	FEDERATION EUROPEENNE DE LA MANUTENTION **SECTION II** **CONTINUOUS HANDLING**	**FEM** **2.122**
	RECOMMANDATION FOR THE CALCULATION OF TROUGHPUT, POWER REQUIREMENT AND TENSILE FORCES IN BELTS AND CHAINS OF **VERTICAL BUCKET ELEVATORS**	1 st edition GB 01.1981

1 - Scope

This recommendation describes the method of calculation for the establishment of the design of vertical bucket elevators used for bulk handling.

2 - Description/Definition of bucket elevators

A bucket elevator consists of an endless belt or chain as traction element to which buckets as carrying elements are attached at regular intervals for the vertical transportation of pulverized, granulated or lump bulk materials.

The turning traction element, with the buckets attached to it, passes on its top and bottom either on belt pulleys or chain wheels.

The bucket elevator comprises :

— A head with a drive unit and the necessary return device for the traction element;

— A boot, comprising a return device for the traction element and, in most cases, a tensioning device;

— A single or double casing as a protection for the moving bucket strands;

— In the area of the elevator boot a device serving to feed the conveyed material and to fill the buckets;

— In the area of the elevator head a device serving to unload the buckets and to guide the material off.

3 - Field of application

This recommendation applies to bucket elevators with chains or belts for the vertical transportation of bulk material.

In principle, the present recommendation does not apply to inclined bucket elevators, to those presenting partially horizontal and partially vertical phases and to digging elevators. However, the design of these can be calculated in implementing artfully the aforesaid recommendation by extension or deduction.

4 - Preliminary remarks

The throughput of bulk material that can be obtained and the required driving power are closely related. Both depend on the geometrical of the conveyor route, on the nature of the conveyor material, and on the operating conditions, as well as on the design parameters, the most important factors being taken into consideration in the present recommendation.

This recommendation describes essentially the calculation method and indicates relatively simple formulae, without taking into account all possible variations and subtleties of construction pertaining to bucket elevators.

The calculation thus carried out reaches a limited precision, which — in fact, proves to be more than sufficient in most cases. The empirical coefficients given in the following formulae are based on a long experience gained in the design and the operation of bucket elevators.

5 - Symbols and Units

Symbols	Designation	Units
a	buckets pitch	m
g	acceleration due to gravity	m/s²
k	starting factor	—
q	mass of the traction element per meter	kg/m
t	chain pitch	m
v	conveying speed	m/s
D	diameter of chain wheels	m
F_{A1}	inertial forces due to acceleration of the conveyed material on the conveying speed	N
F_{A2}	inertial forces due to acceleration of the conveyed material on the peripheral speed at the head station	N
F_C	maximum tensile force in the traction element	N
F_{dyn}	additional dynamic forces resulting from the polygonal effect of the chain	N
F_F	forces coming from the process of bucket-filling	N
F_H	lifting force	N
F_R	friction forces	N
F_U	peripheral force = total resistance to motion	N
F_V	pretension force	N
H	difference of height between the filling and the emptying point of the buckets	m
I_M	throughput-mass	kg/s
I_V	throughput-volume	m³/s
K	factor to take into account secondary resistances	—
P_{mot}	necessary motor power	W
V	nominal bucket capacity	m³
η	efficiency of the driving unit (without motor)	—
λ	additional height in order to take into account the resistance to motion when filling the buckets	m
ρ	density of the conveyed material	kg/m³
φ	filling ratio of the buckets	—

6 - Throughput calculation

The throughput of a bucket elevator is calculated according to the $\varphi \cdot V$ content of a bucket, the speed v of the bucket strand and the buckets pitch a.

6.1. Volume throughput

The volume throughput I_V is as follows :

$$I_V = \varphi \cdot V \cdot \frac{v}{a}$$

6.2. Mass throughput

Considering the density ρ of the conveyed material, the mass throughput I_M is :

$$I_M = \rho \cdot \varphi \cdot V \cdot \frac{v}{a}$$

6.3. Capacity of the buckets

The actual content of a bucket is the product of the nominal capacity V and the filling ratio φ.

6.3.1. *Nominal capacity of the buckets*

The nominal capacity V of a bucket results from the geometrical dimensions of the bucket, under the assumption of a filling with a horizontal surface (water capacity) for a vertical bucket strand.

The geometrical dimensions of the bucket depend on the size of the bucket elevator and its operation mode and in particular on its conveying speed, as well as on the filling and emptying functions as foreseen.

The dimensions of the buckets and the relevant filling values may be taken for example from the international standards ISO : DIS 5050 and DIS 5051 or in certain cases from the corresponding national standards.

6.3.2. *Filling ratio*

The filling ratio φ is the measure for the practical use to be made of the nominal bucket capacity

$$\varphi = \frac{\text{Bucket filling}}{\text{Bucket capacity}}$$

If the bucket filling is equivalent to the bucket capacity, then $\varphi = 1$.

The filling ratio depends on the physical properties of the conveyed material, on the technical data and on the operating conditions of the bucket elevator.

The important values are :
- — Feeding mode of the material
- — Loading mode of the buckets
- — Conveying speed
- — Buckets pitch
- — Shape of the buckets.

Generally speaking, φ lies between 0,4 and 0,9, the values comprised between 0,7 and 0,75 being the most frequent ones.

In special cases, only when favorable transportation properties are linked to good technical data and operating conditions, φ can be slightly higher than 1 from time to time.

6.4. Throughput

Distinction has to be made between the nominal, maximum and average throughput.

6.4.1. *Nominal throughput*

The nominal throughput is equivalent to the transportation throughput when $\varphi = 1$.

It is a defined calculation value which can be calculated on the basis of precise technical data.

6.4.2. *Maximum throughput*

The maximum throughput can be smaller or, in special cases, higher than the nominal throughput, according to the properties of the conveyed material.

The maximum throughput of a bucket elevator to be expected is the determing factor for the design corresponding to the requirements pertaining to the strength of the components. This factor must therefore be evaluated in advance. If it is impossible to obtain a more accurate evaluation, the maximum filling ratio of φ max at least 1 should be implemented for the design corresponding to the requirements pertaining to the strength of the components.

6.4.3. *Average throughput*

For the following reasons, the average throughput is generally much smaller than the nominal one : First, the filling ratio reached in practice is usually smaller than 1 because of the physical properties of the conveyed material and according to the operating conditions and, secondly, since the highest attainable practical throughput cannot be obtained in permanence, taking also the operating conditions into account.

Therefore, the average throughput depends also largely on the way the conveyed material is fed to the bucket elevator.

When giving the average throughput attained, it is also necessary to indicate the time intervals during which the said throughputs could actually be obtained (One hour/one working shift/one month, etc...).

6.5. Conveying speed

The conveying speed v is equivalent to the peripheral speed of the bucket strand. This is one of the most important factors with respect to a bucket elevator, which is closely linked to the type of traction element foreseen, as well as to the filling and emptying mode of the buckets, as planned (refer to ISO/DIS 7190).

Distinction can be made between the following types of bucket elevators :
- — Low speed bucket elevators with v up to approximately 1 m/s, with chains or belts as traction elements, filling direct and/or by the drawing effect of the buckets and emptying mainly by gravity ;
- — Rapid bucket elevators with v lying approximately between 1 and 2 m/s with chains or belts as traction elements, filling direct and/or by the drawing effect of the buckets, the emptying taking place essentially through centrifugal forces ;
- — Highspeed bucket elevators with v comprised between approximately 2 and 4 m/s with belts as traction elements, filling direct and/or by the drawing effect of the buckets, being only appropriate for materials with easy-flowing and drawing properties ; emptying of the buckets mainly through centrifugal forces.

Chain bucket elevators do not frequently exceed a speed of 1,5 m/s.

6.6. Pitch of buckets

The buckets pitch depends on the profile of the buckets and the conveying speed in relation to the filling and emptying processes.

If gravity emptying is planned with the material sliding on the back of the preceding bucket, it is necessary to place the buckets as near as possible to each other, in order to reduce the distance between buckets as much as possible. In that case, the buckets pitch is equal or slightly superior to the height of the buckets.

For other emptying mode (emptying through centrifugal force ; emptying towards the inside by gravity ; emptying towards the outside by gravity, with the bucket strand deflected), the bucket pitch can be larger and will thus greatly depend on the filling operation. For these cases, the determining factors are on one hand the properties of the conveyed material, such as ease of