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INDUSTRIAL PLANTS

Chapter twenty:

Elevators

DOUBLE DEGREE MASTER IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

SEAT OF PORDENONE

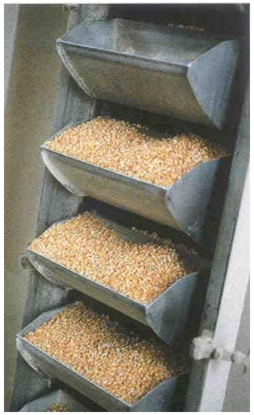
UNIVERSITY OF TRIESTE

Bucket elevators

The **bucket elevators** are continuous transport systems for be used for lifting the bulk materials are not excessively large or vertically to a height such that the transport belt is not able to overcome.

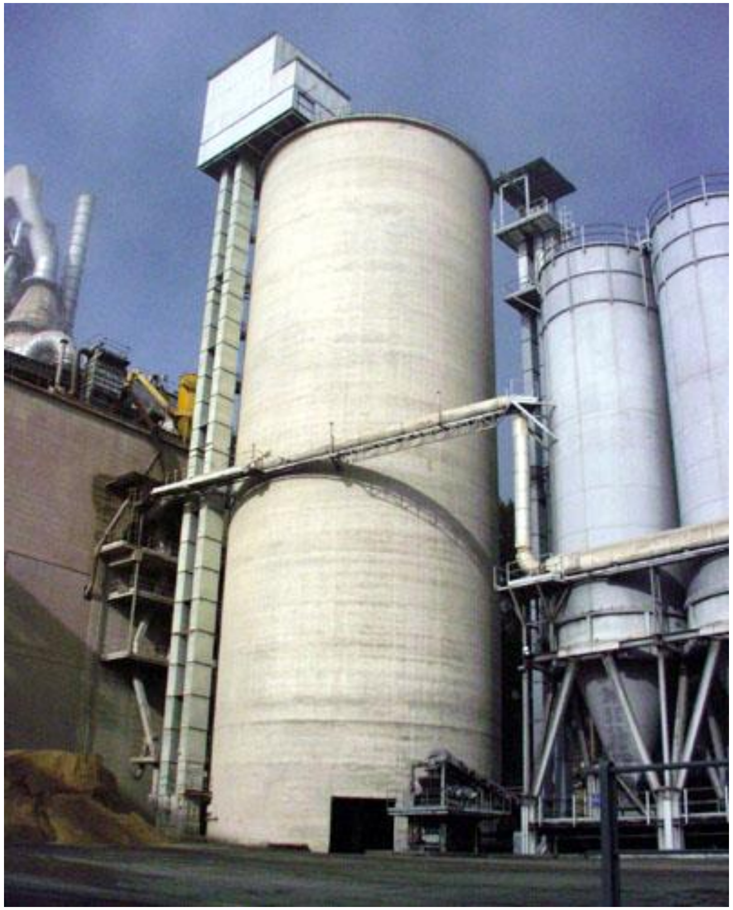
Diffused for the transport of bulk materials in vertical, are realized elevations of the material even of tens of meters. The bucket elevators are the most common systems for the filling of the storage silos or for the raising of the raw materials in process plants in where the handling of the materials takes place later by gravity (for example the mills).

A bucket elevator is a relatively simple system, consisting of two wheels connected by a system of chains (one or two) or belt to which are placed the buckets for the transport of the material.



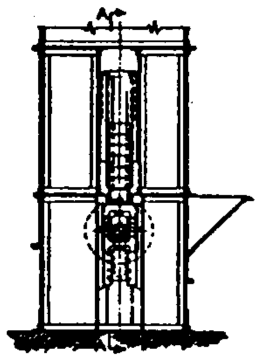
Bucket elevators

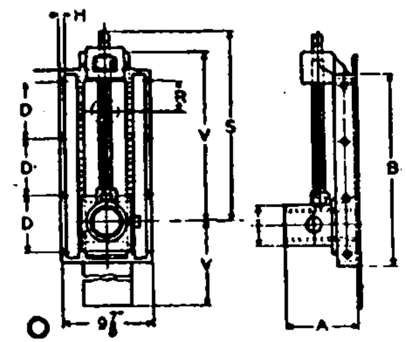
Bucket elevators: general scheme and application



Bucket elevators

Of the two wheels, the upper one is the drive wheel, so that the tensile force is exerted directly on the length of chain or belt more loaded. On the lower wheel (moved) the system is placed a chain tensioner or tensioner, which allows to maintain in pull the chain or belt, recovering any play that are generated. The system to tensioner or chain-tensioner can be to screw or to spring. In systems to screw, the game is retrieved by the action of an adjusting screw (figure), while in that to spring, the action of the spring allows to keep the system constantly with the degree of required traction.





Bucket elevators

The power supply of the material is continuous in the area or the lower base of the elevator. The buckets can be filled directly from the feed material in falling or fills the entire feeding zone and exploiting the progress of the digging bucket. The first power supply system is suitable for conveyors with a high number of buckets, while the second type to elevators of the longer pitch, which are adapted for materials with high sliding, ad example materials that fall with ease. If you adopted with materials with a low slip, materials that are difficult fall, such ad example as cement, it may have significant problems of feeding the buckets.

The buckets can be placed close together (continuous bucket elevators) or variable distances (bucket elevators spaced) and they are made of welded plate or cast steel or light alloy.

Bucket elevators

The discharge of the material can occur in two main ways:

- **for centrifugation of the material**

  The speed of rotation of the drive wheel is such as to ensure that the material, due to the centrifugal force to which it is subjected, is affected by a real launch exhaust;

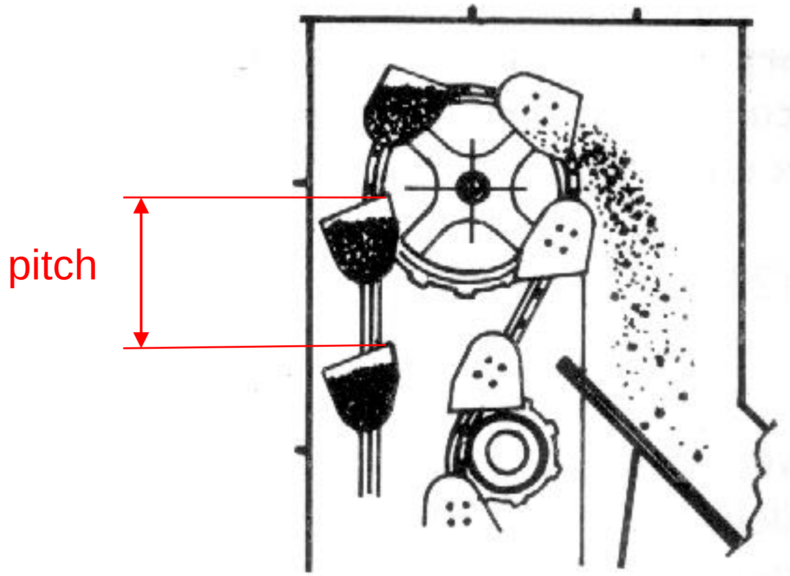
- **for fall of the material**

  The force of gravity prevails on the centrifugal force, and the material is discharged by gravity, falling on the back of the blade immediately preceding. By suitable anchoring systems of the bucket you can avoid this phenomenon. Finally in some cases the discharge of the material is facilitated by tilting the elevation system.

Bucket elevators

The pitch of the elevator influence the coefficient of filling of the bucket, since the greater the pitch, the greater will be the filling. The discharge takes place by centrifugation, while in other cases is by gravity; elevators with a greater number of cups are characterized by discharge of the material on the cup immediately preceding.

The speed of the bucket elevators mounted on chains does not exceed the 1.5 m/s (average values of 1 m/s), while in those tape does not exceed 3 m/s.



Preliminary design of a bucket elevator

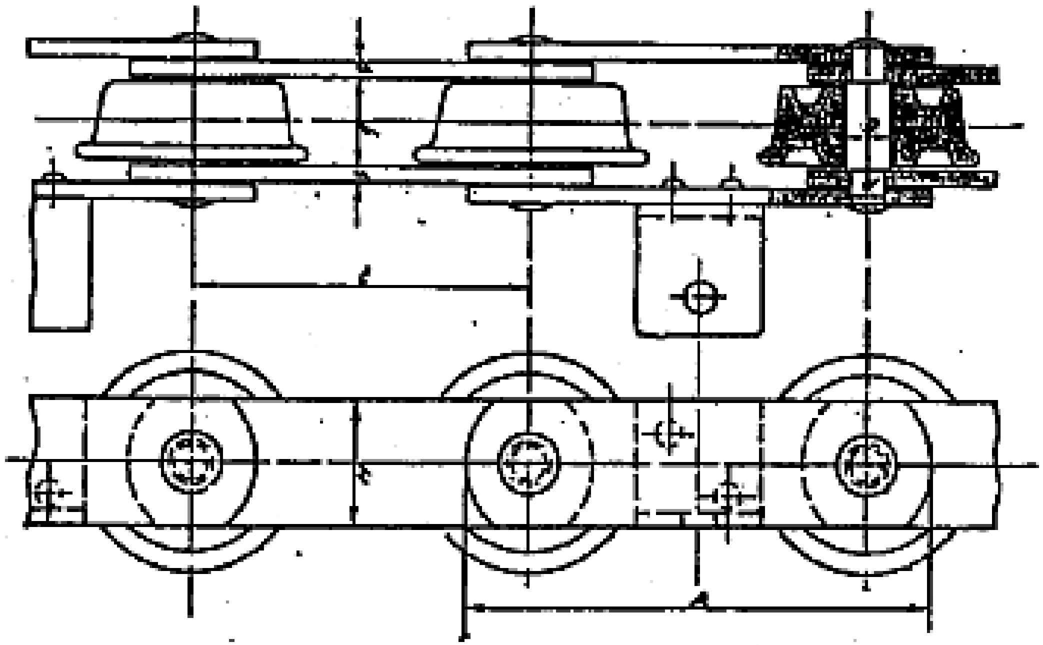
One of the issues presented handling systems for bulk materials and thus also of bucket elevators, is made by calculating the capacity and the power. He wants do the sizing a bucket elevator for the handling of gravel.

The project data are:

- capacity transport Q = 130 t/h
- lifting height H = 14 m
- specific gravity apparent (of pile) γ = 15686 N/m^3

Preliminary design of a bucket elevator

Is chosen for the transport a bucket elevator interspersed with chains to bars two in number, which bind the single cup on the sides.



Preliminary design of a bucket elevator

For the capacity the following relationship holds:

$$Q = C \cdot \gamma \cdot \alpha \cdot \frac{v}{p} \cdot 3600$$

where:

C = nominal capacity of the single bucket (m^3), whose values are tabulated

α = coefficient of filling of the cup. Remember that no one can fill bucket total, but this represents 70% of the nominal value for heavy and poorly flowing materials, like the case of iron

v = lifting speed of the bucket (m/s)

p = pitch between the buckets, whose values are tabulated. A big step implies a bad use of the chain with excessive localized overloads, while a small step implies a bad use of buckets with little filling.

The optimal value p is twice the height of the bucket (m)

Preliminary design of a bucket elevator

You must set consistently the parameters C, v and p.

They are used chains to bars whose pitch p_{tazza} must conform to the height of the bucket p_{tazza} to avoid interference:

$$p_{tazza} < 2 * p_{catena}$$

To determine the pitch of the buckets we proceed iteratively according to the following procedure:

- is fixed the capacity C;
- Is fixed the p_{tazza}, which is supposed to twice the pitch of the chain p_{catena};
- is proposed a coefficient of filling of the bucket α;
- is obtains the transport speed v from the previous report, which must not exceed a fixed limit noted from table

C (m^3)	p_{catena} (mm)	p (mm)	α	v (m/s)	v_{limite} (m/s)
0,0083	125	250	0,7	0,99	1,14
0,0083	150	300	0,7	1,19	1,18

Preliminary design of a bucket elevator

Whose value is very close to that limit and therefore can be considered a suitable value to ensure discharge of material by gravity.

Most common form of the buckets

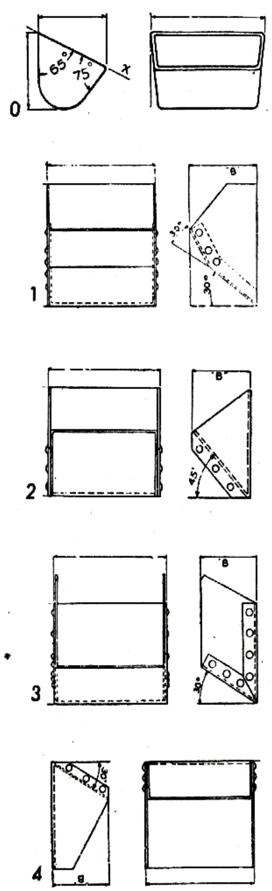


Fig. 601.

Bucket for bucket elevators spaced

Lenght A	Width B	Height useful H	Height maximum H'	Capacity Useful	Type: Light – Thick-neess	Type: Light – Weight	Type: Studded – Thick-neess	Type: Studded – Weight	Type: Molten – Thick-neess	Type: Molten – Weight
mm	mm	mm	mm	dm^3	mm	kg	mm	kg	mm	kg
100	95	60	90	0,35	2	0,36	3	1	4	0,7
120	100	70	110	0,5	2	0,4	3	1	6	1,4
140	120	80	120	0,7	2	0,5	3	1,2	6	1,8
160	120	90	130	1	2	0,7	3	1,5	6	2,4
180	120	100	140	1,4	2	0,9	3,5	2	6	3
200	130	110	150	1,9	2	1,2	3,5	3	6	3,6
220	130	110	160	2,2	2,5	1,5	3,5	4	6	4,5
240	150	110	160	2,4	3	2	4	5	7	5
260	160	110	160	3	3	2,4	4	6	7	5,8
300	180	110	160	[illegible]	3,5	3	4	7	7	6,2
350	180	120	180	4,6	3,5	3,6	5	9	7	8
400	220	130	200	[illegible]	3,5	4	5	11	7	9
450	250	140	220	8,3	3,5	5	6	14	7	10
500	250	140	220	9,5	3,5	6	6	18	7	12

Buckets for elevator to buckets continuous

Dimensions in mm: Lenght A	Width B	Height maximum H'	Theoretical capacity in dm^3, type 1	2	3	4	Unit weight in kg if in sheet of mm 2,5	3,5	5	6
mm	mm	mm								
180	110	145	1,4	1,4	2	1,4	2,5	—	—	—
200	140	195	2,8	2,8	3,2	2,8	2,9	3,6	—	—
230	150	220	3,9	3,9	4,3	3,9	3,3	3,4	—	—
250	150	220	4,3	4,3	5	4,3	3,6	4,6	—	—
240	170	300	7	7	7,8	7	4,6	6,2	—	—
300	150	220	5,2	5,2	5,6	5,2	4	5,2	—	—
300	170	300	8	8	9,2	8	5,4	7	9	—
300	200	300	9,2	9,2	10,5	9,2	6	7,3	10	—
350	200	300	9,4	9,4	11	9,4	6	7,6	11,5	—
350	200	300	11	11	12	11	6,4	8,5	12	—
400	300	300	12,5	12,5	15	12,5	7,3	9	11,5	15
450	200	300	14	14	17	14	8	10	13	17
450	300	450	30	30	35	30	12	15	21	27
500	200	300	15	15	16	15	8	11,2	15	19
500	300	450	35	35	40	35	—	17	23	30
600	250	300	23	23	28	23	—	13	17	23
600	300	450	42	42	48	42	—	19	26	34

Preliminary design of a bucket elevator

From the following table is obtained:

Elevators at chians						Elevators at belt in rubber		
Size bucket: length x width mm	Minimum distance between the buckets mm	Reccom-mended speed in m/s	Minimum diameter of the idler wheels mm	Manimum size of parts mm in total	Manimum size of parts mm only 10% of the total	Reccom-mended sheave diameter mm	Recommended speed in m/s: Maximum material until smooth (grain, sand dry)	Recommended speed in m/s: Moderate for coal, gravel, cement, ecc. m/s
150 × 100	330	1,14	500	12	60	540	1,35	1,12
200 × 125	380	1,18	550	18	75	500	1,45	1,16
250 × 150	400	1,18	600	25	85	600	1,60	1,30
300 × 175	430	1,30	650	30	100	750	1,80	1,48
350 × 180	460	1,30	650	30	100	900	2,00	1,60
400 × 200	480	1,30	650	38	110	1000	2,20	1,80
						1200	2,30	1,90
						1500	2,60	2,15
						2000	3,10	2,50

Preliminary design of a bucket elevator

Comparing now with the table, that matches the experimental data on speed, distance between the buckets, diameter of the idler wheels higher, minimum size for the elevators to discharge centrifugal, the calculated speed.

If the velocity v is higher than the limit value, the calculation is repeated by changing the capacity C or pitch of the chain p_{catena}.

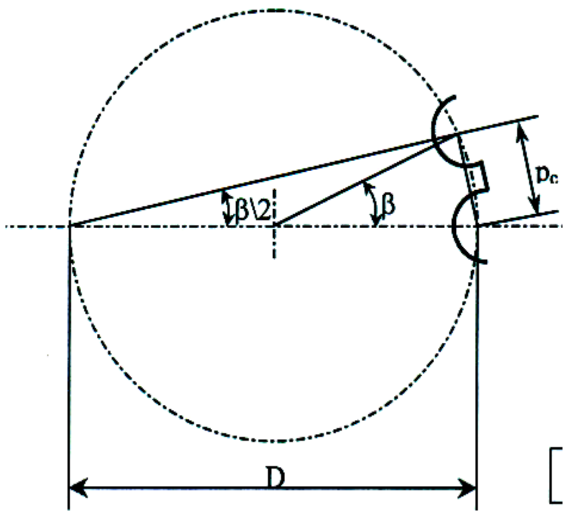
From the calculation, the value of the speed is very close to that limit and therefore can be considered a suitable value to ensure the discharge by gravity. Also as previously mentioned, the velocities of bucket elevators mounted on chains does not exceed 1.5 m/s, then the calculated value of the speed 1.34 m/s can be accepted.

Preliminary design of a bucket elevator

From the table general, it is noted:

- length of the bucket 400 mm
- width of the bucket 200 mm
- useful height 130 mm
- maximum height 200 mm
- capacity 0,0072 m^3
- weight of the metal bucket (type cast) thickness 7 mm, and weight 88 N.

Referring to the scheme in the figure, it is determined hours the number of meshes and the pitch of the chain p_{catena}:



Preliminary design of a bucket elevator

The number of meshes and the pitch of the chain p_{catena} is determined by the relationship:

$$p_{catena} = D \cdot \sin\frac{\beta}{2}$$

where:

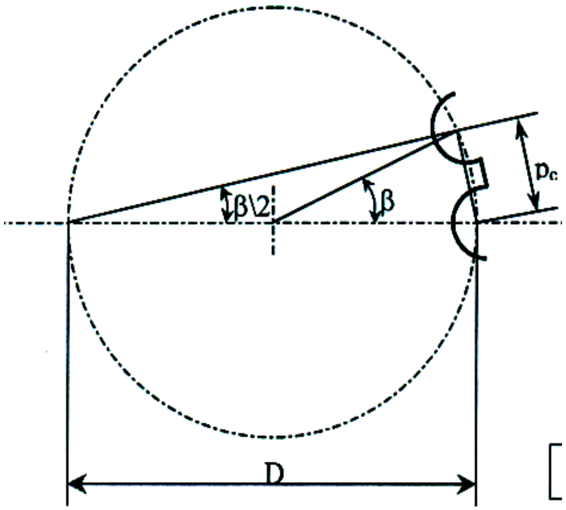
D = diameter of the pulley

β = angle at the center identified by the pitch of the chain

The number of teeth z of the pulley is detectable by the relation:

$$z = \frac{2 \cdot \pi}{\beta}$$

One proceeds fixing the number of teeth of the pulley, z = 6, from which β = 1,04 rad (60°) and known the value of the pitch of the chain, it is detects the diameter of the pulley:



$$D = \frac{p_{catena}}{\sin\left(\frac{\beta}{2}\right)} = \frac{0{,}150}{\sin\left(\frac{60}{2}\right)} = 0{,}30 \ m$$

Preliminary design of a bucket elevator

The number of the meshes of chain N is given by the relation:

$$N = \frac{2 \cdot H}{p_{catena}} + \frac{\pi \cdot D}{p_{catena}} = \frac{2 \cdot 14}{0{,}150} + \frac{\pi \cdot 0{,}30}{0{,}150} = 192$$

With this value of the number of meshes N varies the distance between the pulleys, ad example the difference in height H, and then the new value is:

$$H = \frac{N \cdot p_{catena} - \pi \cdot D}{2} = \frac{192 \cdot 0{,}150 - \pi \cdot 0{,}30}{2} = 14 \ \ m$$

The number of buckets will be:

$$N_t = \frac{N \cdot p_{catena}}{D} = \frac{192 \cdot 0{,}150}{0{,}30} = 96$$

Preliminary design of a bucket elevator

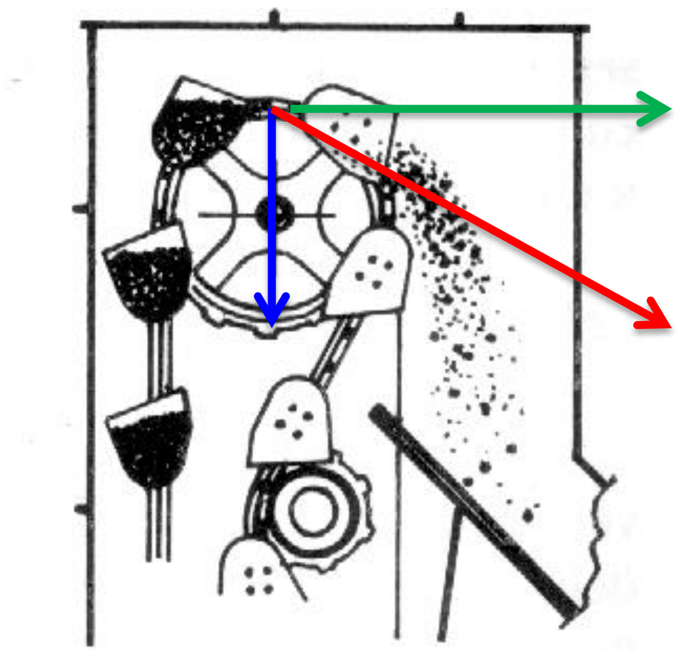
Because the material can be launched, the speed of the elevator must be such that:

$$m \cdot \frac{v^2}{R_{puleggia}} > m \cdot g$$

where:

m = mass of the material transported;

$R_{puleggia}$ = radius of the pulley.



Preliminary design of a bucket elevator

It is noted:

$$\frac{1{,}19^2}{0{,}242} = 9{,}83 > 9{,}81$$

The speed is sufficient to ensure the launch of the material and then the appropriate drain of the elevator, which allows to verify the relationship inherent in the effects of centrifugal and gravitational ones.

Preliminary design of a bucket elevator

It must therefore carry out the verification on the resistance of the chain.

The effort acting on a chain during the ascending phase is due to the following contributions:

- the weight of the chain;
- the weight of the buckets divided between the two chains in the ascending phase;
- the weight of the material along the ascending portion insistent divided between the two chains;
- the forces of friction of the moving parts (pins for reference junction mesh), which assume proportional to the axis in motion;
- the frictional forces during the loading phase.

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

The counterweight is needed to balance the shot in the act of the loading, while the moment of resistance is opposed to the rotation of the pulley for reference and without counterweight this would be dragged away.

a) weight of the chain

The weight of the chain is found known that both the linear mass of the chain, that is detectable by the table from which we get:

$$\rho = 1{,}90 \text{ kg/m}$$

For which the weight of the chain is:

$$R_1 = p \cdot H = 1{,}9 \cdot 14 = 26{,}6 \ \ kg = 260 \ \ N$$

p = weight of the chain = 1,9 kg/m

H = difference in level of lift

Preliminary design of a bucket elevator

Breaking load of the chain Pr kg	Pass t mm	Width: plate H mm	Width: inner between of the plates, internal b mm	Width: inner between of the plates, external b mm	Diameter of the: pin D mm	Diameter of the: compass Do mm	Diameter of the: roller Dr mm	Thickness of the plates: external Se mm	Thickness of the plates: internal Si mm	External width Hg mm	Weight for meter type a: smooth rollers kg	Weight for meter type a: rollers with edge kg
2 700	100	25	16	26	10	15	32	4	4	40	2,5	
	125	»	»	»	»	»	»	»	»	»	2,2	
	150	»	»	»	»	»	»	»	»	»	1,9	
5 000	100	40	20	32	12	18	48	4	5	45	5,5	
	125	»	»	»	»	»	»	»	»	»	4,9	
	150	»	»	»	»	»	»	»	»	»	4,5	
10 000	100	50	26	42	17	23	65	5	7	60	11,3	
	125	»	»	»	»	»	»	»	»	»	10,1	
	150	»	»	»	»	»	»	»	»	»	9,2	
	200	»	»	»	»	»	»	»	»	»	8,1	
16 000	125	60	38	58	20	28	90	8	9	18	18	—
	150	»	»	»	»	»	»	»	»	»	17	18
	200	»	»	»	»	»	»	»	»	»	15	16
	250	»	»	»	»	»	»	»	»	»	13	14
	300	»	»	»	»	»	»	»	»	»	12	13
20 000	150	62	38	58	20	28	90	8	9	80	18	19
	200	»	»	»	»	»	»	»	»	»	16	18
	250	»	»	»	»	»	»	»	»	»	15	16
	300	»	»	»	»	»	»	»	»	»	13	14
25 000	150	65	38	58	22	30	90	8	9	80	19	20
	200	»	»	»	»	»	»	»	»	»	17	17
	250	»	»	»	»	»	»	»	»	»	16	18
	300	»	»	»	»	»	»	»	»	»	14	15
35 000	300	65	38	65	22	30	120	11	13	95	21	22
	350	»	»	»	»	»	»	»	»	»	20	21
	400	»	»	»	»	»	»	»	»	»	19	20
	450	»	»	»	»	»	»	»	»	»	18	19

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

b) weight of the buckets

Given that the mass of the single buckets is obtained from table m_{tazza} = 9 kg for buckets spaced-type molten, is obtained:

$$R_2 = \frac{H}{d} \cdot (P + P') = \frac{14}{0{,}3} \cdot 9 = 420 \ \ kg = 4116 \ \ N$$

where:

H = difference in level of the elevator

P’ = weight of a bucket with his attack (9 kg)

d = pitch between two subsequent bucket

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

c) weight of the material

Assuming that there are only two buckets on the upper pulley and consider only the ascending branch, it has:

$$R_3 = \frac{H}{d} \cdot (P + P') = \frac{14}{0{,}3} \cdot 11{,}52 = 538 \ kg = 5380 \ N$$

where:

H = difference in level of the elevator

P = weight of material transported from a bucket (11,52 kg)

d = pitch between two subsequent bucket

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

d) friction due to the motion

Part of the moving masses have already been calculated, however, lacks the mass of the pulleys to be shared between the two branches. The mass of the pulley is assumed to be to $m_{pulegge}$ = 200 kg. Assuming a coefficient of friction f = 5%:

where:
$$R_4 = f \cdot \left(p_{catena} + P_{tazze} + P_{materiale} + P_{pulegge}\right)$$

whereby:
$$P_{puilegge} = \frac{m_{pulegge} \cdot g}{2} = \frac{200 \cdot 9{,}81}{2} = 981 \ N$$

$$R_4 = 0{,}05 \cdot \left(260 + 4116 + 5380 + 981\right) = 536 \ N$$

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

e) friction in the loading phase

The resisting force at the time of loading is assumed, by appropriate experiments and taking into account the possibility that the material in the loading becoming jammed between the buckets and the external structure, equal to:

$$R_5 = 1{,}4 \cdot Q = 1{,}4 \cdot \frac{13000}{3600} = 505 \;\; N$$

f) tension on the lower court to ensure the support of the chain on the pulley

$$R_6 = 0{,}1 \cdot (R_1 + R_2 + R_3 + R_4 + R_5) = 0{,}1 \cdot (260 + 4116 + 5380 + 981 + 451 + 505) = 1169 \;\; N$$

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

g) tension acting on the chain

The total tension acting on a chain that is:

$$T = (R_1 + R_2 + R_3 + R_4 + R_5 + R_6) = (260 + 4116 + 5380 + 981 + 451 + 505 + 999) = 12692 \ N$$

From the above table is calculated for the chain used a breaking load T_r = 27000 N, for which the safety coefficient of the chain is of 2.45

The tension is the sum of these contributions, you must add the tension obtained with a counterpoise applied to the pulley for reference.

h) dimensioning of the motor

It must take into account the maximum capacity of buckets, which is:

- maximum load uphill F_1:

$$F_1 = 14 \cdot 11{,}52 \cdot \frac{0{,}7}{0{,}3} \cdot 9{,}81 = 3760 \ N$$

- frictions $F_2 = R_2$ = 46 kg
- stress load $F_3 = R_3$ = 51 kg

$$F = F_1 + F_2 + F_3 = (376 + 46 + 51).9{,}81 = 4730 \ N$$

Preliminary design of a bucket elevator

Power to the tree: this is the power that must be available to the drive pulley (upper pulley):

$$P_{albero} = F \cdot 9{,}81 \cdot \frac{v}{1000} = 6{,}21\ kW$$

To determine the power to be supplied by the electric motor engaged for the rotation of the upper pulley P_{motore}, must be taken into account:

- the performance of the transmission system $\eta_{trasmissione} = 0{,}95$;
- a coefficient of increase ε = 4/3, why is it that the engine works at ¾ of its maximum power;
- the performance of the electric motor $\eta_{elettrico} = 0{,}8$.

whereby:

$$P_{motore} = \frac{P_{albero}}{\eta_{trasmissione}} \cdot \varepsilon = \frac{6{,}21}{0{,}95} \cdot \frac{4}{3} = 8{,}71\ kW$$

Preliminary design of a bucket elevator

The power line will provide power $P_{elettrica}$ equal to:

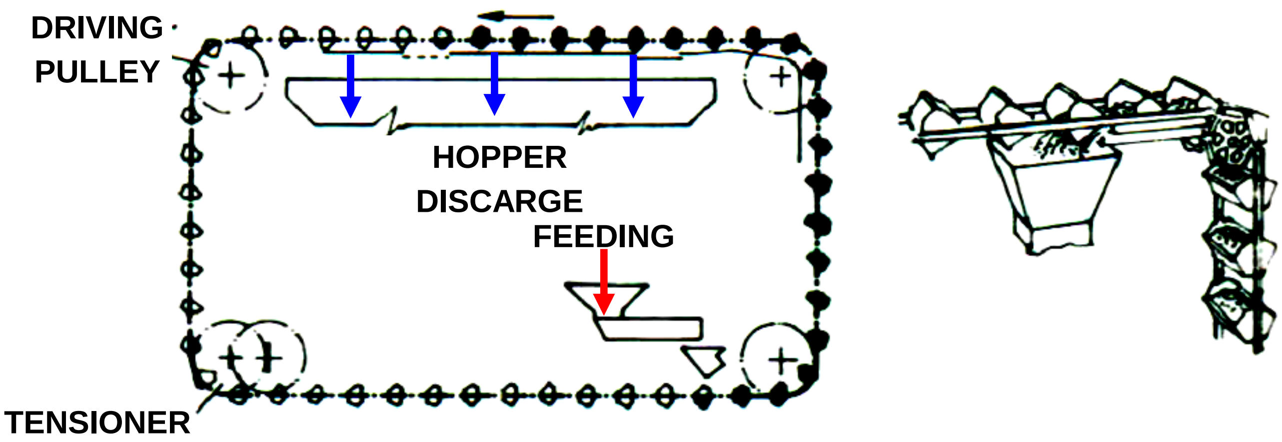
$$P_{elettrica} = \frac{P_{motore}}{\eta_{elettrico}} = \frac{8,71}{0,92} = 9,47\ kW$$

Considering a system with three-phase mains with voltage V = 400 V, assuming a power factor cosφ = 0,95, there is a current I equal to:

$$I = \frac{P_{elettrica}}{V \cdot \cos\varphi \cdot \sqrt{3}} = \frac{9470}{400 \cdot 0,95 \cdot \sqrt{3}} = 7,94\ A$$

Rotating and fixed bucket elevators

The **rotating bucket elevators** movement the bulk materials in the horizontal and vertical.
At appropriate intervals, two chains bear the buckets, that can rotate at the point of discharge by means of a suitable device of reversal.



They are heavy and expensive and are often replaced by those **with fixed buckets** in which the loading/unloading are easier.
The latter, function as a normal in vertical bucket elevators and as conveyors at scraper shovels as in horizontal.

Elevator at slingbars or paternoster

They consist of two chains (or two cables), a series of pairs of upper wheels and a lower part, a series of slingbars (shelves) at constant intervals, which bear the materials to be handled, and a motor assembly on the pair of upper wheels.

They are suitable for the continuous handling of cassettes vertically, boxes, packages etc.

The loading and unloading of materials is carried out by hand or automatically with appropriate devices in different planes.

The elevator in certain cases can have an intermediate storage between a working and another, while in other cases it may be installed in cooking ovens or drying or other thermal treatment plants.

Are employed velocity around the 6 - 15 m/minute inversely proportional to the weight of loads.

Elevator at slingbars or paternoster

The potential of transport Q is very variable, and is given by the relation:

$$Q = k \cdot p \cdot \frac{P \cdot v}{d}$$

where:

k = constant that dependent on the units of measurement used

P = shipping weight of each slingbar

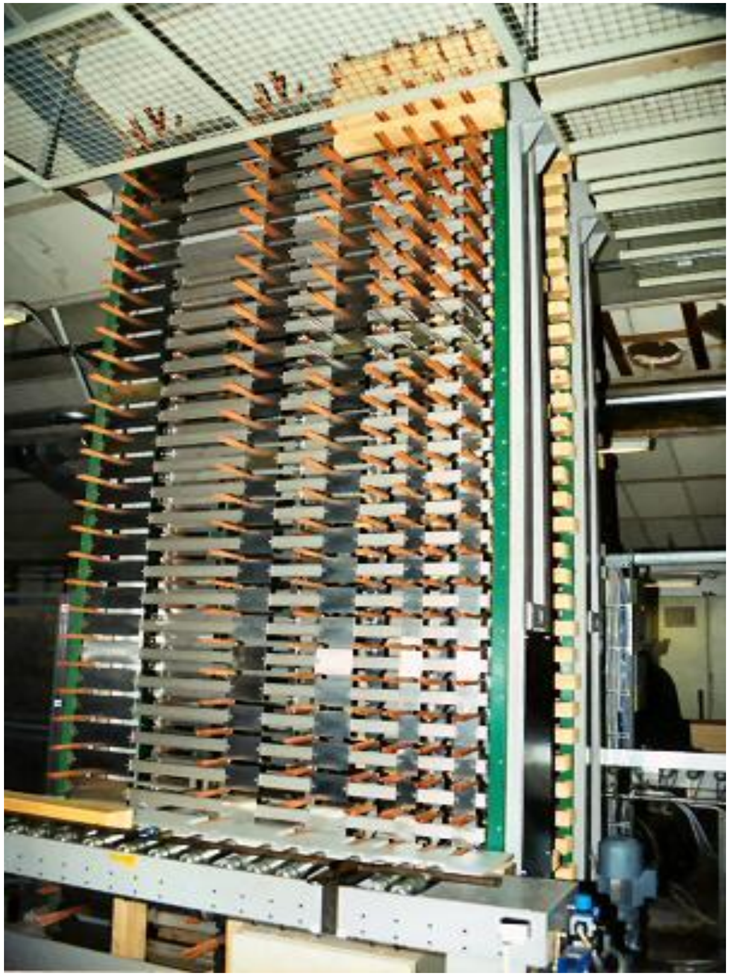
v = speed of the elevator

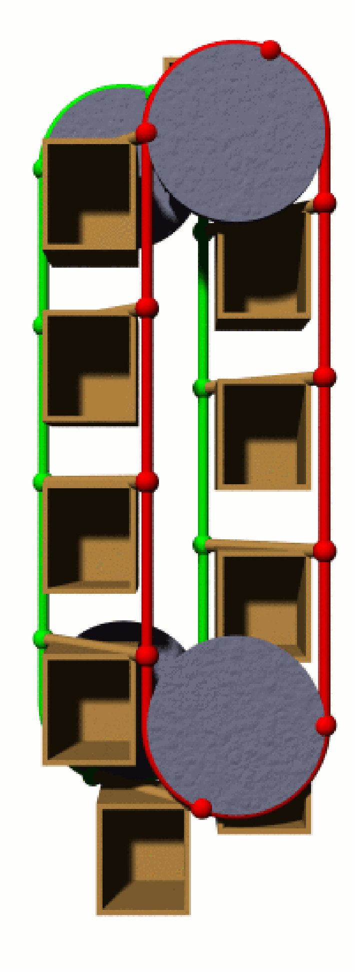
d = pitch between the slingbars

p = coefficient of utilization average of the slingbars (≤ 1)

The strain on the chains tracting is calculated in the same manner of the bucket elevators. Similar is the determination of the absorbed power.

Elevator at slingbars or paternoster





Special elevators

Adopted at the constant lifting of boxes, packages, boxes etc. are the vertical-lift-veyor or veyor or escaveyor.

Special elevators

A belt or rollers conveyor feeds the shelves with packages moving of the elevator (blinds shutters or bars of support). When the movable shelves arrive in the highest position, discharge the load on another conveyor and, invert the motion, they return in the position of the lower load.

Special elevators

The lift-veyor may perform uphill, downhill or in both directions.

The distance between the movable shelves depends on the size of the load more cumbersome.

The potential can reach 8 to 10 pieces or units of load per minute, weighing over 2 tons.