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Tips, Tools for Pulling An Effective Vacuum

Knowing how vacuum tools and equipment work and their advantages can help technicians properly and safely apply them when evacuating refrigerant from a system

BY BILL WEST

It is important to understand what vacuum is and how it is measured in order to correctly apply it in the hvacr industry. The dictionary defines vacuum as "a space with nothing in it." In the real world there is no such place because molecules of various elements are everywhere. It is the density of these molecules within an enclosed space that we measure as pressure.

For our purposes, a vacuum is a space where the density of molecules is less than that of the earth's atmosphere. In other words, a space with a vacuum has less than atmospheric pressure.

The inventor of the mercury barometer, Evangelista Torricelli, first measured atmospheric pressure in 1643. A long glass tube with one sealed end was filled and then inverted in a bath of mercury.

Torricelli found that at sea level the earth's atmosphere exerts enough force to support a column of mercury 760 millimeters (29.921 inches) high at a temperature of 32° F. The resulting empty space at the top of the tube was a (nearly) total vacuum.

The unit of measurement for vacuum was named for the inventor, and one atmosphere of pressure is now referred to as 760 Torr, a measurement of absolute pressure. If it were possible to achieve a vacuum of zero Torr, we would have a perfect vacuum or zero absolute pressure.

When vacuum is measured in inches of mercury it must be remembered that atmospheric pressure (gauge pressure) is the starting point and that the gauge readings are negative numbers. Thus, -29.921 inches Hg is a perfect vacuum. It is not practical to measure a deep vacuum (low absolute pressure) in inches of mercury because the units are so large; it is measured in microns. There are 1,000 microns in a millimeter (Torr) and 25,400 microns in 1 inch of mercury, so the use of this unit makes the measurement of deep vacuum much more precise.

Applying vacuum to hvacr

Refrigeration and air-conditioning equipment must properly be evacuated prior to charging to prevent unwanted molecules — primarily water vapor — from damaging the system. Moisture in a system can cause freeze-ups in capillary tubing and expansion valves. The natural tendency of moisture to cause corrosion is multiplied when it reacts with certain refrigerants and forms hydrochloric or hydrofluoric acid.

Refrigeration oils — especially the newer POE and PAG oils — absorb moisture, and the combination forms what is commonly referred to as sludge. The most practical method for removing these molecules is to connect a high vacuum pump to the system and reduce the absolute internal pressure (vacuum) to less than 1,000 microns. Reducing the pressure lowers the boiling point of water vapor so it can be removed from the system at temperatures below 32° F.

If a system is wet, reaching this pressure may take quite some time and require several changes of pump oil due to water vapor contamination. After evacuating, the system must be isolated and the pressure must be maintained at less than 2,000 microns for a reasonable length of time. This ensures that there are no leaks or significant contamination present. Either of these conditions may result in premature system failure and a warranty service call.

Understanding the way molecules behave in a vacuum explains why they are so difficult to remove. Molecules in a vacuum do not flow through hoses and orifices the way that they do under positive pressure. At near-atmospheric pressure the molecules flow in much the same way they do at positive pressures.

As the pressure is reduced the distance between molecules increases until, in a deep vacuum, the molecules recoil off of the surfaces at odd angles, eventually making their way through the vacuum pump. At pressures below 2,000 microns most of the molecules are attached to the surface in layers. It may require some time for them to detach from the surfaces and make their way to the pump.

Knowledge of the limitations of the gauges available is necessary in order to choose the proper gauge to produce an intended result

When a system is isolated from the vacuum pump, the molecules continue to detach from the surfaces and start to bounce around in the void left by the molecules that were removed. This results in an increase in pressure (rise in the micron reading). A fast rate of rise must be interpreted as either a leak or as a contaminant (usually moisture) in the system.

If a leak is suspected, find the leak using standard leak detection equipment and procedures and fix it. If moisture in the system is suspected, continue to evacuate and isolate and recheck to see if the system will maintain the vacuum. Continue to evacuate until readings are acceptable.

Types of gauges

Various types of gauges are used to measure vacuum at different ranges and each type has its place in the hvacr industry. Common sense dictates that a tape measure should not be used to measure highly accurate machined parts, and a micrometer should not be used to measure a football field.

Mechanical dial gauges are used for rough measurements of pressure while evacuating refrigerant from a system.

That same logic tells us that a dial gauge should not be used for measuring deep vacuum and an electronic vacuum gauge should not be used for measurements near atmospheric pressure. Knowledge of the limitations of the gauges available is necessary in order to choose the proper gauge to produce an intended result. The following is a list of gauges and their advantages and disadvantages:

- **Mercury barometers:** These are fragile instruments containing a hazardous substance. Their use has been discouraged and mostly discontinued for this reason. With the exception of some very sophisticated laboratory gauges such as the McLeod gauge, they do not have the accuracy required for the measurement of pressures below 1,000 microns.
- **Mechanical dial gauges:** These are useful for rough measurements of vacuum only. The accuracy of compound dial gauges on charging manifolds used by refrigeration technicians is at best +/-1 percent of the full-scale reading.

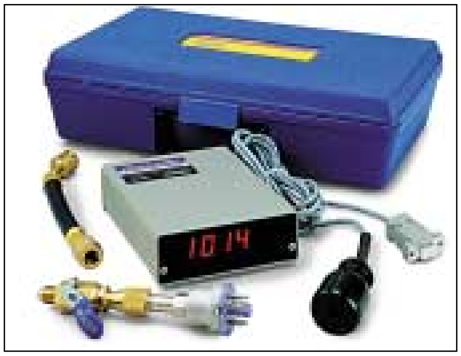
On a low-side gauge with a maximum pressure of 120 psi this translates to an accuracy of +/-1.2 psi or 62,000 microns. Even when using a large dial gauge that is graduated for vacuum only, +/-1 percent accuracy would be accurate only to +/-7,600 microns.

- **Electronic pressure transducers:** These rely on the deflection of a metal diaphragm as it acts on a piezoelectric crystal to produce a signal that is proportional to the pressure acting on it. With the exception of the extremely expensive capacitance manometer, vacuum transducers also tend to have limited accuracy due to the lack of sensitivity.

Constant current or voltage is applied to thermistor-style electronic vacuum gauges, like the one pictured above, while evacuating refrigerant.

- **Barometers, mechanical gauges and transducers:** These measure pressure that directly acts on the sensing device, which then registers a change in the reading. At pressures of less than 1,000 microns the density of molecules is quite low and not enough force is exerted on the sensing device to cause mechanical elements to respond. What is needed at this low pressure is a method to indirectly measure the density of molecules, and this is exactly what electronic vacuum gauges are designed to do.
- **Electronic vacuum gauges:** Most of these gauges available to the refrigeration trade operate on the principle of thermal conductivity. The short explanation is this: when an ele-

ment within an enclosed housing is heated, molecules that collide with the element carry the heat away to the sensor housing. The absolute pressure (vacuum) can be determined from the rate of heat loss. Thermal conductivity gauges generally are either thermistor gauges or thermocouple gauges.


The response of a thermocouple gauge like the plug-in style gauge above is extremely quick.

• **Thermistors:** They are thermally-sensitive resistors. Either a constant current or a constant voltage is applied to the thermistor. As heat is removed, the resistance of the heated element changes and this change is relayed to the user as a reading – usually in microns. In the past these gauges required the user to manually adjust the unit to compensate for ambient temperature.

Modern thermistor gauges use two thermistors, one of which helps to compensate for ambient temperature changes. It is important to note that thermistors have a surface area hundreds of times greater than a thermocouple gauge filament, resulting in a corresponding increase in response time and decrease in accuracy compared to a thermocouple gauge.


A battery-powered thermocouple gauge is connected to an air-conditioning system to ensure proper refrigerant evacuation.

• **Thermocouple gauges:** They have a thin wire filament with a tiny thermocouple junction welded to it. These wires are a fraction of the diameter of a human hair. The temperature of the heated filament is measured by the thermocouple, and this value corresponds to a pressure that is displayed in microns. Because the filament is so thin, the gauge response is extremely fast, and no compensation for ambient temperature is necessary. Automated assembly techniques will produce sensors with very consistent characteristics, so they usually can be interchanged without recalibrating the instrument.

A type of electronic gauge that does not rely on thermal conductivity uses a quartz crystal that is electrically stimulated to oscillate at a given frequency. The frequency changes that occur as molecules are removed from the environment is monitored and then displayed as an indication of pressure.


A vacuum pump is connected to an air-conditioning system during refrigerant evacuation. Both a mechanical-dial and thermocouple-style gauge are used together to optimize measurement accuracy.

• **Thermal conductivity gauges:** These tend to be less accurate at pressures greater than 25,000 microns, although still useful for giving a rough indication of the evacuation process. As pressures fall below 5,000 microns, the electronic vacuum gauge is the only suitable instrument available that will give an accurate indication of the vacuum inside a system.

Do it right the first time

Doing the job right the first time always is more cost-effective than doing the job quickly. When a contractor must send a service technician back for a warranty repair, in addition to eroding customer confidence, it is a triple loss of revenue.

The first loss is incurred because the return service call is not billable. The second loss is the replacement cost of the equipment that failed due to improper installation. The third loss is due to the technician not being available for profitable calls during this time.

In summary, an electronic vacuum gauge is the only tool that can verify that a system has been properly evacuated before recharging it with refrigerant. And a thorough evacuation is one of the best ways to protect your profits against needless warranty repairs.◆

Bill West is vacuum products engineer for Ritchie Engineering Co.

Evacuation Tips

- A vacuum pump is NOT for refrigerant recovery. It is for removing water vapor (moisture) from a system before charging. Connecting a vacuum pump to a pressurized line can damage the pump and vent refrigerant to the atmosphere – which is against the law.
- A properly evacuated system must be at 2500 microns or less – impossible to detect without an electronic vacuum gauge. (69060, 69070, 69075 etc.)
- Micron gauges (electronic vacuum gauges) should be connected directly to the system – not at the pump – to check the vacuum at the system. Use a Vacuum/Charge valve (18975, 18990 or similar) to put the sensor directly on system port.
- Stainless steel hoses are the best for vacuum because they have no permeation, and do not outgas. Copper tubing is also excellent but lacks flexibility.
- Look for frost on the outside of the system – especially at control devices – during evacuation. This indicates that ice has formed *inside* the system. Use a heat gun (69092) to thaw these spots.

To reduce evacuation time:

- Use the correct size pump (see system size chart).
- Use clean YELLOWJACKET™ vacuum pump oil. Frequent oil changes are a must for optimal performance. White (milky) oil is saturated with water, limiting the pump's ability to remove moisture.
- Remove valve cores from the access fittings with a Vacuum/Charge Valve (18975, 18990). This will reduce the evacuation time by at least 20%.
- Evacuate both the high and low sides at the same time.
- Use short, large diameter hoses. YELLOWJACKET SuperEvac™ Systems (93865, 93875, 93885) can reduce the evacuation time by over 70%.
- Heating the system with a 69092 Heat Gun helps the molecules move to the pump much faster. It will also help achieve a better more complete vacuum.

Selecting a vacuum pump

- Size does matter. These guidelines have proven to be helpful:

System Size (tons) automotive and domestic refrigeration	Minimum Pump CFM
1 – 10	1.5
10 – 15	2
15 – 30	4
30 – 45	6
45 – 60	8
60 – 90	10
90 – 130	18
Over 130	24

- Choose a pump rated at 15 microns (or less) at normal operating temperature to pull a deeper vacuum more quickly.
- A large inlet allows you to connect large diameter hoses – a "must" for fast evacuation times.
- A large oil capacity allows the pump to remove more moisture and contaminates from the system between oil changes.
- A large sight glass allows you to monitor the oil level and condition easily.
- Rugged construction allows your pump to provide reliable service for years of use.
- Availability of accessories such as inlet manifolds and exhaust filters allow versatility for your specific needs.
- You depend on your tools. buy them from a manufacturer with a reputation for high quality.

Microns – absolute pressure (.001 millimeters of mercury)	Vacuum (inches of mercury below ATM)	Boiling point of water in degrees Fahrenheit)
760000	0	212
500000	10.24	192
200000	22.05	152
100000	25.98	125
50000	27.95	101
30000	28.74	84
20000	29.13	72
15000	29.33	63
10000	29.53	52
8000	29.69	39
4000	29.76	29
2000	29.84	15
1000	29.88	1
500	29.90	-12
300	29.91	-21
200	29.91	-28
150	29.92	-33
100	29.92	-40
50	29.92	-50
0	29.921	-90

(25,000 microns = 1" Hg)

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