The Energy Consumption of Different Types of Pneumatic Conveying Feeders

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Abstract

There are described several types of pneumatic conveying feeders (a vessel feeder, a screw feeder, a rotary feeder, an ejector (Venturi) feeder, a flow feeder) from the point of view of their function as conveying pipelines non-return closures in the paper. Energy which is lost during its work is specified for each feeder type. Different types of feeders are compared from their energy consumption. In the end of the paper, there is compared energy consumption of two types of feeders that were used at two pneumatic conveying systems equipped with almost the same conveying pipeline.

1 INTRODUCTION

Any pneumatic conveying equipment consists of a system of individual linked technical devices. Only a perfectly harmonized system can serve its purpose. An overpressure pneumatic conveying system (Fig. 1) usually consists of

- feeder
- conveying pipeline
- terminal separator
- conveying air source
- air duct
- conveying air de-dusting system

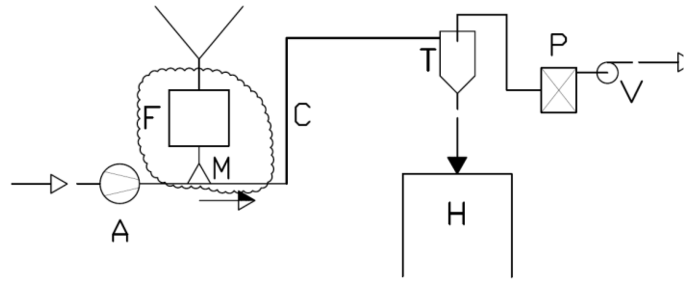

Fig. 1:Pneumatic conveying scheme (positive pressure)

Each of the above-mentioned parts has a certain energy loss. The loss depends on passive resistance in case of pipeline systems, installed electric inputs and drive efficiencies in case of conveying air sources and de-dusting systems, and by internal resistances or losses in case of feeders. This paper focuses on the energy demand of the overpressure pneumatic conveying feeders. Assessment of the energy demand of other sources of energy losses in pneumatic conveying systems does not fall into the scope of this paper.

2 PNEUMATIC CONVEYING FEEDERS AND THEIR ENERGY DEMAND

Pneumatic conveying feeders play two basic roles – first, they feed material into the conveying pipeline (i.e., into the stream of conveying air) and secondly serve as the air lock of the conveying pipeline. This means that they seal the conveying pipeline at its entry so that the material and conveying air mixture flows towards the end of the conveying pipeline and not against the material feed direction.

There are several types of feeders used in the overpressure conveying:

- vessel feeder
- rotary feeder
- screw feeder
- ejector (Venturi) feeder
- flow feeder

Each of the above-mentioned feeders has its advantages and disadvantages, each is suitable for different applications and has different energy demand. Each feeder also forms the air lock in a different manner. From the principle of their function, all feeders need energy for their operation and for airlock formation. This energy does not contribute to the conveying process in the conveying pipeline and is thus lost during the conveying.

3 FEEDERS AS „AIR LOCKS“

Vessel feeder

The air lock of the vessel feeder consists of pressure vessel walls and closures (inlet and de-aeration closure) - see Fig. 2.

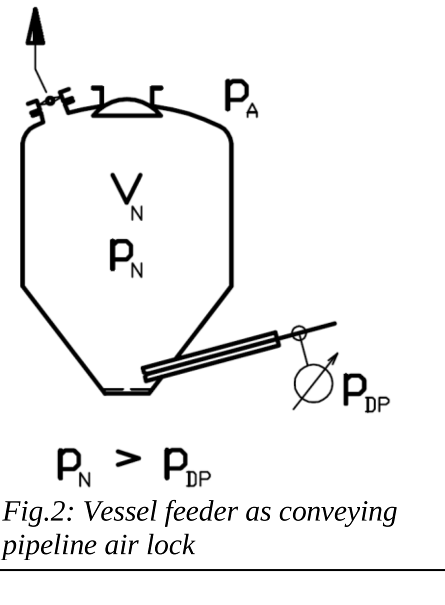

Fig.2: Vessel feeder as conveying pipeline air lock

Pressure in the feeder vessel p_N is balanced with the conveying pipeline resistance p_{DP} increased by the internal loss of the feeder (mixer). Loss energy of the vessel feeder consists firstly of this internal feeder loss and secondly of the energy contained in the compressed air leaving the feeder by vessel de-aeration at the end of each conveying cycle (1). The amount of

$$V_L = \frac{p_a \times V_N \times T_N}{p_N \times \mathrm{T}_0} \times n \qquad (1),$$

where

- V_L is the leaking air flow
- p_a atmospheric pressure
- p_N operating air pressure in the feeder vessel
- V_N feeder vessel volume
- n number of feeder cycles
- T_N feeder fill temperature
- T_0 air temperature under normal conditions

the energy loss varies according to the vessel size, conveying pressure, feeder fill temperature and the number of cycles between 10% and 20% of energy required for conveying air production.

For example, provided that the conveying pressure is 0.55 MPa and the feeder vessel volume is 3.15 m^3, 160.8 $Nm^3.h^{-1}$ of air is discharged into the de-aeration system during 10 cycles per hour.

Rotary feeder

The air lock of the rotary feeder consists of the feeder body and rotor. Resistance due to untightness between the body and rotor of the feeder p_s is balanced with the conveying pipeline resistance p_{DP} during conveying process. Loss energy of the rotary feeder consists of (see Fig. 3):

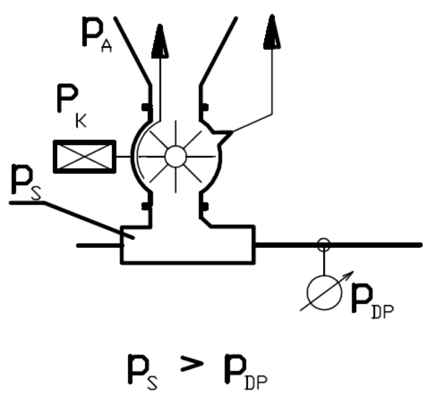

Fig. 3:Rotary feeder as conveying pipeline air lock

- energy contained in the compressed air, which leaks from the feeder through leak points against the fed material,
- energy contained in the compressed air, which is discharged through empty pockets,
- energy required to drive the rotor.

Lost air quantity is determined as the sum of the air leaking through the rotary feeder and that discharged through empty pockets (2).

$$V_L = V_N + V_K \ (2)$$

Quantity of air leaking through the rotary feeder V_N is a characteristic feature of each product and should be specified by the manufacturer, similarly to the example in Fig. 4. However, this

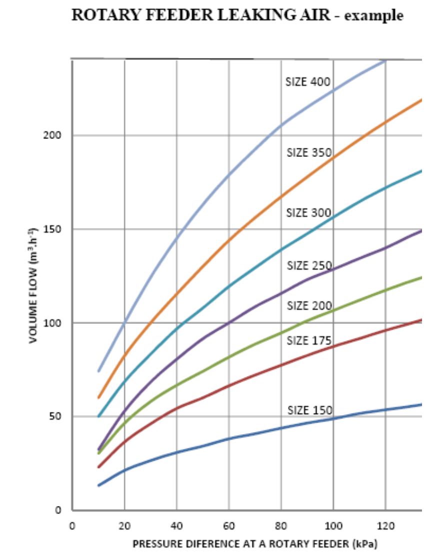

Fig. 4:Air losses through rotary valve leakages

value is often much greater in practice due to the feeder wear. Volume of air discharged through empty feeder pockets V_K depends on conditions of the particular feeder installation in the conveying system (3). Energy required to drive the rotor is determined by the rotary

$$V_K = V_R \times n \times \frac{p \times T_0}{p_a \times \mathrm{T}} \qquad (3),$$

where

- V_K is the pockets leaking air flow
- p_a atmospheric pressure
- p operating conveying air pressure
- V_R feeder rotor volume
- n number of rotations
- T conveying air temperature
- T_0 air temperature under normal conditions

feeder manufacturer with regard to the feeder size, its design, and characteristics of the fed material.

The total amount of energy loss of the rotary feeder depends on the size and rotating speed of the feeder, on the quality of its design and model, on its technical condition (in particular on wear by abrasion), on the conveying air pressure, and on the characteristics of fed material. It varies between 10 and 25%.

Screw feeder

The air lock of the screw feeder consists of the material plug formed at the end of the screw by compressed material. Resistance of the material plug p_z is in balance with the resistance of the conveying pipeline p_{DP} increased by the internal loss of the feeder (mixer head) during the conveying process - see Fig. 5. Loss energy of the screw feeder consists of the energy

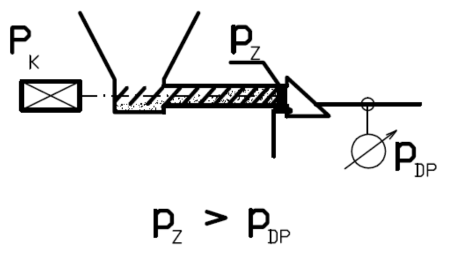

Fig. 5:Screw feeder as conveying pipeline air lock

required to drive the screw and thus to move material to the feeder head and to create sufficiently tight material plug. Approximate values of the rated input for material plug formation differ for individual feeder sizes and pressures in the mixer head. They are

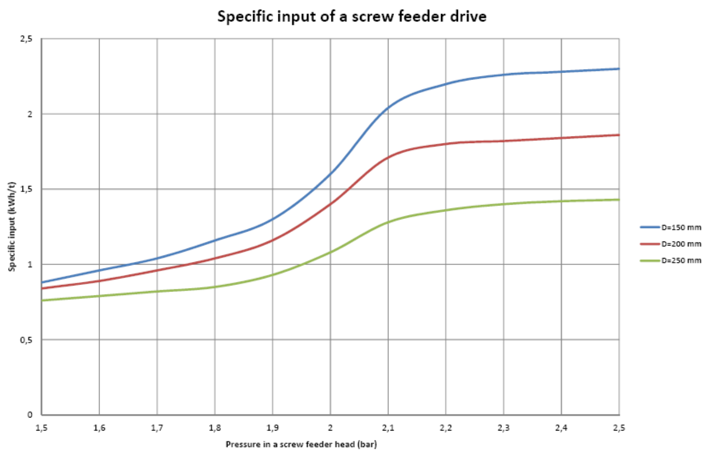

Fig. 6:Screw feeder drive input

indicated in Fig. 6 as example. The amount of energy loss of the screw feeder is considerable and it varies - depending on the size and speed of the feeder, conveying capacity, resistance of the conveying pipeline, and properties of the supplied material - between 40 and 55%.

Ejector feeder

The air lock of the ejector feeder (Fig. 7) is achieved by ejection effect of the conveying gas

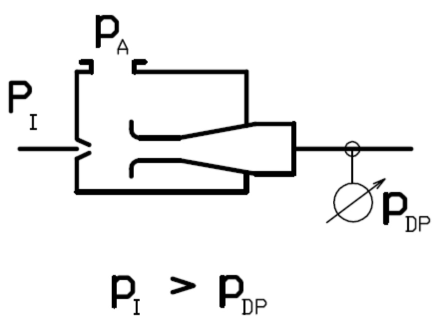

Fig. 7:Ejector feeder as conveying pipeline air lock

stream. Decrease of the static pressure of flowing gas downstream the feeder jet p_E is balanced with the conveying pipeline resistance p_{DP} during conveying. The loss energy of the ejector feeder consists of the energy required to achieve the ejection effect (blowing away the air and material in the feed chamber by ejection air stream produced by the ejector jet) and pressure loss in the confusor and diffusor. The amount of the energy loss of the ejector is considerable and varies around 50 to 65% depending on the conveying pipeline resistance.

Flow feeder

The air lock of the flow feeder is achieved by pressure of high fluidized bed of the aerated material collected in the gravity chamber of the feeder. This pressure can be compared to hydrostatic pressure of a liquid. The "hydrostatic" pressure of the aerated material depends on material column height and its bulk density in the fluidized condition according to Vollheim's formula (4).

$$h = h_0 - \frac{p_0}{g \times \rho_m} \times \left(\frac{1-\varepsilon_{m0}}{\varepsilon_m} \times ln\frac{p}{p_0} + \frac{p}{p_0} - 1 \right) \qquad (4)$$

where
- h - fluidized bed height
- p - pressure
- ρ_m - material density
- ε_m - material concentration in the fluidized bed
- index 0 – condition at the fluidized bed level

“Hydrostatic pressure” p_H is in balance with the resistance of the conveying pipeline p_{DP} increased by the internal pressure drop of the feeder (mixer) during the conveying process –

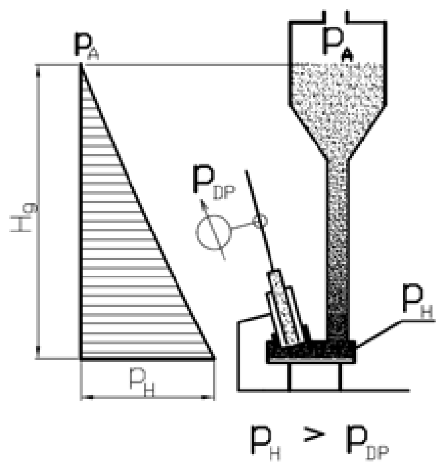

Fig. 8: Flow feeder as conveying pipeline air lock

see Fig. 8. The flow feeder does not have any energy loss due to air plug formation and its operation only requires the "hydrostatic" pressure energy of the material collected in the gravity chamber. Great part of the compressed air (minimum of 50%) used for fluidized bed formation in the flow feeder leaves with the fluidized material into the conveying pipeline and thus contributes to the material flow through the pipeline. Therefore, a greater part of the energy contained therein cannot be considered as lost. Compressed air consumption for the fluidization depends on the particular flow feeder's fluidizing equipment design, it is however negligible compared to the conveying air consumption. Energy of the compressed air required for the fluidizing and passing through the high fluidized material bed (thus lost) represents considerably less than 1% of the total energy consumption of the pneumatic conveying system only.

4 ENERGY DEMAND OF PNEUMATIC CONVEYING FEEDERS COMPARISON

Comparison of loss energies of the feeders is shown in the chart in Fig. 9. For all of the above-mentioned feeder types used in real-life pneumatic conveying systems, this chart indicates the portion of energy contained in the conveying air passing through the conveying pipeline and thus required for conveying (bottom segment of columns), as well as the portions of energy required for air lock creation, i.e. the loss energy that does not directly contribute to the conveying process in the conveying pipeline. These energy losses consist of:

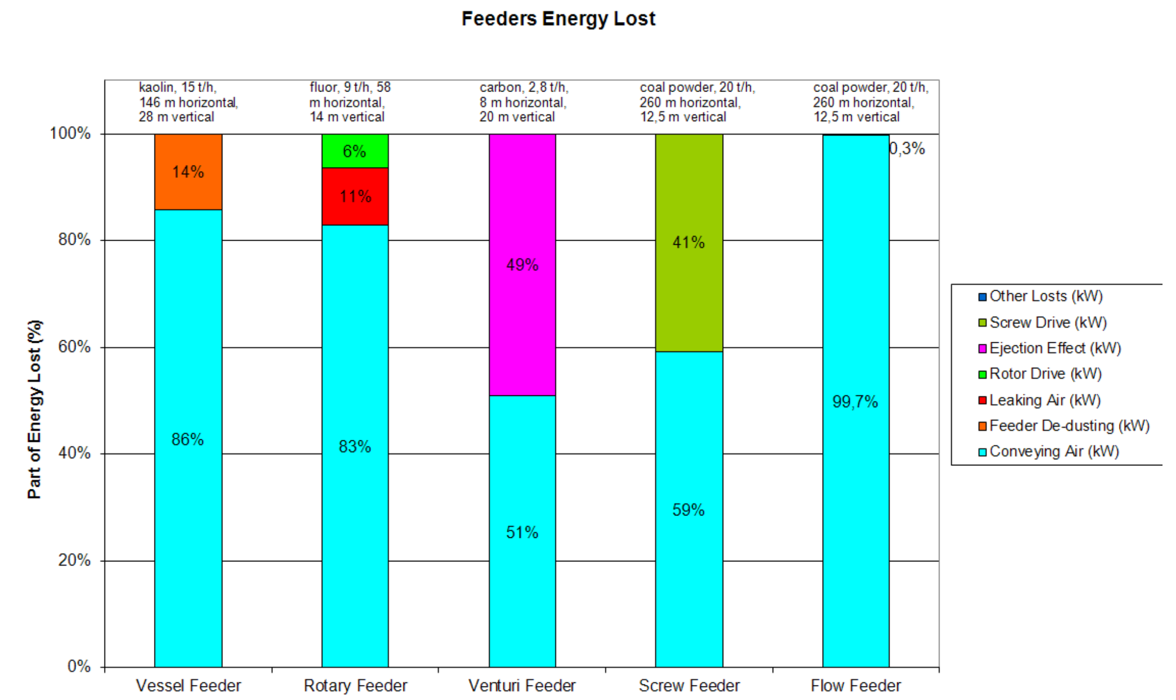

Fig. 9: Grafic comparison of the feeders energy loses

- increasing the shaft inputs of compressed air sources required for production of leaked compressed air (vessel feeder, rotary feeder)
- increasing the shaft input of the compressed air source required for production of compressed air to pass through the fluidized material bed in the gravity chamber – estimated to 50% of the aeration air (flow feeder)
- increasing the shaft input of the compressed air source required for increasing the conveying air pressure (ejector feeder)
- shaft input of the screw or rotor drive (screw or rotary feeder)

5 COMPARISON OF ENERGY DEMAND OF TWO PNEUMATIC CONVEYING SYSTEMS WITH DIFFERENT FEEDERS

As obvious from the above-mentioned analysis, selection of a suitable feeder type can significantly influence the technical and economic parameters of the pneumatic conveying system. There are limited opportunities for objective comparison of two alternative solutions of a pneumatic conveying system in the technical practice. An exceptional opportunity appeared in ALPIQ Kladno heating plant (CZ) in pneumatic conveying of desulfurization limestone from the storage silo into the daily storage bin. With the aim of eliminating the operating issues, increasing the conveying capacity, and reducing the energy consumption relating to the conveying, a parallel pneumatic conveying system has been designed. Its route in fact copied the conveying pipeline of the original system. Moreover, both routes had the same nominal diameter in accordance with the investor's requirement. Scheme of both

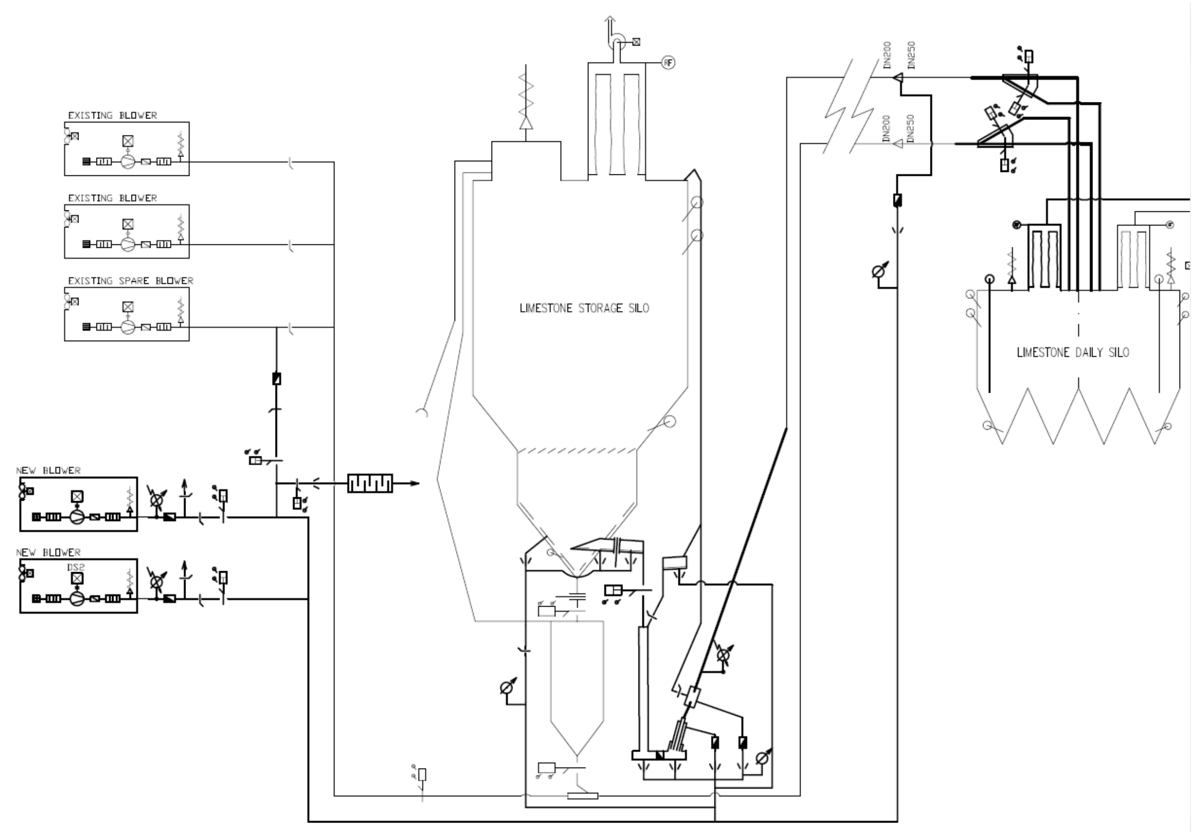

Fig. 10:ALPIQ Kladno – functional chart of original and new equipment

systems is shown in Fig. 10. The original system is shown with thin line and the new system is highlighted with bold line. The vessel feeder and flow feeder, which stand next to each other, are shown in Fig. 11.

Fig. 11: ALPIQ Kladno – the vessel feeder and the flow feeder

The original system uses a vessel feeder with bottom discharge and with control valve at the outlet. The conveying route is staged, its first part is designed as DN200 and the second part is designed as DN250. Two parallel ROOTS blowers with the discharge overpressure of 100 kPa serve as the conveying air source.

The new system has been designed with a flow feeder. Two parallel ROOTS blowers with the discharge overpressure of 75 kPa serve as the conveying air source. The conveying route is almost identical for both systems. This enabled comparison of the two conveying methods (and thus also the two feeders) from both technical and operating perspective after successful implementation and control of the new system. Whereas the two conveying routes are identical, the impact of the conveying pipeline on the operating parameters can be neglected and individual feeder types can be thus compared. Technical parameters of both systems are shown in Table No. 1 and graphic comparison of most parameters is shown in Fig. 12. The

Parameter	**Unit**	**Existing equipment (vessel feeder)**	**New equipment (flow feeder)**
Conveying capacity	$t.h^{-1}$	12 - 15*	18
Material to be conveyed	---	limestone D5	limestone D5
Material bulk density	$kg.m^{-3}$	1200 - 1600	1500
Conveying pipeline total length	m	172	172
Elevation	m	19,2	19,2
Conveying pipeline diameter (inner)	mm	206/259	206/259
Feeder - volume of vessel /grav. chamber	m^3	3	0,26
Blowers number (working)	---	2	2
Blowers capacity	$m^3.h^{-1}$	2 x 2595	2 x 2524
Blowers outlet pressure	kPa(g)	100	75
Installed input of blowers	kW	2 x 110	2 x 75
Blowers input (at clutch)	kW	2 x 98	2 x 66,4
Built-up area (by feeder)	m^2	3,4	0,6
Feeder space requirements (incl. support construction)	m^3	18,2	3,2
Specific energy consumption	$kWh.t^{-1}$	16,333 - 13,07*	7,38
Specific energy consumption related to 100 m of the conveying pipeline	$kWh.t^{-1}.100\ m^{-1}$	9,49 - 7,60*	4,29
Note: * depending on bulk density and features of limestone, really measured 14 mph			

Table 1:ALPIQ Kladno – comparison of the parameters of the new and the existing equipment

comparison clearly shows that it is possible to achieve significant savings by correct selection of pneumatic conveying system - not only on the side of investment costs but mainly on the side of operating costs.

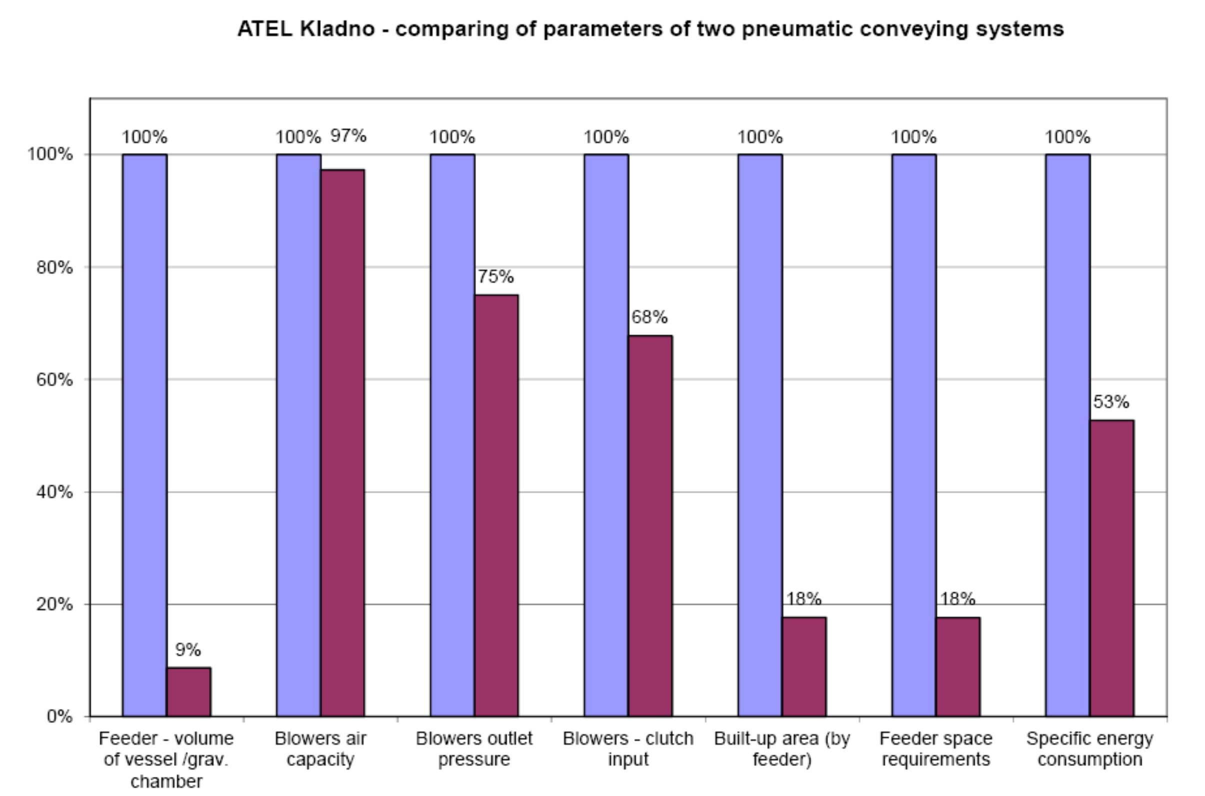

Fig. 12:ALPIQ Kladno – comparison of the parameters of the new and the old equipment

6 SUMMARY

The above-mentioned analysis of energy losses of various pneumatic conveying feeder types and in particular the example from technical practice clearly document that calculation and design of conveying pipeline should not be the only consideration while designing a pneumatic conveying system. It is equally important to focus on the pneumatic conveying system as whole, i.e., on proper selection of the conveying and feeder type with regard to the energy demand minimization. As obvious from the above-mentioned example, an optimal design of the feeder (with equal conveying pipeline clearance and with approximately identical conveying air consumption) can provide energy consumption (and thus operating costs) saving of up to 50%.

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