VACUUBRAND®

Practical guide for your vacuum in the laboratory

Requirements and specific solutions for biopharma, chemistry, analytics, physics and renewable energies

www.vacuubrand.com

Clever vacuum technology for reliable, safe and efficient processes

‘The right tool saves time’

This saying applies not only on the construction site, but also in the laboratory. The role of vacuum is often underestimated precisely because it is intangible. Yet for many laboratory applications it is invaluable. Clever vacuum technology from VACUUBRAND makes your processes reliable, safe and efficient. This is why we have been dedicated to continuous innovation, first-class performance and outstanding quality for decades. In this brochure, we present important distinguishing features to help you find the right vacuum supply for your laboratory and your applications.

Contents

Why vacuum?

Many people use vacuum every day in the laboratory. But what is the actual purpose behind it? Vacuum is used for many standard applications in the preparation and processing of samples. In most cases, the vacuum is not the focus, but it is absolutely essential. The most well-known applications for vacuum are vacuum filtration, evaporation or distillation and drying.

Of course, you could filter without vacuum as well – like brewing coffee – by letting gravity do the work for you. However, while this may work for coffee, it does not always work in the laboratory like this because of the broad spectrum of solvents and solid substances used there.

To speed up the process, low-pressure – i.e. vacuum – is created in a filter flask. The pressure difference in between the inside of the flask and the environment causes a perceived suction effect, causing the sample to flow through the filter more quickly.

However, on a drying process the aggregate state of the sample changes from liquid to gaseous. We could simply let the drying process take place, just as we dry laundry in the air. However, remove this would also take far too much time, a vacuum is also used for drying. Under vacuum, less of compressive force acts on the molecules which enables the transition from fluid to gaseous condition more rapidly. This physical phenomenon is also responsible for the fact that less heat energy is required to vaporise solvents as the pressure decreases. The processing of heat-sensitive sample material is therefore only possible with the aid of vacuum. Vacuum remove takes care for performing processes in laboratory more rapidly and more gently.

Requirements for vacuum technology

The vacuum requirements always depend on the individual application and the use of different substances such as solvents or buffer systems.

Fundamental questions are:

- For which laboratory application do I need vacuum technology?
- Which substances do I use?
- What volumes do I work with?
- How precisely do I need to be able to work?

Characteristics such as boiling point, risk of corrosion and the quantity of solvent to be evaporated play an important role in the selection and dimensioning of the devices. For example, it makes a decisive difference whether methanol, dimethyl sulphoxide (DMSO) or a multi-component mixture is to be evaporated at a certain temperature, since these substances all have different boiling points. Depending on the area of application, there are therefore different requirements for vacuum generation, measurement and control.

Ultimate vacuum and pumping speed

A vacuum pump is characterized by two key parameters: The lowest achievable pressure – also called ultimate vacuum – and the pumping speed. The ultimate vacuum is often specified in millibar (mbar).The lower the value, the stronger, deeper or better the vacuum. In chemical and life science laboratories, a pressure range down to about 10^{-3} mbar is usually required. Between atmospheric pressure (~ 1000 mbar) and 1 mbar we speak in terms of a rough vacuum, while the range between 1 and 10^{-3} mbar is commonly referred to as fine vacuum. In physics laboratories and in analytics, pressures below 10^{-3} mbar are often required. These pressure ranges are referred to as high vacuum and ultra-high vacuum (Fig. 1).

Depending on the respective pressure range, different pump technologies are used for vacuum generation. While the rough vacuum range can be covered most efficiently with diaphragm pumps, rotary vane pumps are often used to generate fine vacuum. Specialized screw pumps can be used in both the rough vacuum and fine vacuum range.

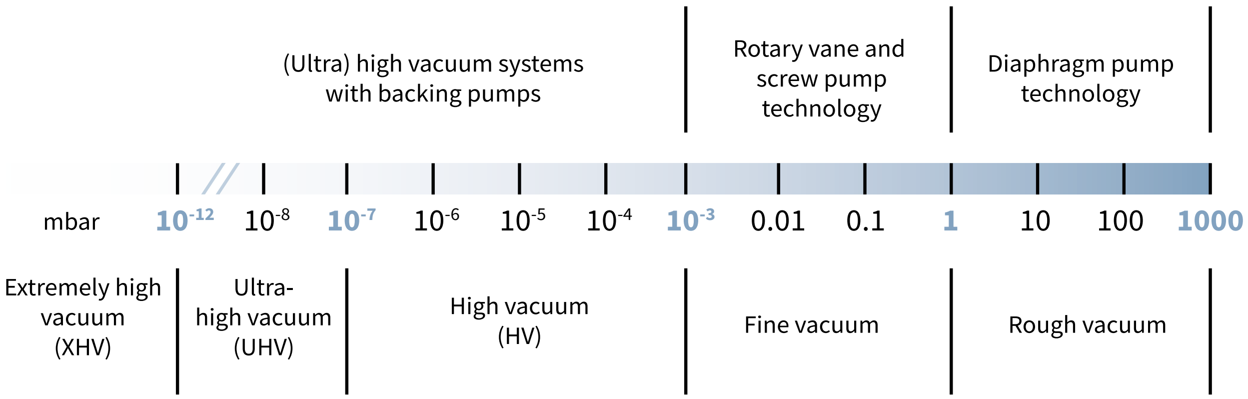


Fig. 1: Pressure ranges and technologies

Typical applications

- Drying processes
- Analytics
- Molecular distillation
- Evacuation of the sample chamber in analysis devices
- Fore vacuum for turbomolecular pumps
- Heat treatment
- Degassing
- Coating
- Filtration
- Solid phase extraction
- Fluid aspiration
- Solvent degassing
- Vacuum concentration
- Drying of protein gels
- Drying substances in the drying oven
- Evaporation by means of rotary or parallel evaporators

The pumping speed is specified in cubic metres per hour [m³/h] or litres per minute [l/min] (1 m³/h ≙ 16,7 l/min). The greater the pumping speed, the faster the pump can evacuate a certain volume. However, when selecting the right vacuum pump and comparing the pumping speeds of two different pumps, attention should not only be paid to the maximum pumping speed, but in particular to the pumping speed at the actual process pressure. It is therefore worthwhile for the user to take a look at the pumping speed curve. This shows the pumping speed as a function of pressure. The shape of this curve makes it easy to recognize how powerful the pump is in the area of the desired process vacuum.

The pumping speed varies with the pressure and decreases in the direction of the ultimate vacuum. The amount of this loss of performance varies from pump type to pump type and also depends, among other things, on design-related details.

At working pressure, there must be sufficient pumping speed to reach and maintain the process pressure. Leaks in the complete system sometimes play a significant role here. Particularly in the process pressure range, the vacuum pump must provide sufficient power to compensate for potential system leakage in addition to the actual process requirements. Otherwise, the maximum achievable ultimate vacuum can deviate significantly from the technical specifications.

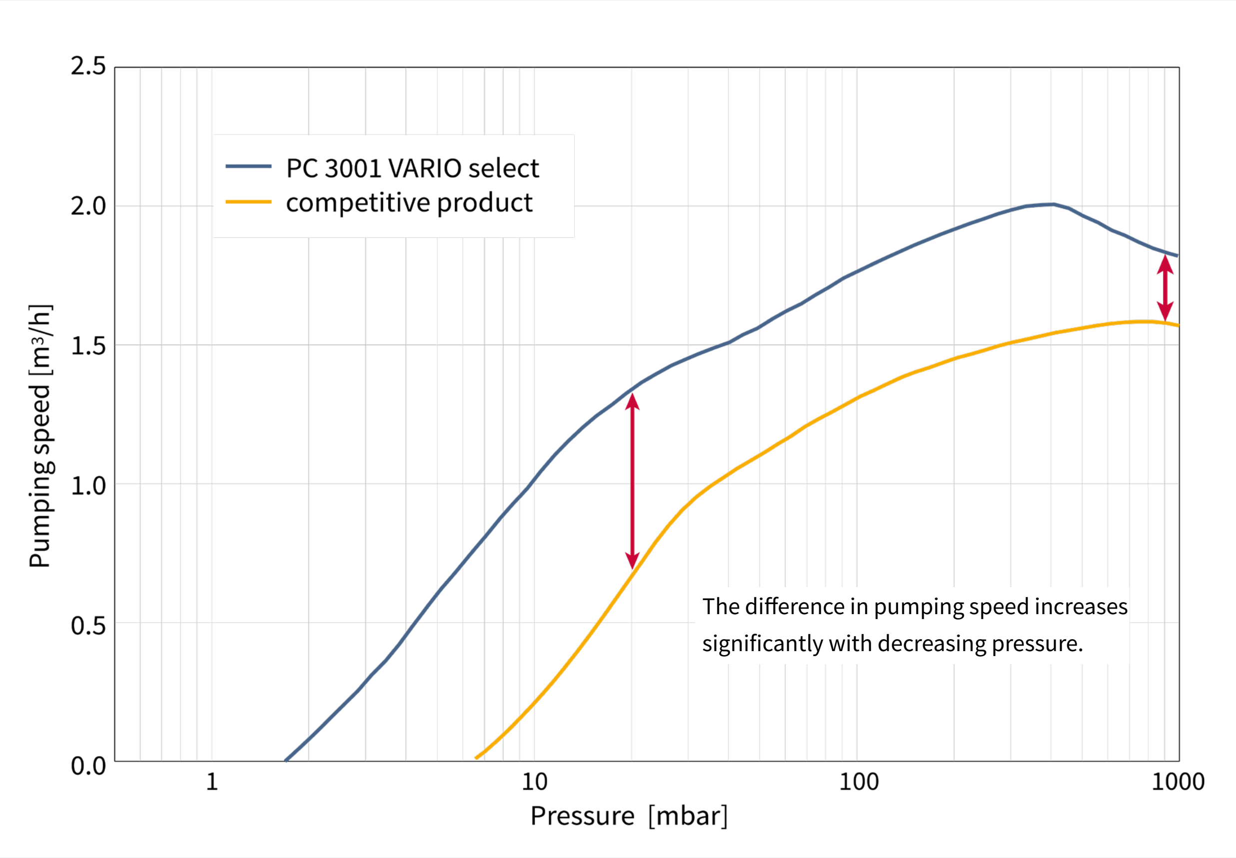


Fig. 2: Comparison of the pumping speed curves: PC 3001 VARIO select vs. competitor's product

Suitability for chemical processes

Depending on the application and substances used, it is important that corrosion-resistant pumps are used. This is primarily ensured by the use of chemically resistant plastics in the wetted area (components in contact with the process media like liquids, gas, or air).

In addition, when chemicals are mentioned, solvents, i.e. flammable substances, are usually used. Most VACUUBRAND chemistry diaphragm pumps are therefore equipped with an ATEX approval of device category 3 (suitable for zone 2) in the internal, wetted area, so that almost all common solvents can be used in standard laboratory quantities without hesitation.

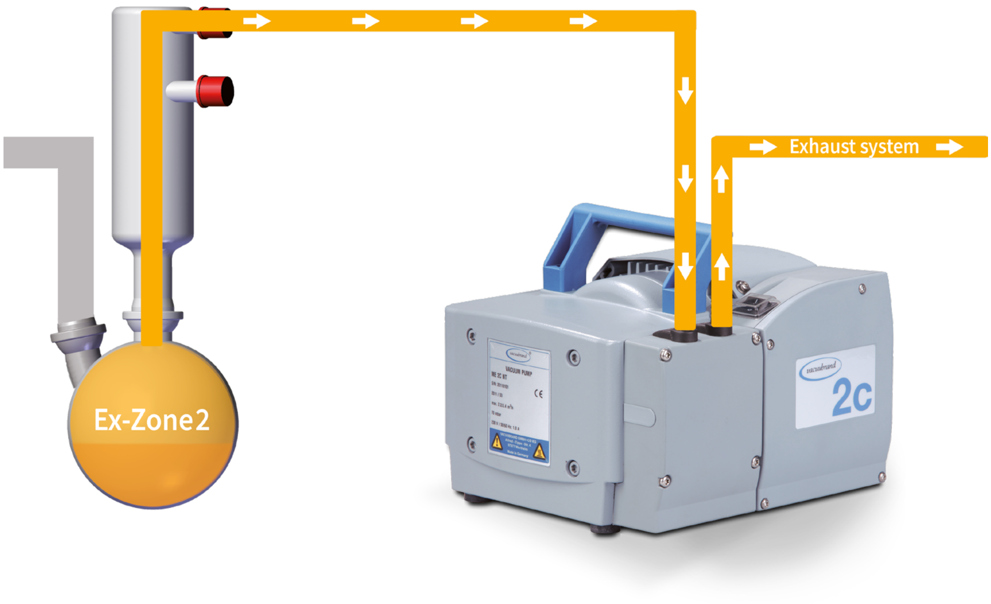


Fig. 3: Wetted area Ex-Zone 2

Precision and comfort

In order to carry out reaction sequences and processes in the laboratory in a controlled and reproducible manner, the pressure in the reaction vessel is measured and regulated by the vacuum controller depending on the application. A classic example is evaporation in a rotary evaporator. The vacuum generated must correspond as closely as possible to the boiling pressure of the solvent to be evaporated. If the pressure is too high, the process takes an unnecessarily long time; if it is too low, the mixture to be evaporated foams up and over, the sample is lost and the evaporation process has to be repeated.

The intelligent control technology of the VACUUBRAND VARIO® pumps makes the user's work much easier. This technology can automatically determine and adjust the vacuum so that even in sensitive processes, foaming over does not occur and solvent mixtures are optimally and quickly evaporated.. This not only achieves the desired results. It also eliminates unnecessary time spent monitoring the application and the process can be easily reproduced at any time.

Technology

There are a variety of technical solutions for the requirements described above. However, the performance and robustness of a pump are also heavily dependent on design details and the quality of the materials used. Further distinguishing features result from the accessories used. There are significant quality differences, particularly in the area of control technology. The following section provides an overview of the most important technical features and their functions.

Dry compressing diaphragm pumps down to approx. 1 mbar

In a diaphragm pump, one or more diaphragms are moved up and down so that the pump chamber increases and decreases in volume, creating a pumping effect. The diaphragm hermetically (airtight) seals the pump chamber, in which the gases and vapors are sucked in and compressed, from the drive with the motor (Fig. 4). The pump chamber is therefore completely dry (no operating fluids / lubricants) and the pumped gases are not contaminated. Two mechanical valves ensure that extracted gas is aspirated from the correct tube and then ejected into the other. This ensures the flow of gas from the application through the pump towards the exhaust.

The assembly of mechanical components around the individual pump chamber through which the media is pumped is called the pump head. It is crucial that the materials used in the pump head are chemically resistant. Special fluoroplastics with high long-term stability and impermeability are used to manufacture different parts in the pump head (Fig. 5). Although fluoroplastics are extremely chemically resistant, they are not very mechanically stable, which is why a metallic stability core inside is extremely important.

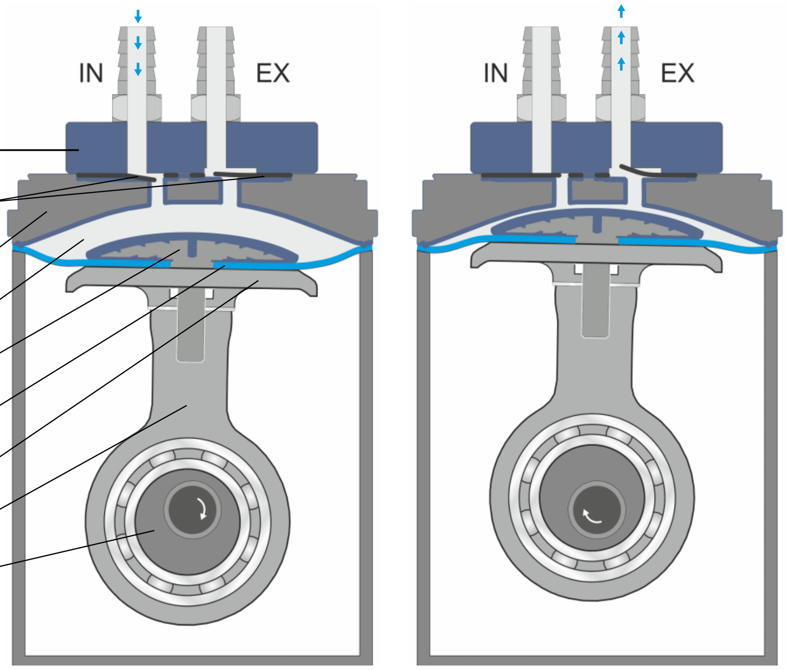
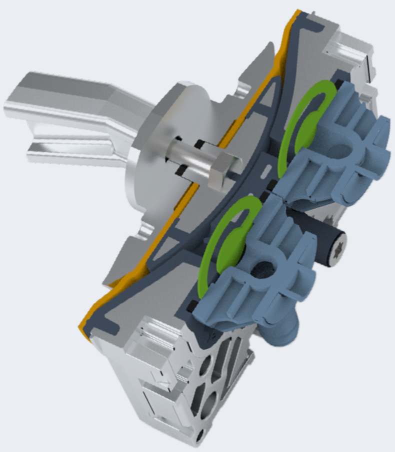


Fig. 4: Schematic illustration of a diaphragm pump



PTFE:	Polytetrafluoroethylene
ETFE:	Ethylene tetrafluoroethylene
ECTFE:	Ethylene chlorotrifluoroethylene
FFKM:	Perfluoroelastomer

Fig. 5: Consistent use of chemically resistant plastics for all wetted materials in the pump chamber

You can find more detailed information on chemical resistance in our corresponding flyer!

Chemistry compatibility flyer

Oil sealed rotary vane pumps down to 10^{-3} mbar

In an oil-sealed rotary vane pump, an eccentrically mounted cylinder with movable vanes rotates in the pump chamber cylinder and pushes the incoming gas towards the outlet. At a certain point in the rotation, the eccentric position causes the gas to be compressed by the movement of the vanes (Fig. 6). As soon as the gas pressure exceeds the opening pressure of the outlet valve, the gas escapes through the exhaust. Oil is used here for lubricating and sealing the vanes to the metal cylinder.

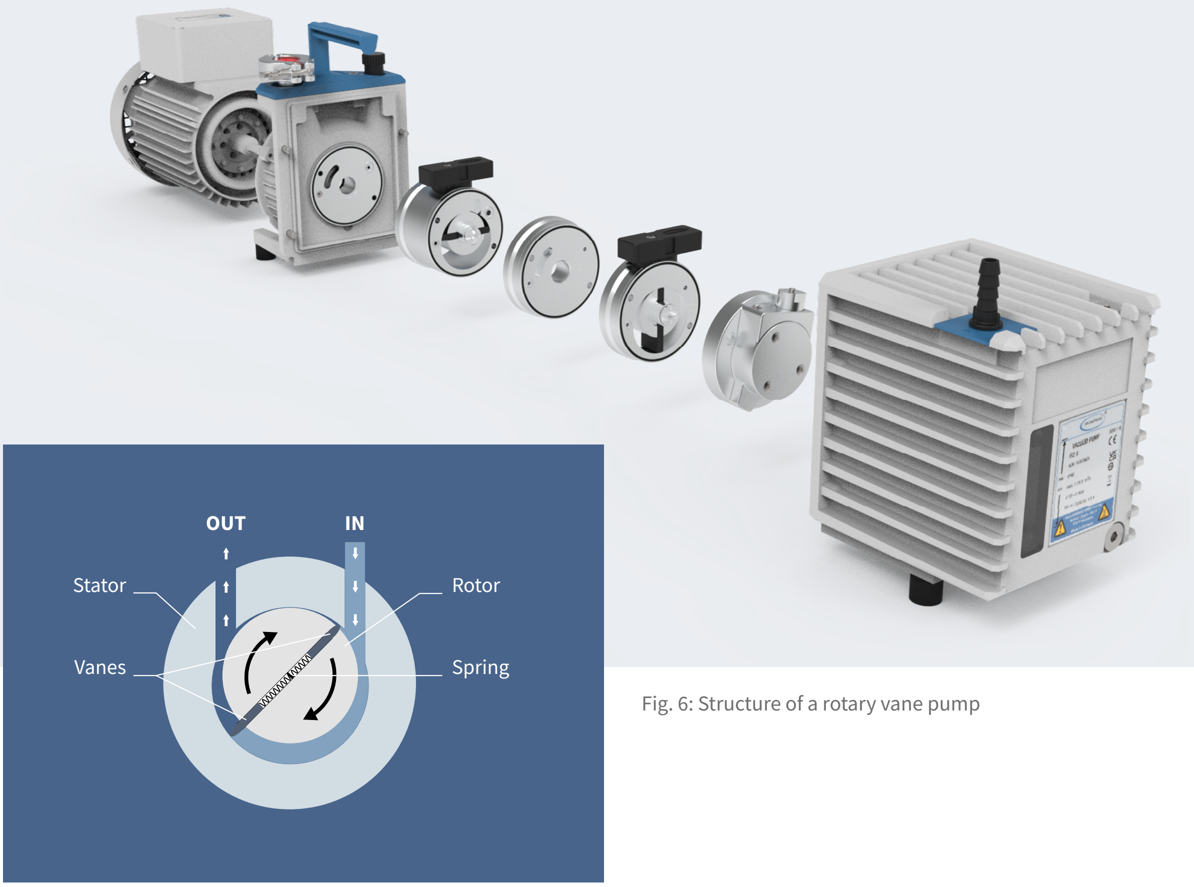


Fig. 6: Structure of a rotary vane pump

The advantage of this technology in comparison to diaphragm pump technology is the better ultimate vacuum of two-stage rotary vane pumps of down to 10^{-3} mbar. The lower chemical resistance should be noted, as many pump parts are made of metal and can corrode on contact with chemicals. In addition, the pumped gases come into contact with oil. Oil vapors disrupt sensitive processes and at the same time the oil is attacked or diluted by the pumped substances. The pump must therefore be protected from corrosive chemicals and condensates by appropriate devices (see page 15). Cold traps filled with liquid nitrogen or dry ice are usually used for this purpose.

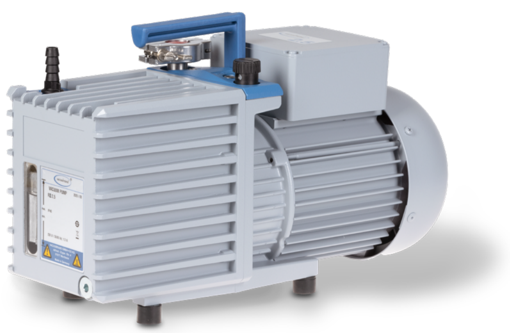


Fig. 7: Rotary vane pump RZ 2.5

The RC 6 chemistry-HYBRID pump is a good alternative in such cases. It combines a two-stage rotary vane pump with a chemically resistant diaphragm pump to create a corrosion-optimized solution. The diaphragm pump permanently evacuates the oil chamber of the rotary vane pump. In this way, it prevents condensation in the oil-sealed part under appropriate pressure and temperature conditions, even with a large number of corrosive vapors. Typical areas of application are freeze drying, distillation, vacuum drying ovens and Schlenk Line.

- Reduced internal corrosion when working with corrosive vapors
- Significantly reduced waste oil due to extended oil change and maintenance intervals
- Easy maintenance thanks to telescopic design
- In practical operation, a cold trap is often no longer necessary

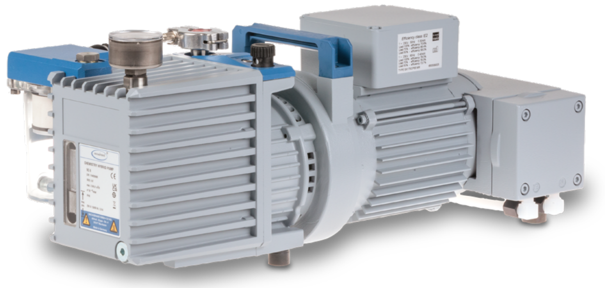


Fig. 8: Chemistry-HYBRID pump RC 6

Single-stage or multi-stage?

The ultimate vacuum and the pumping speed of a pump depend on the modular connection of the cylinders. Connecting cylinders in parallel increases the pumping speed, while connecting them in series results in a better vacuum – i.e. lower ultimate pressure (Fig. 9). VACUUBRAND connects up to four stages in series in its diaphragm pumps and achieves ultimate vacuums between 100 mbar (single-stage) and 0.3 mbar (four-stage). A maximum of two stages are used in the rotary vane pumps, which enable an ultimate vacuum in the range of 10^{-3} mbar.

The pumping speed of diaphragm pumps is influenced by the parallel connection of the cylinders as well as the number of cylinders and the volume of the pump chamber. In contrast, the pumping speed of rotary vane pumps depends solely on the volume of the pump chamber.

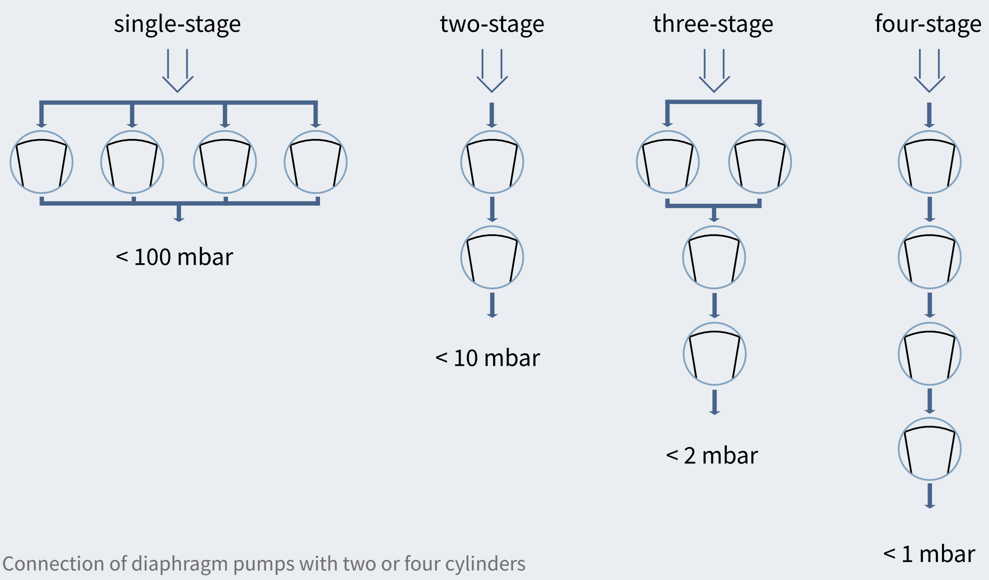


Fig. 9: Connection of diaphragm pumps with two or four cylinders

Dry compressing screw pumps down to 10^{-3} mbar

Vacuum generation in a screw pump is based on gas transport in gap-sealed chambers: Two rotating spindles interlock without contact and create several chambers together with the stator surrounding them. Their very narrow gaps are in the micrometre range. While the spindles rotate synchronously in opposite directions, the chambers transport the gas: a mass flow is created along the spindle axis from the inlet on the suction side to the outlet on the pressure side.

Screw pumps enable the generation of deep vacuum down to 10^{-3} mbar. This pump technology with its special design enables processes without contamination by oil or abrasion (e.g. also hydrocarbons) and is characterized by its low maintenance requirements. Thanks to the contactless design of the spindles, no abrasion or wear can occur. Screw pumps also contain no seals in the working chamber that could wear out. In addition, they do not require any operating fluids such as oil.

With the VACUUBRAND screw pump, the general advantages of this versatile pump technology have been further enhanced by targeted design developments specifically for use in the laboratory. The dry-running VACUU·PURE® 10C screw pump is designed for applications and processes that require particularly chemically resistant, condensate-compatible and absolutely oil-free vacuum pumps:

- Drying
- Distillation
- Thermal treatment
- Schlenk Line
- Freeze drying
- Degassing
- Coating

...and many more

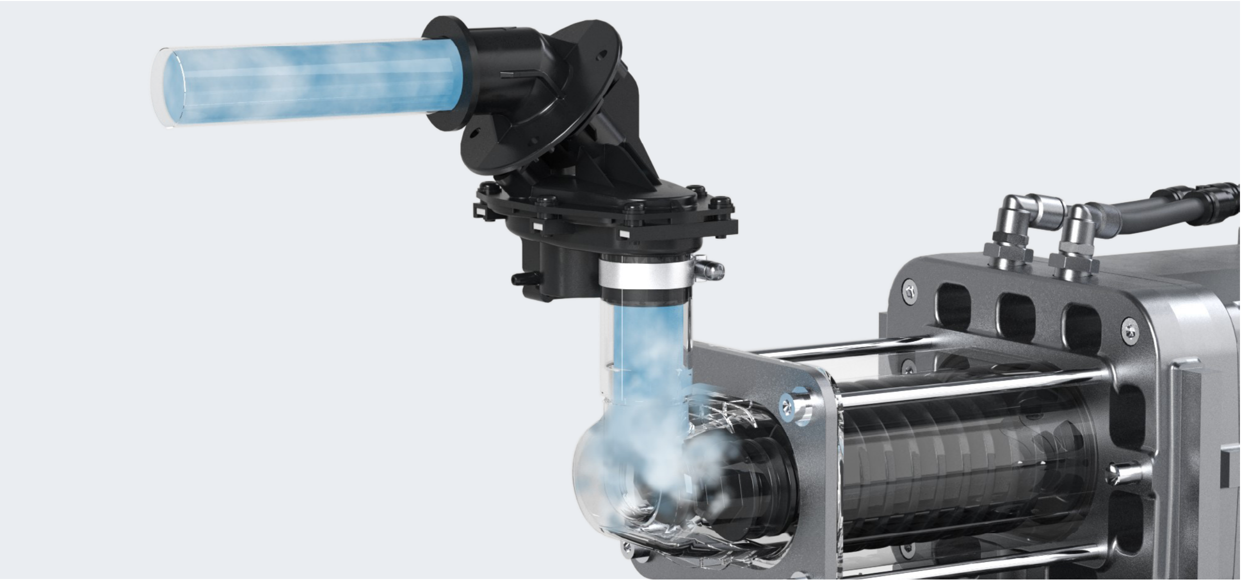


Fig. 10: Screw pump design

Fig. 11: Screw pump VACUU·PURE® 10 C

Protection of the pump and environment

The formation of condensation inside the pump impairs its function and sooner or later leads to damage. This problem mainly affects diaphragm and rotary vane pumps. Many pumps therefore have a so-called gas ballast, which allows small amounts of air or inert gas into the pump through a valve. This reduces the condensation of gases in the pump. For many applications in the chemical industry, this function is indispensable for protecting the pump. Good ultimate vacuum is therefore very important, even with the gas ballast valve open (Fig. 12). It is recommended to allow the pump to run for about half an hour with the gas ballast open and the pump inlet closed before switching off. This will remove any condensate from the pump. Rotary vane pumps should also warm up with the valve closed before starting the process, as the correct operating temperature of the oil helps to reduce condensate formation.

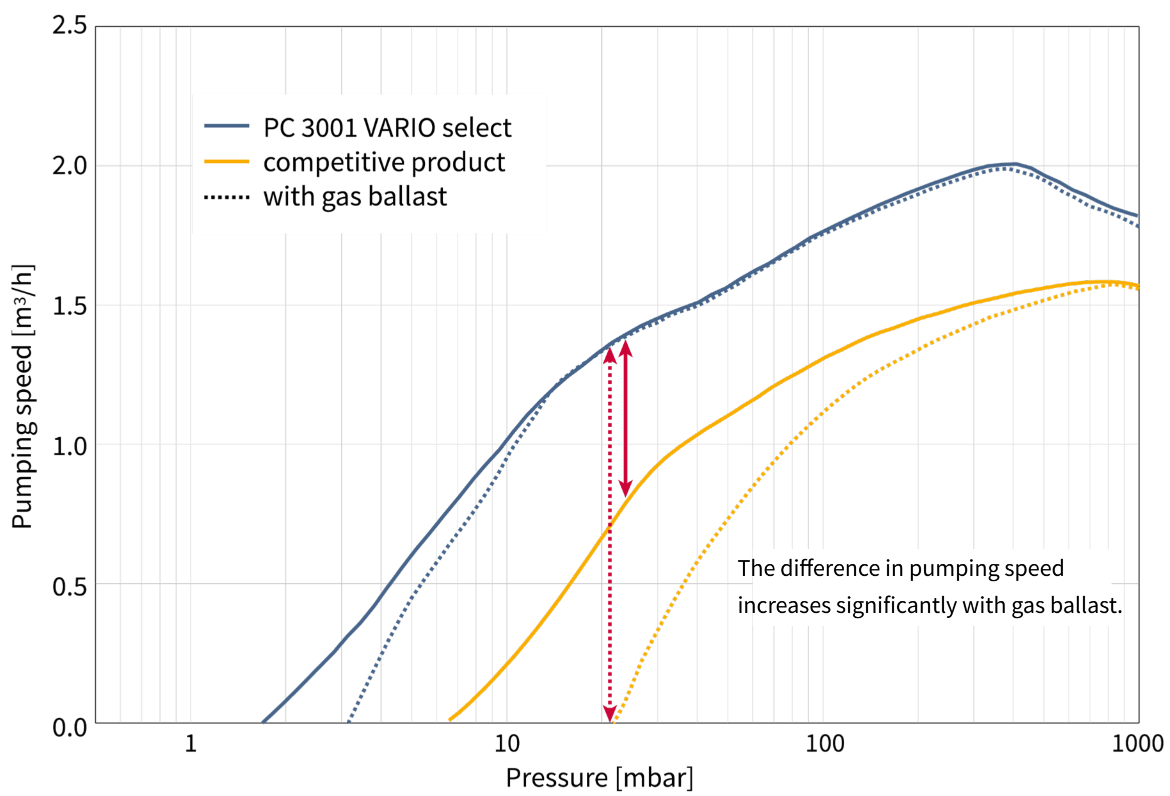


Fig. 12: Comparison of pumping speed curves with and without gas ballast: PC 3001 VARIO select vs. competitor's product

Due to the lower chemical resistance of rotary vane pumps, it may be necessary to install a cold trap upstream to collect corrosive chemicals and condensates before they enter the pump inlet. The use of a chemical hybrid pump also makes sense, especially in chemical laboratories where a strong ultimate vacuum is required. Oil mist filters are often used on the exhaust to prevent contamination of the room air and the inhalation of oil vapors.

Fig. 13: RZ 6 rotary vane pump in the package version with exhaust filter and vacuum valve

Modern diaphragm pumping units have a so-called ‘condensate separator’ at the pump inlet, which protects the pump from condensate droplets and solid particles. An ‘emission condenser’ on the exhaust side protects the environment from solvent emissions and enables their recovery. However, the round bottom flasks not only collect solvent residues or condensates, but also act as a silencer, as they significantly reduce noise emissions.

Fig. 14: PC 3001 VARIO select pumping unit with the modern VACUU·SELECT vacuum controller, separator (rear) and emission condenser (front)

Due to the high condensate compatibility of the VACUU·PURE® screw pump's design, no gas ballast is required, even with high vapor volumes. The integrated regeneration mode also enables the pump to dry quickly after the end of the process. Another advantage is that the use of a cold trap is no longer necessary in most cases. Risks from coolants such as liquid nitrogen or dry ice are thus avoided.

Fig. 15: VACUU·PURE® screw pump with shuttle, separator (left) and emission condenser (right)

Measuring vacuum

Depending on the pressure range, different pressure sensors are used for vacuum measurement. The rough vacuum range is best covered by capacitive sensors. The deflection of a diaphragm is measured capacitively and converted into a pressure display. In the laboratory, the use of ceramic diaphragms makes sense as they are chemically resistant and very robust. This method offers further advantages, such as measurement independent of gas type, high accuracy, low temperature dependence and good long-term stability. The disadvantage is the limitation of the measuring range due to the diaphragm thickness.

A so-called Pirani sensor is therefore often used for the fine vacuum range. This sensor, named after its inventor Marcello Pirani, measures the thermal conductivity of the gas related to the respective pressure and can thus determine the existing vacuum precisely. The advantage of this method is the extended measuring range from atmospheric pressure down to 10^{-3} mbar, however, inherent to its functional principle, the best precision is achieved in the range from 10 to 10^{-2} mbar. The disadvantage of the Pirani sensor compared to the ceramic diaphragm is the dependence on the type of gas for the measured results, which, depending on the thermal conductivity of the gas, deviates from the setting for air. In comparison to conventional Pirani sensors, the VACUUBRAND Pirani measuring devices are distinguished by their extraordinary chemical resistance and robustness thanks to their combined plastic and ceramic construction.

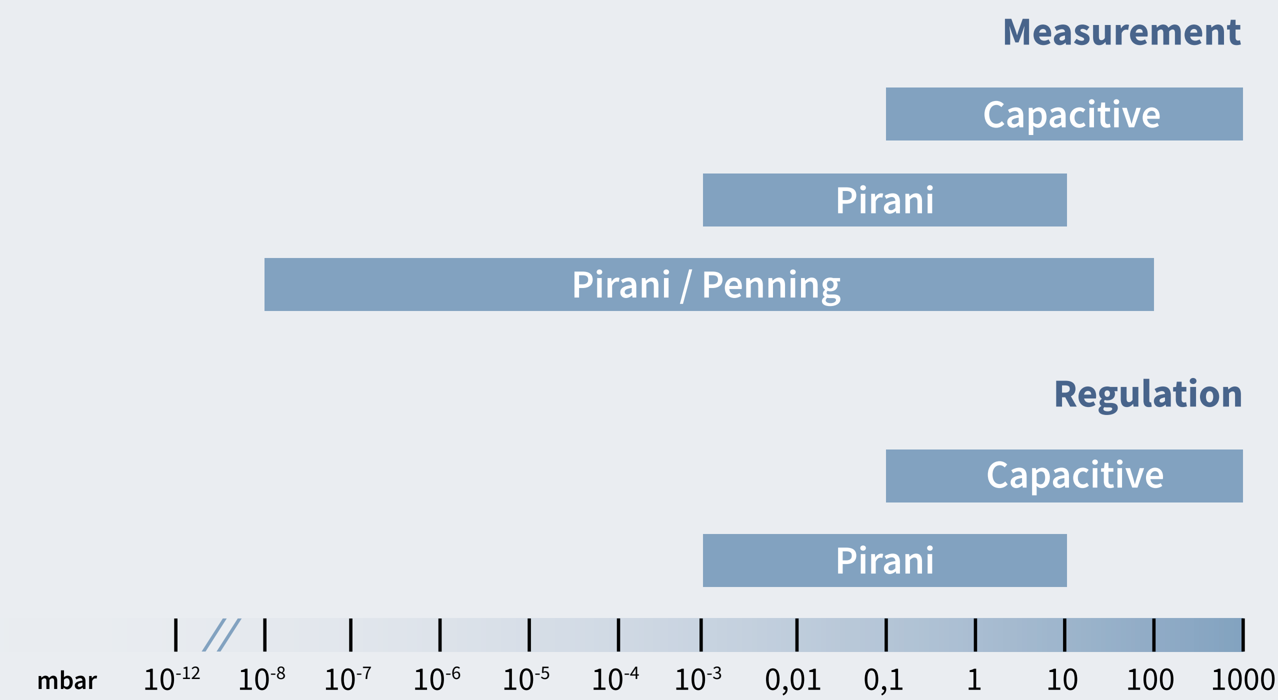


Fig. 16: Optimum areas of application for vacuum measurement and control

If measurements are required to be made across the complete pressure range of rough and fine vacuum, the advantages of both capacitive and Pirani sensor can be used in combination. From the outside, such a combination sensor is not recognizable to the user. Figure 17 shows, for example, the VACUUBRAND combination gauge, which is no bigger than a clenched fist.

To verify the required measurement accuracy, customers can have their devices tested and marked in certified laboratories. VACUUBRAND itself operates a DAkkS calibration service that is inspected regularly by the German Accreditation Office.

Fig. 17: Combination gauge VACUU·VIEW extended

Controlling vacuum

The control of vacuum in the reaction vessel can be achieved in three different ways:

- by manual alteration of the flow rate
- by electronic valve switching
- by rotational speed control

With a simple manual valve alteration of the flow rate, the vacuum can be influenced coarsely without the need for additional aids. However, active and accurate vacuum regulation can only function either electronically via valve switching or via regulation of the rotational motor speed. In valve switching, also often called on-off control, an electromagnetic valve placed in the suction line between the pump and application is opened and closed. This causes the vacuum to fluctuate between two freely definable tolerance values. This creates a hysteresis (Fig. 19). Diaphragm pumps with speed control of the motor however, enable infinite adjustment of the suction capacity and can achieve the utmost precision in vacuum regulation (Fig. 20). Since, in this case, the pump only runs as fast as necessary, the user obtains huge energy savings (up to 90% in comparison to non-regulated systems). Additionally, wear, noise emissions and vibration are significantly reduced.

Fig. 18: The modern vacuum controller VACUU·SELECT

Control technology

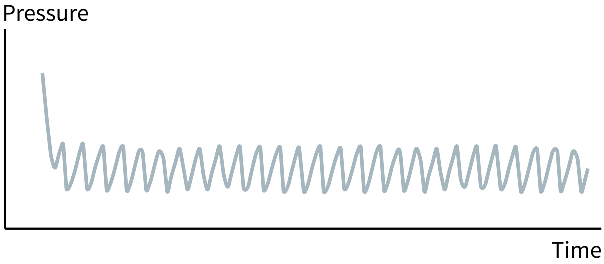


Fig. 19: On-off control through valve switching

Fig. 20: Pinpoint regulation via speed control

Vacuum regulation which incorporates an automatic function greatly facilitates research work. For this, VACUUBRAND uses the vacuum controller VACUU·SELECT which in on-off mode uses its detect function to enable automatic boiling pressure determination. The VACUU·SELECT controller offers even more possibilities in combination with a variable speed pump from VACUUBRAND. This VARIO® regulation not only finds the boiling pressure, but also reacts to changes in it thanks to a unique vapor pressure tracking system. Thus, the vacuum is continuously tracked using vapor pressure and then continually optimized to the process demands. In this manner, the results can be achieved in the shortest possible time with just the push of a button, without the need for monitoring and intervention (Fig. 21).

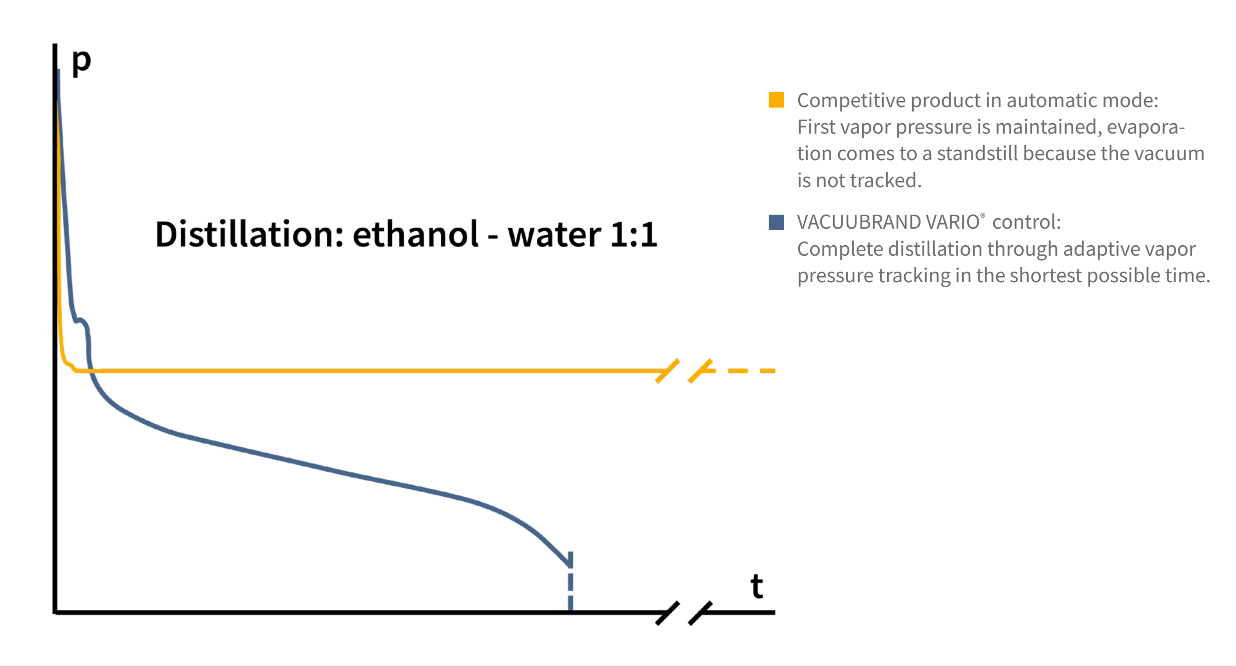


Fig. 21: Conventional automatic mode vs. automatic VARIO® control

Single workstation or network solution?

Both individual pumps and pumping units as well as vacuum network solutions can be used for vacuum supply in the laboratory. In a house network, all workstations in a building are supplied by a large, centralized vacuum pump. However, in-house networks have a number of disadvantages in day-to-day work. Mutual interference and contamination from backflowing gases are difficult to avoid in such systems. This not only disrupts the process sequences, but can also result in safety risks such as the formation of explosive mixtures or the release of infectious material. In addition, such pumps are often oversized because they have to be designed for maximum operation. If it is also taken into account that the pump is in operation around the clock, this results in unnecessarily high investment and energy costs.

The better alternative is therefore local networks in which the decentralized vacuum pump only supplies a certain number of workstations in one room. Compared to an individual workstation supply, where each workstation is equipped with a separate vacuum pump, maintenance costs and energy consumption can be reduced in addition to the purchase costs. At the same time, noise emissions and space requirements are lower, as significantly fewer pumps are needed for daily work.

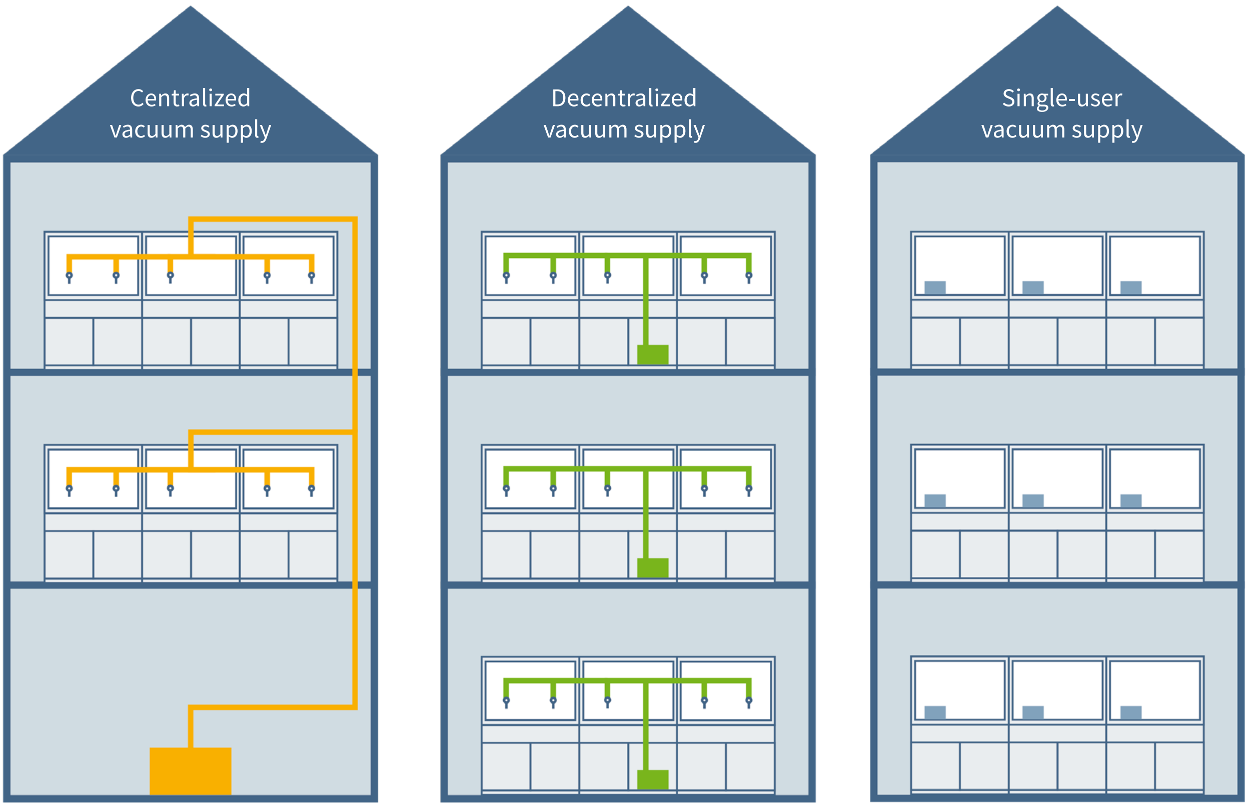


Fig. 22: Various options for vacuum supply

The decision between a single-user supply and a local network solution depends on various factors. These include, for example, the number of workstations, the applications used or the requirements for vacuum control. Therefore, discussion of the framework conditions and various options with an expert in advance is highly recommended. If a network solution is chosen, the requirements for the respective network should be taken into consideration as early as possible in the planning stages for a laboratory. The first step is to search for the right sized, chemically resistant vacuum pump. When choosing the appropriate materials for pipework and fittings, consideration should be given to their chemical resistance and the potential for cross contamination, i.e. the possible influence of the individual vacuum connections on each other.

With the VACUU·LAN® system from VACUUBRAND, a wide range of connecting elements and fittings are available for both manual and electronic operation. The wetted parts, such as the PTFE pipework, guarantee high resistance and corrosion resistance against many chemicals. In addition, all vacuum elements are equipped with non-return valves to minimize the risk of cross-contamination and mutual interference. On request, VACUU·LAN® can also be retrofitted into existing laboratory furniture.

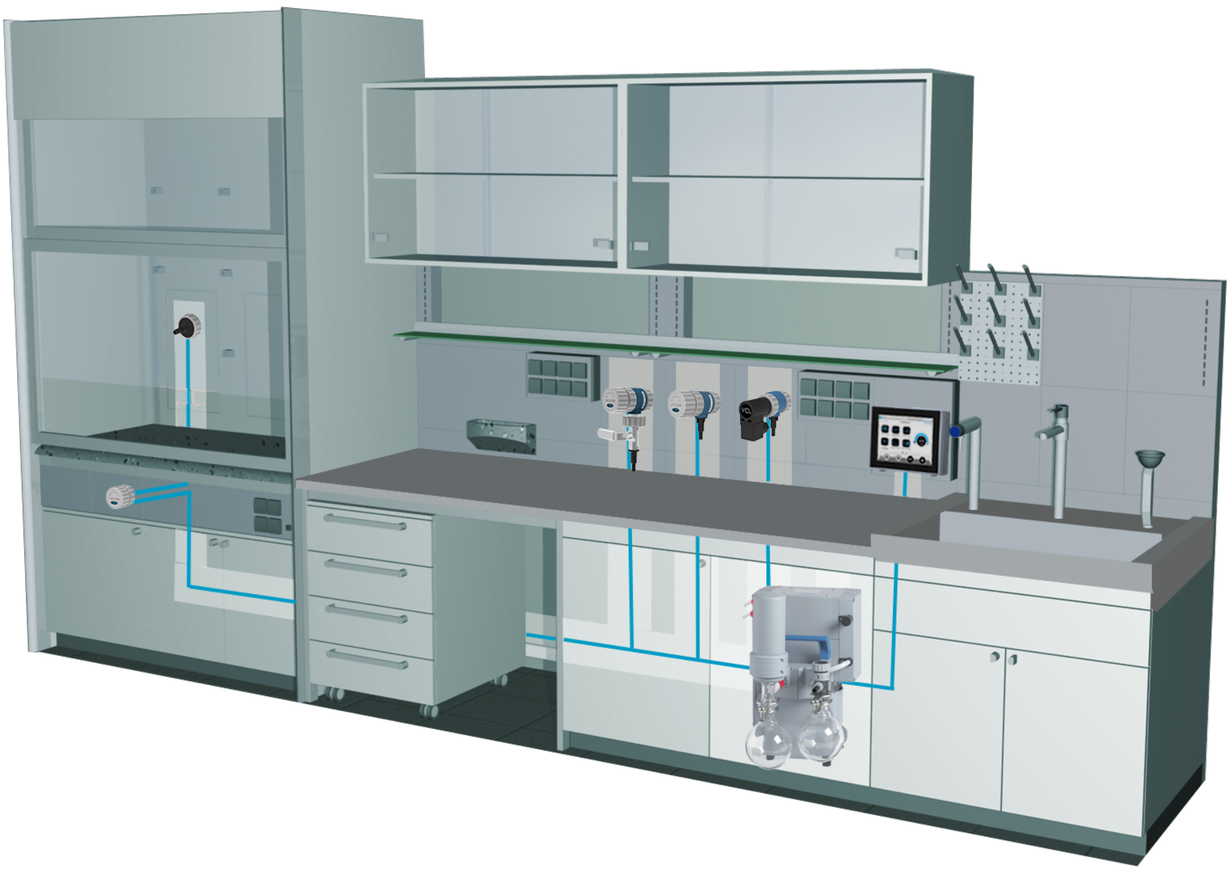


Fig. 23: Local network VACUU·LAN®: One pump in the base cabinet supplies several workstations

Overview

It is always worth taking a closer look at the performance features of a vacuum pump and its equipment. To help you find the best solution for your laboratory, we have summarized the most important distinguishing features for you at a glance.

Pump technology (page 8-13)	Diaphragm pump Chemistry hybrid pump Rotary vane pump Screw pump
Performance (page 5-6)	Max. ultimate vacuum Max. ultimate vacuum with open gas ballast Max. pumping speed Pumping speed curve
Chemical resistance (page 7-9)	Corrosion resistance of the wetted materials
Protection of the pump and the environment (page 14-15)	Gas ballast Cold trap Oil mist filter Condensate separator Emission condenser Chemistry hybrid pump
Measurement technology (page 16-17)	Rough vacuum: Capacitive sensor Fine vacuum: Pirani sensor Rough & fine vacuum: Chemically resistant combination gauge DAkkS certification
Control technology (page 17-18)	Manual flow control Valve switching / Two-point control Speed control / Precise control / VARIO® Automatic boiling pressure detection Automatic vapor pressure tracking
Network solution (page 19-20)	VACUU·LAN®: Supply several workstations with one pump Low investment and operating costs Modular design and expandable at any time

Choosing the right pump

There is a suitable vacuum pump for every laboratory. But how do you find the optimum solution for your application? Our Vacuum Pump Selection Guide offers a selection aid for typical laboratory applications. Crucial questions take centre stage:

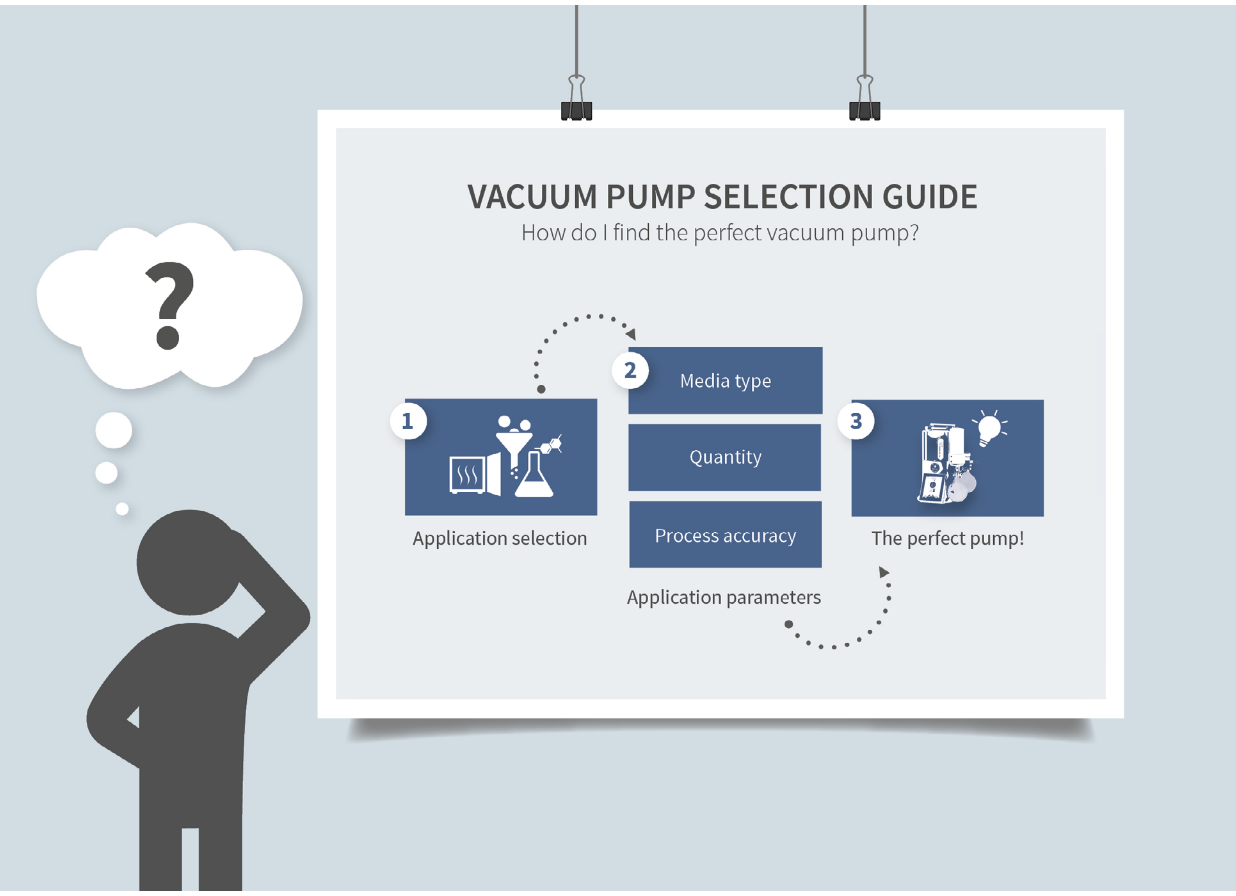
Which media, such as solvents or buffer systems, do you use?
Depending on which substances are used in an application, a specific type of vacuum pump is selected.

What volumes do you work with?
This raises the question of what pumping speed or pumping capacity the vacuum technology must offer.

How precisely do you have to work and regulate the vacuum accordingly?
In some applications, such as vacuum drying ovens or filtration, vacuum control is not absolutely necessary. In other applications, however, such as rotary evaporation, vacuum control is required.

Other specific requirements
Depending on the application, specific requirements such as solvent recovery, biological safety standards or ATEX explosion protection are added.

The Vacuum Pump Selection Guide highlights all of these criteria. Specific questions will guide you step by step to the vacuum pump that best suits your requirements.



Find the right vacuum pump with the Vacuum Pump Selection Guide!

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VACUUBRAND®

VACUUBRAND is part of the Brand group, a manufacturer of high-quality and innovative laboratory equipment and vacuum technology with a global team of approx. 1,000 employees.

With highly motivated and qualified employees, we manufacture the world's most comprehensive product family for vacuum generation, measurement and control for the rough and fine vacuum range in the laboratory.

All with one goal:
Enabling our customers to run reliable, safe and efficient processes. This is why we commit ourselves to continuous innovation, first-class performance, and outstanding quality.

Engineering excellence is central to our ability to deliver products and solutions renowned for their quality, durability, and reliability. Innovative technology, high quality materials and extensive testing deliver unmatched performance - engineered and manufactured in Germany.

Together with you, our experts will find the best solution for your application and provide you with first-class service along the way.

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