System evacuation — fundamentals of dehydrating a refrigeration system (part two)

In last month's skills workshop, HVAC&R Nation examined the problems caused by moisture in refrigeration systems, the effects of pressure and the need for system evacuation to remove moisture.

This month, we look at how to select a vacuum pump and use it to evacuate a system.

Selecting high vacuum pumps

To make the following discussion easier to understand, it would be best from this point on to think of pressure (kPa) as the amount of mercury it will support. Eg: atmospheric pressure at 759.968mm Hg instead of 103.3kPa. This will permit us to use Chart 2 as a visual aid when determining the vacuum which must be attained to boil water under various ambient temperatures.

Chart 2 shows a vacuum pump capable of eliminating all but 25.4 millimetres of mercury. It is able to remove moisture at an ambient temperature of 27°C or over. While any pump pulling within one inch of atmospheric pressure can eliminate moisture, it must also be capable of holding that vacuum throughout the dehydration process. In addition, it must pull that vacuum on the entire system and not simply at the intake of the pump.

Before considering the variables affecting a high vacuum pump's performance, we should first review some general classifications of vacuum pumps relative to their ability to remove moisture by the boiling process.

Vacuum pumps – air compressor type

Air compressors were designed to remove large volumes of air rather than to remove all but a small amount of pressure. This type of vacuum pump will not eliminate any moisture by the boiling method. At best, it cannot pull more than 711.2 millimeters of mercury and consequently should not be considered suitable for high vacuum work.

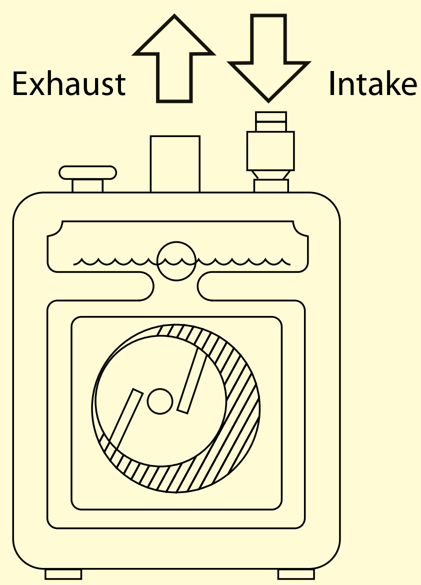
Vacuum pumps – compressor type

For clarification, compressor type vacuum pumps should be separated into two categories: piston type and rotary vane type. Under ideal conditions, a piston type compressor might pull a vacuum of 736.6mm of mercury which will boil water at an ambient temperature of 27°C or over. But it is questionable whether or not it can hold this vacuum once moisture condenses into its oil. Quite a number of these vacuum pumps have been sold as evacuators and are used in conjunction with a true high vacuum pump. By themselves, they cannot remove moisture by the boiling method under normal ambient conditions.

A rotary-type compressor can pull a vacuum as high as 752.60mm. This vacuum will remove moisture by the boiling method, however, because of their limited litres/minute capacity, these pumps should be limited to refrigerator and freezer service work. They are also used in the automotive air conditioning service field.

High vacuum pumps – single stage

Single stage high vacuum pumps are desirable for several reasons. First, they are almost always smaller and lighter in weight than two stage pumps of equal capacity in L/min. Second, single stage pumps are generally less expensive than two stage pumps. These advantages make single stage pumps a good choice for students and technicians just beginning refrigeration/air conditioning service work. A single stage high vacuum pump is also a good choice for a second pump among more experienced servicemen.



Single stage vacuum pump

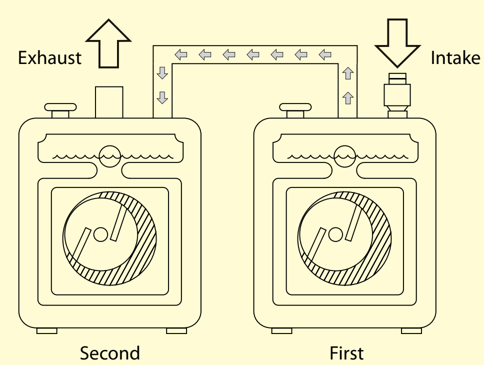
There are single stage vacuum pumps available which can pull down to about 50 microns under ideal laboratory conditions. Single stage pumps discharge directly into the atmosphere, and due to the higher discharge pressure, higher vacuums are not possible at the intake of the pump. A gas ballast feature will help single stage pumps to keep the oil free of moisture and other contaminants for a longer period of time than similar units without. Most single stage pumps with the gas ballast open will pull down to about 1000 microns. There are however, single stage pumps with the gas ballast and high internal temperatures that reduce oil contamination and are therefore able to pull a system to a respectable micron level for most service applications.

High vacuum pumps – two stage

The majority of refrigeration/air conditioning service technicians use a two stage high vacuum pump for the bulk of their service jobs. A two stage pump is usually larger and weighs a little more than a single stage pump of equal l/min capacity.

A two stage pump features a second pumping chamber to enable the pump to reach a higher ultimate vacuum than a single stage model. In a two stage pump, the exhaust of the first pumping stage is discharged into the intake of the second pumping stage, rather than to atmospheric pressure.

The second stage begins pumping at a lower pressure and therefore pulls a higher vacuum on the system than the first stage is capable of on its own.



Two stage vacuum pump

Compound two stage vacuum pumps are capable of pulling down to an extremely high vacuum such as one micron. While they will seldom pull down to this point under field conditions, two stage high vacuum pumps can continuously pull down to 20 microns for prolonged periods of time. For this reason a two stage high vacuum pump is well suited for refrigeration/air conditioning service.

The higher ultimate vacuum capability of a two stage vacuum pump will help to ensure that all moisture and noncondensables are removed from a system. It is important to achieve the highest vacuum possible before recharging a system with refrigerant.

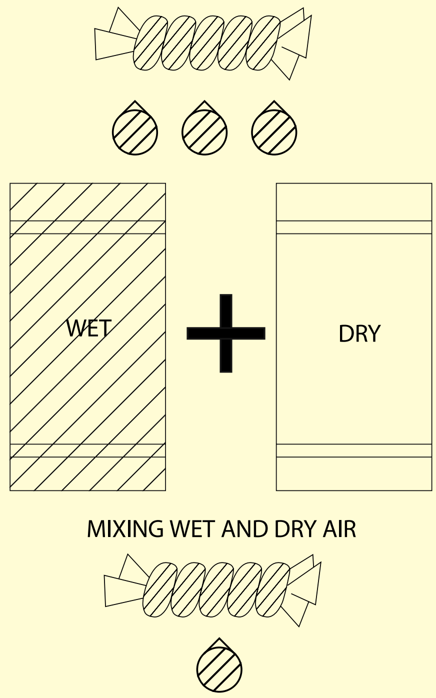
Gas ballast or vented exhaust

The gas ballast or vented exhaust feature is a valving arrangement which permits relatively dry air from the atmosphere to enter the second stage of the pump. This air reduces the compression in the final stage, which helps to prevent the moisture from condensing into a liquid and mixing with the vacuum pump oil.

This may sound complex, but actually it is relatively simple. A comparison should help explain it. Imagine a damp towel being twisted until water drops out. This can be compared to a high vacuum pump which is not equipped with a gas ballast.

Moisture being pulled from a wet refrigerant system is compressed internally in the vacuum pump and condenses into a liquid. Now imagine that same damp towel entwined with a dry towel and then twisted. It would take a considerable amount of twisting before any water would drop out. Thus the process of the gas ballast arrangement. It permits the moisture laden air passing through the pump to mix with relatively dry air to such a degree that compression does not cause condensation.

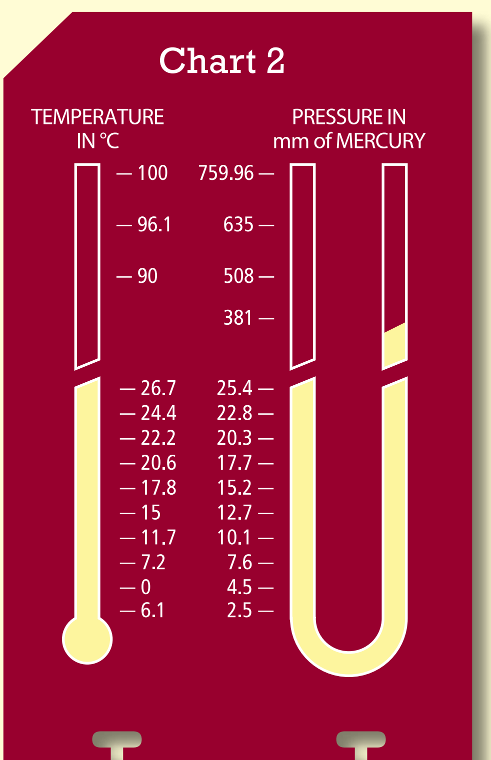
The damp towel comparison also illustrates why this valving feature cannot handle large amounts of moisture. If the towel is almost saturated with water, even the introduction of the completely



dry towel will not prevent some of the water from dropping out when the two are compressed. Because of this, some pumps are designed to run with both high internal temperatures (to reduce moisture condensation in the oil) and a gas ballast.

Due to the 'severe' application of a vacuum pump when used to 'boil water', it is necessary to select a quality two stage model equipped with gas ballast and high internal running temperatures to achieve adequate performance over a long period of time. It should be emphasised, however, that even with the best pump available, regular maintenance has to be performed.

Frequent oil changes should be anticipated and considered as the single most important factor in a preventative maintenance program. As stated previously, even a pump equipped with gas ballast cannot handle large amounts of moisture without some being condensed into the oil. If allowed to remain inside the pump, this moisture will attack the metal components and result in lock ups or loss of efficiency and/or capacity. Normally, oil changes will not be required during a single dehydration job. But it would be well to change oil after each major pump down. This is especially critical when pumping down a system known to be wet or the result of a compressor burn-out.



Factors affecting the speed at which a pump can dehydrate a refrigerant system

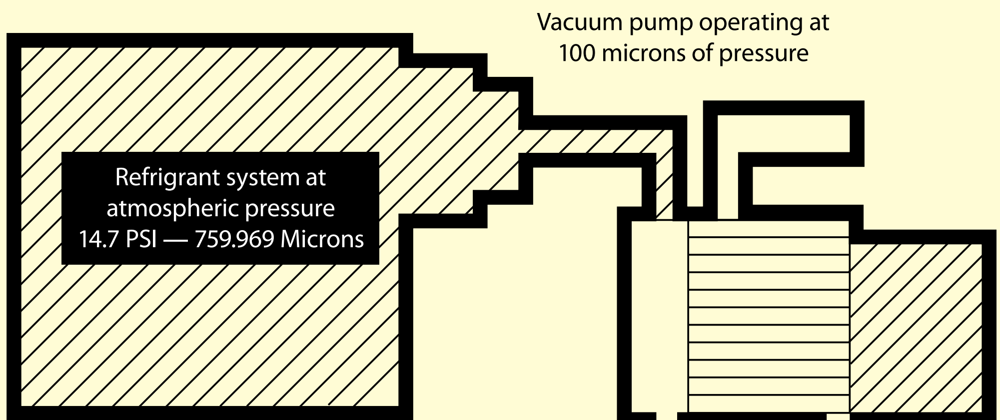
Several factors influence the 'pumping speed' of a high vacuum pump, and thus the time required to remove all moisture from a refrigerant system. Some of the most important are: the cubic capacity of the system itself; the amount of moisture (both visible and invisible) contained within the system; the ambient temperature present; internal restrictions within the system; external restrictions between the system and the vacuum source; and the size of the pump.

The original equipment manufacturers determine the cubic capacity of the system and the internal restrictions. Malfunctions and inefficiencies result from the presence of moisture. And Mother Nature controls the ambient temperature of the day. Consequently, the only factors under the control of the service technician are the external restrictions between the system and the vacuum pump. Nevertheless, this one factor is very important and warrants more discussion.

Let us assume that all other variable factors affecting pump down time are equal. Also for the sake of simplicity, we shall use the illustration above to show a pump hookup to a system.

Vacuum pump hookup

Within a system, variable pressures attempt to equalise one another. In this equalisation, the higher pressure 'flows' toward the lower pressure. The above hypothetical illustration shows variable pressure creating a vacuum of 100 microns and the system at atmospheric pressure. The higher



Vacuum pump hookup

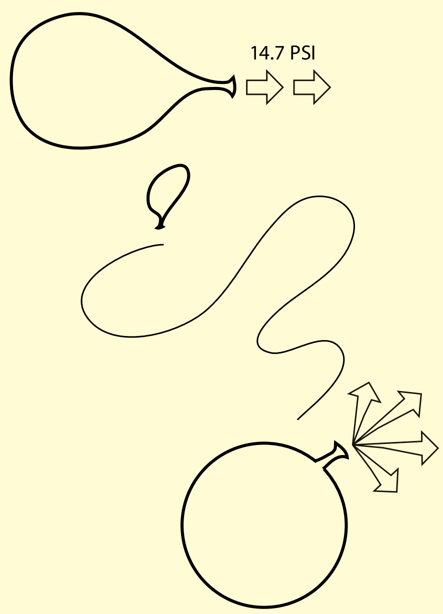
Higher pressure moves towards lower pressure

PULLOUT

pressure in the system will flow toward the vacuum pump until it is reduced or equal to the 100 microns of pressure. The speed at which it will flow is controlled by the inside diameter and length of the connecting line.

Laboratory tests show that pump-down time can be significantly reduced by use of larger diameter hoses. For optimum pumping speed, keep access lines as short in length and as large in diameter as possible.

All of us have released an inflated balloon, allowing the escaping air pressure to propel it on a wild course. At other times you have inflated a balloon and stretched its stem, allowing the air to escape with a squealing sound. You controlled the pitch of the squeal and its duration with the amount of stretch on the stem.



Higher pressure moves towards lower pressure

Atmospheric pressure and boiling points

Water boils at different temperatures depending on atmospheric pressure. Here's some examples:

Boiling temperature (°C)	Atmospheric pressure (kPa)
100	101.325
50	12.327
30	4.233
15	1.696
0	0.606
-31.1	0.033

In effect, you were controlling the connecting inside diameter as in the above illustration and, in turn, controlling the time it took to release all of its pressure.

The principal is identical: the higher pressure is trying to move toward the lower pressure.

The illustrations stress the importance of eliminating all external restrictions whenever possible. It is realised that this is almost impossible because of the size of valves, manifolds and lines commonly used in our industry today.

It is perfectly acceptable to use a 118 litres/minute or larger vacuum pump on small systems. Using too small a pump on a large system. Eg: a 35 L/min vacuum pump on a 140 kW unit could cause the pump to operate in 'free air' condition for an extended period of time, thus risking premature pump wear.

When determining the size of pump needed, use the formula:

$$\text{Pump capacity in litres/min} = \frac{\text{Max. System Size (kW)}}{\text{Factor 1.15}}$$

For example: a 118 Litres/min vacuum pump, when applied to the formula:

$$\frac{118 \text{ litres/min}}{1.15} = 102.6 \text{ kW Maximum system size}$$

On systems larger than the pump's capacity, it is recommended to use either a larger pump or two or more pumps to achieve the correct pump rate.

Size of pump

Chart 3 will give you a reasonable idea of what capacity pump you need for various applications. These are suggested minimum litres/min. Larger capacity high vacuum pumps can easily be used on smaller systems.

How vacuum can be measured

In the refrigeration industry, vacuum is measured with a standard compound gauge, closed end manometer or an electronic thermistor vacuum gauge. Keeping in mind that it is a vacuum and its relationship to the boiling points of water we are attempting to measure, we can refer back to Chart 1 to see the relationship between pressure in terms of millimetres of Hg, and microns.

A standard Bourdon tube compound gauge is a rugged type designed to read low pressures in inches of vacuum. It is suitable for reading vacuums. Eg: -kPa. However, it cannot be expected to read millimetres or microns and because of this, is not suitable for use with high vacuum pumps.

A closed end U tube mercury manometer can be read with good accuracy in millimeters. With one millimeter equal to 1000 microns, it is possible to read 500 microns with this gauge. It is however a fairly delicate instrument, making it more suitable for laboratory or shop work rather than for field service.

Electronic thermistor vacuum gauges are specifically designed for use with high vacuum pumps and can be accurately read as low as 1 micron. Through the use of a sensing tube mounted at some point in the vacuum line, an electronic circuit provides an output calibrated in microns. This output can be an analogue meter scale, a digital display or LED sequence display. One positive effect from a thermistor gauge is that the tube reads total vapour pressure as a unction of the thermal conductivity of a gas. It is sensitive to water vapour and other condensables and can give a good indication of the actual vacuum level within a system. A thermistor vacuum gauge is considered essential as a companion instrument for high vacuum dehydration of a refrigerant system. Although developed as a laboratory instrument, there are electronic thermistor vacuum gauges on the market that are rugged and reliable enough for field service work.

When reading vacuum, you should remember that the location of the vacuum gauge tube will affect the reading. The closer to the vacuum source, the lower will be the reading.

When reading the vacuum created in a refrigeration system, you should isolate the vacuum pump with a good vacuum valve and allow the pressure in the system to equalise before taking a final reading.

If the pressure will not equalise, it is an indication of a leak. If it does equalise at a pressure which is too high, it is an indication of moisture and more pumping time is required. ▲

Chart 3

System size	Suggested high vacuum pump size
Up to 30kW	35 L/min
Up to 75kW	85 L/min
Up to 123kW	140 L/min
Up to 246kW	280 L/min
Up to 370kW	425 L/min

Thanks to Actrol for supplying the material for this skills workshop