, 90 % fine	100 % coarse
θ ≤ 20º	3	5
20º ≤ θ ≤ 30º	6	10

Maximum grain size 250 mm:

B = 3 · Maximum size = 3 · 250 = 750 mm

B=800 mm

BELT CONVEYORS II

TRANSPORT CAPACITY

EXAMPLE

$\lambda = 35º$

$B = 800$ mm

B\λ	0º	20º	25º	30º	35º	40º	45º
500	38 0,0105	74 0,0205	80 0,0222	87 0,0241	91 0,0252	95 0,0263	98 0,0272
650	69 0,0191	133 0,0369	144 0,0400	156 0,0433	164 0,0455	172 0,0477	176 0,0488
800	108 0,0300	208 0,0577	227 0,0630	244 0,0677	258 0,0716	269 0,0747	276 0,0766
1000	173 0,0480	336 0,0933	365 0,1013	394 0,1094	415 0,1152	434 0,1205	445 0,1236
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1600	464 0,1294	898 0,2519	976 1055	1055 0,2965	1110 0,3134	1160 0,3264	1190 0,3355

For 1 m/s:

$Q_{v1} = 258$ m³/s

TRANSPORT CAPACITY

EXAMPLE

Material	B (mm)	V (m/s)
Grains and other materials that have a good fluidity and are not abrasive	500 650 y 800 1000 y 1200 1400 y 2400	2,62 3,35 4,19 5,24
Coal, clay pan, soft minerals and soils, grinned stones of little size	500 650 a 1000 1200 a 1200 1400 a 2400	2,09 3,35 4,19 5,24
Non abrasive	Any width	1,05 – 1,68

$$Q = 3600 \cdot v \cdot A \cdot \gamma \cdot k \quad [\text{t/h}]$$

$$Q_v = \frac{Q}{\gamma} = 3600 \cdot v \cdot A \cdot k \quad [\text{m}^3/\text{h}]$$

– **Because $A_{v1} = A_{v2}$:**

$$Q_{v2} = \frac{Q_{v1}}{v_1 \cdot k_1} \cdot v_2 \cdot k_2 = \frac{258}{1 \cdot 1} \cdot 3{,}35 \cdot 0{,}95 = 821\,\text{m}^3/\text{hour}$$

$$Q_2 = \gamma \cdot Q_{v2} = 1150\,\text{t/hour} < 1500\ \text{t/hour}$$

TRANSPORT CAPACITY

EXAMPLE

- **We select B = 1000 mm**

B\λ	0º	20º	25º	30º	35º	40º	45º
500	38 0,0105	74 0,0205	80 0,0222	87 0,0241	91 0,0252	95 0,0263	98 0,0272
650	69 0,0191	133 0,0369	144 0,0400	156 0,0433	164 0,0455	172 0,0477	176 0,0488
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TRANSPORT CAPACITY

EXAMPLE

- **We select B = 1000 mm**

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Coal, clay pan, soft minerals and soils, grinned stones of little size	500 650 a 1000 1200 a 1200 1400 a 2400	2,09 3,35 4,19 5,24
Non abrasive	Any width	1,05 – 1,68

So as not to over design

v=3,35 m/s

- **Standard speeds in m/s (DIN 22101)**

0,66	0,84	1,05	1,31	1,68	2,09	2,62	3,35	4,19	5,24

TRANSPORT CAPACITY

EXAMPLE

- **Selecting B = 1000 mm ⇒ Q_{v1} = 415 m³/h y v_2 = 3,35 m/s**

$$Q_{v2} = \frac{Q_{v1}}{v_1 \cdot k_1} \cdot v_2 \cdot k_2 = \frac{415}{1 \cdot 1} \cdot 3{,}35 \cdot 0{,}95 = 1320{,}7\ \text{m}^3/\text{hora}$$

$$Q_2 = \gamma \cdot Q_{v2} = 1849\ \text{t/hour}$$

OK

B = 1000 mm and v = 3,35 m/s