PVA™ PIAB Vacuum Academy

PIAB VACUUM ACADEMY EMPHASIZES THE BASICS

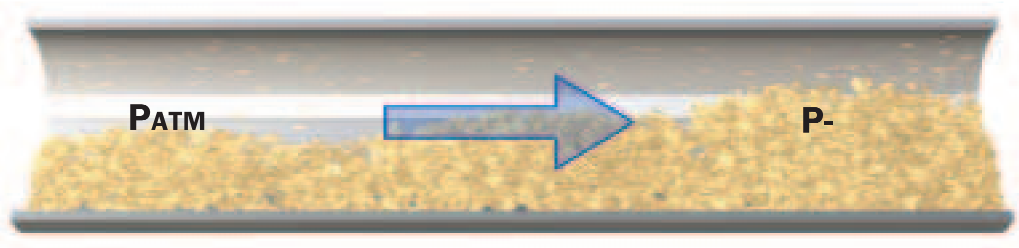
In industry today there is an accelerating trend toward ever more customized solutions that can be made available at short notice. Product development times and production runs are both becoming shorter. Changes are becoming more sudden and harder to predict.

Competence and willingness to change are being challenged by a never-ending parade of new situations. Training that sharpens skills and broadens perspectives enables your personnel – and your company – to handle more sophisticated assignments while accepting highly qualified responsibilities. This makes it easier for you to develop new functions and work pro-cedures while advancing into new markets.

The PIAB Vacuum Academy trains your company’s employees to make sounder pre-purchasing de-cisions, find new fields of applica-tion, develop production process-es and make your business more profitable.

Training courses are held wher-ever PIAB is represented. More-over, they can be held on your company’s premises and be adapted to meet special needs whenever you desire.

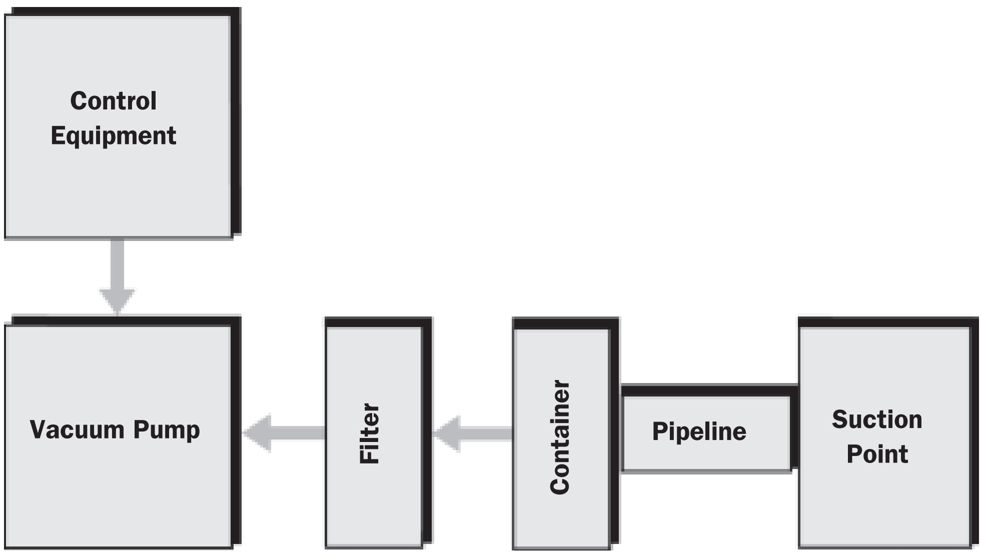
PRINCIPLES OF VACUUM CONVEYING



In the field of vacuum conveying technology we speak of vacuum conveyors being used for "sucking" material. What actually happens is that the air is evacuated from the suction pipe and the pressure of the atmosphere pushes the material into the suction pipeline. It is the atmospheric pressure that indirectly performs the work. The stream of air that is formed upon pressure equalisation pulls the solid particles into the pipeline.

All vacuum conveyors work according to the same main principle, as illustrated below. The material is conveyed from a suction point through a pipeline to a container, where the air and the material are separated. The filter cleans the air before it passes through the vacuum source. A control unit regulates the operating sequence.

Block Sketch, Vacuum Conveying



A TYPICAL VACUUM CONVEYING SYSTEM

A. PIAB vacuum pump

B. Bottom valve

C. Inlet container

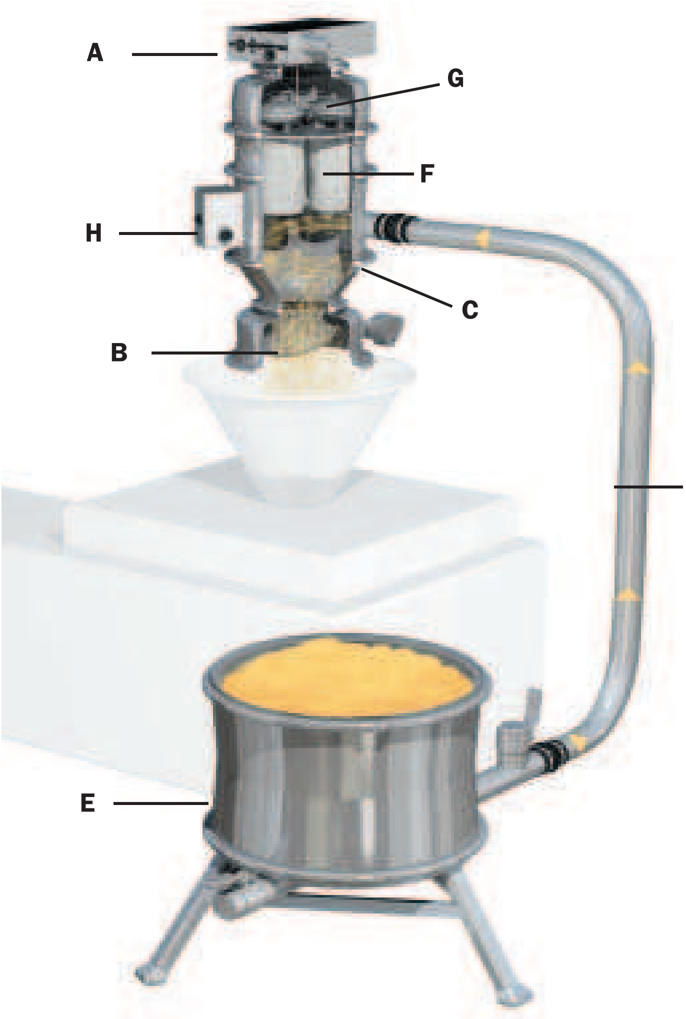
D. Pipeline (hose or pipe system)

E. Feed station

F. Filter

G. Air shock tanks

H. Control system



1. Vacuum is generated by a compressed air-driven PIAB vacuum pump (**A**). The pump can easily be automatically controlled. Since it has few moving parts, the pump is virtually maintenance-free.
2. The bottom valve (**B**) is closed, and vacuum is raised in the container (**C**) and the conveying pipeline (**D**).
3. From the feed station (**E**) the material is drawn into the conveying pipeline and then on to the container.
4. The filter (**F**) prevents dust and fine particles from being drawn into the pump and escaping into the surroundings.
5. During the suction period, the air shock tanks (**G**) are filled with compressed air.
6. When the material container is full, the vacuum pump is stopped. The bottom valve opens and the material in the container is discharged. At the same time, the compressed air in the filter tank is released and cleans the filter
7. When the pump is restarted, the process is repeated and a new cycle begins. The suction and discharge times are normally controlled by pneumatic or electrical control systems (**H**).

MATERIAL HANDLING

MATERIAL FLOW

The material flow is determined by the diameter of the conveying pipeline, the vacuum flow, conveying distance and not least by the characteristics of the material.

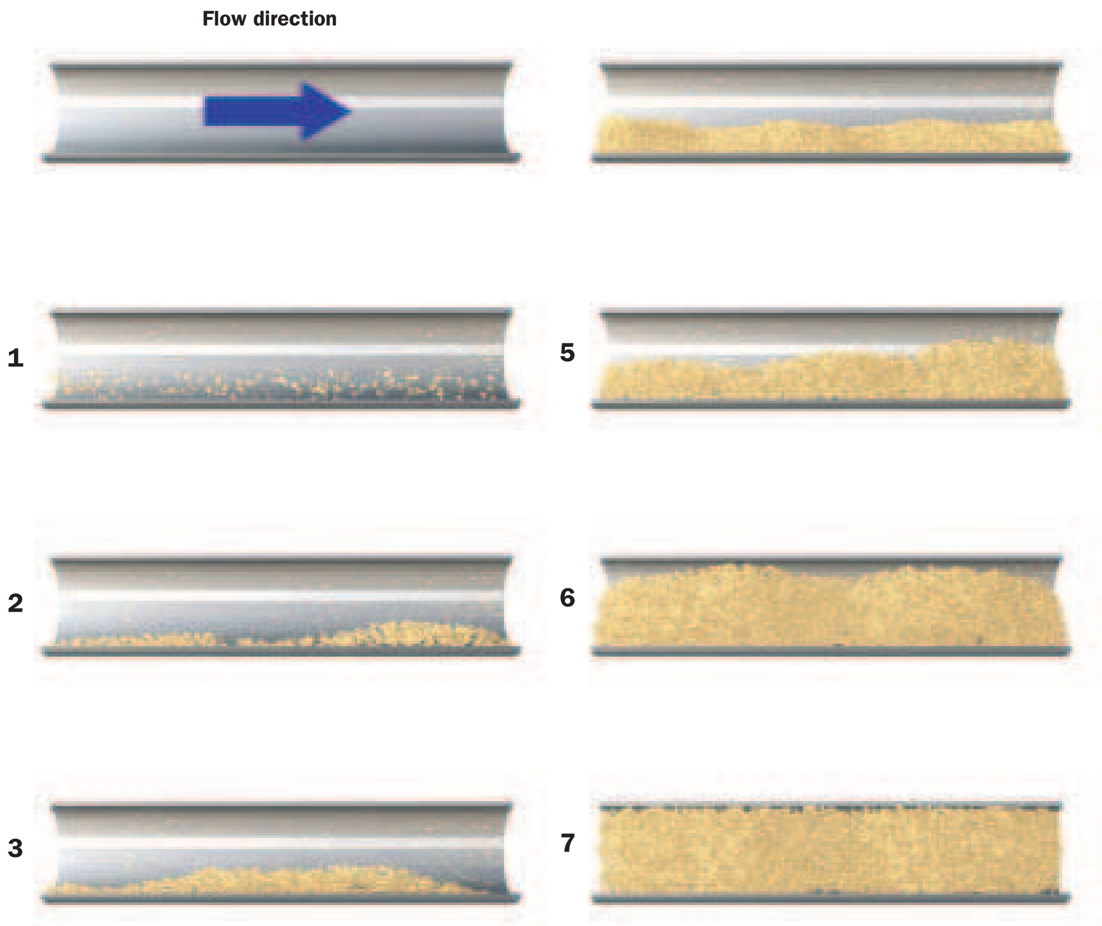
The relationship between material flow and vacuum flow is usually stated as phase densities and is a dimensionless quantity. If the phase density is the same as the bulk density, it means that there is no air in the conveying pipeline and that the pipeline is blocked. The converse also applies. If the phase density is equal to zero, there is no material in the conveying pipeline. Between these two limits, a range of phase densities may occur.

Dense phase means that the material is conveyed in separate plugs in the conveying pipeline. For most materials, the phase density is a factor above ten for dense phase. Some materials can be conveyed in dense phase.

Another conveying phase is “dilute phase”. The phase density is usually below ten. Conveying speed in dilute phase is usually >10 m/s.

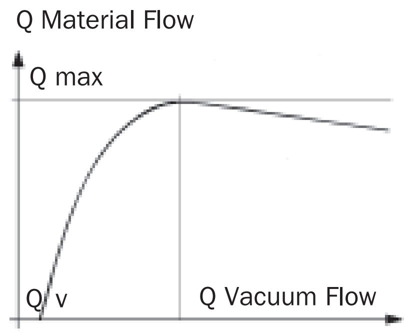
The figure below shows conveying phases with different phase densities. From very dilute phase (1), over dense phase (6) to blocked pipeline (7).

$$* \text{ Phase density} = \frac{\text{Material flow}}{\text{Vacuum flow}} \qquad \frac{\text{material kg/h}}{\text{conveying air kg/h}}$$



It is generally the case that in dense phase, because the material moves in the form of plugs, the vacuum level is usually 30–65%, while in dilute phase it is 10–30%.

When sizing a conveying installation, it is important to find the optimum conveying phase for a specific material. A common misapprehension is that the greater the vacuum flow, the higher the material flow. The relation between material flow and vacuum flow may, for example, be as shown in the opposite figure. The diagram shows that the maximum material flow Q_{max} is equivalent to the vacuum flow Q_v. When the vacuum flow increases, the material flow will decrease.



When sizing a conveying installation, it is important to find the optimum point of the curve. The only way of ascertaining the position of maximum material flow for a specific product is to experiment with varying degrees of aeration and vacuum flow. For this purpose many manufacturers have special test plants.

MATERIAL CLASSIFICATION

When sizing a conveyor, it is important to determine the fluidity of the material that is to be conveyed.

To sum up, the following points should be included in the material classification:

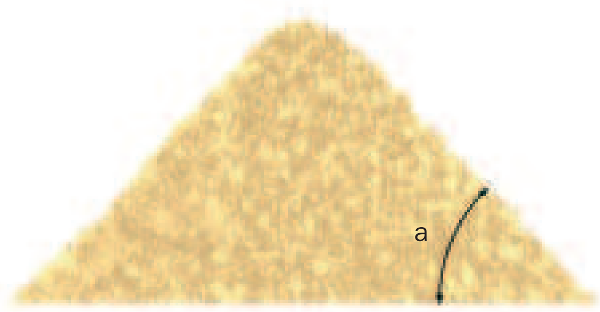
- Fluidity/angle of repose
- Bulk density
- Abrasion factor
- Particle
  – size
  – distribution
  – form
  – density
  – hardness
- Moisture sensitivity (hygroscopicity)
- Explosion hazard
- Harmfulness/poisonousness

FLUIDITY

The fluidity is one of the most important qualities when the conveying possibilities of a material shall be decided. One way of making a rough assessment of the fluidity is to determine the material's angle of repose by pouring out the material from a height and measuring the angle (a).

A small angle of repose means good fluidity and a large angle of repose, poor fluidity. The factors that determine the fluidity of the material are particle size, geometric shape, tendency to pick up static electricity and degree of moisture sensitivity. Plastic granules generally have good fluidity while cornflour has poor fluidity and is also sensitive to moisture.

Material with poor fluidity can often be fluidised. For fluidisation to work, the material must be reasonably fine so that it is lifted by the fluidising air. If the material consists of coarse particles, fluidisation will not be so effective.



BULK DENSITY

The term "bulk density" refers to the weight/volume of a material, in other words, how much one litre of the material weighs. As one litre of powder contains both material and air, the bulk density will vary considerably depending on how closely a particular material is packed. In other words, the same material will have different bulk density values if you weigh a litre of material that has been poured into a beaker and a litre of material that has been shaken and packed. It is therefore important to measure bulk density under conditions that are as similar as possible to the actual conveying conditions.

PARTICLES

Individual particle weight, size, distribution, form and hardness are all parameters that determine a material's flow ability and thus its conveying characteristics.

The weight (density and size) of the individual particles determines the vacuum flow that is required to lift the material into the conveyor pipe and move it forward in the pipeline.

The term "particle distribution" refers to how much of various-sized particles, from the smallest to the largest, make up the material's composition.

MOISTURE SENSITIVITY

Different materials are more or less hygroscopic. If test running is carried out on a particular material, it is important that the conditions are kept as similar as possible to those that will apply on installation. A moisture-sensitive material may form lumps that catch in the material intake, stick in the pipeline or block up the filter.

EXPLOSION RISK

In connection with handling of finely ground material, there may be a risk of dust explosion. Dust explosions can occur when certain types of particles are mixed with air at a certain ratio and a source of ignition is present. Rapid expansion and pressure increase are characteristics of dust explosions.

Dust explosions that occur during conveying of materials are commonly caused by sparks from static electric discharge. You can read more about this in the statute book of the Swedish Board for Occupational Safety and Health (Arbetarskyddsstyrelsen) AFS 1981:5 concerning dust explosions.

In a vacuum conveyor, the ratio of the air-to-material mixture (phase density) varies and the risk of a dangerous mix cannot be eliminated entirely. The risk of ignition can, on the other hand, be minimized by preventing electrostatic discharge and thus the generation of sparks. This can be achieved by connecting the various parts of the conveyor system to the same earth point (equipotential connection).

Many common materials have a tendency to cause dust explosions. Examples of such materials are given below. A complete list may be found in the above-mentioned statute book published by the Board for Occupational Safety and Health.

- Aluminium
- Aspirin
- Carbon
- Coffee
- Cork
- Cotton
- Flour
- Grain
- Iron
- Nylon
- Sugar
- Tea

HARMFULNESS AND TOXICITY

A vacuum conveying system is appropriate for conveying harmful materials, as any leakage in the system does not allow the conveyed material to leak out into the surroundings because of the lower pressure within the system.

The air extracted from the system may need to be filtered particularly carefully by means of a special filter or be piped away to a central filter system

PNEUMATIC CONVEYING SYSTEMS

GENERAL

From a technical point of view, pneumatic conveying is based on conveying of solid particles mixed with a gas, usually air.
By means of pneumatic conveying, solid particles of varying sizes can be conveyed between points, for example, from a storage to a processing machine.

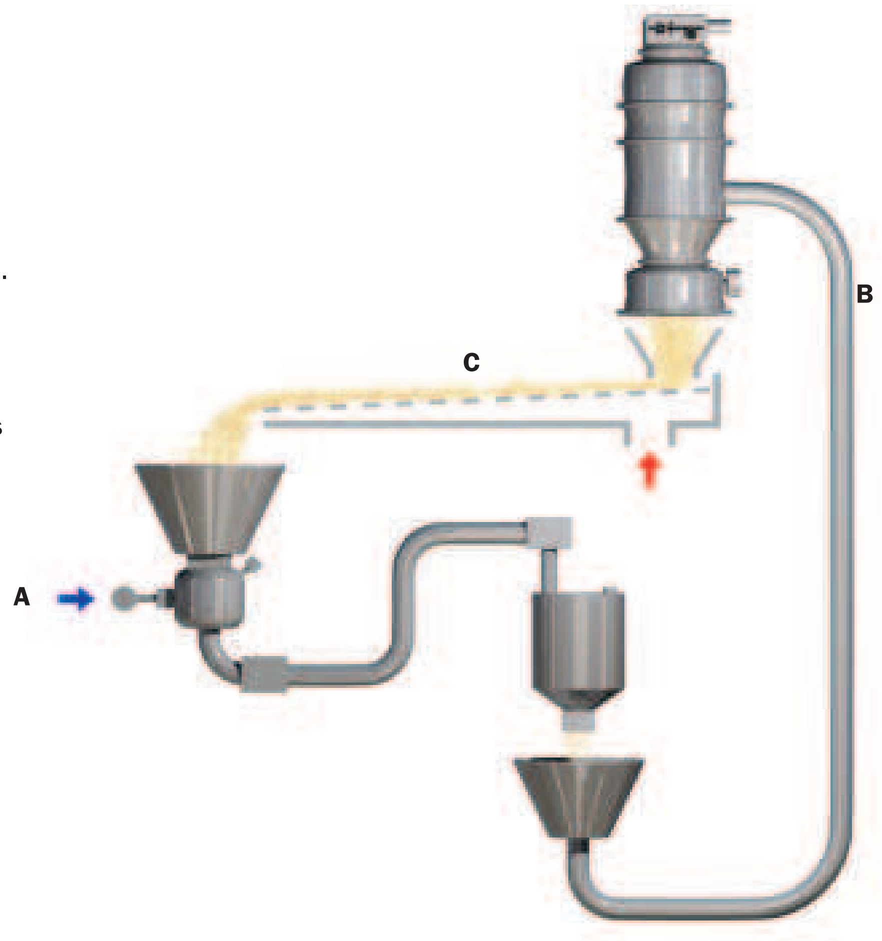
Pneumatic conveying depends on access to compressed air or a source of vacuum, a feed device where air is mixed with the solid particles, a conveying pipeline and a receiving device that separates the carrier air from the particles.

PNEUMATIC CONVEYING SYSTEMS ARE DIVIDED INTO THREE CATEGORIES:

A. Positive-pressure systems, where the material is blown through the conveying pipeline by compressed air.

B. Negative-pressure systems where the material is "sucked" through the conveying pipeline.

C. Fluidised beds. The force of gravity is utilised in combination with fluidisation.
The fluidising layer of air lowers the friction and makes the material run like a liquid.



POSITIVE-PRESSURE CONVEYING SYSTEMS

Positive low-pressure system,
pressure about 0.1 MPa

The advantage of positive-pressure systems is that bulk material can be distributed from one source to several locations through a system of valves.

Usually, positive-pressure systems are divided into low-pressure and high-pressure systems. A high-pressure system has much greater capacity in regard to the quantity of material that can be conveyed and also allows significantly longer conveying distances than are possible with low-pressure systems.

In low-pressure systems (pressure 0.1 MPa) bulk material is usually fed in with the help of a rotary valve or screw. The low-pressure system provides a continuous flow. In the receiving container, the carrier air is filtered out through a filter cartridge.

Positive high-pressure systems (0.7–0.8 MPa) can provide much higher material flows (>150 ton/h) over much longer conveying distances (>2 km). In order to avoid leakage through the feed device, the material is put into a blower tank. The valve between the storage silo and the blower tank is closed and compressed air blows out the material. The tank is refilled and the procedure repeated. The carrier air is filtered in the receiving silo.

Positive high-pressure system,
pressure 0.7–0.8 MPa

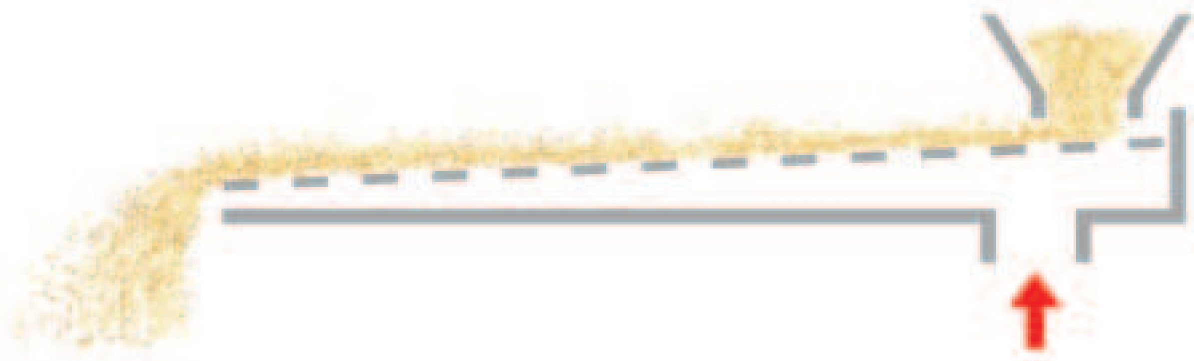
VACUUM CONVEYING SYSTEMS

With vacuum systems, material can be sucked from several pick-up points and collected at one receiving point. This is the opposite of what happens in positive-pressure systems. Vacuum systems have lower material flows than positive-pressure systems. Maximum conveying distances may, with favourable materials, be 100–150 m.

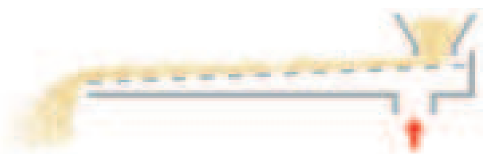
The limitation of the conveying capacity is due to the fact that vacuum systems utilise only atmospheric pressure, while in positive-pressure systems considerably higher pressures can be achieved.

FLUIDISED BEDS

In fluidised beds the air passes through a porous filter material. The passage of air lowers the friction, and gravity causes the material to run like a liquid. Very high material flows can be achieved but the material must have specific properties that allow fluidisation. A gentle slope of one or two degrees is required to set the material in motion.



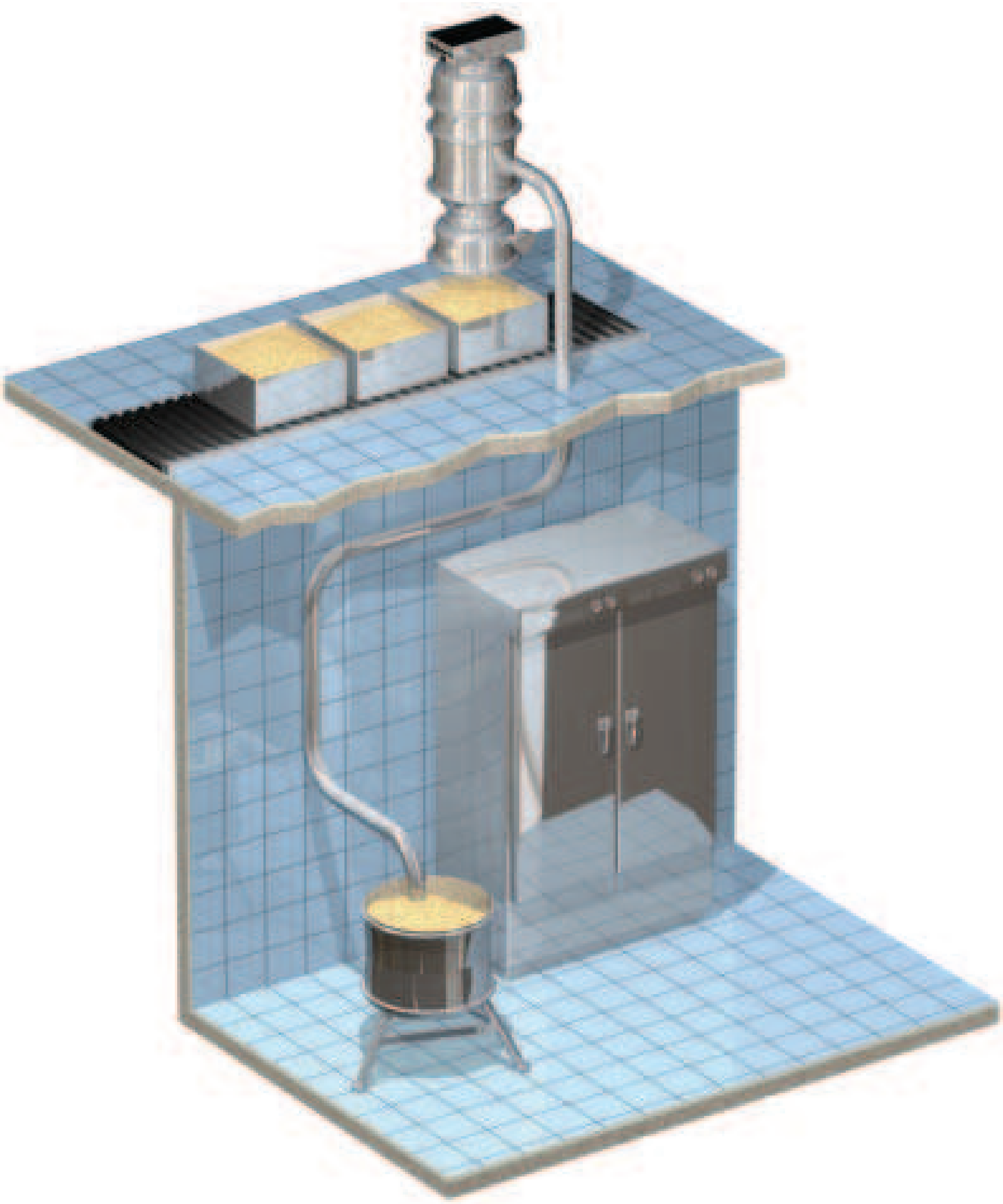
ADVANTAGES - DISADVANTAGES OF DIFFERENT PNEUMATIC CONVEYING SYSTEMS

Conveying system	Advantages	Disadvantages
Positive high-pressure system 	▶ Long distance conveying ▶ High capacities	▶ Risks of leakage ▶ Heavy installations ▶ Expensive components ▶ Wear on material and system
Positive low-pressure system 	▶ Little wear on material and system ▶ Continuous flow	▶ Limited conveying distance ▶ Risks of leakage ▶ Feeder often needed
Vacuum conveying system 	▶ No leakage of material ▶ Simple to install ▶ Dustless ▶ Easy to control	▶ Limited conveying distance ▶ Limited capacity ▶ Usually intermittent operation
Fluidised beds 	▶ Angle of conveying from only 2–3° slope ▶ No moving parts	▶ Dusty conveying ▶ Open system

HANDLING DRY PRODUCTS HYGIENICALLY

Vacuum can be used at great advantage to convey dry products such as powders and granules. PIAB's vacuum conveyors C21, C33 and C56 have been developed especially for handling dairy, food and pharmaceutical products. Some of the models have been examined by USDA – United States Department of Agriculture, and conform with their guidelines concerning dairy products. Through this, the conveyors also comply with the hygienic standards that organizations such as 3-A Sanitary Standards and EHEDG – European Hygiene Engineering Design Group, have established. USDA works closely together with 3-A, and 3-A works in close cooperation with EHEDG. To manufacture equipment according to these requirements is GMP – Good Manufacturing Practice.

PIAB's vacuum conveyors are made of acid-proof stainless steel, ASTM 316L, and withstand the most demanding conditions that they may be subjected to.



COMPONENTS OF A VACUUM CONVEYING SYSTEM

A vacuum conveying system always consists of a number of components. The components are suction point, conveying pipeline, collecting container, filter, vacuum pump and control equipment. Support components may be fluidisation, pipeline valves, various sack dischargers, weighing equipment, etc.

THE SUCTION POINT

For automatic or semi-automatic systems a feed station or different types of feeding adapters can be used. A feed station is a special feeding adapter that can mix air with the material and, if necessary, be provided with fluidisation.

The suction point can also consist of an aspirated feed nozzle, which entrains extra air to the conveying.

A feeding adapter with adjustable intake for air and material, that can be mounted on, for example, a silo.

CONVEYOR PIPELINE

One of the many advantages of pneumatic conveying systems is that they are simple to install. Friction in pipes and hoses can reduce the material flow considerably. For permanent installation, rigid pipes should always be used. Pipes have lower friction than hoses. A good pipe installation may mean an increase in the material flow so that pump capacity can be reduced and thus lower running costs achieved.

COLLECTION CONTAINER

The collection container is the vessel or volume that is placed under vacuum in connection with the suction cycle and in which the material is collected. At the bottom of the container there is a discharge device that opens when the suction cycle is complete and the material flows out and then closes again in preparation for the next suction cycle.

If necessary, the discharge device may be fitted with fluidisation for better discharge.

FILTER

The filter separates the conveyed material from the carrier air. If some particles should follow the air up to the filter, they will be filtered away, and the clean air will continue out through the vacuum pump. Most filters are fitted with some kind of cleaning device.

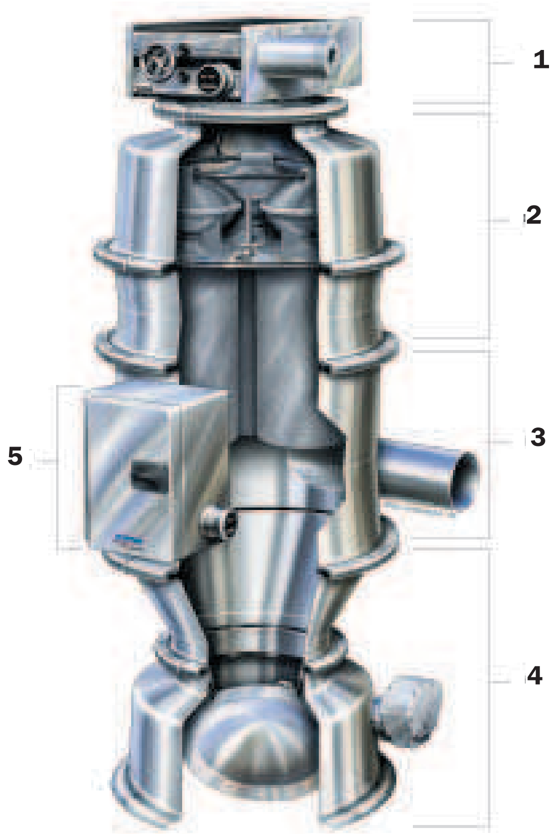
VACUUM PUMP

The heart of the system is the vacuum pump that creates the reduction of pressure or suction that moves the material.

By using a compressed air-driven vacuum pump, a complete explosion-proof unit is achieved, which is important in order to avoid dust explosions. Vacuum pumps driven by compressed air also have the advantage of being virtually maintenance-free, silent and not emitting any heat. They are also easy to control as they react very quickly. The pump can be controlled by means of the compressed-air supply, which means that the pump runs only during the suction period and is at rest, saving energy, at other times.

CONTROL EQUIPMENT

As a vacuum conveyor works intermittently, some form of control equipment that regulates running time, standstill time, discharge, fluidisation, etc., is required.



1. Pump unit
2. Filter unit
3. Connection unit
4. Bottom valve unit
5. Control unit
6. Nylon tubing kit (not in picture)

SYSTEM DESIGN

As mentioned previously, there are many parameters that affect a vacuum conveying system. Naturally, the system design itself is also extremely important. However, as most vacuum conveying systems are unique it is hard to give direct instructions. Certain general basic principles do of course apply and the most important of these are described below.

GENERAL

Some general rules to bear in mind when planning a vacuum conveying system are:

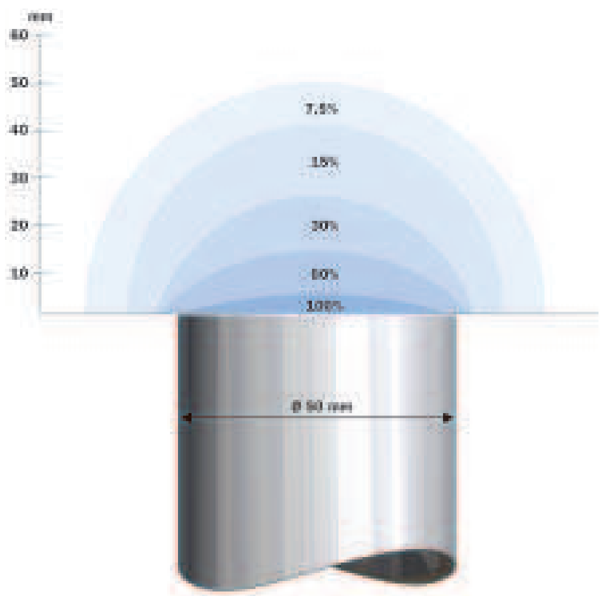
- Short conveying distance reduces system and running costs.
- Keep pipe bends to a minimum to reduce system and running costs.
- Avoid running the conveying pipeline on an inclined plane.
- Use rigid pipes where possible.

SUCTION POINT DESIGN

In order to be able to suck material into a conveying pipeline and then convey it, the conveying air must have a certain minimum speed. Most materials need additional air in order to be set in motion. If a system is to function satisfactorily, the feed, i.e., the suction point, must be designed correctly. It is important that the material is placed close to the intake on the conveying pipeline as the suction capacity decreases by the square of the distance.

When the suction point is designed as a feed station, there are normally two valves, one for air and one for the material, which can be controlled to give the right proportions of material and air in the pipeline. Another way of supplying air, particularly with material that is hard to convey, is to fit the feed funnel with fluidisation.

If a suction nozzle is used, the simplest way of supplying additional air is by using a double-mantled feed nozzle, where the input air is regulated by means of a valve on the handle. The inner tube can also be regulated upwards and downwards in relation to the outer one, and this setting also has an effect on conveying.

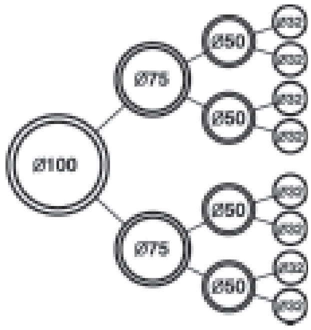


AUTOMATIC ASPIRATING VALVE UNIT

With the help of a Y-piece, a vacuum switch and a valve, additional air can be automatically introduced into the conveying pipeline. In the first part of the conveying pipeline, a Y-piece is fitted (exactly where depends on the material). On the open part of the Y-piece, a valve that is controlled by a vacuum switch is fitted. The vacuum switch senses the vacuum level in the conveying pipeline and when the set value is reached, the switch gives a signal that opens the valve and lets air into the system. To protect the conveyed material from contamination, the inlet is fitted with a filter.

PIPE DIMENSIONS

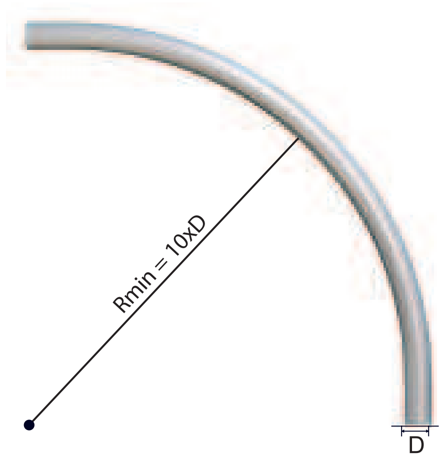
Pipe diameter is of vital importance for the capacity of a conveying system. In principle, the greater the diameter of the pipe, the greater the capacity of the system, provided the speed is kept constant. In practice this means that if you want to increase the capacity, you usually have to overhaul the entire system, including vacuum pump and containers as well as tube dimensions. In certain cases, however, a capacity increase may be made possible with smaller pipes and the same pump. This is due to the fact that it may be possible to move the material in another phase (dense phase). The ratio of the various pipe diameters is shown by the adjacent figure. For example, a pipe with a diameter of 75 mm is equivalent to two pipes with a diameter of 50 mm.



The speed of the material is directly related to the speed of the air in the pipeline. As the pressure in the pipeline falls the closer you get to the conveyor, the speed of the air and the material increases correspondingly. That is why in certain cases stepped pipelines (pipes of increasing diameter) have to be used to keep down the speed of the material so that it is not broken to pieces.

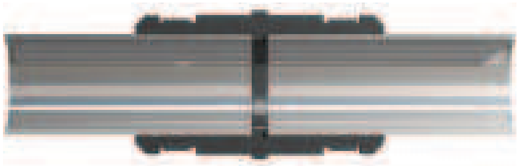
PIPE BENDS

A large bending radius is one way of avoiding unnecessary wear and pipeline resistance. Hoses are often used in bends so that they can be simply and cheaply replaced when they wear out.



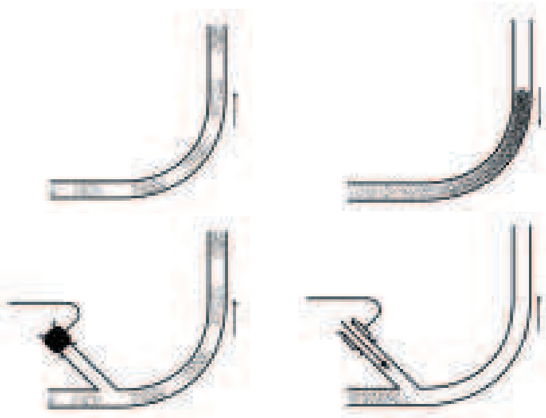
PIPE JOINTS

Pipe joints must be constructed correctly so that material does not build up around the joints. Rounded edges and a good seal are important points to remember.



EMPTYING THE PIPELINE

Vacuum conveying systems can lift materials through relatively large vertical distances, 10–20 m, and in some cases even higher. As the conveyor works intermittently there is a risk that, when the pump stops and the material falls down, a plug will form at the bottom of the vertical part of the system. To avoid this, the tube has to be emptied from time to time from the beginning of the vertical part right up to the conveyor. This may be achieved by inserting a valve that can be opened to let in air before the rise. This means that no material is conveyed before the rise and all material is discharged from the pipe up to the conveyor.

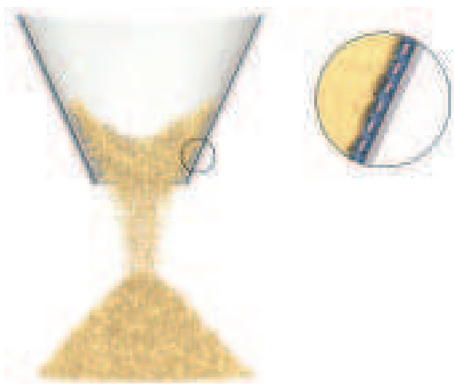


1 and 2 = Without pipeline emptying
3 and 4 = With pipeline emptying

FLUIDISATION

In cases where the material to be conveyed has poor flow capacity, fluidisation may be an option. Fluidisation may take place both at the feed station, to ensure supply of material to the conveyor, and in the conveyor container to improve discharge.

Fluidisation means that compressed air passes through a porous filter material where it is finely distributed. The finely distributed air creates a cushion or film that reduces the friction quite considerably between material and base. What is more, the air is mixed with the material in such a way that friction is also reduced between the particles in the material, which means that the material "flows like water". Not all materials can be fluidised.



WEIGHING

Checking or weighing how much material has been conveyed may take place according to three main principles. The feed station can measure how much has been taken away, the conveyor container can be weighed to measure how much has reached it, and the receiving container may be weighed to ascertain how much has been discharged. Usually, the last weighing option provides the greatest accuracy. The degree of accuracy that can be achieved with the various systems is entirely dependent on the properties of the material conveyed and the construction of the system. In cases where the aim is to meter out a certain quantity of material it is best to place special metering equipment between the conveyor and the receiving container. There are many different types of equipment in the market and the properties of the material determine type and make.

REGULATION AND CONTROL

All vacuum conveying systems require some form of control, which may be designed in many different ways depending on industry and application. Control may be fully pneumatic (suitable where there is a risk of explosion, for example), fully electrical or a combination of both. The system may be a separate unit with independent control or part of a larger system where slave units receive signals from the main system.

Normally, vacuum conveying takes place intermittently (in batches) and more or less automatically and a cycle may have the following sequence:

1. The vacuum pump starts.
2. The bottom valve closes.
3. The material is conveyed.
4. The vacuum pump stops.
5. The filter is cleaned.
6. (Fluidisation, if any, starts.)
7. The bottom valve opens.
8. The product is discharged.
9. (Fluidisation, if any, stops.)

VARIOUS SPECIAL DEVICES

A conveyor may be fitted with a rotary valve so that it can be run continuously. Another method of making a continuous material flow possible is for two conveyors to be run alternately in what is known as a twin set (see fig.).

In a twin set the conveyors are controlled in such a way that while one is sucking the other one is discharging. On changeover there is an overlap period when both conveyors run together for a short time. Sometimes, continuous conveying may be made possible by eliminating the separate container and conveying directly down into a vacuum-proof vessel.

SEVERAL DIFFERENT MATERIALS

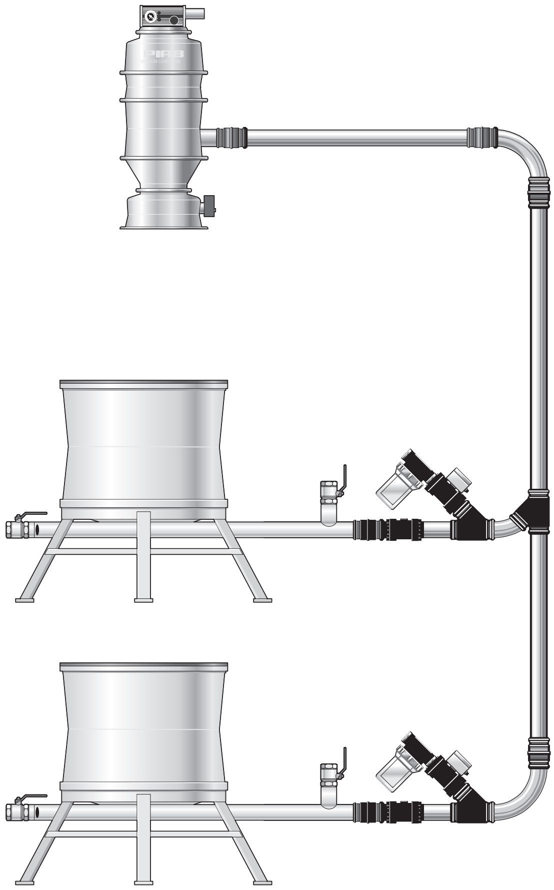
It is simple to connect a vacuum conveyor to different feed stations and thus it can convey different materials to one and the same container, but only one material at a time. If you want to mix different material to a recipe, the system can be fitted with load cells for weighing.

SYSTEM EXAMPLES

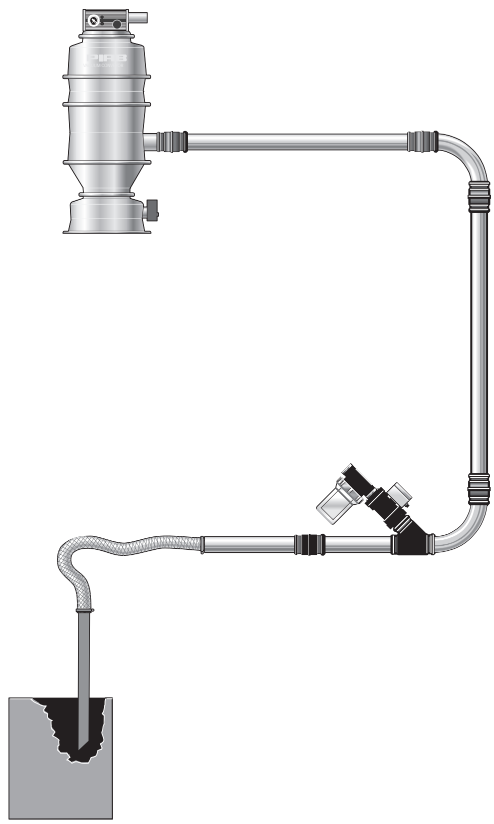
The most common application is to have a conveyor (1), a feeding point (2) and a conveying pipe for the material to be conveyed (3) between point (1) and (2). In order to achieve an even and smooth conveying phase, an aspiration valve unit (4) is sometimes used to open and introduce material-carrier air at regular intervals.

In some applications it is desirable to empty the conveyed material at different points in the production chain. This may be conveying of wheat flour from a loading platform, for example, to three different dough-mixing machines.

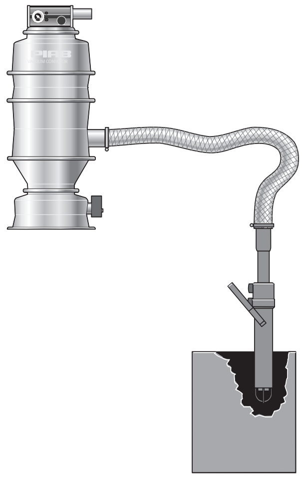
Sometimes one needs to be able to convey different materials from different points of suction to one and the same point of collection in the production chain.



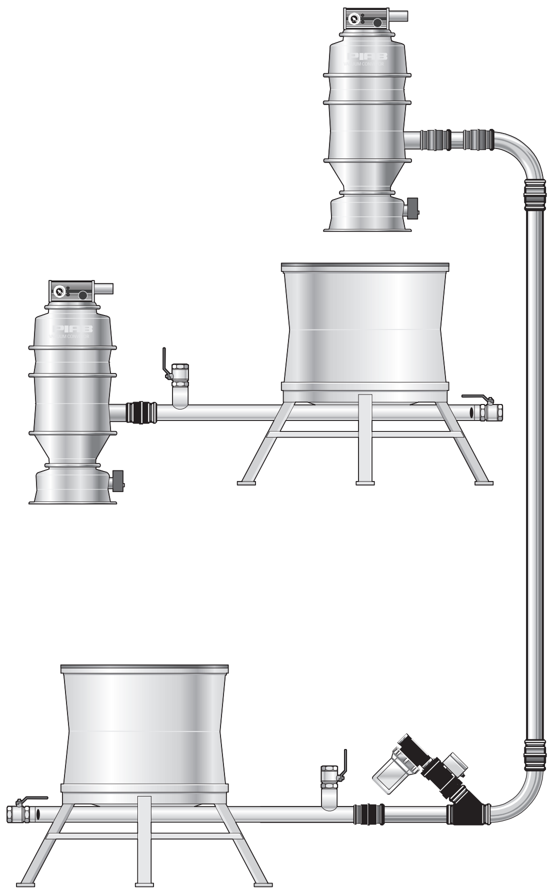
This picture illustrates manual handling at the point of suction by using only one pipe that is entered into the material, with the conveyor located quite far away from that point.



This picture illustrates manual handling at the point of suction by using PIAB's original feed nozzle that is used to control the product-carrier air in the material.

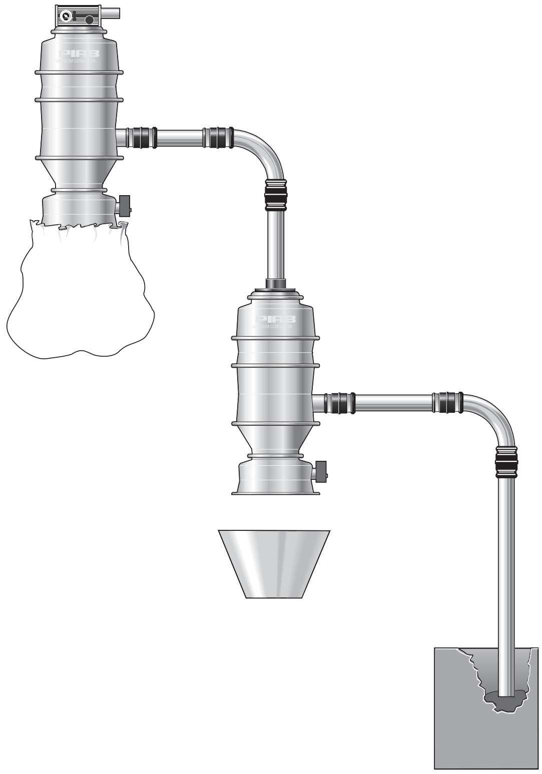


There may be reason for conveying a material in two stages, for example, when the conveying distances are very long, or in applications where the material is to be conveyed up to a considerable height.

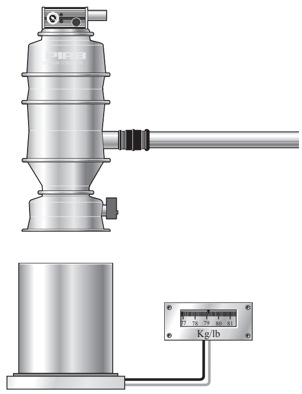


A so-called twin installation is used when one wants to convey the material continuously. One of the conveyors then empties the material at the same time as the other conveyor conveys the material, and vice versa.

Continuous conveying is achieved by collecting the material in a container (2) that can hold a large volume, at a place that lies before the conveyor (1). This solution is ideal also when one has to convey in a vertical direction. If the vertical distance is very long, the container may be positioned at a point halfway of the conveying distance to make it all work smoothly.



There may be instances when one would like to separate two different materials having differing physical properties. Then the heavier particles fall down into the container (2) while the lighter ones are conveyed to the conveyor (1).



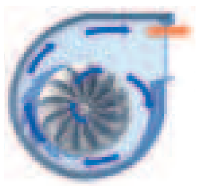
In many cases one has to be very precise when it comes to metering the material. By placing a weighing device (2) under the conveyor (1) it is quite easy to measure how much material is conveyed.

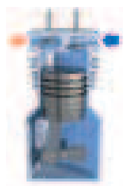
VACUUM PUMPS

MECHANICAL PUMPS

The main principle for all mechanical pumps is that they convey, in one way or another, a certain volume of air from the suction side (the vacuum side) to the exhaust side. In that way they create a vacuum.

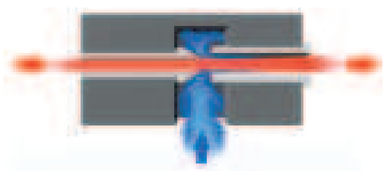
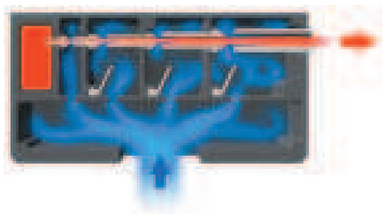
Mechanical pumps usually have an electric motor as power source, but it can also be an internal combustion engine, a hydraulic or a compressed air-driven pump.

Fans		Advantages	Disadvantages
	Centrifugal blower	Few moving parts Large suction volumes Strong	Low maximum vacuum Slow start-up and long stop time High noise level
	Regenerative blower	Few moving parts Large suction volumes Low energy consumption	Low maximum vacuum Slow start-up and long stop time High noise level

Displacement pumps		Advantages	Disadvantages
	Piston pump	Relatively low price	High heat emission Low maximum vacuum
	Membrane pump	Few moving parts Compact Low price	Small suction volumes
	Vane pump	High vacuum and flow Relatively low noise level	Sensitive to contamination Relatively high price High service requirements High heat emission
	Roots pump	High flow Low service requirements	High price High heat emission High noise level

COMPRESSED AIR-DRIVEN EJECTOR PUMPS

All ejector pumps are driven with pressurised gas, usually compressed air. The compressed air flows into the ejector pump, where it expands in one or more ejector nozzles. When expanding, the stored energy (pressure and heat) is converted into motive energy. The speed of the compressed air jet increases rapidly, while the pressure and the temperature go down, attracting more air and thereby creating a vacuum on the suction side. Some ejector pumps may also be used to blow air.

Compressed air-driven ejector pumps		Advantages	Disadvantages
	Single-stage ejector	Low price No heat emission Compact	High noise level Gives either high flow or high vacuum Poor efficiency
	Multi-stage ejector	High efficiency Low energy consumption High reliability Low noise level No heat emission	
	COAX® technology	High efficiency Low energy consumption High reliability Low noise level No heat emission Operates even at low feed pressure Integrated features Modularly built Easy to supplement and upgrade later on Easy to clean	

COMPRESSOR ENERGY CONSUMPTION

According to manufacturers specifications the electrical power consumption is 5.5 – 6 W per l/min, for a 0.7 MPa compressor. This means that an air-driven pump, which consumes 100 l/min, takes 100x6 = 600 W compressor power (0.7 MPa compressor). With 100% running time of the Maxi L600 vacuum pump the air consumption at 0.6 MPa = 2520 l/min.

A vacuum conveying test performed at the PIAB AB test facility.	
Vacuum conveyor	C3304-600
Feed pressure at vacuum pump	0.6 MPa
Material	Granulated sugar
Average particle size	200 µ
Total conveying length	20 m
Pipe diameter	∅76 mm
Measured capacity	2.0 ton/h
Suction time per cycle	10 s
Discharging time per cycle	5 s
Total cycle time per batch of sugar	15 s

- In the test the suction time (running time of pump) is only 2/3 of the total cycle time, which gives the actual air consumption:

  $2 \times 2520/3 = 1680$ l/min.

- The power requirements for this test is:

  $1680 \times 6 = 10080 = 10$ kW.

  The energy consumption per hour = 10 kWh. Assume that the cost for 1 kWh = 0.1 Euro.

- The cost to run the conveyor per hour is:

  $10 \times 0.1 = 1$ Euro.

- Bases on an eight hour running shift per day, 172 hour per month, the energy cost for this test is:

  $172 \times 1 = 172$ Euro/month.

- Comment: In this specific test where two tons of sugar is conveyed every hour, the cost per ton of material is:

  1 Euro/2.0 ton = 0.5 Euro/ton.

CONCLUSION

- To run a small-size conveyor C21, at an eight-hour shift per day, the energy cost per month is:

  Energy cost = 20–100 Euro.

- To run a mid-size conveyor C33, at an eight-hour shift per day, the energy cost per month is:

  Energy cost = 100–200 Euro.

- To run a large-size conveyor C56, at an eight-hour shift per day, the energy cost per month is:

  Energy cost = 200–400 Euro.

TABLES

In everyday speech, many different expressions and units are used for both pressure and flow. It is important to agree on what is meant by them.

PRESSURE

P=F/A (Force/Area).
SI unit (Système International d'Unités): Pascal (Pa). 1 Pa = 1 N/m^2.
Common multiple units: MPa and kPa.

Pa (N/m^2)	bar	kp/cm^2	torr	psi (lb/in^2)
1	0.00001	10.1972×10^{-6}	7.50062×10^{-3}	0.145038×10^{-3}
100 000	1	1.01972	750.062	14.5038
98 066.5	0.980665	1	735.559	14.2233
133.322	1.33322×10^{-3}	1.35951×10^{-3}	1	19.3368×10^{-3}
6 894.76	68.9476×10^{-3}	0.145038×10^{-3}	51.7149	1

1 torr = 1 mm HG à 0° C,
1 mm column of water = 9.81 Pa

PRESSURE ABOVE ATMOSPHERIC

kPa	bar	psi	kp/cm^2
1013	10.13	146.9	10.3
1000	10	145	10.2
900	9	130.5	9.2
800	8	116	8.2
700	7	101.5	7.1
600	6	87	6.1
500	5	72.5	5.1
400	4	58	4.1
300	3	43.5	3.1
200	2	29	2
100	1	14.5	1
0	0	0	0

PRESSURE BELOW ATMOSPHERIC

	kPa	mbar	torr	-kPa	-mmHg	-inHg	% vacuum
Sea level	101.3	1013	760	0	0	0	0
	90	900	675	10	75	3	10
	80	800	600	20	150	6	20
	70	700	525	30	225	9	30
	60	600	450	40	300	12	40
	50	500	375	50	375	15	50
	40	400	300	60	450	18	60
	30	300	225	70	525	21	70
	20	200	150	80	600	24	80
	10	100	75	90	675	27	90
Absolute vacuum	0	0	0	101.3	760	30	100

CHANGE IN ATMOSPHERIC PRESSURE IN RELATION TO ALTITUDE (HEIGHT ABOVE SEA LEVEL)

A vacuum gauge is normally calibrated with normal atmospheric pressure at sea level as a reference, 1013.25 mbar, and is influenced by the surrounding atmospheric pressure in accordance with the table below.

Barometric pressure			The reading on the vacuum gauge at 1013.25 mbar				
mm Hg	mbar	Equiv. m above sea level	60 -kPa	75 -kPa	85 -kPa	90 -kPa	99 -kPa
593	790.6	2,000	37.7	52.7	62.7	67.7	76.7
671	894.6	1,000	48.1	63.1	73.1	78.1	87.1
690	919.9	778	50.7	65.7	75.7	80.7	89.7
700	933.3	655	52.0	67.0	77.0	82.0	91.0
710	946.6	545	53.3	68.3	78.3	83.3	92.3
720	959.9	467	54.7	69.7	79.7	84.7	93.7
730	973.3	275	56.0	71.0	81.0	86.0	95.0
740	986.6	200	57.3	72.3	82.3	87.3	96.3
750	999.9	111	58.7	73.7	83.7	88.7	97.7
760	1013.25	0	60.0	75.0	85.0	90.0	99.0

** at normal barometric pressure.*

The vacuum gauge shows the differential pressure between atmospheric pressure and absolute pressure. This means that the gauge shows what vacuum level is available at different heights.

FLOWS

Flows, volume per unit of time.
Quantity designations: Q, q, = V/t (volume/time).
SI Unit: cubic metres per second (m^3/s).
Common multiple units: l/min, l/s, m^3/h.

m^3/s	m^3/h	l/min	l/s	ft^3/min (cfm)*
1	3600	60000	1000	2118.9
0.28×10^{-3}	1	16.6667	0.2778	0.5885
16.67×10^{-6}	0.06	1	0.0167	0.035
1×10^{-3}	3.6	60	1	2.1189
0.472×10^{-3}	1.6992	28.32	0.4720	1

**1 ft ≈ 0.305 m*

VOLUME FLOW VERSUS GAS FLOW

Unit		Vacuum level -kPa										
		0	10	20	30	40	50	60	70	80	90	99
Volume flow	l/s	10	10	10	10	10	10	10	10	10	10	0
	m^3/h	36	36	36	36	36	36	36	36	36	36	0
Free air	Nl/s	10	9	8	7	6	5	4	3	2	1	0
	Nm^3/h	36	32.4	28.8	25.2	21.6	18	14.4	10.8	7.2	3.6	0

LEAKAGE FLOWS

The table below shows the leakage flow at different levels and through an opening of 1 mm^2.

Vacuum level -kPa	Leakage flow l/s and mm^2
10	0.11
20	0.17
30	0.18
40	0.2*

** From about 47 -kPa to 100 -kPa the flow is constant.*

PRESSURE DROP IN COMPRESSED AIR HOSES

When installing compressed air hoses, it is important that the dimension (diameter) and length do not lead to excessive pressure drops. PIAB vacuum pumps are supplied with recommended hose dimensions that will not cause excessive pressure drops at lengths below 2 m.

In cases when the pressure drop has to be calculated, the formula below can be used.

ΔP	=	Pressure drop in kPa
qv	=	Flow in m^3/s
d	=	Inner diameter in mm
L	=	Length of compressed air hoses in m
P1	=	Absolute starting pressure in kPa

$$\Delta P = \frac{1{,}6 \times 10^{12} \times qv^{1{,}85} \times L}{d^5 \times P1}$$

$$d = \left(\frac{1{,}6 \times 10^{12} \times qv^{1{,}85} \times L}{\Delta P \times P1}\right)^{0{,}2}$$

WEIGHT

	kg	g	oz	lb
1 kg	1	1000	35.27	2.205
1 g	0.001	1	0.03527	0.002205
1 oz	0.02835	28.35	1	0.0625
1 lb	0.4536	453.6	16	1

FORCE

Force	
1 N =	0.10197 kp
1 kp =	9.8066 N
1 N =	0.2248 lbf
1 lbf =	4.4482 N

TEMPERATURE

Melting point of ice	Boiling point of water at 101.3 kPa	Absolute zero
0°C	100°C	273.15°C
32°F	212°F	459.67°F
273.15K	373.15 K	0K

$°F = 1.8(°C) + 32$

PARTICLE AND FILTER PORE SIZE

mesh	micron	inches
4	5205	0.2030
8	2487	0.0970
10	1923	0.0750
14	1307	0.0510
18	1000	0.0394
20	840	0.0331
25	710	0.0280
30	590	0.0232
35	500	0.0197
40	420	0.0165
45	350	0.0138
50	297	0.0117
60	250	0.0098
70	210	0.0083
80	177	0.0070
100	149	0.0059
120	125	0.0049
140	105	0.0041
170	88	0.0035
200	74	0.0029
230	62	0.0024
270	53	0.0021
325	44	0.0017
400	37	0.0015*
550	25	0.0009
800	15	0.0006
1250	10	0.0004
…	5	0.0002
…	1	0.000039
* Threshold of visibility		

THREAD SYSTEMS

1. ISO THREAD:

Cylindrical Metric thread, designated with the letter M. Example: M5.

Cylindrical Inch thread (also called Unified thread): designated with the letter UNF. Example: 10-32UNF.

2. BSP THREAD

(British System of Pipe threads):

The threads have a 55° profile angle and are dimensioned in inches.

Cylindrical thread is designated with the letter G. Example: G 1/8“.

3. DRY SEAL THREAD

(American system of pipe threads):

The dry seal system consists of cylindrical and conical pipe threads. The threads have a 60° profile angle and are sealed without packing or seal rings (please note that when these are used in other combinations of thread systems, “sealing“ is not applicable). The dimensions are given in inches and PIAB’s catalogue uses the letters NPT and NPSF:

Conical thread is designated NPT.
Example: 1/8“ NPT

Cylindrical thread is noted as the letters NPSF.
Example: 1/8“ NPSF

COMPATIBILITY OF DIFFERENT THREAD SYSTEMS

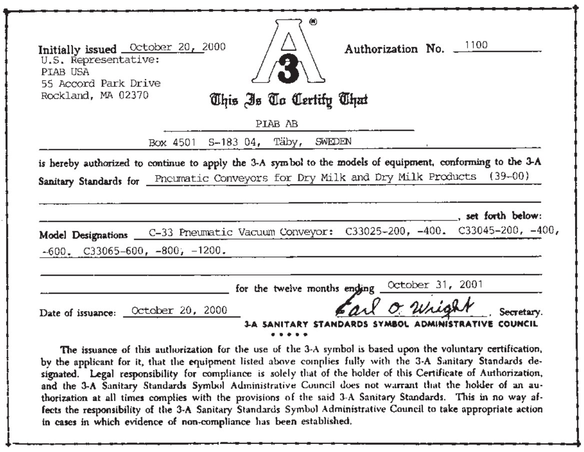
	M5 male	M5 female	G1/8” male	G1/8” female	G1/4” male	G1/4” female	G3/8” male	G3/8” female	G1/2” male	G1/2” female	G3/4” male	G3/4” female	G1” male	G1" female	G2" male	G2" female
10-32UNF female or male	+	+++														
1/8” NPSF female			+++													
1/8” NPT female or male			—	+												
1/4” NPSF female					+											
1/4” NPT female or male					—	—										
3/8” NPSF female							—									
3/8" NPT female or male							—	—								
1/2” NPSF female									+							
1/2” NPT female or male									—	+++						
3/4” NPSF female											+					
3/4” NPT female or male											—	+++				
1” NPT female or male													—	—		
2” NPT female or male															—	—

+++ Fits *+ Fits with short thread* *— Does not fit*

INTERNATIONAL STANDARDS

3-A

- The objective of the 3-A Sanitary Standards is to formulate standards and accepted practices for equipment and systems used to produce, process and package milk, milk products and other perishable foods or comestible products. These standards are developed through the cooperative efforts of local, state and federal sanitarians, equipment manufacturers and equipment users. The ultimate goal is to protect dairy and food products from contamination and to ensure that all product contact surfaces can be mechanically cleaned (CIP) or easily dismantled for manual cleaning, and when necessary, dismantled for inspection.
- 3-A Sanitary Standards are developed to detail the sanitary requirements for a specific type of equipment. Specifications include material selection (FDA compliance), design and fabrication for that type of equipment.
- 3-A Accepted Practices are guidelines for entire systems and include the same sanitary criteria as 3-A Sanitary Standards, in addition to installation criteria where appropriate.
- When a vacuum conveyor is classified as a hygienic device by 3-A, a certificate is obtained to the effect that the “3-A” symbol may be placed on the device. This symbol shows that the device is designed for consumer products that demand a very high degree of hygiene. This certificate is updated annually.



Initially issued October 20, 2000

Authorization No. 1100

U.S. Representative:
PIAB USA
55 Accord Park Drive
Rockland, MA 02370

This Is To Certify That

PIAB AB
Box 4501 S-183 04, Täby, SWEDEN

is hereby authorized to continue to apply the 3-A symbol to the models of equipment, conforming to the 3-A Sanitary Standards for Pneumatic Conveyors for Dry Milk and Dry Milk Products (39-00), set forth below:

Model Designations C-33 Pneumatic Vacuum Conveyor: C33025-200, -400. C33045-200, -400, -600. C33065-600, -800, -1200.

for the twelve months ending October 31, 2001

Date of issuance: October 20, 2000

Earl O. Wright, Secretary.
3-A SANITARY STANDARDS SYMBOL ADMINISTRATIVE COUNCIL

The issuance of this authorization for the use of the 3-A symbol is based upon the voluntary certification, by the applicant for it, that the equipment listed above complies fully with the 3-A Sanitary Standards designated. Legal responsibility for compliance is solely that of the holder of this Certificate of Authorization, and the 3-A Sanitary Standards Symbol Administrative Council does not warrant that the holder of an authorization at all times complies with the provisions of the said 3-A Sanitary Standards. This in no way affects the responsibility of the 3-A Sanitary Standards Symbol Administrative Council to take appropriate action in cases in which evidence of non-compliance has been established.

USDA

- United States Department of Agriculture is an authority that, among other things, reviews and approves equipment intended for processing dairy products such as dry milk and dry milk products. The USDA section intended for reviewing equipment for dairy products is called USDA Dairy Grading Branch.
- All included materials in a product that is examined and recognized by USDA are also recognized by the organization FDA – Food and Drug Administration. USDA and FDA work in close cooperation. USDA and 3-A also work in close cooperation.
- A vacuum conveyor accepted by USDA Dairy Grading Branch complies with the strictest safety requirements for health in regard to conveying of dairy, food and other farm products.
- PIAB manufactures and markets a series of vacuum conveyors that have been examined and recognized by USDA.

UNITED STATES DEPARTMENT OF AGRICULTURE
MARKETING AND REGULATORY PROGRAMS
AGRICULTURAL MARKETING SERVICE
DAIRY GRADING BRANCH

EQUIPMENT ACCEPTANCE CERTIFICATE

USDA

EHEDG

- The European Hygiene Engineering Design Group.
- In the European directives it is stated that all handling of food products, packaging, processing, etc., shall be carried out with hygiene as a priority.
- EHEDG, with the help of the European Commission, introduces guidelines that specify how the handling of food products shall be carried out. (It is the same in the USA where USDA and FDA help 3-A to introduce sanitary standards.)
- For many years EHEDG has worked closely with 3-A, which in turn works in close cooperation with USDA. To manufacture devices according to these requirements is GMP – Good Manufacturing Practice and GAP – Good Agricultural Practice.

FDA

- Food and Drug Administration releases ”CFR = Code of Federal Regulations” which is a set of regulations describing material of equipment that can be used in contact with pharmaceutical, dairy, food and farm products.
- PIAB's USDA series of vacuum conveyors contain nothing but materials that agree with the guidelines of FDA.
- FDA works in close cooperation with both USDA and 3-A.

CIP

- Clean In Place is a method by which tanks and piping in processing plants are automatically washed by re-circulating detergent and rinse solutions. CIP means cleaning of the device without moving or disassembling it.
- The system provides reservoirs for detergent and rinse solutions as well as pumping and heating capabilities for the solutions. Computer control handles the program sequences of the washing and rinsing steps.
- The process is used to ensure that production lines, vessels and reactors are free of inorganic and organic contaminants.
- PIAB's vacuum conveyors must be manually disassembled before cleaning, and therefore they cannot be used in processes that require fully automatic CIP procedures.

GMP

- Good Manufacturing Practice is a guideline implemented to assure quality, effectiveness and safety of pharmaceutical products. It concerns the matter of "building in" quality rather than testing the quality.
- GMP is designed to minimise the risks involved in any pharmaceutical production that cannot be eliminated through testing the final product.
- GMP covers all aspects of production from the initial materials, premises, equipment, training and personal hygiene of staff.
- PIAB's USDA series of vacuum conveyors are designed for use in production environments suitable for manufacture of pharmaceuticals.

IAFP

The International Association for Food Protection (formerly IAMFES) issues the 3-A Sanitary Standards and 3-A Accepted Practises that are standards for equipment used mainly in the dairy industry.

CE MARKING OF MACHINES

- Definition of machine:
  - At least one part with a driving function – PIAB vacuum pump.
  - At least one moving part – bottom valve.
  - A unit that controls the machine – PIAB control unit.
- CE marking originates from a European set of regulations to make sure that machines comply with essential health and safety requirements.
- PIAB's vacuum conveyors are CE marked in accordance with European Machine Directive 98/37 EC.

ENCLOSURE CLASSIFICATIONS FOR ELECTRIC EQUIPMENT

Enclosure classifications for electric equipment according to Swedish standard SS IEC 529. The symbols have the form of IPxy.

- The first digit **(x)** denotes the degree of protection that the enclosure gives to human beings as well as to what is present inside.
- The second digit **(y)** denotes the degree of protection that the enclosure gives against damages due to penetrating water.

PROTECTION AGAINST SOLID FOREIGN OBJECTS (X)

0	No protection	
1	Protected against solid foreign objects of 50 mm diameter and greater	Body part, e.g., hand, but no protection against deliberate penetration. Solid foreign objects of 50 mm diameter and greater.
2	Protected against solid foreign objects of 12 mm diameter and greater	Fingers, etc., that are no longer than 80 mm. Solid foreign objects of 12 mm diameter and greater.
3	Protected against solid foreign objects of 2.5 mm diameter and greater	Tools, wires, etc., of a diameter or thickness that exceeds 2.5 mm. Solid foreign objects of 2.5 mm diameter and greater.
4	Protected against solid foreign objects of 1.0 mm diameter and greater	Wires or strips of a diameter or thickness that exceeds 1.0 mm. Solid foreign objects of 1.0 mm diameter and greater.
5	Protection against dust	Dust shall not penetrate in a quantity to interfere with satisfactory operation.
6	Dust tight	Dust cannot penetrate.

PROTECTION AGAINST PENETRATION OF WATER (Y)

0	No protection	
1	Protection against vertically falling water drops	Vertically falling water drops shall have no harmful effects.
2	Protection against vertically falling water drops when enclosure is tilted up to 15 degrees	Vertically falling water drops shall have no harmful effects when the enclosure is tilted at any angle up to 15 degrees on either side of the vertical axis.
3	Protection against spraying water	Water sprayed at an angle up to 60 degrees on either side of the vertical axis shall have no harmful effects.
4	Protection against splashing water	Water splashed from any direction against the enclosure shall have no harmful effects.
5	Protection against water jets	Water projected in water jets from any direction against the enclosure shall have no harmful effects.
6	Protection against powerful water jets	Water projected in powerful water jets from any direction against the enclosure shall have no harmful effects.
7	Protection against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible under standardized pressure and time.
8	Protection against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions that are to be declared by the manufacturer.

APPLICATION FORM FOR VACUUM CONVEYORS NO:

PVA™

Distributor:		
Customer:	Contact:	
Address:		
Country:	Tel:	Fax:
Material information		
Material:	Chemical formula:	
Density: kg/dm³	Bulk density: kg/dm³	
Particle size: Max mm Min µm	Majority between: µm	
Is the material abrasive?	Other special characteristics:	
Angle of repose:	Fluidisation:	
Flowability: p free flowing p bridging p other information:		
The material is: p static p explosive p inflammable p toxic p aggressive in regard to:		
Installation		
Capacity: ton/h ton/24 h ton/shift shift = h		
Conveying distance: m tot.	Horizontally: m	Vertically: m
Number of bends: pcs	Temperature of material: °C	Ambient temperature: °C
Operating time: h/day	The material will be picked up from: p bag p barrel p silo p hopper	
Other solution:	Receiver:	
The installation is: p indoors p outdoors p both indoors and outdoors		
The operation is: p manual p automatic p semi-automatic		
Other information:		

SYSTEM SKETCH: