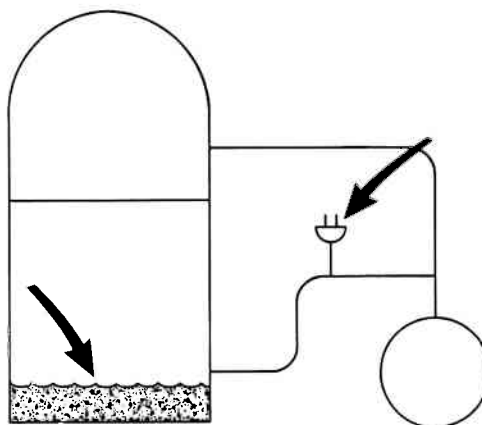


**Fluid Level**

The fluid level may be low. *Reminder:* Do not check the level while the pump is hot. Also, notice the color of the fluid (wipe dip stick on clean lint-free paper). If safe to do so (not on ion implanter systems or any vacuum system using toxic gases), smell the fluid. A burned smell or very dark-colored fluid indicates a need to clean the diffusion pump and replace the fluid. Always replace the fluid fill O-ring with a new one. It is located in a hot zone, and will have taken a set that will almost surely cause a leak if re-used. Use only the recommended O-ring material that can withstand the high temperatures at this location.

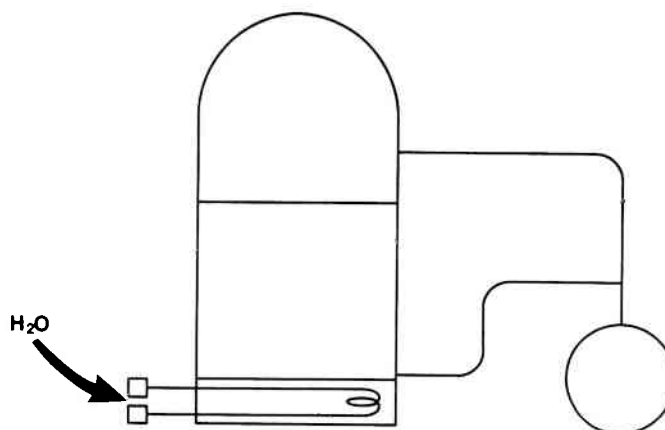
**Contaminated Fluid**

How about contaminated diffusion pump fluid? Besides affecting the ultimate pressure capability of the pump, this also sometimes shows up as a rapid pressure rise in the foreline when the foreline valve is closed, and before the vent valve is opened, particularly when severe contamination exists.

**Water in the Quick-Cool Coil**

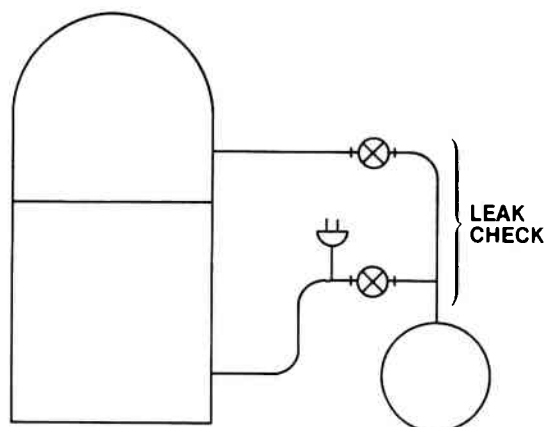
Water in the quick-cool coil? This problem might follow pump maintenance. If during maintenance, water was not drained from this coil, it could cause slow pumpdown until the water boiled away. (If there is no way for the resulting steam to escape, a

dangerous condition exists.) If water is left running, the pump will never warm up sufficiently. To minimize this problem, you could use compressed air or nitrogen to cool, rather than water. *Remember:* No valves on the outlet of the quick-cool coil. The line should always be open.



### **High Forepressure**

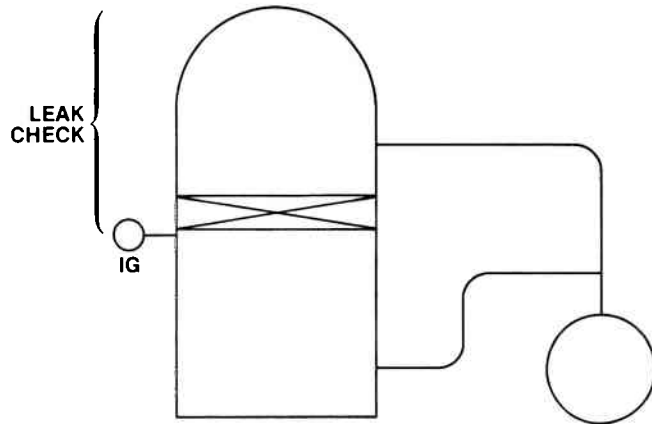
Excessively high forepressure can be caused by a problem in the mechanical pump. Also, it is a good idea to check the foreline area for leaks, as well as the entire roughing manifold. Don't forget that dirty mechanical pump oil can also cause high foreline pressure.



### **High Inlet Pressure**

This is, of course, a familiar enough problem, and it can be caused by a number of troubles. Again, the best approach is to

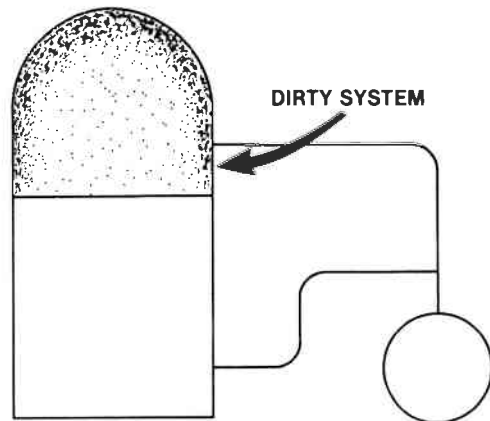
isolate the problem area from the rest of the system as much as possible. From that point, the obvious next approach is to leak-check both halves of the system.



However, the actual problem may not be so simple to solve. Leak checking is one approach to the problem; there are others. A good pressure reading below the closed high vacuum valve might eliminate that part of the system as a problem area.

#### **Contaminated System**

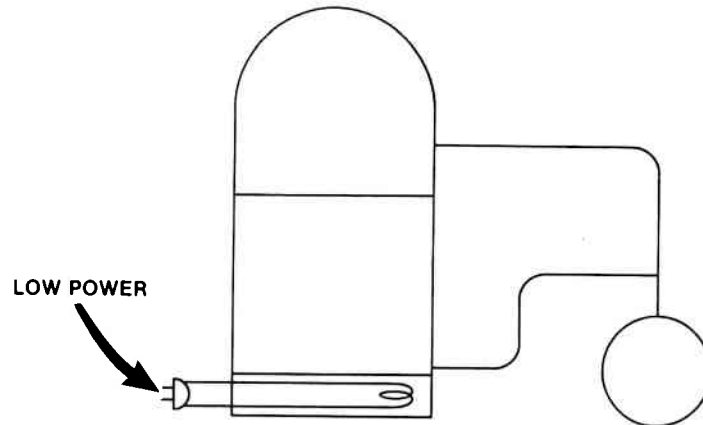
A number of things could be the cause of the problem above the high vacuum valve. For example, a symptom of a dirty system could be an inability to reach proper pressure. We have already discussed pumpdown curves and rate-of-rise curves. This information can be used to help guide us in our approach to the problem.



This doesn't mean that we always need to take exhaustive, time-consuming tests before we decide which approach to take. For example, a systems rate of rise need not be more than a simple "eye-ball check" taking no more than a few minutes. This information, together with a record of the cleaning schedule, can be a great help in determining the cause of a problem, particularly when it appears to be isolated to the upper half of the system.

**Low Power**

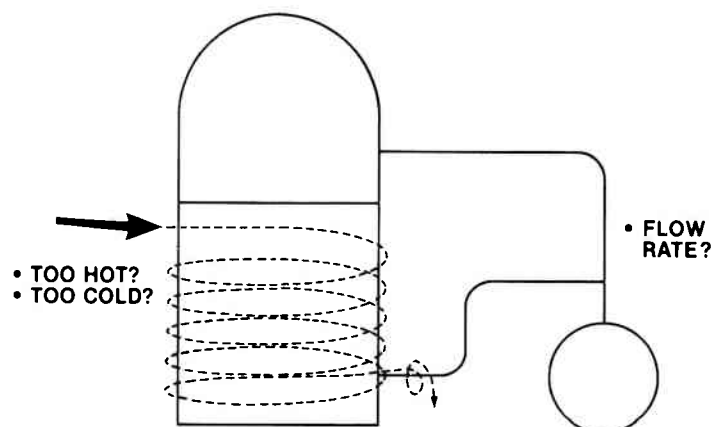
Poor base pressure performance isolated to the bottom half of the system can also have a number of causes. For example, low input power. A voltage check might quickly pinpoint the problem. A clamp-on ammeter check might give even better information. A single burned-out element in a multiple-element heater can be found with an ammeter. Also, inadequate heating due to corroded terminals can cause poor pump performance.



When replacing heating elements, be sure to tighten the elements, the clamps, and the crush plate to provide good intimate contact and good heat transfer. Also, make sure that the proper heating element is used. Check the voltage rating on the replacement element before installing it. If a crush plate is used, replace it with a new one when you replace the element. If wires or wire lugs must be replaced, they must be the nickel wire and lugs provided by the pump supplier.

**Water**

Diffusion pump cooling-water temperature and flow rate are important. If the pump cooling-water discharge temperature is too hot (above 130°F, 55°C), it is not performing its cooling function properly. On the other hand, when the water is too cold, the fluid may become very viscous and not return to the boiler fast enough.



Most modern industrial high-production systems are equipped with water flow-rate meters. These flow-rate meters are adequate for most situations. However, they do not answer all questions. For example, most diffusion pumps have water temperature range specifications. And, they have a flow-rate specification.

The best water check, however, is made at the output on the foreline. The output water temperature should range between 110°F and 130°F (45°C and 55°C). If it is not within the proper temperature range at the output, it is not doing a proper job.

### **Random Pressure Spikes**

Poor pumping performance can be caused by a low fluid level. This may show up as slow pumpdown and poor base pressure. Look for random pressure spikes as a further clue to this condition; there may not be enough oil in the reservoir to supply a steady stream of oil out of the jets. The low fluid level may cause poor heat transfer, which in turn may cause overheating and uneven boiling. Random pressure spikes can also be caused by leaky O-rings in the fill-drain tube.

### **Slow Pumpdown Following Cleaning**

Slow pumpdown following cleaning is to be expected. This is due to a number of factors. Residues of the solvents used for cleaning the equipment will outgas for a period of time. Even with the best of vacuum practice, human oils will contribute to the vacuum environment; even lint-free gloves cannot completely eliminate body oil contamination. Finger cots only protect against the oils produced by the finger tips (not the rest of the hands).

Excessively long pumpdown periods also might be due to incomplete cleaning, incomplete rinsing, and incomplete drying. Pay special attention to grooves such as O-ring grooves and leak-check grooves. Even the mechanical pump and diffusion pump fluids which are used to produce the vacuum require a period of time to outgas.

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Let's go on now to look at vacuum system problems. Note that by changing the words from diffusion pump to cryopump or turbo pump, we find that many of the comments here also apply quite well to other types of vacuum systems.

# The Vacuum System

The next category of problems we will consider relates to the entire system. We will also suggest some ways to help with troubleshooting.

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## Record and Monitor Performance

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A record of normal system performance will establish a basis for comparison against abnormal performance. Abrupt changes from normal are immediately apparent; gradual changes indicate a need for routine maintenance such as cleaning.

As indicated earlier, pumpdown and rate-of-rise curves can be very valuable. When a problem occurs, compare the curves with those previously taken when the system was working normally. We have already discussed how these curves can be used to distinguish between the types of problems.

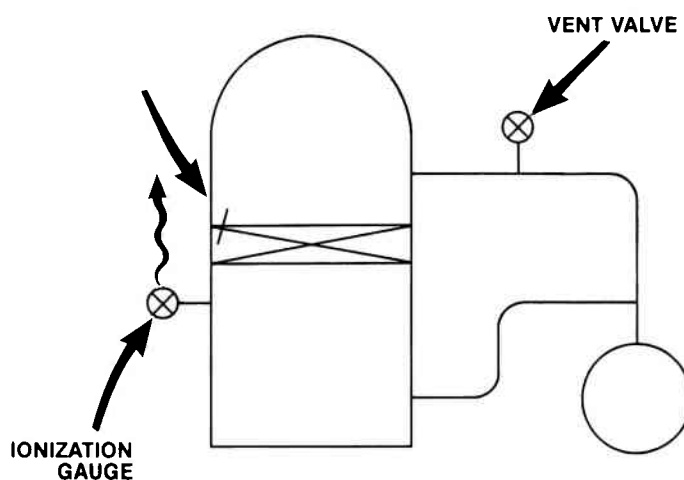
Here's another use for these performance curves. When a problem is definitely indicated, try pumping down twice. Pump down to some low point and record the remainder of the pumpdown from that point. Call this portion of the pumpdown T1. Valve off the suspected portion of the system, allowing the pressure to rise naturally to the point where the period T1 started. Then valve in that portion of the system again and pump down again.

How long did the second pumpdown take? If time T2 is approximately equal to time T1, this would indicate that the problem might be due to an air leak. This is because the source of gas is constant, indicating an unvarying physical leak.

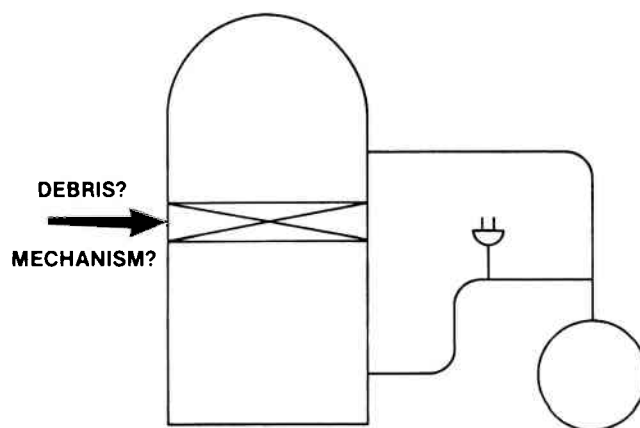
If the test resulted in time T2 being about one-third to one-fifth the pumpdown period of time T1, then this is probably indicative of a virtual leak or an outgassing problem. The reason for this is that during the first pumpdown period, much of the gas load, including the virtual leak and outgassing, was removed. Then, during the second pumpdown, the pump didn't have as large a load to handle, and therefore was able to pumpdown considerably faster.

A similar test using “rate-of-pressure rise” can be done in conjunction with the pumpdown test. If the timed rise in pressure after a volume has been isolated is always the same, an air leak probably exists. If the time for the pressure to rise the same amount becomes longer for each subsequent test, outgassing or a virtual leak is indicated.

## High Vacuum Valve Sealing Problems



If the pressure goes up (indicated on the ion gauge below the high vacuum valve, if you have one) when the system is vented, this is an indication of a high vacuum valve sealing problem. The pressure should not rise even slightly. There could be dirt, debris, hair on the seal, improper adjustment of the high vacuum valve, or insufficient sealing pressure. The foreline TC gauge can also be used for making this check; however, it is not as sensitive as an ion gauge below the high vacuum valve.



After checking for seal problems, check for sealing mechanism problems. Pump the chamber to around 1,000 mtorr. (The high vacuum valve, of course, is still closed.) Now, if the pressure in the gauge below the high vacuum valve or the foreline TC gauge pressure goes down, a sealing mechanism problem is indicated. The reason is that the reduced pressure above the high vacuum valve now allows the sealing mechanism to affect a proper seal. Caution! This check, like many others, is not necessarily 100% perfect. However, it is included here as an aid in solving system problems.

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## Problems After Cleaning

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After a major system disassembly for cleaning or other maintenance work, do not attempt to pump the system to high vacuum immediately. Instead, use the roughing pump to pump the entire system with the diffusion pump off. Monitor the pressure to check for outgassing and/or leaks. Remember that long-term roughing may allow oil vapors to enter your newly cleaned system!

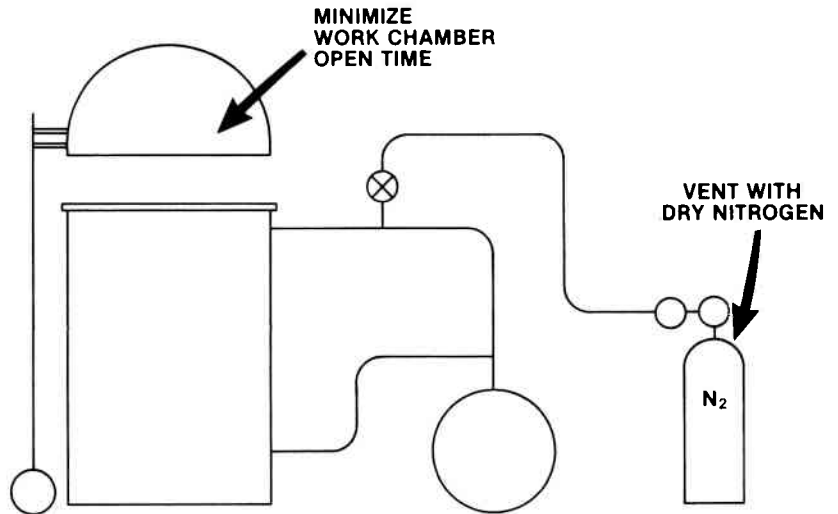
During system reassembly, an O-ring could have worked loose or twisted in its groove, causing a gross leak. If the diffusion pump were to be turned on under this condition, the entire purpose of cleaning the system could easily be defeated. What's more, the diffusion pump fluid could be ruined.

Instead, if the roughing pump cannot evacuate the system, the problem is indicated without risk to the diffusion pump. However, keep in mind that there should be an allowance for outgassing. Residual solvents, fingerprints, and the pump oils themselves must be given a reasonable outgassing period.

## General Tips

Now let's consider a few ideas that will help to minimize problems before they begin.

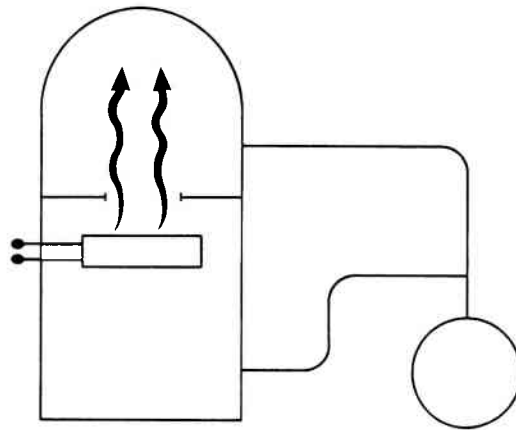
### Minimize Work Chamber Open Time



The time that the work chamber is left open and up to atmosphere should be reduced as much as possible. Five minutes is not unreasonable. When many work pieces are processed per cycle, they generally are mounted on fixtures of some kind. By having spare work-piece holders on hand, it is possible to greatly reduce the chamber open time.

It is also becoming common practice in high-production vacuum processing systems to vent the work chamber to a dry gas, usually nitrogen, instead of exposing the work chamber to atmospheric air (which, of course, contains water vapor). When possible, also store loaded fixtures in a dry nitrogen atmosphere.

### Keep Cryotrap Filled



The liquid nitrogen trap should never be allowed to go dry while the high vacuum valve is open. This is sometimes mistakenly practiced on weekends when the system is on standby. However, as the LN<sub>2</sub> trap warms up, it releases all the trapped gases, particularly water vapor, that it had captured during the work week. A significant amount of water vapor and other contaminants are then free to go back into the work chamber.

### Rough Below Normal

When a subtle, difficult-to-define problem exists, it may pay to try roughing to well below the normal crossover point. This is because if a small leak exists, it is possible for the combined action of the diffusion pump and the mechanical pump to disguise the situation. Now if the mechanical pump is unable to pump the chamber down, the problem area might be somewhat more clarified.

However, it should be kept in mind that a number of factors might cloud the issue. The mechanical pump itself may not have the capacity to reduce the chamber pressure very far below the normal crossover point. Its oil may be slightly contaminated. The roughing lines might be conductance-limited. The chamber walls might be severely contaminated. (Make a visual inspection.) When roughing below normal, be sure to trap the mechanical pump!

### Check Plant Air Pressure

What is the air pressure in the line for the pneumatically-actuated valves? A common enough problem occurs when the plant facility air pressure is not high enough to do the job. Watch out for dirt and water in the house or shop air lines. Use and maintain air line filters and traps.

Note also that a given utility, although adequate as originally designed, may not be able to keep up with the demand of increased work loads.