Bringing the Work Chamber to High Vacuum

To bring the work chamber to high vacuum (or to "pump it down"):

1. Close the vent valve.

2. Close the foreline valve. (Watch TC2. It should not exceed maximum tolerable foreline pressure.)

3. Open the roughing valve.

4. Wait for the chamber pressure to reach the crossover pressure. (Watch TC1 and TC2. Pump may require foreline pumpdown.)

5. Close the roughing valve.

6. Open the foreline valve.

7. Open the hi-vac valve.

8. Turn on the ion gauge.

These directions should allow us to safely and properly operate our "typical" diffusion pump system. They may need some modification to work for your diffusion pump system because of particular design or process requirements.

Start-up Procedure

Now, how do we start our system safely and properly? Let's look at a typical start-up procedure. Assume the system is properly installed and connected to all services. All system valves are closed. All system switches are OFF. The system does not have large leaks. Check to see that the pumps have oil and that all services are in a safe condition and will not result in harm if turned on as we suggest here.

1. Turn on the main power to the system.

2. Turn on the mechanical pump.

3. Open the roughing valve and pump the chamber to about 100 mtorr pressure. (Watch TC1.)

4. Close the roughing valve.

5. Open the foreline valve. Pump the diffusion pump and trap to about 50 mtorr pressure. (Watch TC2.)

6. Turn on the diffusion pump (electrical power and cooling water).

7. Fill the LN_2 trap (may be done before step 6 if oil vapor is of concern).

8. Allow 30 minutes to 1 hour for the diffusion pump to warm up. Monitor TC2—it should remain well below maximum tolerable foreline pressure.

9. Check the chamber pressure. Rerough if necessary. (Close foreline valve, open roughing valve, pump to crossover pressure, close roughing valve, open foreline valve.)

10. Open the hi-vac valve slowly.

11. Turn on the ion gauge. Monitor the chamber pressure.

12. You are on your way! Cycle the system per directions above.

Remember that improper operation of the diffusion pump system can result in mechanical pump oil and/or diffusion pump oil in the work chamber. Also, "dumping" the diffusion pump to air by improper valving procedures will tend to decompose (perhaps even burn) the pump oil. Proper operation, on the other hand, will give many months of successful operation with minimum maintenance needs.

A Turbomolecular Pump System

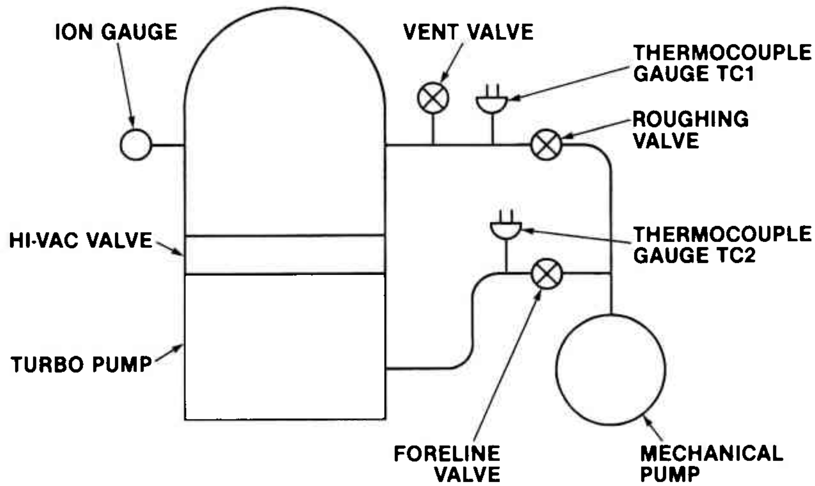
Putting the System Together

This system is much like a conventional diffusion pump system. Turbomolecular pump (TMP) systems are often assembled with a separate roughing line and foreline. The entire roughing and foreline section is the same as that in a diffusion pump system. The requirements for sizing the forepump are two-fold. It must be able to accept the maximum gas load from the turbo pump exhaust. Also, the forepump should provide an acceptable chamber roughing time.

It is desirable to use a high vacuum isolation valve to isolate the turbo pump if roughing the chamber through a separate roughing line, similar to the way diffusion pump systems are manifolded.

This is especially true on fast cycling applications such as load locks, where you want to cycle the load lock at a rate approaching the start-up time of the turbo pump. To reach the fastest cycle time, the system must transfer to the turbo pump (which is rotating at full speed) after initial roughing of the chamber through a roughing line. As a general "rule of thumb," it is advisable to use a valved system if the chamber is going to be cycled from atmosphere to vacuum to atmosphere repetitively, with a total cycle time of less than 10 minutes.

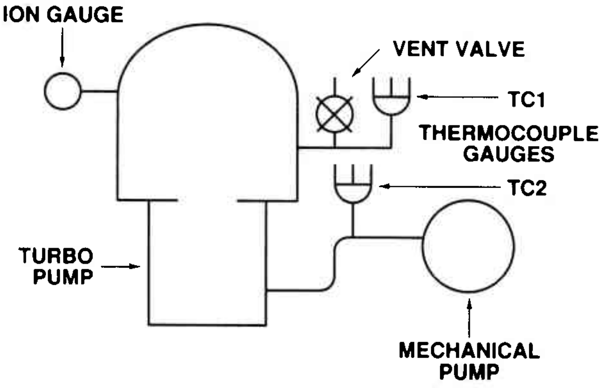
A valved system as shown here should be used when evacuating a large vacuum chamber. Roughing the chamber through the turbo pump will be slower, since the turbo pump will have rather large conductance losses due to the small exhaust port on the turbo pump.



TURBO PUMP SYSTEM

Turbo pumps allow great flexibility in the choice of vacuum manifolding. For moderately sized chambers, the turbo pump can be mounted directly to the chamber without a high vacuum isolation valve. In this case, the turbo pump is cycled from atmosphere to high vacuum with the chamber, and the chamber is roughed through the turbo. Usually, the turbo pump and mechanical pump are started and stopped simultaneously. Most modern turbo controllers can switch the mechanical pump contactor on and off with single switch control of both mechanical pump and turbo pump from the front panel.

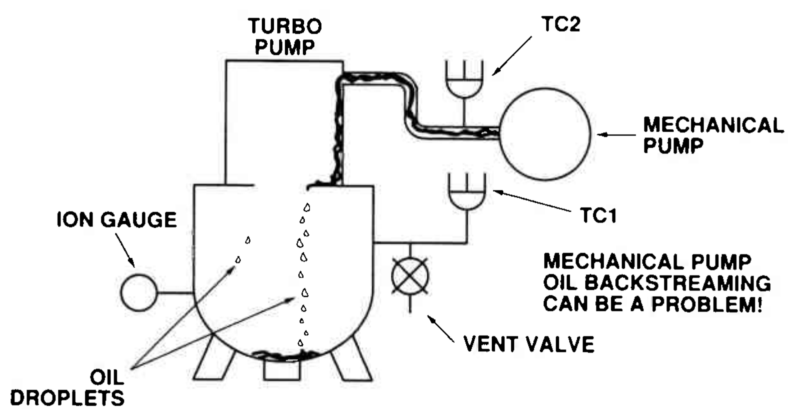
Alternatively, if the chamber is larger and cannot be roughed through the turbo pump to several hundred millitorr within the turbo pump start-up time, you can use a delayed start with a thermocouple gauge set point to delay starting the turbo pump until the pressure falls into the high millitorr range. The advantage of roughing through the turbo is that a simple system with minimal valving can be built. A disadvantage is the increased time needed to reach high vacuum pressure levels.



TURBO PUMP SYSTEM
ROUGHED THROUGH TURBO PUMP

Mounting Orientation

The oil-lubricated pump must be oriented within 10° of vertical. Grease-lubricated turbo pumps may be oriented in any position. Condensation of mechanical pump oil in the TMP forevacuum area is normal, since the mechanical pump operates near its base pressure. When the pump is inverted, oil droplets may contaminate the system, so we recommend using a foreline trap to prevent mechanical pump oil from entering the pump and the system, contaminating both.



INVERTED TURBO PUMP SYSTEM
ROUGHED THROUGH TURBO PUMP

If the pump is to be mounted horizontally, orient the foreline port downward and use a foreline trap between the mechanical pump and the turbo pump.

When you mount the pump vertically, no trap is required.

There will be the normal accumulation of mechanical pump oil condensate in the forevacuum of the TMP (mechanical pump backstreaming near its base pressure). A trap in the foreline would help protect the system from improper shutdown or accidental dumping of the pump.

Please remember that foreline traps require regular maintenance or they become a source of oil vapor.

Pump Cooling

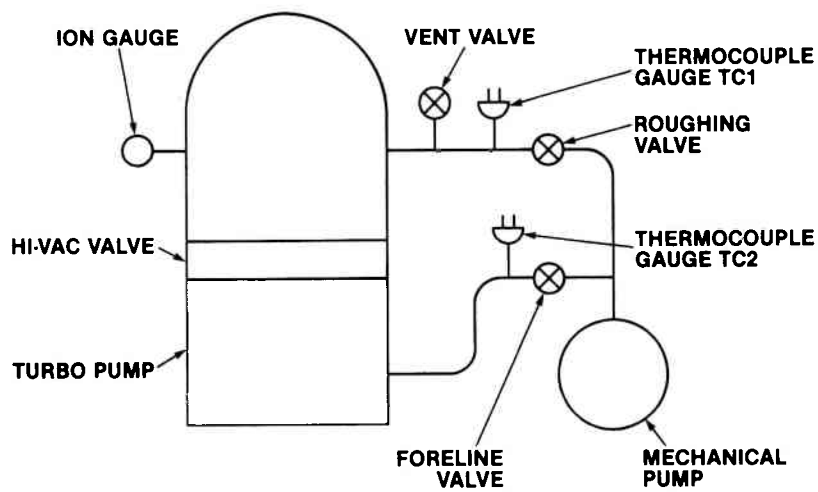
Continuous operation of the turbo pump at high pressure usually requires water cooling. Consult the manufacturer for recommended cooling method for your application.

If the pump is overheated, the thermistor on the motor stator will sense the excess heat and safely shut the pump down (at 80°C).

Overcooling your turbo pump can cause problems. If the pump is overcooled, stiffening of bearing O-rings will occur, the lubricating oil will become more viscous, the pump vibration level will increase and this, of course, may shorten bearing life.

No liquid nitrogen trap is needed on a turbomolecular pump to stop bearing or mechanical pump fluid backstreaming when the pump is operated properly. The compression ratios for all gases but hydrogen and helium, the lightest gases, are high enough so that little will flow from the foreline side to the high vacuum side, provided that the pump is rotating at the rated speed. The liquid nitrogen trap is often used with the turbo pump to increase pumping speed for water vapor.

System Operation



TURBO PUMP SYSTEM

Let's look at operating this system. The operation of the turbomolecular pump system shown above is much like that of a diffusion pump system.

Bringing the Work Chamber to Air

1. Turn off the ion gauge.
2. Close the hi-vac valve.
3. Open the vent valve.

Bringing the Work Chamber to Vacuum

1. Close the vent valve.
2. Close the foreline valve.
3. Open the roughing valve.
4. Wait until the chamber pressure has reached the crossover pressure (usually 80–100 mtorr).
5. Close the roughing valve.
6. Open the foreline valve.
7. Open the hi-vac valve.
8. Turn on the ion gauge.
9. Begin operation.

Start-up Procedure

Now let's look at a start-up procedure for the turbomolecular pump. We are assuming that the system is in place, all services properly connected and plumbed. All system valves are closed. There are no large leaks.

1. Turn on the electrical power.
2. Turn on the mechanical pump.
3. Open the foreline valve.
4. Rough the pump and foreline to about 100 mtorr.
5. Turn on the turbo pump. (May need water as well as electrical power.)
6. Allow 5–10 minutes for the pump to get up to speed (longer for large pumps).
7. Close the foreline valve.

8. Open the roughing valve.

9. Rough the chamber to about 100 mtorr.

10. Close the roughing valve.

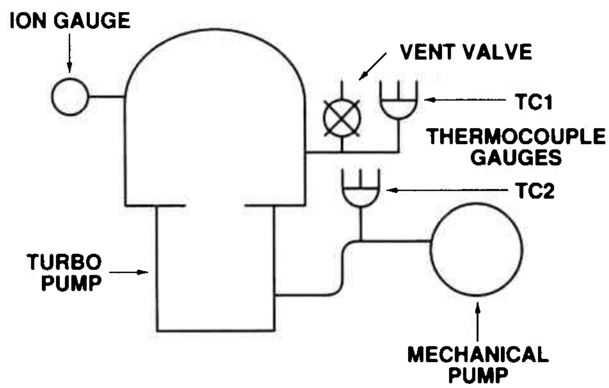
11. Open the foreline valve.

12. Open the hi-vac valve.

13. Turn on the ion gauge. You are in business!

Now, let's look at operating the other system we have discussed.

Operation of Turbo Pump System Roughed Through Turbopump



TURBO PUMP SYSTEM
ROUGHED THROUGH TURBO PUMP

This is a much simpler system to operate. Let's look at its operation.

Bringing the Work Chamber to Air

1. Turn off the ion gauge, the turbo pump, and the mechanical pump.

2. Immediately (within one quarter of the coast-down time) open the vent valve. (Vent slowly.)

Bringing the Work Chamber to Vacuum

1. Close the vent valve.

2. Turn on the pumps. (May need a delay time on start of turbo pump.)

3. When the pressure level is satisfactory in the work chamber, begin process.

Other System Considerations

Venting a Turbo Pump

Use of a vent control will afford control over a "delay time" before air-releasing a turbo pump, once the turbo is shut down or in case of power failure. A "delay time" will prevent undesired venting in case of a power failure of short duration.

Pumps must be vented before they stop rotating to prevent contamination by mechanical pump oil and possible bearing damage upon subsequent air release ("hammer effect").

Each model of turbo pump has a "coast-down time," which is the time it takes for a pump to stop spinning after power is removed if it is left under vacuum. As a rule of thumb, the maximum time delay before venting a pump after switching off power should be no more than one quarter of the coast-down time.

Also available on most vent controls is an adjustable "venting time" setting, to help conserve bottled venting gas.

The minimum venting time is the time needed to reach a pressure of about 375 torr inside the pump. This pressure is high enough to avoid mechanical pump oil backstreaming and contamination of the turbo pump.

If there is no high vacuum valve isolating the turbo from the system, the required venting times will be extended, based upon chamber size. If reaching pressures less than 10^{-6} torr in a minimum time is important, the pump should be vented to a dry gas.

Particulates

Turbo pumps should not be used in applications that generate a large quantity of particulates. Particulates will make their way to the bearings and cause bearing seizure or erode pump blades. The inlet screen provided with turbo pumps collects all large particles and prevents them from entering the pump but it is ineffective against a continuous stream of fine particulates. Screen cleaning must be performed on a regular basis.

A Cryopump System

Putting the System Together

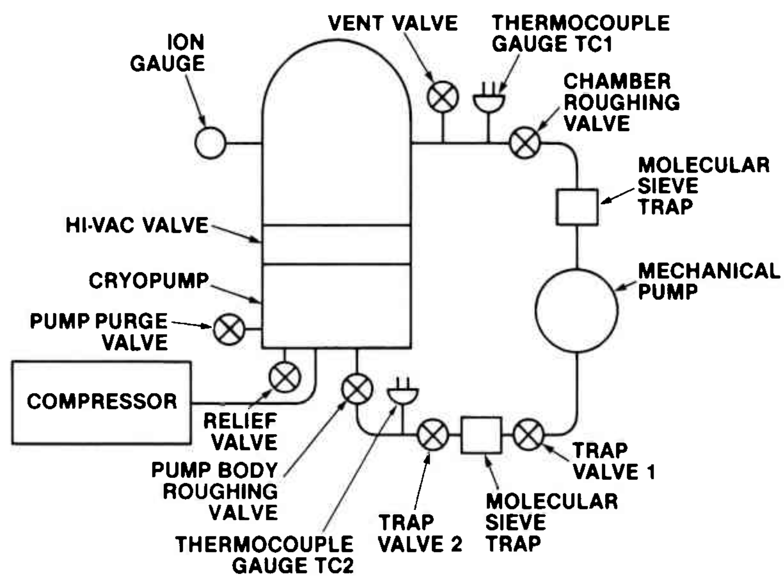
A diagram of how a cryopump fits into a vacuum system is shown on the next page. In this discussion, we refer to the vacuum system as having three major portions:

1. The *vacuum chamber*, which consists of the chamber(s), load locks, etc., where the work is being processed; the high vacuum valve; and the associated hardware and instrumentation (ion gauge, etc.).

2. The *cryopump*, which consists of the pump module, the compressor module, and the interconnecting flexible hoses.

3. The *roughing manifold*, consisting of the roughing pump, sieve trap(s), roughing valves, lines to the vacuum chamber, and roughing (TC) gauges.

Look at the cryopump system drawing. Note that the valves and plumbing have an arrangement suitable for a capture pump or storage pump. No forepump is required.



CRYOPUMP SYSTEM

Here is a set of specific instructions for various operations on this system.

Bringing the Work Chamber to Air

1. Turn off the ion gauge.

2. Close the hi-vac valve.

3. Open the vent valve.

Bringing the Work Chamber to High Vacuum

1. Close the vent valve.

2. Open the chamber roughing valve.

3. Pump the chamber to crossover pressure.

4. Close the chamber roughing valve.

5. Open the hi-vac valve.

6. Turn on the ion gauge.

Start-up Procedure

Here's a start-up procedure for a "typical" cryopump system. We are assuming the system is properly installed and connected to all services. All system valves are closed. There are no large leaks.

1. Turn on the mechanical pump.

2. If the condition of the molecular sieve traps is not known, open trap valve 1 and bake both traps for a minimum of 1 hour.

3. When the traps have cooled, open trap valve 2 and verify a pressure of 10 mtorr or less on TC2.

4. Check the pump pressure by closing trap valve 2 and opening the pump body roughing valve. If TC2 is above 50 mtorr, rough pump the body until it is below 50 mtorr, and then close the pump body roughing valve and trap valves 1 and 2.

5. Turn on the compressor. (Wait for chilldown, i.e., 20°K.)

6. Rough the chamber (to 150 mtorr). Close the roughing valve.

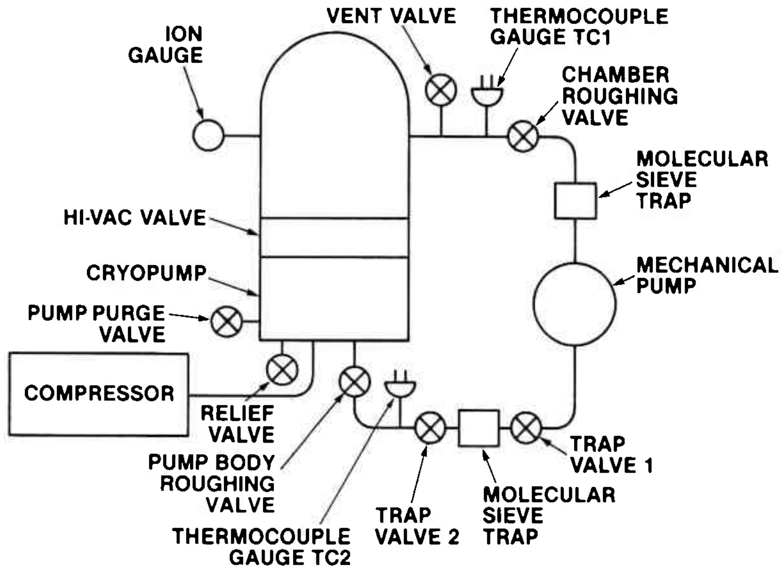
7. Open the hi-vac valve.

8. Turn on the ion gauge. Monitor the pressure.

9. Start process.

Regeneration Procedure

Because the cryopump is a storage pump, we must empty it when it is getting full. Here is a procedure for regeneration.



CRYOPUMP REGENERATION

1. Close the hi-vac valve and turn off the ion gauge.

2. Turn off the compressor.

3. Purge the pump body with nitrogen (regulated to 15 or 20 psig) for the time specified by the manufacturer or until pump reaches 295°K (room temperature). If heated nitrogen is used, the temperature at the pump body must not exceed 120°C. Isolate the molecular sieve trap(s) from the cryopump. Bake the trap(s) while pumping on the trap with the mechanical pump. Nitrogen purge of the trap during bakeout is advisable, and gas ballasting the mechanical pumps may be necessary.

4. Rough the pump body to about 10 mtorr.

5. Turn on the compressor. (Continue roughing for 10 to 20 minutes, then close the roughing valve.)

6. Periodically monitor the pressure inside the pump—it should be about 50 mtorr or less.

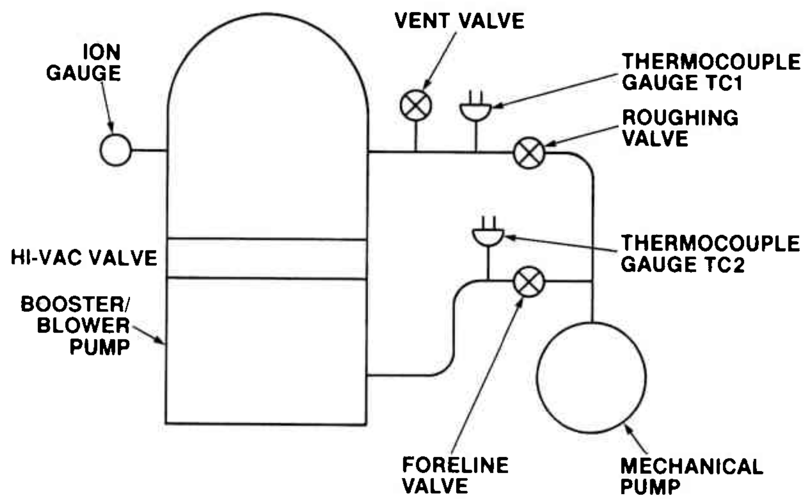
7. After the pump has chilled to 20°K or less, return to normal operation.

Cryopump systems differ in their operation in that they are storage pumps. Also, they do not need the assistance of a fore-pump while they are on-line and pumping. However, most people leave the rough pump running because they need to rough the chamber frequently during use. We strongly urge the use of molecular sieve traps between the rough pump and the cryo-pump. Also, use them between the rough pump and the chamber to prevent mechanical oil from backstreaming or migrating into the vacuum system.

A way to avoid the traps, etc., is to use a dry roughing pump, which contains no oil, or use sorption roughing pumps.

A Booster/Blower System

A system using a blower as its main pump should be considered a medium-range vacuum system.



BOOSTER/BLOWER SYSTEM

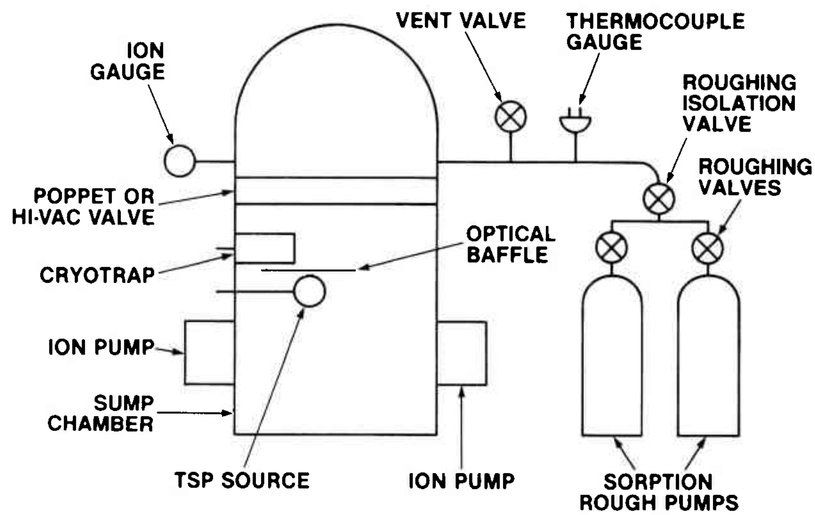
Wide variations of pumpdown sequence exist, depending to a great extent on chamber volume and the volume-to-pump speed ratio. The blower is not made to pump continuously at pressures above 10 torr. The base pressure will usually be in the range of 10^{-4} to 10^{-5} torr. Its operation parallels that of the diffusion pump, or turbo pump, but valving actions may occur safely at higher pressures.

The operating concerns are similar to those of the turbomolecular pump system. Both are mechanical, high rotational speed pumps. In general, the blower is more rugged, but cannot work at low pressures like the turbo pump does. This type of system is often roughed directly through the blower. A bypass valve is also often used to direct gases around the blower at high pressures. The bypass valve is closed as the crossover pressure is reached. These techniques eliminate the need for a separate roughing line.

An Ion Pump System

Putting the System Together

Ion pump systems may operate much as the systems we have discussed. They also may be pumped down to ultrahigh vacuum and kept there. A load-lock entry may be used for getting materials in and out of the vacuum chamber without having to vent and rough the whole work chamber. We will not cover these operations here.

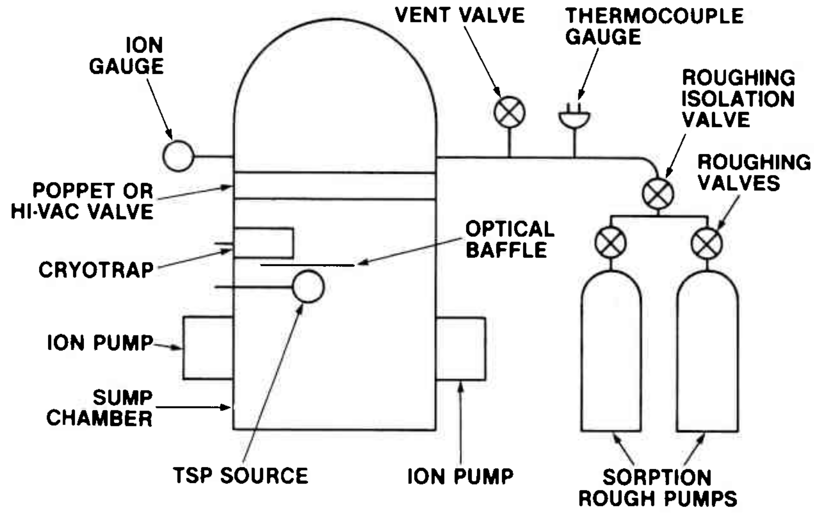


ION PUMP SYSTEM (MANUAL ONLY)

Start-up Procedure

Here's a start-up procedure for a manually operated ion/TSP pump system.

Let's assume that the system is at atmospheric pressure, the isolation and roughing valves are closed, hi-vac valve open, gauges off, vent valve closed, LN_2 trap dry. Remember that we are using sorption pumps for roughing. Of course, it is properly connected to all services. There are no large leaks.



ION PUMP SYSTEM

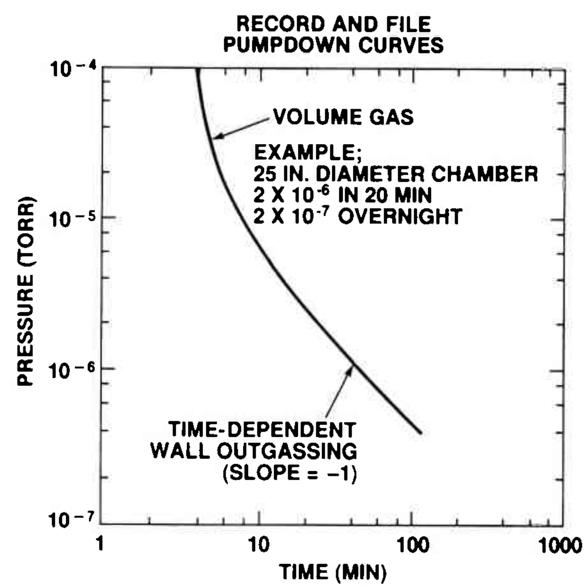
1. Pre-chill the sorption pump(s) with liquid nitrogen.
2. Turn on the thermocouple gauge.
3. Rough the complete system using the sorption pumps in sequence. Continue roughing with the second pump.
4. Fill the LN_2 trap (optional).
5. Outgas the TSP (100% duty cycle) starting it at 30 mtorr.
6. When sump pressure is less than 10 mtorr, switch the ion pump to "start mode." Turn on the power.
7. Close the main roughing isolation valve and the last sorption roughing valve.
8. Turn on the ion gauge.
9. Switch the TSP to "standby."
10. Bake out 12 hours (250°C); then cool down (8 hours).
11. Outgas the TSP (again).
12. Refill the LN_2 trap (optional).
13. Continue TSP cyclng in accordance with system instructions.
14. At very low pressure, the TSP need only be used for about 5 minutes once or twice a day.

Characterizing Your System

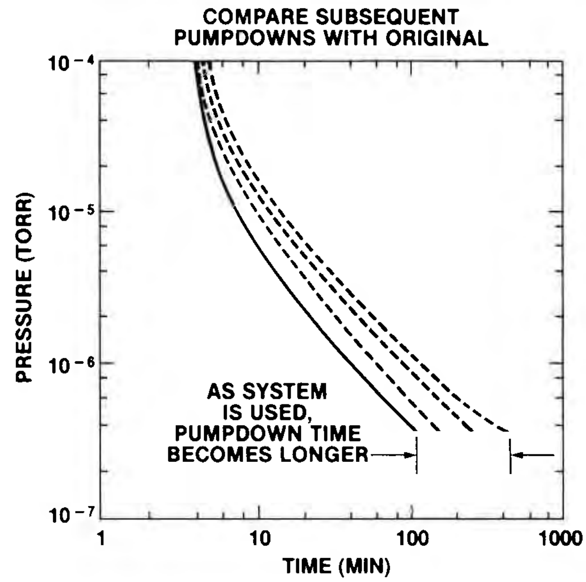
We have seen a variety of systems, but by no means have we seen them all – only the more common ones. Having compared and operated the various systems, let's next turn our attention to characterizing a system. It is necessary to determine how a system operates and how it behaves under various conditions. Recording this information in a log book will prove to be of great help when trying to determine problems with the system.

Rate of Pumpdown

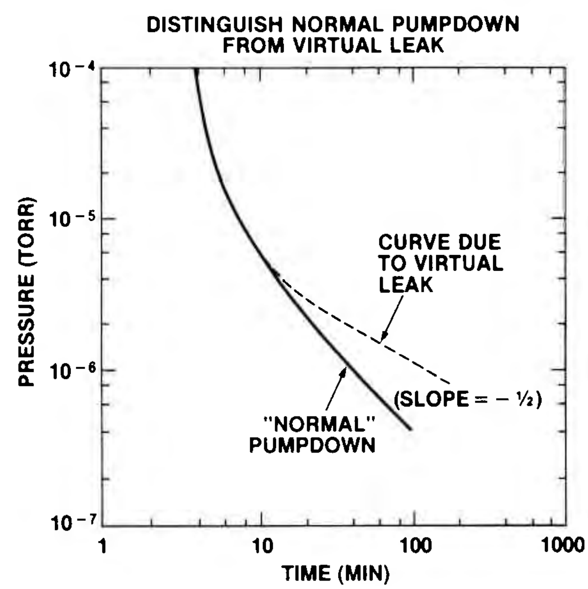
First, consider pumping time. This is necessary to establish the behavior pattern of the system.



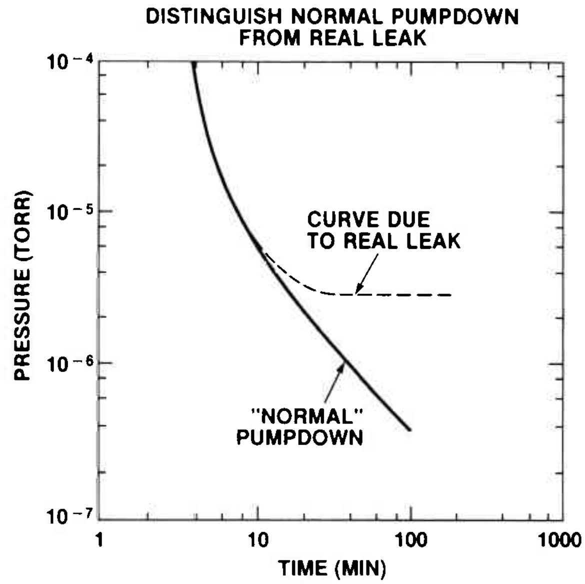
A pumpdown curve should periodically be recorded and filed for the system. The curve shown here is a plot of the inlet or system pressure on the vertical axis against time. This shows how fast the system pumps down to a base pressure. The above curve is for a typical 25-inch diameter chamber system. The system should pump to 2×10^{-6} torr in 20 minutes, and 2×10^{-7} torr in 12 hours. Once the pumpdown characteristics of a system are determined, a basis for comparison will have been established.



Having recorded and filed the pumpdown curve for a system, it is possible to compare subsequent pumpdowns with the original. Note that as the system is used, pumping performance will naturally degrade as the various process materials build up on the chamber surfaces. This will show up as a shift to the right on the pumpdown curves. The natural shift to the right is very helpful in scheduling downtime for cleaning purposes. Notice, however, that the shape of the curve remains basically the same as the original, even though pumpdown time takes longer with each subsequent use.



The pumpdown curves are also very useful for distinguishing normal pumpdowns from problem pumpdowns; in this case, from a problem due to a virtual leak. Notice how the normal pumpdown curve is compared against a virtual leak pumpdown. Notice how the virtual leak pumpdown curve shifts rather dramatically.

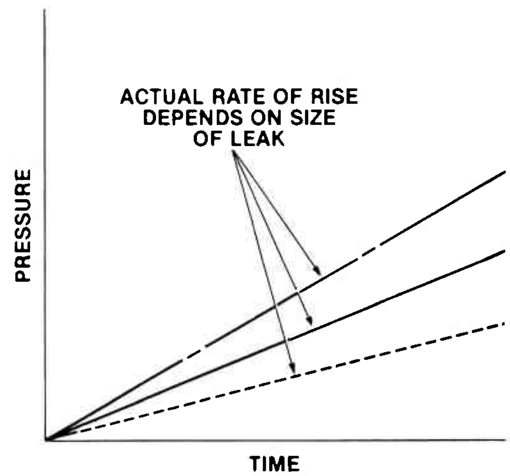


Pumpdown curves also help to distinguish normal pumpdowns from those under a real leak situation. The reason that the pumpdown curve flattens out, as shown by the dotted curve, is that at some point in the pumpdown, the incoming air through the leak exactly matches the pumping ability of the system. Therefore, the gas being expelled is exactly matched by the amount of gas being introduced through the leak. Another way to look at it is that when the pumping speed of the pumping mechanism is equal to the gas load of the system (Q), it can't reduce the system pressure any further.

Rate of Pressure Rise

Another useful set of curves is the rate-of-rise curves. These curves are developed by pumping the chamber down, then valving off the chamber so that no further pumping occurs. At that point, the pressure in the chamber will naturally rise with time. The rate of rise, and the changing rate of rise, can be useful in determining the cause of the changes. This pressure increase is from two major factors: the normal time and temperature-dependent wall outgassing, which the pumps are expected to remove; and the gas load entering the system through real leaks from outside the system.

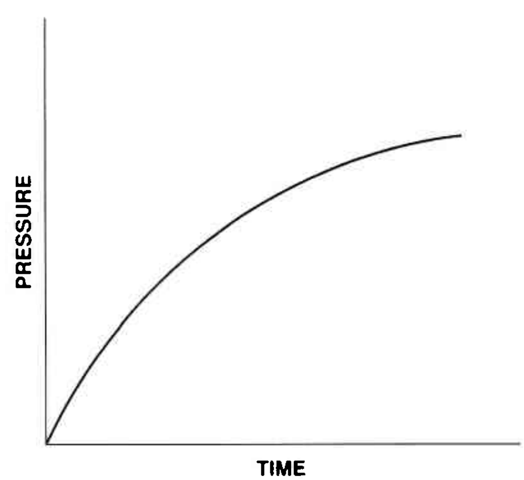
RATE-OF-RISE CURVES
(AIR LEAK)



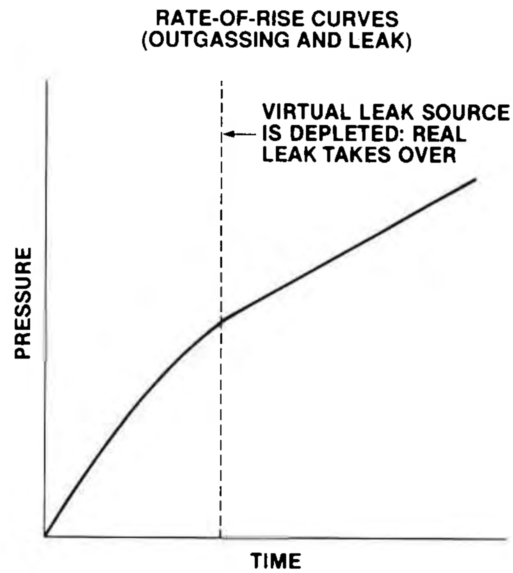
Plot the pressure on a vertical axis, and the time on the horizontal axis. To be most useful, it is best that both axes be on log scales. After pumping the chamber down to some low pressure, it is valved off or isolated from the pumping mechanism. Then the pressure is monitored as it naturally rises with time. As with the pumpdown curves, it is a good idea to establish a set of rate-of-rise curves with a system that is generally considered to be vacuum-tight in order to set up a basis of comparison.

The rate of rise of pressure, of course, will vary, depending on a number of factors. The rate of rise can be affected by the chamber volume and the amount of contamination that exists in the chamber. It can also be affected by leaks and the size of leaks. The set of rate-of-rise curves shown here indicates that the rate of rise definitely will depend on the size of the leak. Obviously, the larger the leak, the faster the pressure will rise in the chamber after the chamber is valved off from the pumping mechanism. We can distinguish between a real leak and a virtual leak.

RATE-OF-RISE CURVES
(OUTGASSING)



The rate-of-rise curve shown here is due to outgassing and/or trapped volumes. Again, the pressure rise is plotted against time on log-log paper. With an air leak, we saw that the rate of rise for pressure was linear with time. That is, it rose at a steady rate. When severe outgassing or trapped volumes exist, the curve is distinctly different. In this case, the pressure rises quickly, depending on the amount of outgassing due to contamination, or due to a virtual leak. Then, as the source of gas causing the rise in pressure reaches equilibrium, the rate of that rise slows down. That is, although the pressure may continue to rise, it no longer will rise at the same rate, as seen in the plot.



The rate of rise in pressure due to a virtual leak plus a real air leak shows up as a combination of the last two plots. That is, the rate of rise due to outgassing from contamination or through a source of trapped gas will vary with time. Then, as the source of outgassing reaches equilibrium, the rate of rise due to a real leak will become linear. This is because the amount of air entering the system through a real leak does not vary with time, but instead is constant. Therefore, the rate at which the pressure rises with time from that point is also constant.

Summary

We've looked at the advantages and disadvantages of the major types of vacuum systems and learned about putting together an operating system. We've also learned how to characterize a system through the use of pumpdown and rate-of-rise curves. Now let's take a look at how to troubleshoot vacuum systems.

Notes

8 Troubleshooting

When you have completed this chapter, you will be able to:

1. Identify the most common faults in vacuum system components.

2. Check out problems in common vacuum pumps.

3. Troubleshoot common vacuum system problems.

Introduction

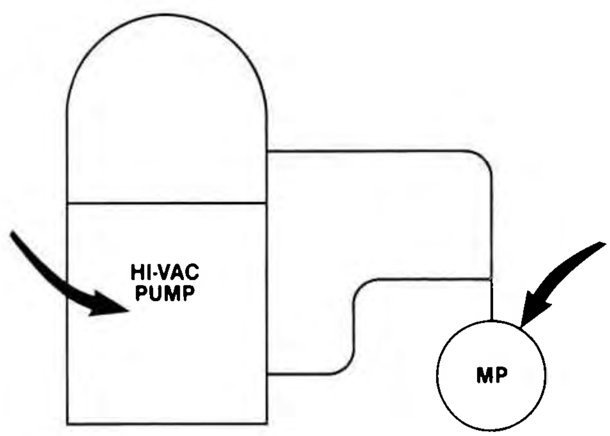
Next, let's look at troubleshooting a faulty vacuum system. Of course, we recognize that any equipment will, from time to time, be plagued by one problem or another. We also recognize that the solutions to many vacuum-related problems can be rather hard to pin down.

Vacuum malfunctions have a variety of symptoms. Some problems have overlapping symptoms, which increase our difficulties. We'll try in this chapter, therefore, to provide a guide for a systematic approach to determine the cause of vacuum system problems.

Categories of Faults

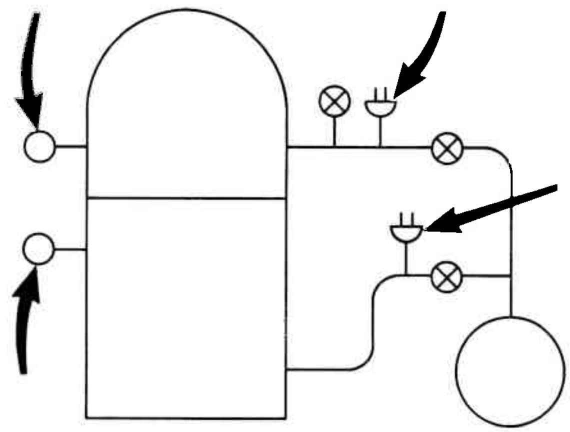
When a problem occurs in a vacuum system, it is often best to approach the situation in a systematic manner. This is better than trying to resolve the problem by any means that may occur to us at random.

For purposes of our discussion here, therefore, let's start by identifying the types, or categories, of faults that occur in vacuum systems. After we have identified the major categories, we will consider the various elements in greater depth.



Vacuum Pumps

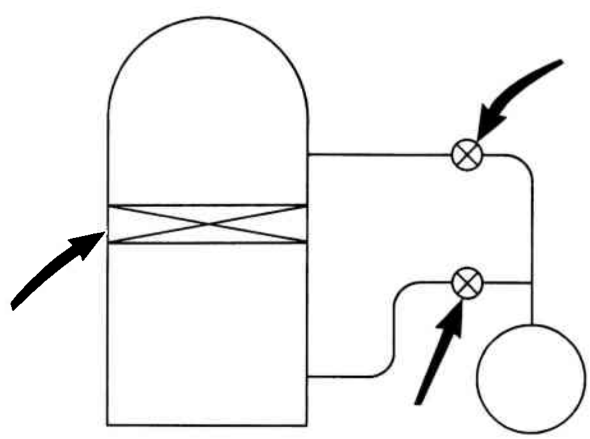
We need to consider the vacuum pumps. These mechanisms are the devices needed to create the vacuum environment. Therefore, if they are malfunctioning, our environment may be less than ideal, if not completely unusable.



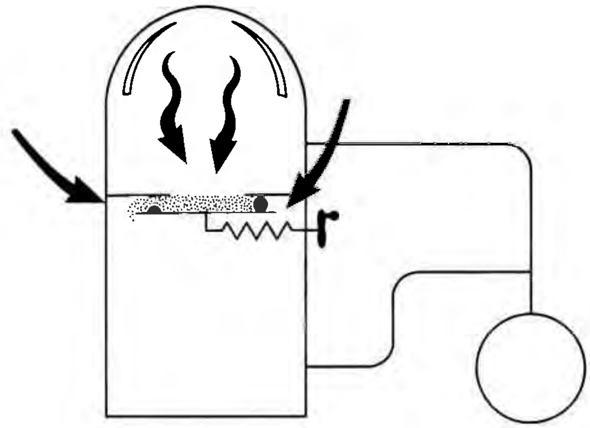
The first indication of a system malfunction is provided by the pressure gauges. However, we must also recognize that the gauges themselves can malfunction, either failing completely, or giving us false information as to the system status. Failure to recognize this fact can lead to the wrong conclusion.

Hardware

Faulty hardware can be the source of many vacuum system problems. Hardware can malfunction in a variety of ways, or can be affected by the condition of the system.

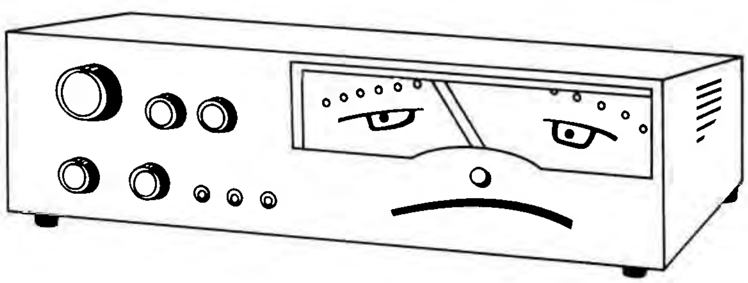


Valves can malfunction. Wear, caused by high friction forces, can prevent proper sealing. The seals wear in time. The actuating air pressure on pneumatic valves may be too low to provide proper sealing. Solenoids may be faulty.



Debris, particularly at the valve seals, is quite often the cause of system failure. Bellows or other feedthrough devices can leak. Double O-ring shaft seals can be the sources of virtual leaks.

Control Units, Gauge Tubes and Connections

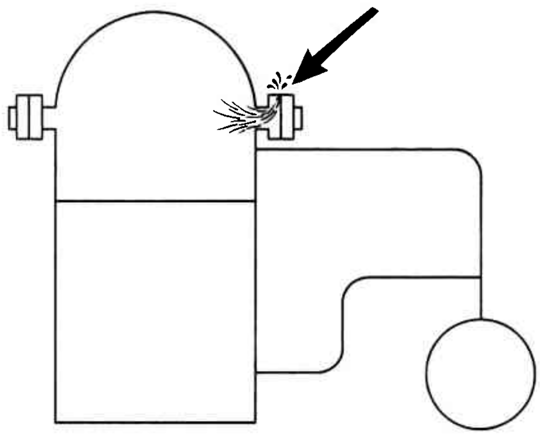


Control units, like gauges, can malfunction, or go out of calibration, giving erroneous data. Cable terminations and other interconnections can become loose or intermittent. Automated equipment may have faulty hardware or software.

Gauge tubes can become contaminated by pump oils and other materials. This may produce false pressure readings.

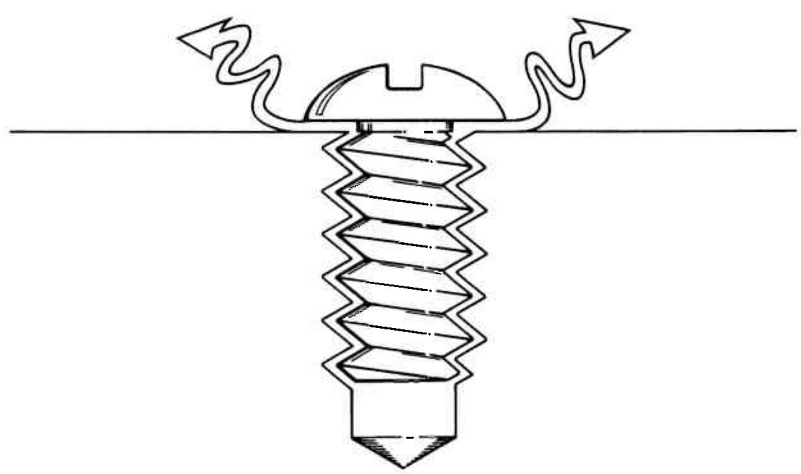
Leaks and Outgassing

Air Leaks

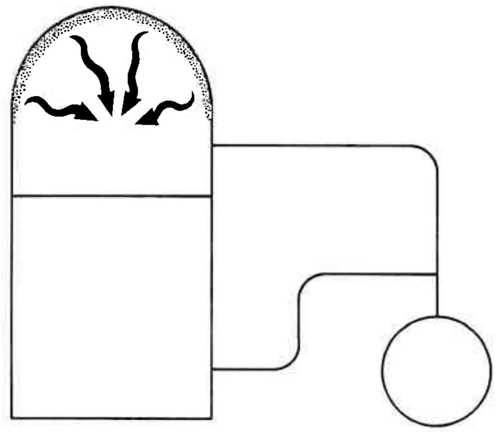


Leaks certainly are a major reason for system malfunctions. Air leaks are not uncommon. If small enough, leaks of this type can be ignored in many processes. (We'll consider sizes of leaks, or leak rates, in the Leak Detection chapter.)

Virtual Leaks

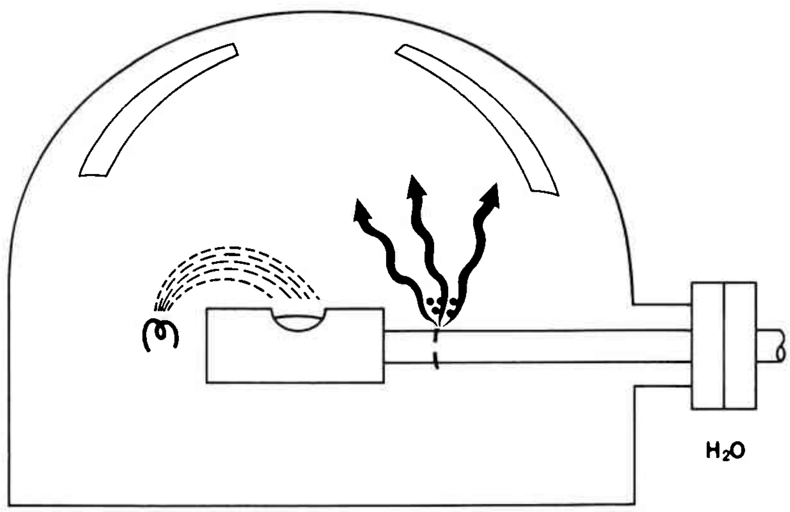


Virtual leaks, which we have already discussed, can be the cause of excessively long pumpdown times, if not complete system failures.



Outgassing, which may be considered to be a virtual leak, can also cause long pumpdown times. In production systems, long pumpdown times reduce the amount of work that can be produced by the system. Outgassing can also seriously affect the quality (yield) of the work. Simple outgassing can be often corrected by systematic, scheduled cleaning procedures.

Water Leaks



Water leaks inside the vacuum system, even very small ones, are always serious. And they often are hard to find. If small enough, their damage can be insidious, resulting in yield problems that might not be discovered until later in the manufacturing process. Additional expensive effort must then be expended on work pieces that were previously made useless by the water leak. The probability that leaks of this type will occur is increased by the number of water-cooled devices in the work chamber. Remember that water can exist as a gas, so you might not "see" a water leak! Silicone gaskets and O-rings are permeable to water vapor and can be a source of water in the vacuum system.

Utilities

The plant utilities such as air, water, electricity, process gases and liquid nitrogen can cause problems because of pressure variations, voltage, purity and temperature.

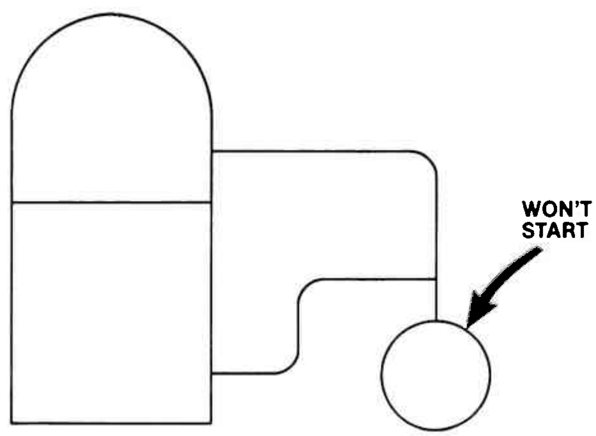
Vacuum Pumps

We have made a broad listing of several possible problem areas. Now, let's consider the various categories in somewhat greater detail, starting with the vacuum pumps.

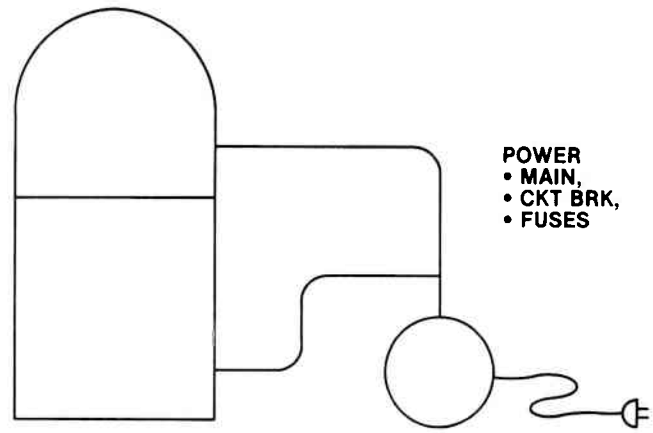
Mechanical Pump

We'll start with the mechanical roughing pump. These pumps are simple, but can be plagued by a number of problems which, as we have already said, can show up in a variety of ways. Let's look at a few of the ways.

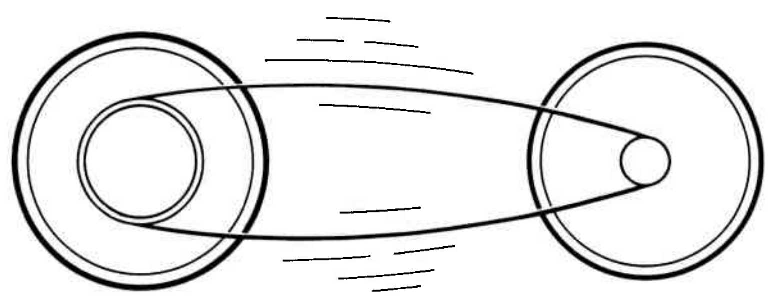
No Start-up



Start with the simplest things first. Consider a gross problem: the mechanical pump simply doesn't start when "turned on."



Check the easy things first. Is power arriving at the unit? If not, possibly a circuit breaker has opened. If the system is equipped with fuses, they may be burned out. Also, consider loose or broken connections. A pump or drive motor might be frozen, or seized. This condition might show up as a characteristic whining or buzzing sound as the unit struggles to turn, as overheating, as odor, or as all three of these symptoms.

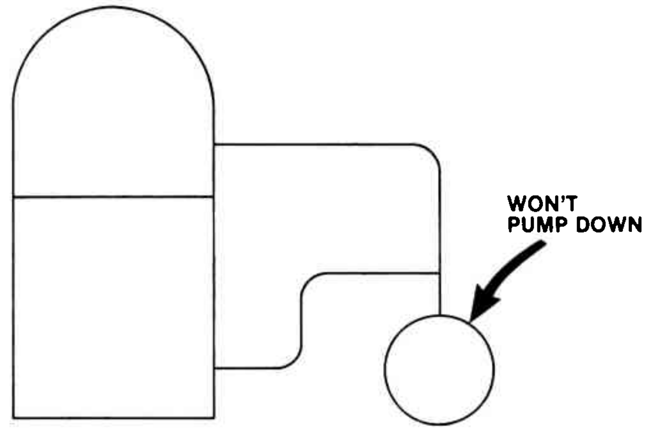


A very loose or broken drive belt can prevent a mechanical pump from operating at all. A loose drive belt might be heard slapping against the belt guard. On a single-belt drive, a broken belt will bring the pump operation to a halt; a broken belt in a multiple-belt drive unit may not be so obvious. A loose belt may not be turning the pump module at the rated speed, thus causing longer pumpdown times.

When the mechanical pump is connected to the foreline of a diffusion pump, a complete shutdown of the mechanical pump will very quickly lead to a catastrophic failure, unless the foreline pressure is monitored and action taken, or automatic shutdown is started by an interlock system.

Poor Operating Pressure

A less obvious mechanical pump problem occurs when it's impossible to reach the appropriate operating pressure normally reached by a given pump.



Contaminated Oil

Contaminated oil can result in poor operating pressure. Contamination can be caused by condensed water vapor, solvents or gases introduced into the system during the process. Or, it could also be due to failure to change the oil at the appropriate intervals.

Visually inspect the oil through the sight glass. Does it look cloudy, milky or streaky? If so, these conditions help to confirm that contamination exists. Remember to use the gas ballast if water is a problem.

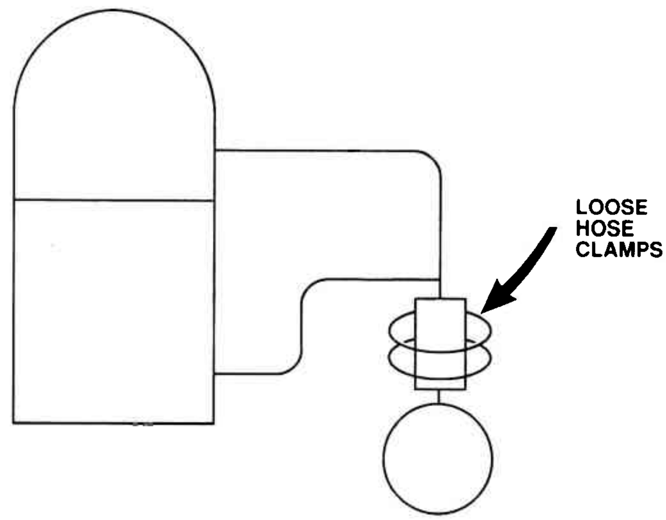
The statement has been made that 95% of mechanical pump problems can be solved by changing the pump oil.

Loose Drive Belt

Poor operating pressure can result from a loose drive belt. Belt tension can, of course, be adjusted. Frayed belts should be immediately replaced. When replacement is indicated in multiple-belt drives, all belts should be replaced together, regardless of the condition of any one of them. Preferably, the replacement belts should be a matched set. In direct-drive pumps, coupling problems between the motor and the pump module seldom occur.

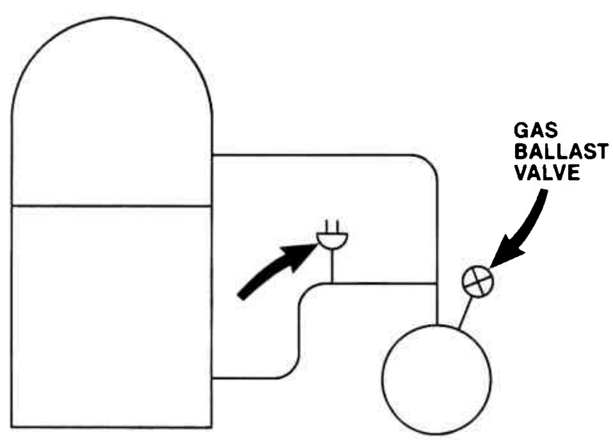
Hoses

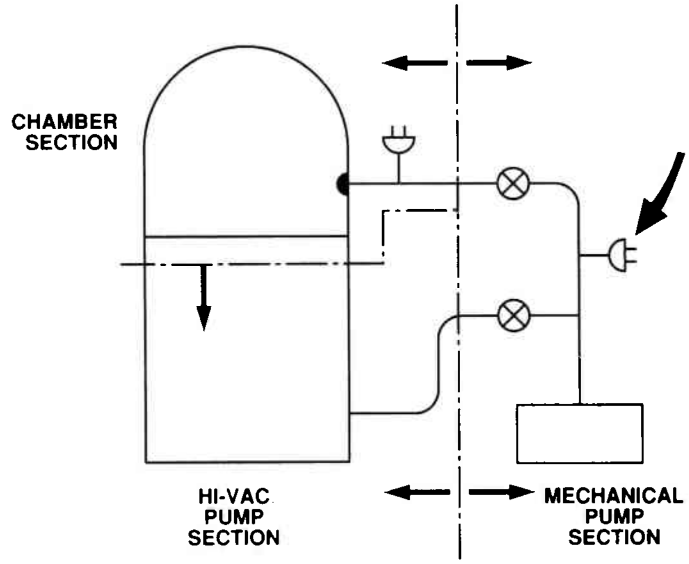
Hose clamps may have worked loose due to pump vibration. (In small work areas, bumping against the hose connections may loosen them.) Hoses may deteriorate, particularly in hot environments. Annual replacement of hoses is good preventive maintenance.



Open Gas Ballast Valve

An open gas ballast valve makes it impossible to achieve normal base pressure. The gas ballast valve may have been opened to prevent water vapor condensation, or to clear the pump of water contamination, then left open unintentionally. This can often happen in a multiple-shift operation: someone on one shift may open the gas ballast valve, and the person on the next shift may be unaware that it was left open.



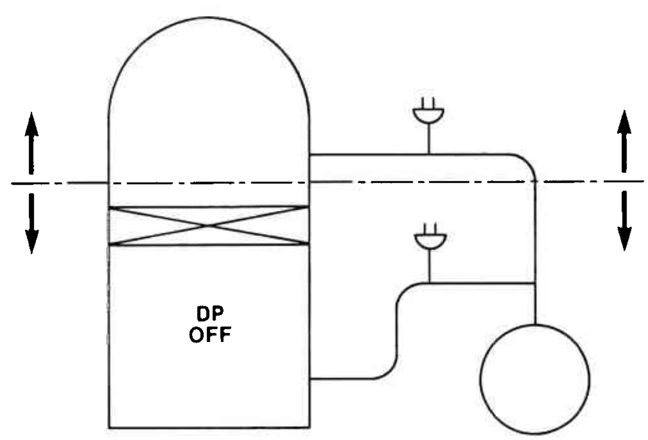


Use of valve isolation and pressure readings to identify cause of poor base pressures.

Measuring Base Pressure

A quick way to establish the base pressure of the mechanical pump is to isolate it from the rest of the system. This can be done by closing the roughing and foreline valves, and reading the pressure with a manifold TC (roughing) gauge. If a manifold TC gauge is not built into the system, the roughing valve can be left open, and the chamber roughing port can be plugged. Then the pressure can be monitored with the regular TC (roughing) gauge, if no leaks exist in the valve or manifold.

Isolation into sections by this technique also helps to establish whether the problem is in the high vacuum portion of the system, or in the roughing side. Keep in mind that manifold or valve leaks can produce abnormally high pressures.



Hi-vac valve isolation technique.

An isolation check shown in the previous drawing that is more time-consuming is one that involves turning off the diffusion pump (allow it to cool). By appropriate valving, check the mechanical pump roughing capability in both the diffusion pump and chamber sections.

If the pressure is significantly higher on one side, that section may have a leak. (A contaminated TC gauge, particularly in the fore-line, may be the cause of a substantially higher reading in that section!)

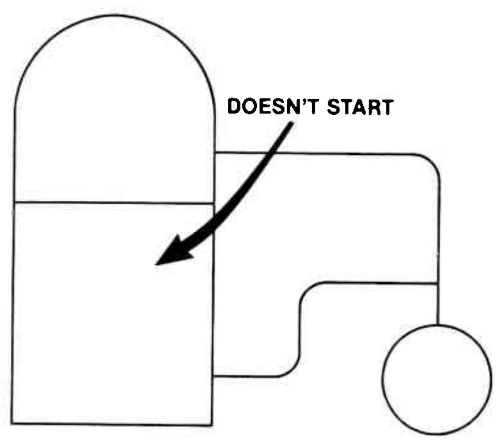
If both sections are high, the oil may be contaminated, so visually inspect again. A new change of oil may be indicated. Also, more extensive mechanical pump maintenance may be required.

Diffusion Pump

Next, let's consider the diffusion pump.

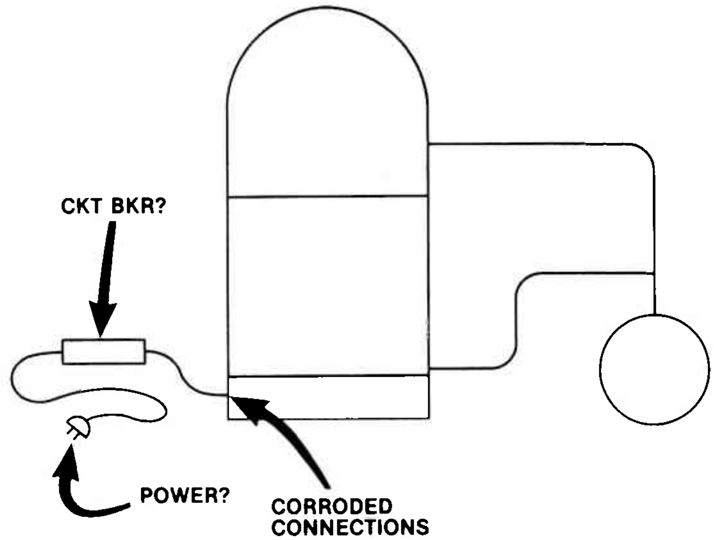
No Start-up

Again, let's start with the most obvious problems. For example, the pump doesn't start.



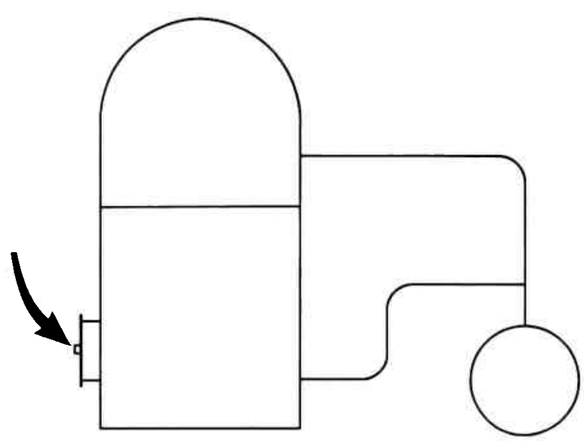
Main Input Power

Is the pump attached to a power source? How about open circuit breakers? Broken or loose connections are often sources of power failures.



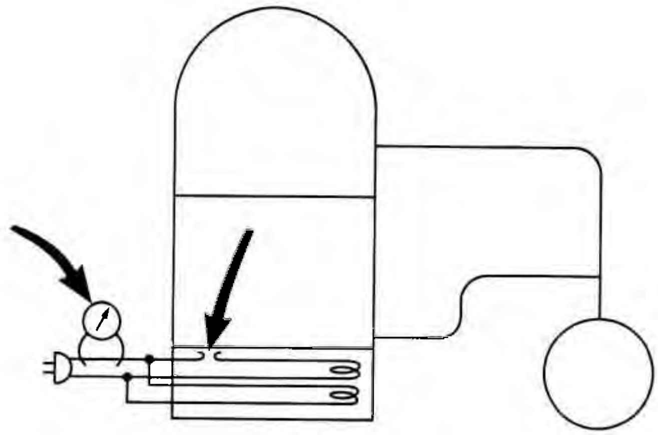
Thermal Protect Switch

The thermal protect switch may be open. Keep in mind that the protect switch may have opened for a very good reason. Therefore, before resetting it (providing the pump is thoroughly cold), check the fluid condition and level. If not thoroughly cool, it may even be a good idea to wait for cool-down to make these checks. Many pumps have a quick-cool water coil wrapped around the boiler to speed up the time required to cool the diffusion pump. Be sure to drain the quick-cool coil before starting the pump. Do not install a valve on the outlet of the quick-cool line. It should always have access to an open drain.



Heater

A burned-out heater in a single-element heater design will prevent pump warm-up. However, an element that burns out in a multiple-heater pump may not be so obvious. Reduced performance may cause one to look elsewhere for the source of the problem.



A clamp-on ammeter will establish whether the correct current level is being delivered to the pump. Although an ohmmeter resistance check might seem easier, particularly on single-element heaters, an ohmmeter check can overlook power-robbing, corroded terminals. Resistance is a poor indication of heater condition except for an open heater circuit.

Poor Base Pressure

Next, let's look at some of the problems that can result in poor base pressure in a diffusion pump system.