Классификация насосов:

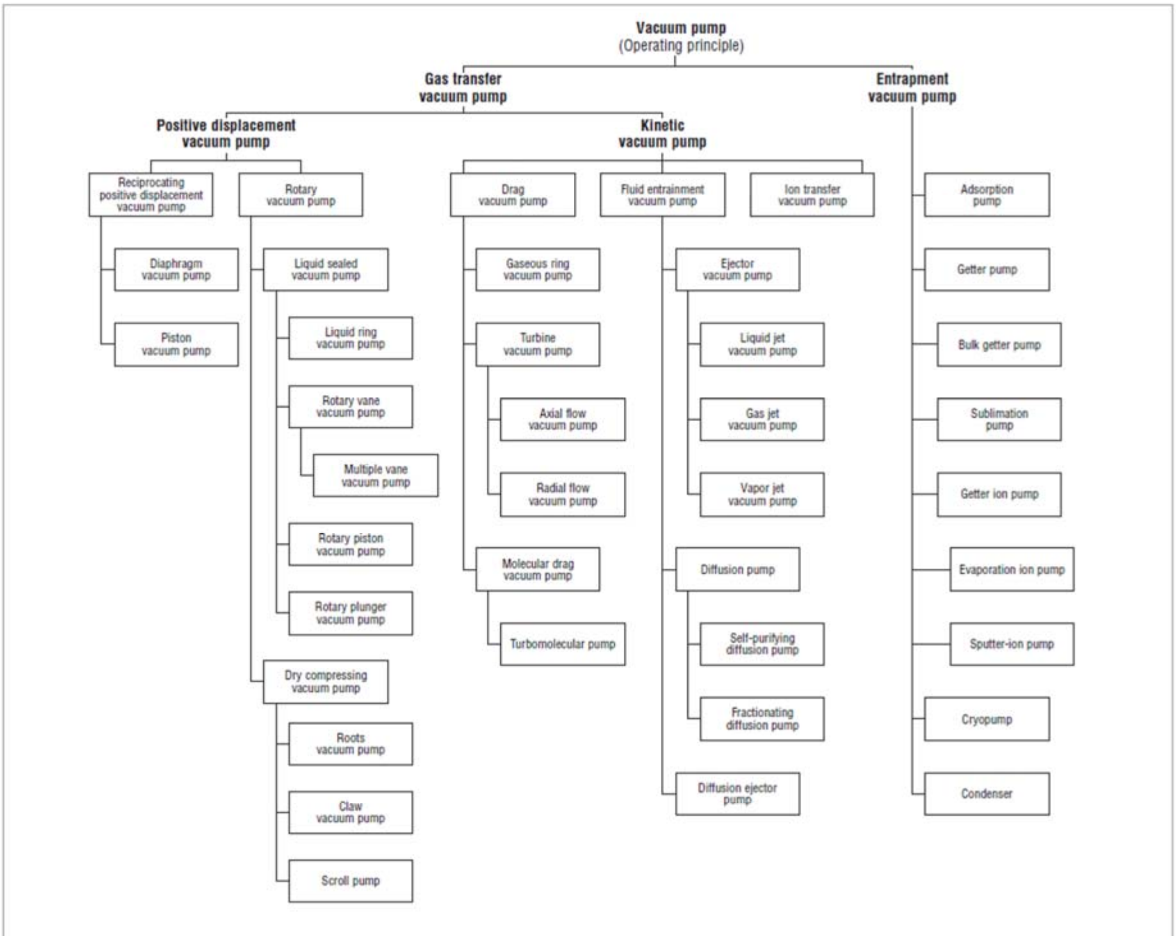


Table 2.1 Classification of vacuum pumps

Про их пределы использования:

The *lowest pressure* which can be achieved by a pump at its inlet, is determined either by the leakage in the pump itself, or by the vapour pressure of the fluid utilized in the pump. This pressure determines the low pressure end of the pressure range in which the various pumping types are effective (fig. 5.1).

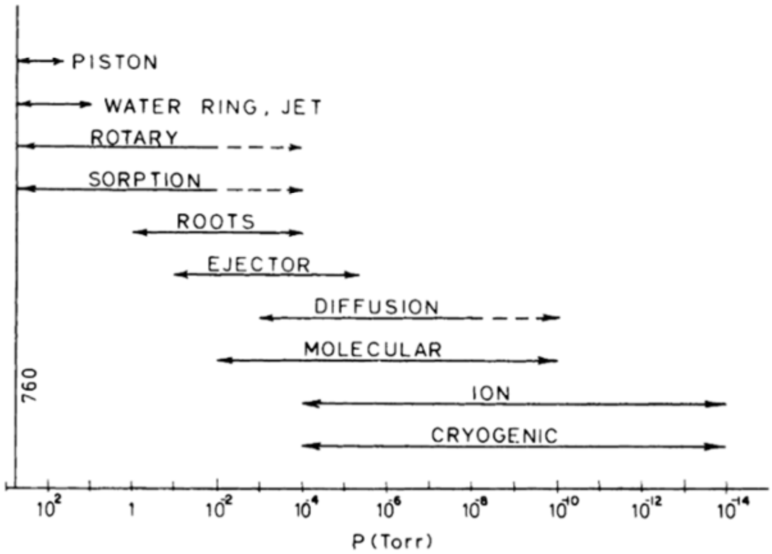


Fig. 5.1 Pressure ranges of vacuum pumps.

Про пластинчато – роторный насос :

5.2.4. *Rotating-vane pumps*

The rotating-vane pump, known also as "rotary pump", is constituted of a stator and an eccentric rotor which has two vanes (blades) in a diametral slot, (figs. 5.9 and 5.10). The stator is a steel cylinder the ends of which are closed by suitable plates, which hold the shaft of the rotor. The stator is pierced by the inlet and exhaust ports which are positioned respectively a few degrees on either side of the vertical. The inlet port is connected to the vacuum system by suitable tubulation usually provided with some kind of dust filter. The exhaust port is provided with a valve, which may be a metal plate moving vertically between

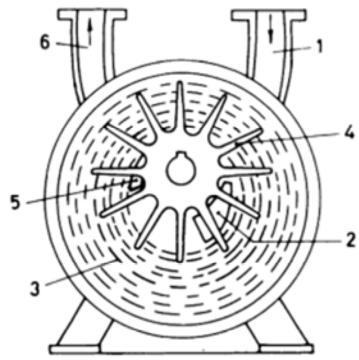


Fig. 5.8

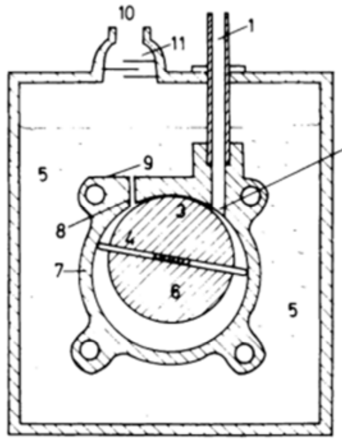


Fig. 5.9

Fig. 5.8 Cross section of a water ring pump. 1. Suction; 2. Suction port 3. Water ring; 4. Impeller; 5. Discharge port; 6. Discharge.

Fig. 5.9 Cross section of a rotating-vane pump. 1. Inlet tube; 2. Inlet port; 3. Top seal; 4. Vanes; 5. Oil; 6. Rotor; 7. Stator; 8. Exhaust port; 9. Exhaust flap valve with backing plate; 10. Exhaust outlet; 11. Oil splash baffles.

arrester plates, or a sheet of Neoprene, which is constrained to hinge between the stator and a metal backing plate.

The rotor consists of a steel cylinder mounted on a driving shaft. Its axis is parallel to the axis of the stator, but is displaced from this axis (eccentric), such that it makes contact with the top surface of the stator, the line of contact lying between the two ports. This line of contact known as the *top seal* (fig. 5.9) between rotor and stator must have a nominal clearance of 2–3 microns (see fig. 7.13). A diametrical slot is cut through the length of the rotor and carries the vanes (fig. 5.10). These are rectangular steel plates which make a sliding fit in the rotor slot and are held apart by springs which ensure that the rounded ends of the vanes always make good contact with the stator wall. The whole of the stator–rotor assembly is submerged in a suitable oil. Lubrication problems of vacuum pumps are discussed by Webb (1974), oil back-migration by Baker *et al.* (1972), Harris (1978), Hablanian *et al.* (1987), Laurenson *et al.* (1988), while selection of fluids for rotary pumps is discussed by Kuhn and Bachmann (1987). Pumps with direct drive are discussed by Nelson (1980).

The action of the pump is shown in Fig. 5.11. As vane A passes the inlet port (fig. 5.11a), the vacuum system is connected to the space limited by the stator, the top seal, the rotor and vane A. The volume of this space increases as the vane sweeps round, thus producing a pressure decrease in the system. This continues until vane B passes the inlet port (fig. 5.11b), when the volume of the gas evacuat-

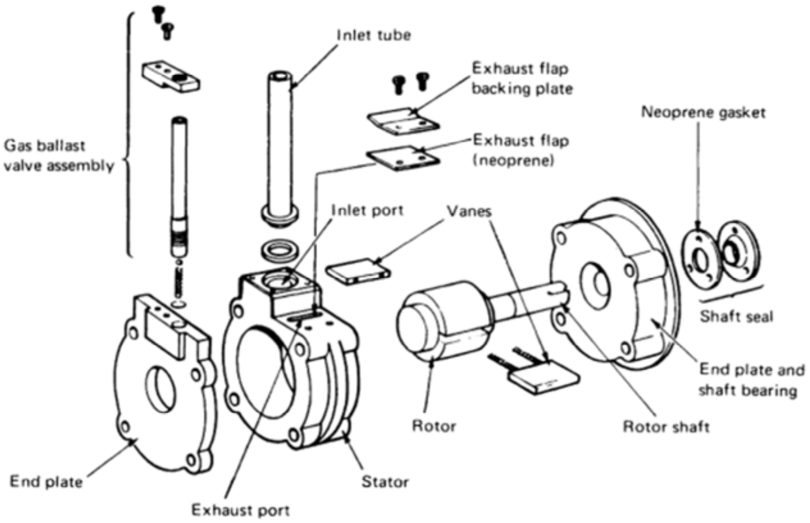


Fig. 5.10 Exploded view of a rotating-vane pump. Reprinted from Ward and Bunn (1967), by permission of Butterworths Publ. Co., London.

ed is isolated between the two vanes. Further rotation sweeps the isolated gas around the stator until vane A passes the top seal (fig. 5.11c). The gas is now held between vane B and the top seal, and by further rotation it is compressed until the pressure is sufficient (about 850 Torr) to open the exhaust valve, and the gas is evacuated from the pump.

Since both vanes operate, in one rotation of the rotor a volume of gas equal to twice that indicated in fig. 5.11b is displaced by the pump. Thus, the volume rate at which gas is swept round the pump, referred to as *pump displacement* S_t is

$$S_t = 2Vn \tag{5.4}$$

where V is the volume between vanes A and B (fig. 5.11b), and n is the number of rotations per unit time (usually 350–700 r.p.m.). Pumps with direct drive have 1500–1700 r.p.m.

The contacts of the vanes and rotor with the stator form three separate chambers each containing gas at different pressure. These contacts must therefore make vacuum-tight seals, especially for the top seals which must support more than one atmosphere pressure difference. For this reason the inner surfaces of the stator, that of the rotor and vane, are very carefully machined. Hence, great care must be taken to ensure that no abrasive material or gas which is likely to corrode the metal surfaces enters the pump chamber.

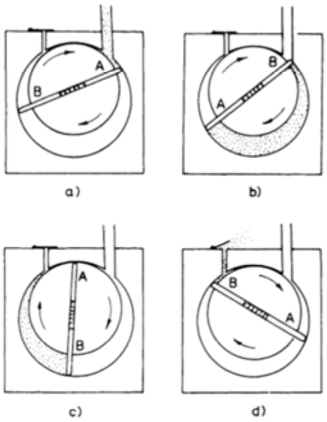
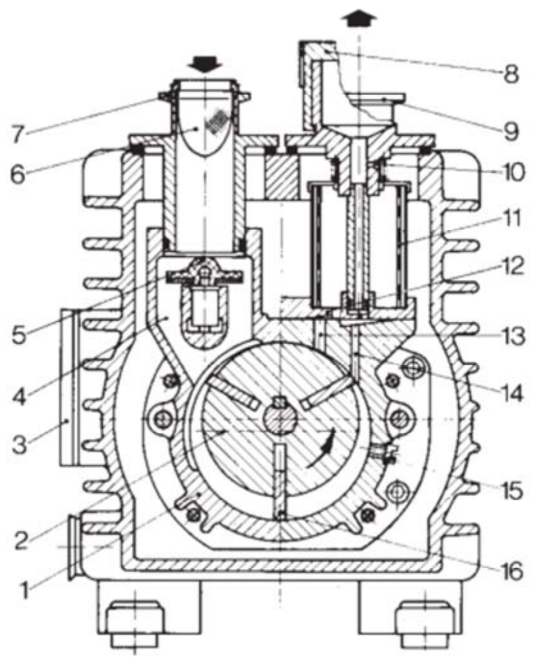


Fig. 5.11 Action of the rotating-vane pump.

In theory, the lowest pressure achieved by the pump is determined only by the fact that the gas is compressed into a small but finite "dead volume". When the system pressure becomes so low that, at maximum compression, the gas pressure is still less than that of the atmosphere it cannot be discharged from the pump. Subsequent pumping action re-expands and recompresses the same gas without further decreasing the pressure in the system. The ratio of the exhaust pressure to the inlet pressure is termed the *pump compression ratio* (see also eq. 5.3). Thus, to produce pressures of the order of 10^{-2} Torr, pumps having compression ratios of the order of 10^5 are required. In addition to lubrication and sealing, the oil also performs the function of filling the dead volume, thus increasing the compression ratio. Oil suck-back preventing systems are discussed by Harris and Budgen (1976).

The lowest (*ultimate*) *pressure* achieved by a single stage rotary pump is about 5×10^{-3} Torr, as measured by a McLeod gauge (permanent gas pressure). If the pressure is measured by a Pirani gauge (total pressure), pressures of about 10^{-2} Torr will be recorded for the same single stage pump. This higher reading is due to the vapour pressure of the sealing oil or its decomposition products in the pump. Modern two-stage pumps can achieve 1×10^{-5} Torr (about 1×10^{-3} Pa) inlet pressure while discharging to atmosphere, i.e. achieve a compression ratio near to 10^8.

из другой книги:



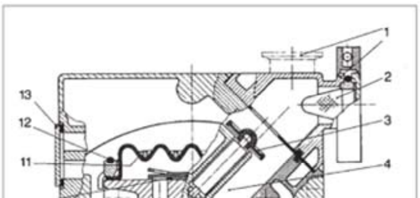
1	Pump housing	9	Exhaust port
2	Rotor	10	Air inlet silencer
3	Oil-level sight glass	11	Oil filter
4	Suction duct	12	Exhaust valve
5	Anti-suckback valve	13	Exhaust duct
6	Dirt trap	14	Gas ballast duct
7	Intake port	15	Oil injection
8	Lid of gas ballast valve	16	Vane

Fig. 2.5 Cross section of a single-stage rotary vane pump (TRIVAC A)

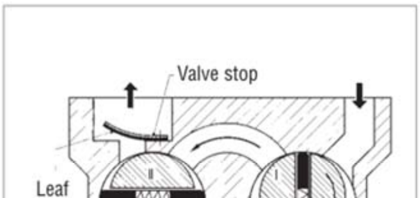
2.1.2.2.1 Rotary vane pumps (TRIVAC A, TRIVAC B, TRIVAC E, SOGEVAC)

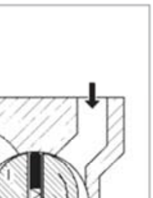
Rotary vane pumps (see also Figs. 2.5 and 2.6) consist of a cylindrical housing (pump-ing ring) (1) in which an eccentrically suspended and slotted rotor (2) turns in the direction of the arrow. The rotor has vanes (16) which are forced outwards usually by centrifugal force but also by springs so that the vanes slide inside the housing. Gas entering through the intake (4) is pushed along by the vanes and is finally ejected from the pump by the oil sealed exhaust valve (12).

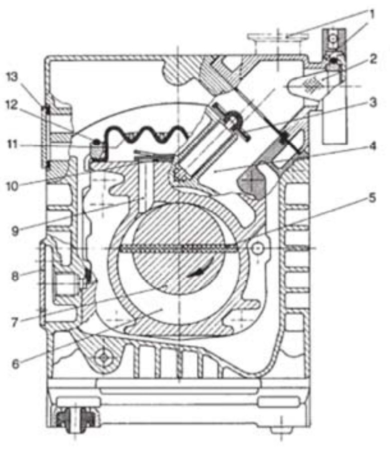
both cases the vanes are forced outwards by the centrifugal forces without the use of springs. At low ambient temperatures this possibly requires the use of a thinner oil. The A-Series is lubricated through the arising pressure difference whereas the B-Series pumps have a geared oil pump for pressure lubrication. The TRIVAC B-Series is equipped with a particularly reliable anti-suckback valve; a horizontal or vertical



the oil box (user friendly design). In combination with the TRIVAC BCS system it may be equipped with a very comprehensive range of accessories, designed chiefly for semiconductor applications. The oil reservoir of the rotary vane pump and also that of the other oil sealed



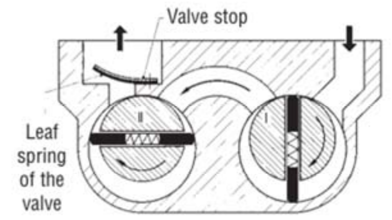




1 Intake port
2 Dirt trap
3 Anti-suckback valve
4 Intake duct
5 Vane
6 Pumping chamber
7 Rotor
8 Orifice, connection for inert gas ballast
9 Exhaust duct
10 Exhaust valve
11 Demister
12 Spring
13 Orifice; connection for oil filter

Fig. 2.6 Cross section of a single-stage rotary vane pump (TRIVAC B)

arrangement for the intake and exhaust ports. The oil level sight glass and the gas ballast actuator are all on the same side of the oil box (user friendly design). In combination with the TRIVAC BCS system it may be equipped with a very comprehensive range of accessories, designed chiefly for semiconductor applications. The oil reservoir of the rotary vane pump and also that of the other oil sealed displacement pumps serves the purpose of lubrication and sealing, and also to fill dead spaces and slots. It removes the heat of gas compression, i.e. for cooling purposes. The oil provides a seal between rotor and pump ring. These parts are "almost" in contact along a straight line (cylinder jacket line). In order to increase the oil sealed surface area a so-called sealing passage is integrated into the pumping ring (see Fig. 2.4). This provides a better seal and allows a higher compression ratio or a lower ultimate pressure. LEYBOLD manufactures three different ranges of rotary vane pumps which are specially adapted to different applications such as high intake pressure, low ultimate pressure or applications in the semiconductor industry. A summary of the more important characteristics of these ranges is given in Table 2.2. The TRIVAC rotary vane pumps are produced as single-stage (TRIVAC S) and two-stage (TRIVAC D) pumps (see Fig. 2.7). With the



I High vacuum stage
II Second forevacuum stage

Fig. 2.7 Cross section of a two-stage rotary vane pump, schematic

two-stage oil sealed pumps it is possible to attain lower operating and ultimate pressures ompared to the corresponding single-stage pumps. The reason for this is that in the case of single-stage pumps, oil is unavoidably in contact with the atmosphere outside, from where gas is taken up which partially escapes to the vacuum side thereby restricting the attainable ultimate pressure. In the oil sealed two-stage displacement pumps manufactured by LEYBOLD, oil which has already been degassed is supplied to the stage on the side of the vacuum (stage 1 in Fig. 2.7): the ultimate pressure lies almost

	TRIVAC A	TRIVAC B	TRIVAC BCS	TRIVAC E	SOGEVAC
Vanes per stage	3	2	2	2	3 (tangential)
Pumping speed [m_3/h]	1 – 1.5 2 – 4 8 – 16 30 – 60	1.6 4 – 8 16 – 25 40 – 65	– 16 – 25 40 – 65 –	– 2.5 – –	16 – 25 40 – 100 180 – 280 585 – 1200
Sealing passage	yes	yes	yes	yes	no
Ultimate pressure, single-stage [mbar]	$< 2 \cdot 10^{-2}$	$< 2 \cdot 10^{-2}$	$< 2 \cdot 10^{-2}$	–	$< 5 \cdot 10^{-1}$
Ultimate pressure two-stage [mbar]	$< 2.5 \cdot 10^{-4}$	$< 1 \cdot 10^{-4}$	$< 1 \cdot 10^{-4}$	$< 1 \cdot 10^{-4}$	–
Oil supply	Pressure difference	Gear pump	Gear pump	Eccentric pump	Pressure difference
Slots	Comparable for all types: about 0.01 to 0.05 mm				
Bearing/lubrication	Axial face / oil	Axial face / oil	Axial face / oil	Ball / grease	Ball / oil
Special characteristics	–	Hydropneumatic anti-suckback valve	Coated parts in contact with medium	Many accessories	Cost-effective
Media	No ammonia	Clean to light particles	Aggressive and corrosive	Clean to light particles	Clean
Main areas of application	Multi-purpose	Multi-purpose	Semiconductor industry	Multi-purpose	Packaging industry

Table 2.2 Rotary vacuum pump ranges

Про турбомолекулярный насос :

2.1.7 Turbomolecular pumps

The principle of the molecular pump – well known since 1913 – is that the gas particles to be pumped receive, through impact with the rapidly moving surfaces of a rotor, an impulse in a required flow direction. The surfaces of the rotor – usually disk-shaped – form, with the stationary surfaces of a stator, intervening spaces in which the gas is transported to the backing port. In the original **Gaede molecular pump** and its modifications, the intervening spaces (transport channels) were very narrow, which led to constructional difficulties and a high degree of susceptibility to mechanical contamination.

At the end of the Fifties, it became possible – through a turbine-like design and by modification of the ideas of Gaede – to produce a technically viable pump the so-called **"turbomolecular pump"**. The spaces between the stator and the rotor disks were made in the order of millimeters, so that essentially larger tolerances could be obtained. Thereby, greater security in operation was achieved. However, a pumping effect of any significance is only attained when the circumferential velocity (at the outside rim) of the rotor blades reaches the order of magnitude of the average thermal velocity of the molecules which are to be pumped. Kinetic gas theory supplies for $\bar{c}$ of the equation 1.17:

$$\bar{c} = \sqrt{\frac{8 \cdot R \cdot T}{\pi \cdot M}}$$

in which the dependency on the type of gas as a function of molar mass M is contained.

Whereas the dependence of the pumping speed on the type of gas is fairly low ($S \sim \bar{c} \sim 1 / E\sqrt{M}$), the dependence of the compression k_0 at zero throughput and thus also the compression k, because of $k_0 \sim e^{\sqrt{M}}$ $\log k_0 \sim \sqrt{M}$, is greater as shown by the experimentally-determined relationship in Fig. 2.55.

Example:

from theory it follows that

$$\frac{\log k_0(He)}{\log k_0(N_2)} = \sqrt{\frac{4}{28}} = \sqrt{\frac{1}{7}} = \frac{1}{2.65}$$

$$\Rightarrow \log k_0(N_2) = 2.65 \cdot \log k_0(He)$$

this with k_0 (He) = $3 \cdot 10^3$ from Fig. 2.55 results in:

$\log k_0 (N_2) = 2.65 \cdot \log (3 \cdot 10^3) = 9.21$

or $k_0 (N_2) = 1.6 \cdot 10^9$.

This agrees – as expected – well (order of magnitude) with the experimentally determined value for k_0 $(N_2) = 2.0 \cdot 10^8$ from Fig. 2.55. In view of the optimizations for the individual rotor stages common today, this consideration is no longer correct for the entire pump. Shown in Fig. 2.56 are the values as measured for a modern TURBOVAC 340 M.

In order to meet the condition, a circumferential velocity for the rotor of the same order of magnitude as $\bar{c}$ high rotor speeds are required for turbomolecular pumps. They range from about 36,000 rpm for pumps having a large diameter rotor (TURBOVAC 1000) to 72,000 rpm in the case of smaller rotor diameters (TURBOVAC 35 / 55). Such high speeds naturally raise questions as to a reliable

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The calculation involving cgs-units (where $R = 83.14 \cdot 10^6$ mbar $\cdot$ cm^3/mol $\cdot$ K) results in the following Table:

Gas	Molar Mass M	Mean thermal velocity (m/s)
H_2	2	1761
He	4	1245
H_2O	18	587
Ne	20	557
CO	28	471
N_2	28	471
Air	28.96	463
O_2	32	440
Ar	40	394
CO_2	44	375
$CC_{13}F$ (F11)	134.78	68

Table 2.4 $\bar{c}$ as a function of molar mass M

bearing concept. LEYBOLD offers three concepts, the advantages and disadvantages of which are detailed in the following:

- Oil lubrication / steel ball bearings
  - \+ Good compatibility with particles by circulating oil lubricant
  - \- Can only be installed vertically
  - \+ Low maintenance
- Grease lubrication / hybrid bearings
  - \+ Installation in any orientation
  - \+ Suited for mobile systems
  - ± Air cooling will do for many applications
  - \+ Lubricated for life (of the bearings)

- Free of lubricants / magnetic suspension
  - + No wear
  - + No maintenance
  - + Absolutely free of hydrocarbons
  - + Low noise and vibration levels
  - + Installation in any orientation

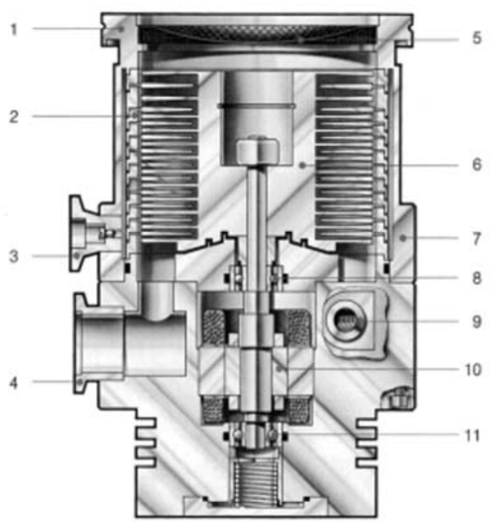
Steel ball bearings / hybrid ball bearings (ceramic ball bearings): Even a brief tear in the thin lubricating film between the balls and the races can – if the same type of material is used – result in microwelding at the points of contact. This severely reduces the service life of the bearings. By using dissimilar materials in so called hybrid bearings (races: steel, balls: ceramics) the effect of microwelding is avoided.

The most elegant bearing concept is that of the **magnetic suspension**. As early as 1976 LEYBOLD delivered magnetically suspended turbomolecular pumps – the legendary series 550M and 560M. At that time a purely active magnetic suspension (i.e. with electromagnets) was used. Advances in electronics and the use of permanent magnets (passive magnetic suspension) based on the **"System KFA Jülich"** permitted the magnetic suspension concept to spread widely. In this system the rotor is maintained in a stable position without contact during operation, by magnetic forces. Absolutely no lubricants are required. So-called touch down bearings are integrated for shutdown.

Fig. 2.52 shows a sectional drawing of a typical turbomolecular pump. The pump is an axial flow compressor of vertical design, the active or pumping part of which consists of a rotor (6) and a stator (2). Turbine blades are located around the circumferences of the stator and the rotor. Each rotor – stator pair of circular blade rows forms one stage, so that the assembly is composed of a multitude of stages mounted in series. The gas to be pumped arrives directly through the aperture of the inlet flange (1), that is, without any loss of conductance, at the active pumping area of the top blades of the rotor – stator assembly. This is equipped with blades of especially large radial span to allow a large annular inlet area. The gas captured by these stages is transferred to the lower compression stages, whose blades have shorter radial spans, where the gas is compressed to backing pressure or rough vacuum pressure. The turbine rotor (6) is mounted on the drive shaft, which is supported by two precision ball bearings (8 and 11), accommodated in the motor housing. The rotor shaft is directly driven by a medium-frequency motor housed in the forevacuum space within the rotor, so that no rotary shaft lead-through to the outside atmosphere is necessary. This motor is powered and automatically controlled by an external frequency converter, normally a solid-state frequency converter that ensures a very low noise level. For special applications, for example, in areas exposed to radiation, motor generator frequency converters are used.

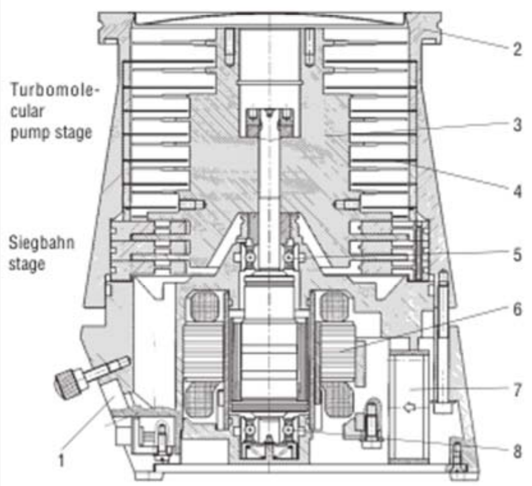
The vertical rotor – stator configuration provides optimum flow conditions of the gas at the inlet.

To ensure vibration-free running at high rotational speeds, the turbine is dynamically balanced at two levels during its assembly.



1 High vacuum inlet flange
2 Stator pack
3 Venting flange
4 Forevacuum flange
5 Splinter guard
6 Rotor
7 Pump casing
8 Ball bearings
9 Cooling water connection
10 3-phase motor
11 Ball bearings

Fig. 2.52 Schematic diagram of a grease lubricated TURBOVAC 151 turbomolecular pump



1 Vacuum port
2 High vacuum flange
3 Rotor
4 Stator
5 Bearing
6 Motor
7 Fan
8 Bearing

Fig. 2.52a Cross section of a HY.CONE turbomolecular pump

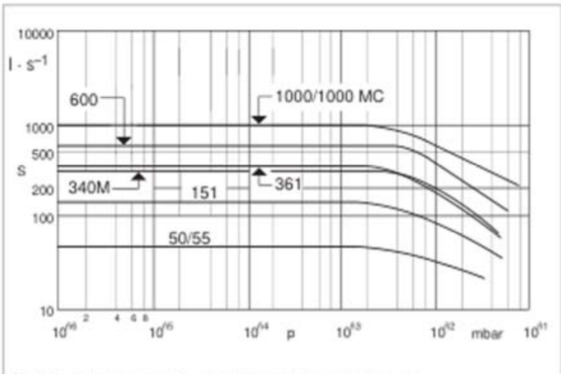


Fig. 2.53 Pumping speed for air of different turbomolecular pumps

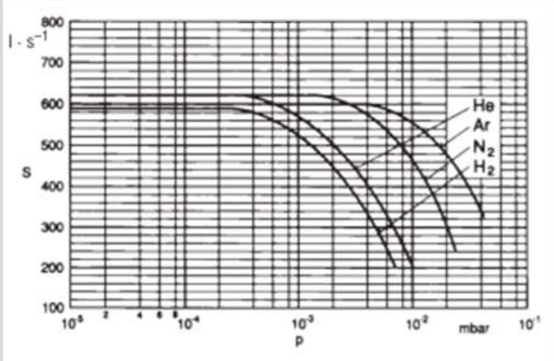


Fig. 2.54 Pumping speed curves of a TURBOVAC 600 for H_2, He, N_2 and Ar

The **pumping speed** (volume flow rate) **characteristics** of turbomolecular pumps are shown in Fig. 2.53. The pumping speed remains constant over the entire working pressure range. It decreases at intake pressures above 10^{-3} mbar, as this threshold value marks the transition from the region of molecular flow to the region of laminar viscous flow of gases. Fig. 2.54 shows also that the pumping speed depends on the type of gas.

The **compression ratio** (often also simply termed **compression**) of turbomolecular pumps is the ratio between the partial pressure of one gas component at the forevacuum flange of the pump and that at the high vacuum flange: maximum compression k_0 is to be found at zero throughput. For physical reasons, the compression ratio of turbomolecular pumps is very high for heavy molecules but considerably lower for light molecules. The relationship between compression and molecular mass is shown in Fig. 2.55. Shown in Fig. 2.56 are the compression curves of a TURBOVAC 340 M for N_2, He and H_2 as a function of the backing pressure. Because of the high compression ratio for heavy hydrocarbon molecules, turbomolecular pumps can be directly connected to a vacuum chamber without the aid of one or more cooled baffles or traps and without the risk of a measurable partial pressure for hydrocarbons in the vacuum chamber (hydrocarbon-free vacuum! – see also Fig. 2.57: residual gas spectrum above a TURBOVAC 361). As the hydrogen partial pressure attained by the rotary backing pump is very low, the turbomolecular pump is capable of attaining ultimate pressures in the 10^{-11} mbar range in spite of its rather moderate compression for H_2. To produce such extremely low pressures, it will, of course, be necessary to strictly observe the general rules of UHV technology: the vacuum chamber and the upper part of the turbo-

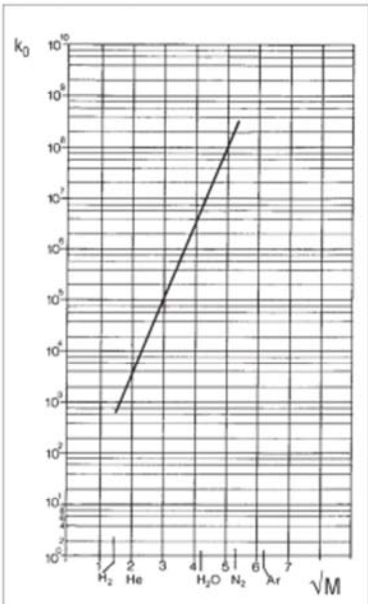


Fig. 2.55 TURBOVAC 450 – Maximum compression k_0 as a function of molar mass M

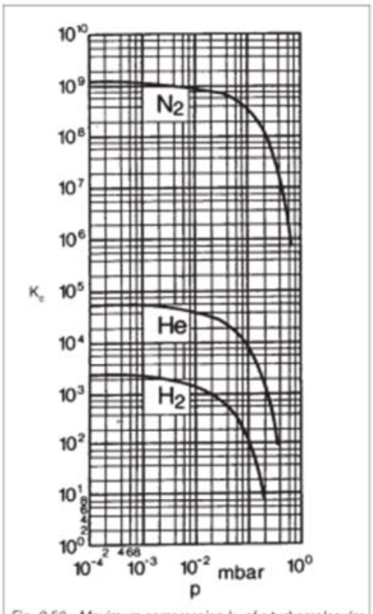
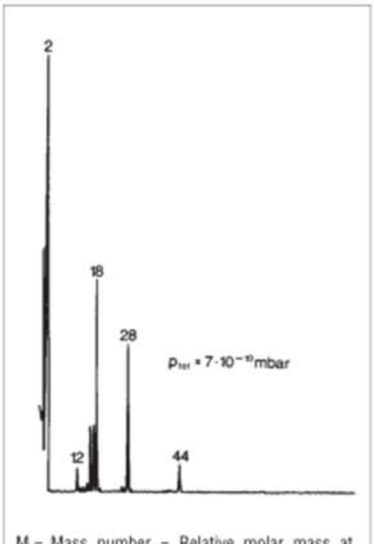


Fig. 2.56 Maximum compression k_0 of a turbomolecular pump TURBOVAC 340 M for H_2, He and N_2 as a function of backing pressure



M = Mass number = Relative molar mass at an ionization 1
I = Ion current

Fig. 2.57 Spectrum above a TURBOVAC 361

molecular pump must be baked out, and metal seals must be used. At very low pressures the residual gas is composed mainly of H_2 originating from the metal walls of the chamber. The spectrum in Fig. 2.57 shows the **residual gas composition** in front of the inlet of a turbomolecular pump at an ultimate pressure of $7 \cdot 10^{-10}$ mbar nitrogen equivalent. It appears that the portion of H_2 in the total quantity of gas amounts to approximately 90 to 95 %. The fraction of "heavier" molecules is considerably reduced and masses greater than 44 were not detected. An important criterion in the assessment of the quality of a residual gas spectrum are the measurable hydrocarbons from the lubricants used in the vacuum pump system. Of course an "absolutely hydrocarbon-free vacuum" can only be produced with pump systems which are free of lubricants, i.e. for example with magnetically-suspended turbomolecular pumps and dry compressing backing pumps. When operated correctly (venting at any kind of standstill) no hydrocarbons are detectable also in the spectrum of normal turbomolecular pumps.

A further development of the turbomolecular pump is the hybrid or compound turbomolecular pump. This is actually two pumps on a common shaft in a single casing. The high vacuum stage for the molecular flow region is a classic turbomolecular pump, the second pump for the viscous flow range is a molecular drag or friction pump.

LEYBOLD manufactures pumps such as the TURBOVAC 55 with an integrated Holweck stage (screw-type compressor) and, for example, the HY.CONE 60 or HY.CONE 200 with an integrated Siegbahn stage (spiral compressor). The required backing pressure then amounts to a few mbar so that the backing pump is only required to compress from about 5 to 10 mbar to atmospheric pressure. A sectional view of a HY.CONE is shown in Fig. 2.52a.

Information on the operation of turbomolecular pumps

Starting

As a rule turbomolecular pumps should generally be started together with the backing pump in order to reduce any backstreaming of oil from the backing pump into the vacuum chamber. A delayed start of the turbomolecular pump, makes sense in the case of rather small backing

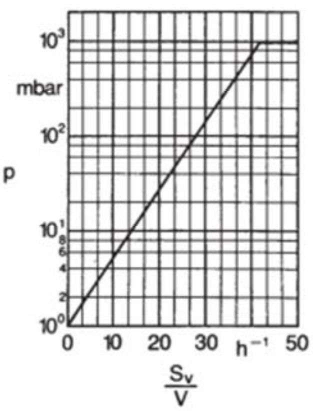


Fig. 2.58 Determination of the cut-in pressure for turbomolecular pumps when evacuating large vessels

pump sets and large vacuum chambers. At a known pumping speed for the backing pump S_V (m^3/h) and a known volume for the vacuum chamber (m^3) it is possible to estimate the cut-in pressure for the turbomolecular pump:

Simultaneous start when

$$\frac{S_v}{V} > 40 h^{-1}$$

and delayed start when

$$\frac{S_v}{V} < 40 h^{-1}$$

at a cut-in pressure of:

$$p_{V,Start} = e^{\left(\frac{S_v}{6 \cdot V}\right)} \text{mbar} \qquad (2.24)$$

When evacuating larger volumes the cut-in pressure for turbomolecular pumps may also be determined with the aid of the diagram of Fig. 2.58.

Venting

After switching off or in the event of a power failure, turbomolecular pumps should always be vented in order to prevent any backdiffusion of hydrocarbons from the forevacuum side into the vacuum chamber. After switching off the pump the cooling water supply should also be switched off to prevent the possible condensation of water vapor. In order to protect the rotor it is recommended to comply with the (minimum) venting times stated in the operating instructions. The pump should be vented (except in the case of operation with a barrier gas) via the venting flange which already contains a sintered metal throttle, so that venting may be performed using a normal valve or a power failure venting valve.

Barrier gas operation

In the case of pumps equipped with a barrier gas facility, inert gas – such as dry nitrogen – may be applied through a special flange so as to protect the motor space and the bearings against aggressive media. A special barrier gas and venting valve meters the necessary quantity of barrier gas and may also serve as a venting valve.

Decoupling of vibrations

TURBOVAC pumps are precisely balanced and may generally be connected directly to the apparatus. Only in the case of highly sensitive instruments, such as electron microscopes, is it recommended to install vibration absorbers which reduce the present vibrations to a minimum. For magnetically suspended pumps a direct connection to the vacuum apparatus will usually do because of the extremely low vibrations produced by such pumps.

For **special applications** such as operation in strong magnetic fields, radiation hazard areas or in a tritium atmosphere, please contact our Technical Sales Department which has the necessary experience and which is available to you at any time.

Про криоконденсационный насос:

Cryocondensation is the physical and reversible bonding of gas molecules through Van der Waals forces on sufficiently cold surfaces of the same material. The bond energy is equal to the energy of vaporization of the solid gas bonded to the surface and thus decreases as the thickness of the condensate increases as does the vapor

из другой книги:

5.6. Cryopumping

5.6.1. *Cryopumping mechanism*

Cryopumping is the process by which gases (vapours) are condensed at low temperatures in order to reduce the pressure. The ultimate pressure which can be achieved by such a process was described by eq. (4.9), while the pumping speed which can be obtained was expressed by eq. (4.12).

Cryopumping may involve three mechanisms: cryocondensation, cryosorption and cryotrapping (Schäfer and Häfner, 1987). *Cryocondensation* occurs when gas molecules impinge on molecules of the same species adhering to the cold surface; by this process condensation layers of millimeters (thickness) may grow. *Cryosorption* is the physical adsorption of gases on cold surfaces; the sorption capacity is increased by enlarging the adsorbing surface, e.g. using a layer of activated charcoal (inner surface of up to 1000 m^2 per gram of charcoal). *Cryotrapping* is the process by which gases are trapped (buried) in the growing solid condensation layer of a second gas, e.g. trapping of H_2 or He in N_2, Ar or CO_2.

Review discussions of cryopumping have been published by Gareis and Hagenbach (1965), Power (1966), Redhead *et al.* (1968), Kidnay and Hiza (1970), Hobson (1973), Benvenuti (1977), Schäfer (1978), Weston (1978), and Haefer (1981). The measurement of the sticking coefficient is discussed by Habets *et al.* (1975).

In order to understand the cryopumping phenomenon Moore (1962) analyzed it in some detail. He considered the molecular flow (see §3.1.1) of a gas between two infinite parallel planes; one a gas source and the other a cryopump condenser (gas sink), as shown in fig. 5.52. For this analysis Moore made the following assumptions: (1) The distance L between the surfaces is small compared to the mean free path (molecular flow). (2) The condensing surface is covered with a deposit of condensed solid (formed from gas from the source surface), and the deposit has an exposed surface temperature T_2. (3) Of the stream of molecules that strike the solid on the condensing surface (the mass flow rate w_1) the fraction f stick and the rest are diffusely reflected. (4) The reflected molecules leaving the condenser constitute a mass flow $(1-f)w_1$, and have a velocity distribution corresponding to the temperature T_2, i.e. the accommodation coefficient (eq. 2.104) is unity. (5) In addition to the reflected molecules, the solid deposit also emits molecules by evaporation at the temperature T_2, and at the same rate We_2 as if it were in equilibrium with a gas at temperature T_2; (6) The mass flow, w_1, from the source consists of the flow W_1 emitted by the source and that of diffusely reflected molecules w_2 which strike the source surface. The mass flow w_1 is constituted of molecules having a velocity distribution corresponding to the temperature T_1. (7) The velocity distributions of all molecular streams are Maxwellian (eq. 2.38).

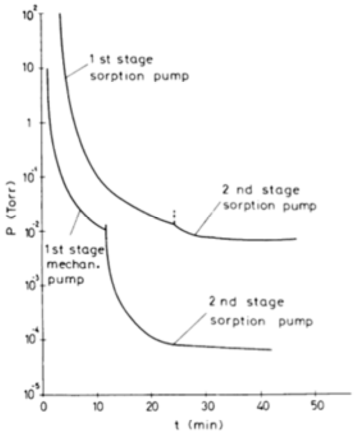


Fig. 5.51

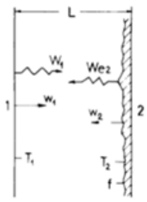


Fig. 5.52

Fig. 5.51 Two-stage sorption pumping, with two different combinations of pumps. After Turner and Feinleib (1962).

Fig. 5.52 Model for analysis of cryopumping between infinite parallel planes. 1. Source; 2. Condenser with thin deposit. After Moore (1962).

According to these assumptions, the gas between source and condenser (fig. 5.52) can be considered composed of two streams* moving in opposite directions: w_1 flowing from source to condenser, and w_2 flowing from condenser to source: w_1 and w_2 have velocity distributions corresponding to temperatures T_1 and T_2 respectively.

Since the net mass flow input to the system is given by

$$W_1 = w_1 - w_2 = w_1 f - We_2 \tag{5.20}$$

the mass flow for the two opposite streams results as

$$w_1 = (W_1 + We_2)/f \tag{5.21}$$

$$w_2 = W_1 (1-f)/f + We_2/f \tag{5.22}$$

* Directional detectors are discussed by Tuzi and Kobayashi (1983).