The HVACR Training Authority

EVACUATION OF A REFRIGERATION SYSTEM

By: Revised by Earl Rader, CM, RSES Educational and Examining Board

INTRODUCTION

The service technician must thoroughly understand the use of vacuum as a service “tool” to properly prepare a refrigeration or cooling system to receive its charge of refrigerant.

The purpose of this section is to cover this subject on a practical basis. The various sizes and types of vacuum pumps used in our field and shop service will be reviewed, followed by a brief discussion of the fundamentals of vacuum. Armed with this basic knowledge you can easily follow the discussion of the methods required today to adequately dehydrate and remove the destructive contaminants from a system to meet modern specifications, as well as the use of the proper type of deep precision vacuum gauge.

This complete text will specifically reveal the economy and fundamentals involved in using a deep vacuum pump to remove the moisture and air from a cooling system.

Why should service engineers and the refrigeration, air conditioning, and heat pump manufacturing companies be so concerned about deep evacuation? Because it is the key to an efficiently operating system. It is the answer for a well designed system, properly used and serviced, to have a long, trouble-free life span.

Hermetic and semi-hermetic systems are the most vulnerable to poor evacuation methods due to the internal electric motor. There are those who feel sweeping a system with refrigerant and installing driers is the answer. There are those who feel evacuation is the only answer. Either way, the theory is only partially correct. It takes deep vacuum and driers in the system to protect it. All other gases in a system reduce the operating efficiency. The halogenated refrigerants are some of the finest cleaning solvents we have. They will dissolve some varnishes, carry acids and small particles, and distribute them throughout the system if left alone. The driers will pick up and contain moisture, minute solids, carbon, gasket fibers, and metal that evacuation cannot remove.

Basically our atmosphere is made up of approximately 78 percent nitrogen and 21 percent oxygen; the rest is made up of rare gases and man made pollution, with varying amounts of water vapor. These gases are considered as non-condensables in our trade, when left in a system. By their quantity they create excessive head pressures. Oxygen is the real enemy, since it is an oxidizer. When left in a system associated with heat it will oxidize the oil, turning it black.

The oil being a hydrocarbon associated with oxygen and heat can cause vaporization of motor windings, and will create acids, water, and sludge. The acids, sludges, water and heat form carbon and also attack the metals, at same time destroying the oil. In fact the compressor becomes a chemical plant. Driers do remove acids and sludge to a point, but the destruction process is continuous in the system and in time will prematurely reduce efficiency and cause damage when oxygen and non-condensables are present. More details later.

DEEP VACCUM VS SHALLOW VACUUM

First let us establish what the vacuum and evacuation process is. It is the removal from the system of all or part of the gases which make up our atmosphere. It could also mean the removal of any type or combination of gases at or below atmospheric pressure.

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When discussing atmospheric pressure at sea level the surrounding area has an absolute pressure of 14.696 pounds per square inch. The higher we ascend in elevation above sea level the lower the atmospheric pressure. We mentioned before the main gases in the atmosphere are oxygen and nitrogen with varying amounts of water vapor present.

> **The term used many times, “wet air” is misleading. Water vapor and air do not combine. The water vapor is always an addition to air in varying amounts. The percentage of vapor is called relative humidity. The air itself is always dry.**

Webster’s dictionary describes a “vacuum” as being a void, an empty space, or a space containing nothing. The term “partial vacuum” is used to describe and illustrate the varying reduced levels below atmospheric pressure on down to nearly absolute zero pressure or a void.

We must now establish a distinction between a deep and a shallow vacuum pump. This distinction depends upon the limits of vacuum required for various industries. For example, a vacuum cleaner has its limits of vacuum in the shallow range. If it is too shallow it will not pick up any dust. If it is too deep it will ruin a rug. Yet, the lowest vacuum permissible for a vacuum cleaner is so shallow that it would be useless for our application. Consequently, for our industry, we classify a shallow vacuum pump as one that cannot create a vacuum deeper than 28”, and a deep vacuum pump as one that can create a vacuum considerably deeper than 29”.

To appreciate the many advantages of using a deep vacuum pump, compared to a shallow vacuum pump, you must know how vacuum pumps operate as well as their limitations. This knowledge will help to remove most of the mystery that seems to surround this word “vacuum.” Basically, a vacuum pump is a precision designed type of compressor that operates at pressures less than atmospheric.

HOW DOES A VACUUM PUMP PUMP?

We are not mystified when we observe a liquid pump operating because we can see and measure the liquid being discharged. However, when a vacuum pump is running we do not have this visible assurance that useful work is being done. Instead, we must depend upon the reading of a gauge, the selection of which becomes as important as the selection of the pump.

PRESSURE DIFFERENTIAL

The simple basic fact to keep in mind is that Nature seeks an Equilibrium of Pressures. You can cite countless examples of this law from your own observation.

For example, let us take two tanks of equal size pressurized with the same gas and pressure. We open the valve on tank number one wide open. The gas rushes out and soon ceases to flow. We say it is empty. This is not true. We have only equalized the pressure inside the tank with the outside surrounding pressure. The pressure that is left in the tank is what the vacuum pump is expected to remove. We now open the valve on the second tank but only one fourth open. We have the same velocity out-rush of gas as the first tank, but lack the volume. This tank will take much longer to equalize due to the valve being only one fourth open, causing a restriction or resistance to flow. This analogy becomes important to us later on, when we discuss the importance of using large diameter suction lines between the pump and the unit being evacuated.

RECIPROCATING PUMPS

Keeping in mind this basic fact of “Differential in Pressure,” we will analyze how a vacuum pump pumps. Refer to Figure 1. It is a sketch of a typical reciprocating piston pump.

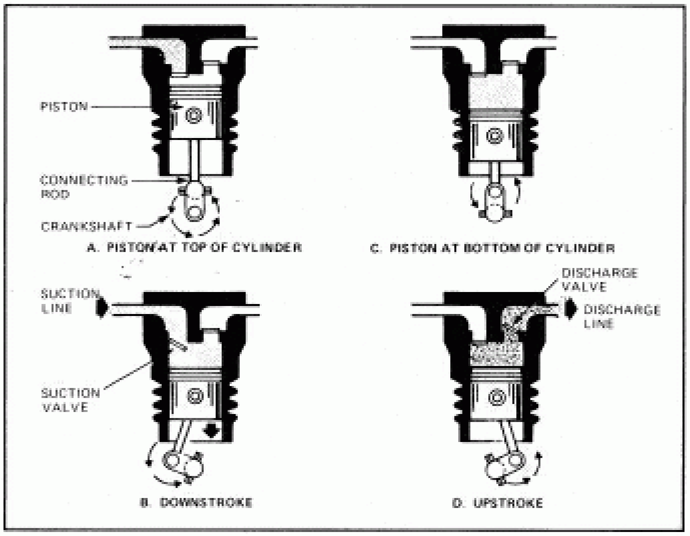

Figure 1

Ordinary Reciprocating Vacuum Pump

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When the piston moves downward enlarging the cavity above the piston, the pressure is lower than the pressure in the system being evacuated. The pressure from the system forces its gases in through the suction valve as the piston travels to the bottom. The pressures then equalize. The piston then rises on its compression stroke, creating a pressure equal to atmospheric pressure plus discharge valve spring pressure and discharges the gases to the atmosphere until the top of the stroke is reached.

LIMITATIONS

This cycle of inlet and discharge action continues to remove air and non-condensables from the unit until the pump ceases to create a sufficient differential in pressure to cause the air to flow into the cylinder from the system. When that state of equilibrium has been reached, the pump continues to run, but it ceases doing any useful work. In other words, its volumetric pumping speed, or capacity, has decreased to zero no matter how long or how fast the pump runs.

This limitation of a vacuum pump is referred to as its “Blank-off Pressure,” for that set of operating conditions. The typical reciprocating vacuum pump, or hermetic compressor as such, cannot create a vacuum much greater than 28” because it has to leave some clearance at the end of its discharge stroke to prevent the piston from contacting the head of the pump. The air that has been compressed in this head-clearance space, will be re-expanded during the next down stroke, thereby severely reducing the ability of such a mechanism to create a deep vacuum. This is due also to the heat from friction and expansion of the metal in the pump.

ROTARY PUMPS

This same principle of the inlet gas and discharge action applies to a rotary deep vacuum pump, but there are several characteristics that make it superior for evacuation of refrigeration systems.

Figure 2 is a graph of the volumetric pumping speed, or capacity, of a typical reciprocating pump versus vacuum. Its pumping speed is zero at 28” vacuum because that is its limiting or Blank-off vacuum. Even at a vacuum of 27” it has lost more than half of its rated displacement. Consequently, it becomes a very inefficient and slow pump-down pump.

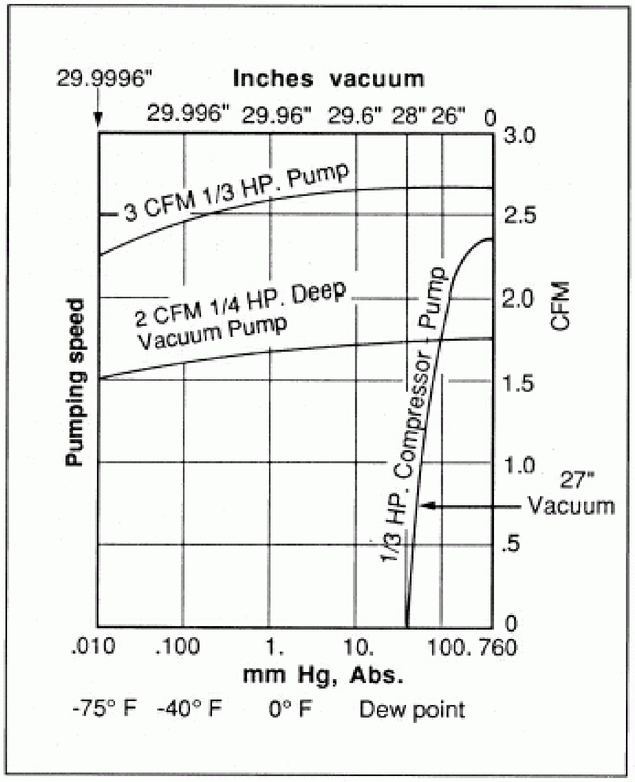

Figure 2

Pumping Speed of Rotary Pump vs. Reciprocating Pump

In contrast, this graph also shows the pumping speed of a typical rotary deep vacuum pump having about the same displacement rating.

Because a rotary deep vacuum pump does not require any head clearance, it can create a blank-off pressure considerably lower than required for modern finishing pressures. This enables a rotary deep vacuum pump to maintain a very constant volumetric pumping speed (capacity) throughout the entire servicing cycle. This is extremely beneficial because it not only makes it a fast pump-down pump, but it can create the necessary large differential in pressure to get a useful vacuum throughout the evacuated system.

ROTARY DEEP VACUUM PUMPS

Rotary deep vacuum pumps generally used for servicing cooling units are two stage compound pumps. They have a continuously overlapping inlet and discharge action during each revolution. A rotary compound pump consists of two pumps in series within a cylinder and separated by a center wall. (See Figure 3).

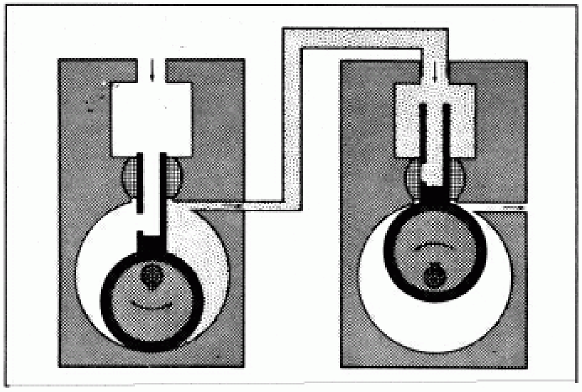

Figure 3

Compound Deep Vacuum Pump

The vacuum line is connected to the inlet of the first stage. This stage has no discharge valve. It discharges, through a channel in the casting, directly into the inlet side of the second stage where the air is sufficiently compressed to force open the discharge valve and be discharged to the atmosphere. All of these pumps use deep vacuum pump oil to seal the machine clearances between the working parts.

The most economical size of deep vacuum pump to use for self-contained cabinet units up to 15 tons is a pump having a displacement rating of 3 cfm. Generally it costs only about 10% more than a 2 cfm pump and 25% more than a tiny pump too small to service anything larger than a small fractional horsepower window unit, freezer or refrigerator. For servicing industrial units, an 8 cfm pump is generally large enough.

All the modern two stage compound pumps, either rotary vane pumps or the cam piston pump, have a hand adjustment valve. This valve has an opening between the first stage and second stage. This valve must be opened at the start of the evacuation process. This allows some atmosphere to enter in between the two stages. This helps the second stage to remove the higher pressure gases faster. This also helps to keep contaminants from entering the pump oil. This valve should then be closed down in the range of 750 to 1000 micron reading. This is a very important step when using a two stage compound vacuum pump. A vacuum pump cannot evacuate the system or remove contamination to a lower point than its own contamination. When a vacuum pump is dirty the contamination in the pump gives off its own vapors, reducing its capacity and creating a blank off point much higher than the pump's design performance.

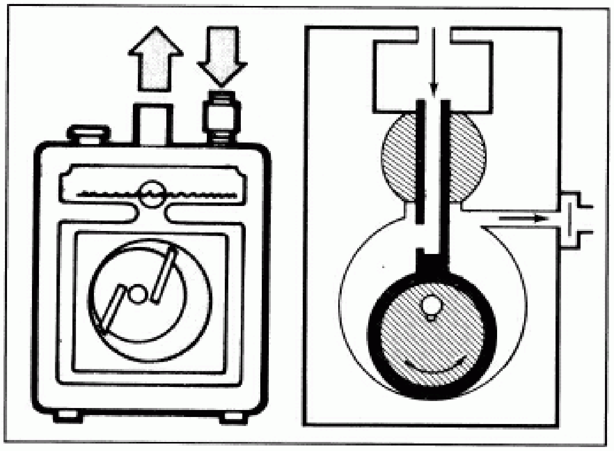

Figure 4

Cam and Piston Pump.

TYPES OF DEEP VACCUM PUMPS

Rotary deep vacuum pumps can be divided into two types, the vane type and the cam and piston type. (Figure 4.)

In the vane type, the vanes slide in and out of their actuating cams to make metal-to-metal contact with the cylinder wall. In some types the vanes are forced out of their cam by the pressure of back-up springs, while in other types, the contact is created solely by the eccentrically located cam. This type design is a short life pump due to contact wear in the cylinder also very susceptible to contamination in the sliding vanes.

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The cam and piston type of pumps do not have metal-to-metal contact between the pistons and their cylinder wall. Their driving cam causes the piston to oscillate with a rolling action tangent to its cylinder wall, but with a small clearance that is effectively sealed by a film of deep vacuum pump oil.

The cam and piston design is an industrial type of pump which is more ruggedly built for continuous heavy duty. Its simplicity of design with large clearances makes it easy to maintain in the field without the aid of special tools or skill. This design is a lifetime pump if properly cared for and if good vacuum oil is used.

The vacuum pump is a precision pressure pump the same as the high pressure pump, only it is designed for a very low density gas with low pressure discharge.

The vacuum pump does not suck the gas from a system or container being evacuated. It does not have any control over incoming gases outside of its own internal chambers. It can only reduce the pressure inside its internal chamber to a point lower than the pressure in the system to be evacuated. The system pressure then being higher than the pressure in the chamber of the pump forces the gases into the inlet of the pump. The pump then pressurizes the gases equal to or higher than the atmospheric pressure and expels them through the discharge.

HIGH VACUUM OIL

The important and distinctive characteristic of an oil for deep vacuum service is that, at 100°F, its vapor pressure is not greater than .005 mm (5 microns) mercury total absolute pressure. Its viscosity, at 100°F, should be 300 SSU. Keep in mind that a vacuum pump cannot create a total absolute pressure less than the vapor pressure of its sealing oil.

This precludes the use of a refrigerant oil for pressures less than 1 mm Hg, because its vapor pressure is too high and variable for deep vacuum service. Instead of a controlled vapor pressure, its major characteristics are a very low floc point and pour point and stability when mixed with refrigerant.

Consequently, to prevent lost time by using an oil of questionable vapor pressure, use an oil that is specially processed for rotary vacuum pump application. Some oil manufacturers are now refining oil two or three times to remove as many impurities as possible. This added refining gives the oil a lighter, almost water clear, color. When this type of oil is used, a good vacuum pump can pump a vacuum down to about 5 microns.

The manufacturers of deep vacuum pumps guarantee their pumps for one year from date of manufacture against defective materials and workmanship. However, the pump must be protected, by a drop-out rap, against solid particles getting into the pump and causing a possible stoppage or breakage of parts. Do not expect any manufacturer to guarantee the pump against such a failure.

When finished with the evacuation process, immediately drain and flush the pump with good vacuum pump oil while the pump is still warm. The oil is thin and drains easily. Then refill the pump with the same vacuum oil normally used and run it for two or three minutes and drain. Refill the pump again and seal off both inlet and outlet. This removes all contaminants, water, sludge and acid which might enter the pump when in use. This also keeps the pump protected from rusting and pitting due to acid and moisture left inside after use.

Then store in a dry place. (Remember oil is much cheaper than pumps.)

Furthermore, pump warranty is voided should you neglect to change the oil as frequently as necessary to prevent the accumulation of water, rust, grit, emulsified or acidic oil. Be prepared to change the oil as frequently as is necessary. Clean and dry deep vacuum oil is the cheapest insurance against breakdown and repair.

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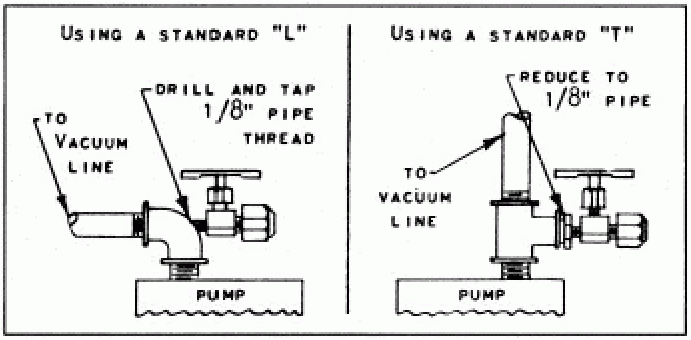

Figure 5

Vacuum Breaker Valve Installed Between Pump and Vacuum Holding Valve. Solenoid Valve May Be Used in Same Manner. Coil is Connected in Parallel With Line Terminals on Motor. Vacuum Holding Valve Must be Closed Before Opening VB Valve.

VACCUM BREAKER VALVE(FIGURE 5)

A rotary deep vacuum pump will not serve as a cut-off valve to hold a vacuum on a system, when shut down. Install a valve in your connecting line for this purpose. Then install at the pump a manually or solenoid operated vacuum breaker valve. Just prior to shutting down the pump, under vacuum, open this vacuum breaker valve to prevent an excessive amount of oil seeping back into the pump from the external oil reservoir, thereby creating an oil-locked condition. An oil-locked pump is not free to be started by a motor. To relieve the oil lock, turn the pump over by hand a couple revolutions and then turn on the motor.

Now that we have reviewed how a pump pumps, along with its limitations, let's proceed with a brief non-technical discussion of the simple fundamentals of vacuum encountered in our type of work.

TERMS USED IN VACUUM WORK

We will start this discussion by reviewing three subjects which, at the moment, do not seem to be related to our problem of removing the moisture and the air from a cooling system. However, make certain that you understand each one as it is individually presented because, later on, you will realize how they become a part of your thinking in solving conditions other than normal.

These discussions will enable you to save hours by evacuating a system in a knowing and logical manner rather than by guesswork and haphazard procedure.

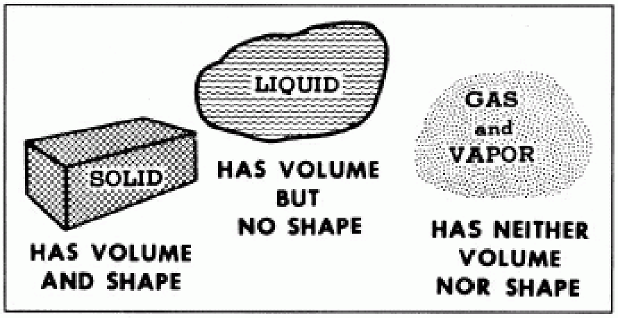

Figure 6

The Three States of Matter

MOLECULAR ACTIVITY

We understand that all matter consists of infinitely small particles called molecules. At the temperatures encountered in our work, these molecules are in a constant state of vibration or chaotic motion. It is generally assumed that this activity is due to their inherent heat energy.

Scientists have difficulty in defining the term "matter." Some are content to define matter as "that which occupies space." Others prefer to define it as "that which is occupied by space." What a challenging statement! However, this classic definition is very enlightening from the viewpoint of vacuum engineering because, very appropriately, it describes the vast "emptiness" of gases, especially when under the increased rarification of a vacuum.

To visualize the truth of this statement, let's examine the molecular activity in a solid, a liquid, and a gas, under ordinary conditions. (See Figure 6.)

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In a solid, the molecules are so close together that their intermolecular attraction is so great that it gives a solid the characteristic of rigidity. Nevertheless, there is more space between the molecules than that occupied by the molecules themselves. A solid has both volume and shape.

In a liquid, the molecules are farther apart, thereby causing a liquid to lose this characteristic of rigidity. A liquid has volume but no shape.

In a gas, the molecules are so far apart that it has neither volume nor shape. A gas is so full of "emptiness" that it can be easily compressed.

From this discussion, retain two facts related to our phase of industry because you are making use of them.

1. The molecules are in a constant state of chaotic motion due to their inherent heat energy and this heat energy increases, or decreases, directly with changes in absolute temperature.

You make use of this fact when you apply hot rags to a cylinder of refrigerant to increase the driving force to hasten the transfer of the refrigerant. You also make use of this fact when you apply heat lamps or a heat gun to a cooling unit to hasten the dehydrating cycle by a deep vacuum pump

2. From this discussion we can establish another point of great significance in our type of work. It is the commonly accepted difference between a gas and a vapor. A vapor is that type of gas which can be easily condensed under normal temperatures and pressures, such as water vapor. A gas remains in the gaseous state, except under abnormal changes in temperature and pressure, such as air, oxygen, etc.

This distinction is of major importance because our problem is to remove the moisture as well as the air from the system. A mixture of vapors and gases are being removed. Both of these forms of gas exist in this mixture at their individual pressure. That part of the total pressure of the mixture contributed by the air is called the "partial pressure of the air" and the part of the total pressure contributed by the water vapor is called the "partial pressure of the water vapor." In other words, the sum of these individual partial pressures constitutes the TOTAL pressure of the mixture.

Keep this summation of partial pressures in mind because, as these discussions progress, you will note that the significant term "total absolute pressure" is quite constantly used. This fact will govern the proper type of gauge to use in our work. This subject will be discussed later.

ATMOSPHERIC PRESSURE

Most of us have not had any reason to be concerned with the pressure created all around us by the atmosphere. Let's discuss it for a moment.

We live on the planet Earth enveloped by a layer of gases and water vapor which we call our atmosphere. You might say that we live in a sea of atmosphere. You know that fish living deep down in the sea are subjected to a greater pressure than those that live near the surface, due to the greater weight of the column of water above the deep sea fish.

Similarly, living in a sea of atmosphere, the pressure around us is due to the weight of the column of air above us. If we live at what is called sea-level, the weight of the air above us creates a normal pressure of 14.7 pounds per square inch.

You might ask, in what way is this discussion related to our problem? The answer is that it is related to our problem of dehydrating a refrigeration or air conditioning system by vacuum because a state of vacuum is defined as any PRESSURE less than atmospheric.

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UNITS OF PRESSURE

As we will be committed to discuss vacuum in units of PRESSURE, let's establish some units of pressure related to absolute zero pressure. Confusion will disappear if you will think of a state of vacuum being any PRESSURE less than atmospheric and extending down to theoretical absolute zero pressure.

We find it convenient to simulate a standard of one atmosphere of pressure by comparing it to the pressure created, on unit area, by a column of mercury. (The chemical symbol for mercury is "Hg.")

Assume that we have a container, 1" square and 30" high. For this non-technical discussion, if we fill this container with mercury at 58.4°F, this column of mercury will weigh 14.7 lbs. This establishes the fact that a 30" column of mercury will create a pressure of 14.7 lbs per square inch.

This "inch" unit of length is a very clumsy unit to use in deep vacuum work. It is not only too large a unit of length but it does not lend itself to small enough sub-divisions for conveniently discussing our modern low total absolute finishing pressures. It is more practical to discuss such pressures in a unit of length in the metric system, namely the millimeter, or fraction thereof.

A millimeter of length is about 1/25th of an inch. There are exactly 25.4 millimeters in an inch. Multiplying 30" by 25.4 mm, creates an equivalent length of 762 mm. For our work it is convenient and sufficiently accurate to refer to this equivalent length as 760 mm.

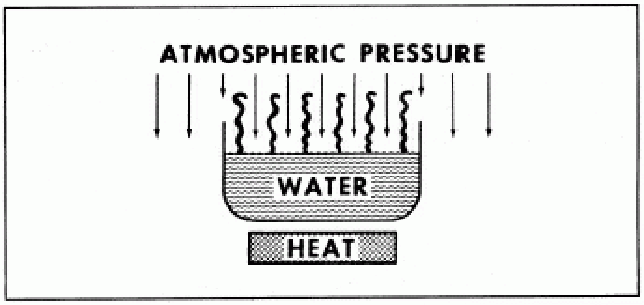

Figure 9

Converting Water Into Vapor By Applying Heat At Atmospheric Pressure

We have now converted the pressure of one standard atmosphere from 14.7 lbs per square inch above absolute zero pressure (14.7 psia), to being equivalent to the pressure created, on unit area, by a column of mercury 760 mm high.

We will now tie together the three subjects independently discussed, namely molecular activity, atmospheric pressure and millimeters of mercury pressure to see how they are related to our problem.

CONVERTING WATER INTO VAPOR AT ATMOSPHERIC PRESSURE

Why, at sea-level, is it necessary to heat water to a temperature of 212°F and remain there, to convert it into a vapor? The answer is that the atmospheric pressure is pressing down on the surface at an absolute pressure of 14.7 lbs per square inch, or that equivalent to the pressure, on unit area, created by a 760 mm column of mercury. However, when the water first attains this 212°F temperature, it does not immediately become converted into a vapor.

To enable it to suddenly burst through this pressure barrier, the water must absorb some additional heat energy to convert it from a liquid to a vapor. This additional heat energy is termed Latent Heat of Vaporization. In the case of water being boiled on a stove, this additional heat of vaporization is supplied externally, thereby maintaining this 212°F temperature. At this temperature the vapor pressure of water exceeds atmospheric pressure, allowing the water to boil. (Figure 9.)

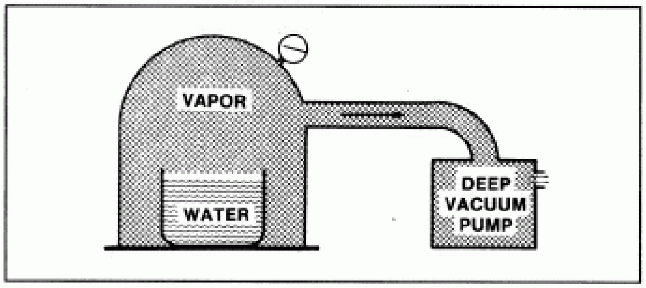

Figure 10

Converting Water Into Vapor At Less Than Atmospheric Pressure

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OUR CONCEPT OF PRESSURE

The impact of the molecules of gas colliding with the walls of the confining vessel creates a force which we convert into a pressure reading by some form of pressure gauge. It is the impact of the molecules of gas, at atmospheric pressure, against the walls of the confining vessel that gives us the impression of having 14.7 lbs per square inch above absolute zero pressure. If the temperature remains constant, it is logical to assume that if some of these molecules are removed, the pressure in the vessel will be reduced in direct proportion to the quantity of molecules removed.

This concept enables us to visualize that by connecting a vacuum pump to a closed vessel, the pumping action will remove molecules from the vessel, thereby reducing the pressure therein. This progressive reduction in pressure will continue until the pump can no longer create the necessary differential in pressure to cause the molecules of gas to flow into the pump and subsequently be discharged to the atmosphere. In other words, the useful pumping action will continue until a state of equilibrium exists for that set of operating conditions, thereby causing the gas flow to cease.

From this concept you might classify a vacuum pump as a pump that removes molecules of gas from a closed system for the purpose of reducing the pressure in the system.

CONVERTING WATER INTO VAPOR AT LESS THAN ATMOSPHERIC PRESSURE

Place a bowl of water, at ordinary temperature, beneath a closed jar, to which is connected a vacuum pump. (Figure 10.)

The pump will reduce the pressure in the jar. By lowering the pressure on the surface of the water, a molecule of water does not have to have as much heat energy to escape from the mass of water. Hence, water can be converted into a vapor at lower temperatures than required at atmospheric pressure, whenever the pressure has been sufficiently reduced.

However, in this example, there is no source of external heat to supply the additional heat of vaporization. Consequently, this additional heat energy must be extracted from the body of water thereby reducing its temperature. This requires a continual decrease in pressure to sustain vaporization.

All of us are conscious of this cooling effect because the refrigeration cycle is based upon it. In this case, however, the refrigerant purposely obtains its heat of vaporization from the article to be cooled, thereby maintaining the refrigeration cycle. Nevertheless, many servicemen overlook the similarity between the vapor pressure versus temperature of water, which is available by referring to a steam table, and the pressure-temperature relationship found in the refrigerant tables.

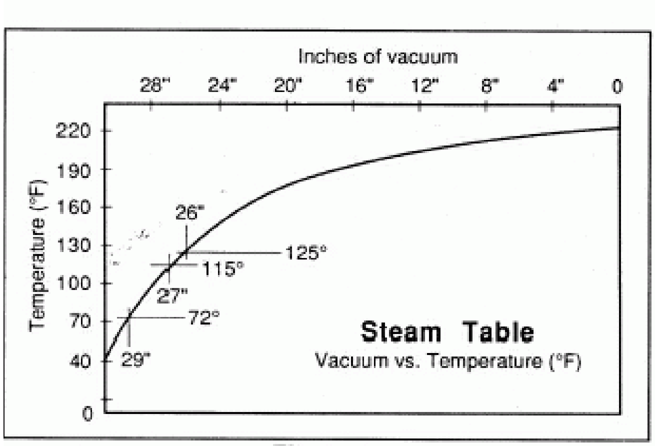

Figure 11

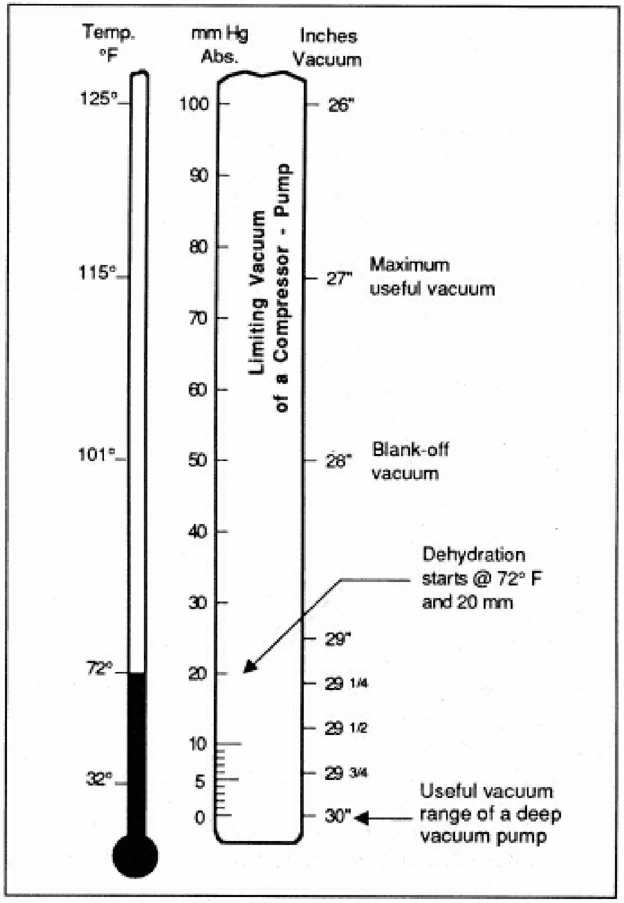

Figure 12

Dehydrating By Vacuum

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STEAM TABLE INFORMATION

From a steam table, we can gain some facts related to dehydrating a unit by vacuum alone. (See Figure 11). Because a shallow vacuum pump cannot create a useful vacuum greater than about 27”, the steam table shows us that the unit being evacuated must be heated to at least 115°F to accomplish any dehydration at all, whether it pumps for a day or a year. To heat a unit in a service shop or in the field to such a temperature is not practical. Should dehydration be desired by vacuum alone, at an ambient temperature of about 72°F, or even cooler, the vacuum in the unit must be greater than 29”, which is easily attained by a high vacuum pump.

Figure 12 is a re-plot of steam table data showing a thermometer alongside a ruler. On one side of the ruler is shown the corresponding vapor pressure of water in mm Hg, and on the other side the vapor pressure in inches of vacuum. This grouping of facts enables you to visualize one of the many limitations of a shallow vacuum pump versus a deep vacuum pump.

Graphically, it shows the limiting useful vacuum of a shallow vacuum pump to be 27” which corresponds to the boiling point of water at 115°. In comparison it shows that a deep vacuum pump can create the necessary vacuum to complete the dehydrating job by straight vacuum at all temperatures commonly encountered in our type of work.

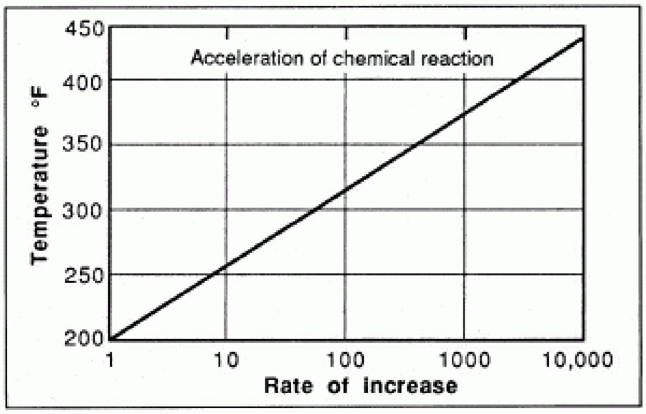

Figure 13

Rate Of Chemical Reaction Versus Temperature Compared To That At 200°F

EVACUATING A SYSTEM TO MEET MODERN SPECIFICATIONS

Several years ago, the removal of the moisture in a refrigeration system in the field was the major factor involved in preparing a system to receive its refrigerant. The removal of the moisture is termed “Dehydrating” the unit. The system was evacuated to about 27” of vacuum and filter driers were depended upon to pick up the moisture. Due to the presence of air remaining in the system, the excessive high head pressure was relieved by bleeding the excessive pressure to the atmosphere.

To maintain the high efficiency built into a modern refrigeration system, and to reduce maintenance and warranty call-backs, it is imperative that we consider a more thorough evacuating procedure.

The increasing demand for water in large cities is bringing about a serious shortage. Foreseeing this situation, manufacturers of refrigeration units changed several sizes of water-cooled units to air-cooled units. This change has resulted in higher head temperatures and pressures and higher condensing pressures, especially for hermetic compressors. With the advent of very low temperature applications, necessitating higher compression ratios, when single stage compressors are used, still higher temperatures are encountered.

Higher head temperatures make it mandatory to remove the air, as well as the moisture, from a unit or cooling system to below the damaging point. The process of reducing the air remaining in the system can be referred to as removing the non-condensables, or “Degassing” the unit. The bad actor is the oxygen in the remaining air. Oxygen is one of nature’s most chemically active elements and its rate of chemical reaction with the oil increases very rapidly with increases in temperature above 200°F.

Therefore, today’s most important factor is the degassing of a system to remove the oxygen of the remaining air to the very minimum. In doing so, the unit will also become adequately dehydrated. Filter-driers are installed to pick up materials of construction, contaminants such as soldering flux, and the small amounts of moisture that may have accumulated beneath a layer of oil.

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To appreciate the importance of reducing the oxygen remaining in the unit to an extremely low amount, we should realize the rapid rate of chemical reaction with oil, when accompanied by increasing temperatures. Unfortunately, this chemical reaction is not in direct proportion to the temperature rise. Instead, for every 18°F rise in temperature above 200°F, the rate of chemical reaction of the oil with the oxygen doubles.

It is a very wise procedure to make certain that the final oxygen content is so low that it will not support any detrimental reaction with the oil after the system has been charged with refrigerant and oil. In reviewing Figure 13, you will note that the chemical reaction at a temperature of about 400°F is 10,000 times greater than at 200°F. Much higher localized temperatures are easily attained, with corresponding astronomical increases in rate of reaction, when “wiredrawing” takes place in the discharge plate area of an air-cooled compressor.

When the oil starts to break down due to reaction with oxygen, deposits build up in the discharge valve area. Sticky and leaky valves create restricted flow and high velocities, resulting in localized temperatures high enough to start a chemical reaction with, and breakdown of, the refrigerant. This establishes an acidic condition which invites a vicious maintenance cycle, or costly burnouts.

Only by the use of a deep vacuum pump and a deep vacuum gauge can a service engineer be certain that the system has been adequately dehydrated and degassed to prevent the early breakdown of the oil and the refrigerant.

There are two basic methods of adequately evacuating an air conditioning or refrigeration system: One is to use a vacuum pump that can create a vacuum deep enough to do the complete job by vacuum alone. The other method is to initially exhaust the system to about 27” of vacuum, then to charge it with anhydrous nitrogen and permit this dry gas to remain in the system at least an hour to diffuse throughout the system to absorb or “blot-up” as much of the moisture as its saturation point permits. Then release this moisture-laden gas to a pressure just above atmospheric pressure. The system then is again evacuated and recharged. After this has been done three times, the system is finally evacuated by using a deep vacuum pump. The use of a deep vacuum pump now permits the use of a simple electronic deep vacuum gauge to check the final condition of the system being evacuated. This method is commonly called the “Triple Evacuation Method.”

Which one of these two methods will prove to be the most time-saving and economical to use, is governed by experience on similar systems. Many variables are involved such as the volume of inlet and discharge lines, convenience and available time of procedure, and wetness of the system to be evacuated. Also to be considered are appropriate procedures to avoid venting refrigerants to the atmosphere, and the increasing cost of refrigerant.

While on this subject of adequate evacuation, let us correct a thought that is quite commonly associated with air conditioning systems. Because an air conditioning system may not operate at low enough temperatures to cause a “freeze-up,” some service engineers do not feel that it is necessary to thoroughly evacuate it. This is not sound thinking, if long uninterrupted life of the system is important. It must be sufficiently evacuated to adequately reduce the amount of air remaining in the air conditioning unit, and to remove moisture which would otherwise lead to corrosion within the refrigerating system.

The primary reason a shallow vacuum pump is used is its initial cost, which is much lower than a deep vacuum pump. However, its limitations are so many and great that, in reality, it becomes the most costly pump to use to economically meet modern specifications. One of its major limitations is that it cannot be used for adequately evacuating a system by straight vacuum alone. Instead, it is limited to using only the multiple evacuation method. Even then, the effectiveness of dehydration and degassing is left to unreliable mathematical assumptions.

Another disadvantage is that the system cannot be finally evacuated to greater than about 27” of vacuum. This is equivalent to a total absolute pressure of 75 mm Hg, or 75,000 microns. Obviously, such a high finishing pressure is not satisfactory when modern specifications call for a finishing pressure of considerably less than 1 mm, or 1,000 microns.

In contrast, should a deep vacuum pump be used, it can adequately evacuate a system by:

1. Straight vacuum alone

2. The multiple evacuation method

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3. A combination of both.

The thoroughness of evacuation and universal application of a deep vacuum pump establishes it as the soundest investment for field and shop use.

Should conditions be favorable to combine the use of a deep vacuum pump with the multiple evacuation method the deep vacuum pump will not only get the job done quickly, but can provide another advantageous feature. As it can create the necessary deep vacuum to register on an electronic deep vacuum gauge, it can, in combination with the gauge, indicate whether a leak exists during this evacuating period and finally, indicate whether the system has been adequately dehydrated and degassed. This is very important to a service engineer. Only by such instrumentation can he be sure that the system has been sufficiently evacuated to rapidly receive its full charge of refrigerant. The reading of the electronic deep vacuum gauge can serve as a guarantee that the system was adequately dehydrated and degassed and is without leaks.

Mathematical calculations of the time required to dehydrate a unit in the field are useless because of the many variables involved; the major one of which is the unknown wetness of the unit. The only guide is experience on a similar installation that has the same magnitude of wetness.

DEEP VACUUM GAUGES

The selection of the proper type of deep vacuum gauge to meet modern specifications is just as important as the selection of the right pump to use.

The standard “Bourdon tube” suction service gauge, no matter how accurate in its intended range, is not adequate for deep vacuum service. It is affected by the variable atmospheric pressure, and various altitudes, and its 0 - 30” dial is not designed to register the deep vacuum in which we are involved today.

MERCURY MANOMETER

The 5” closed-end U-tube mercury manometer is an excellent instrument for stationary installation for indicating total absolute pressures from 120 mm down to two or possibly 1 mm Hg. Mercury manometers are available with a mounted scale, for reading vacuums from 25” to 29-3/4”. For portable field service work, a mercury manometer is not a convenient instrument to use because it requires disassembly and reassembly to remove or replace the protective plunger assembly. This prevents movement of the mercury columns during transit. Should the manometer be laid on its side without this protective plunger in place, the accuracy of the reading of the mercury columns would be destroyed.

SPECIFICATIONS OF A DEEP VACUUM GAUGE FOR DEHYDRATING AND DEGASSING SERVICE

1. The gauge must be designed to register pressures to a fraction of 1 mm Hg.

   The convenience of discussing pressures in units of the Metric System is that the millimeter can be divided into 1000 divisions to establish the next smaller unit of length, which is called a Micron. Hence, 1 mm = 1000 microns; 1 micron = .001 mm; 10 microns = .010 mm; 50 microns =.050 mm; 100 microns =.100 mm; 500 microns = .500 mm; 1000 microns = 1 mm.

   A micron of length is an extremely small unit of length. It is 1/25400th of an inch. The pressures created by a column of mercury 1 micron high is likewise an inconceivably small pressure, as it is about 2/100,000th of a pound per square inch (.00002 psi). Nevertheless, in our use of a deep vacuum pump it is not unusual for the specifications to require exhausting a unit to a finishing total absolute pressure of 100 microns, which is written as .100 mm Hg and corresponds to a pressure of about .002 psia. Consequently, we are involved with minute pressure differences and have to use a gauge that will reliably register these small pressure differences.

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Standard practice is to use atmospheric pressure at sea level as the focal point; pounds of pressure above, and vacuum below, measured in inches of mercury. Above the sea level atmospheric pressure pounds per square inch in gauge is used. Below atmospheric pressure readings are in inches of mercury. This is due primarily to the crude instrumentation in the past.

The problem with this method of measurement is that the standard is not positive. The atmospheric pressure changes above sea level. It changes below sea level. It also changes at sea level due to moisture change relating to air. These changes are called barometric changes.

For Example:

The Salton Sea area is below sea level. It has a higher atmospheric pressure than our standard. Denver, Colorado is known as the Mile High City. The atmospheric pressure there is lower. Its pressure is approximately twelve pounds pressure absolute or 2.696 pounds less than our standard atmospheric pressure of 14.696 pounds absolute. It takes 2.036 inches of mercury pressure to equal one pound pressure.

There are many of us who prefer to eliminate the mercury reading and work with pounds pressure absolute and its percentages. The percentage readings are divided directly into micron readings. In this manner we use absolute zero as our starting point and all pressure readings above this point are positive pressures, direct and accurate. With all readings positive, mercury readings and vacuum are eliminated. This simplifies what is really being accomplished when removing gases below atmospheric pressure. Students learning the trade catch on much faster and have a better understanding when pounds pressure, inches mercury, and micron readings are set side by side for comparison.

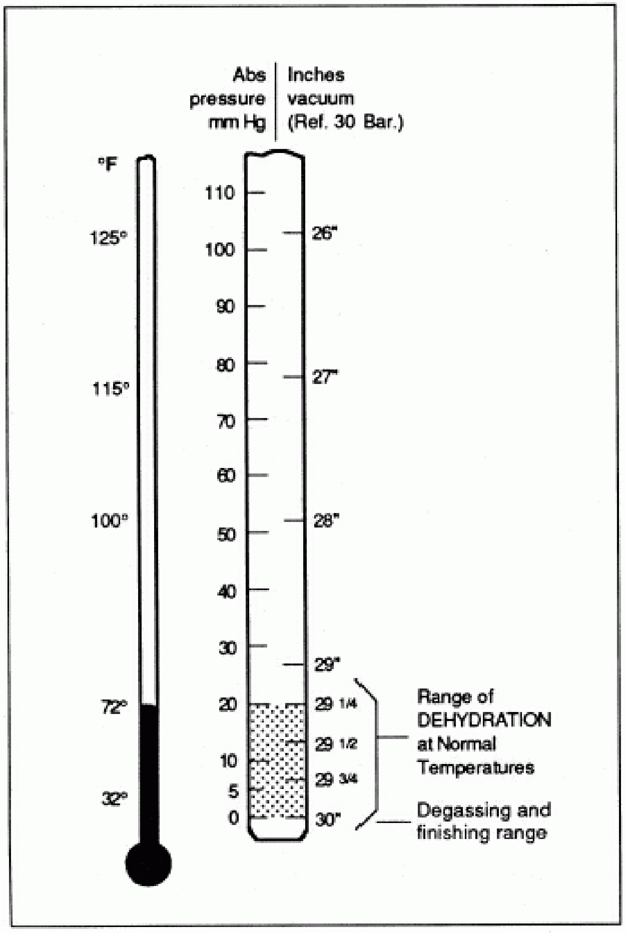

Figure 15

Vacuum vs. Dehydration Temperature

2. The gauge should be an electronic or electric gauge, so that it will give the service engineer a continuous visual registration of the decreasing pressures in a system.

Being an electric type of gauge, it will register, reasonably close, the TOTAL absolute pressure because its sensing element in the gauge tube is exposed to the mixture of vapors and gases being exhausted from the system. However, the reading is not the exact, or true, pressure of the mixture, but one comparative to the single gas against which the gauge was calibrated, which is generally pure dry air. Nevertheless, the reading is sufficiently accurate and reliable for our application because its reading is reasonably close to the true total absolute pressure of the mixture when the pressure decreases to below 500 microns (.500 mm Hg.)

A compression type of gauge of the McLeod type is designed for registering the pressure of dry gases and not a mixture of gases and vapors. Condensable vapors in the mercury will cause the gauge reading to be very erratic.

It will register, with accuracy, only the partial pressure of the air in the mixture of air and water vapor. In dehydrating a unit we are primarily interested in a registration of the relative moisture content of the mixture of water vapor and air remaining in the unit. Hence, we must have a gauge that will register the TOTAL absolute pressure of the mixture being exhausted. In fact, we use the electric type of gauge as a moisture indicator.

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A McLeod type of gauge has the further disadvantage, for our work, that it is intermittent in its manual operation, thereby giving us a "snap" reading instead of a continuous registration of the decreasing pressures. It has to be connected to the system being evacuated by tubing, which can be a source of leaks.

3. The third and time-saving requirement of a gauge depends upon its range of total absolute pressure readings.

   Obviously, the removal of the moisture and the air from a unit is simultaneous because the pump removes moisture laden air. However, because the major portion of the troublesome moisture has been removed by the time that the pressure has been reduced to 1 mm, let us refer to the variable dehydrating cycle as existing between 20 mm to 1 mm, total absolute pressure. From 1 mm down to the desired finishing pressure will be referred to as the degassing cycle.

   From Figure 15, we note that in a system at 72°F, the moisture will start to become converted into a vapor when the pump has reduced the pressure to 20 mm Hg. Because this is the start of the dehydrating cycle, the gauge should likewise start to register at this high millimeter reading.

   A gauge that does not start its reading until the pressure has been reduced to 1 mm, or even 3 mm, is of no benefit in dehydrating a unit. This is because the operator is "flying blind" during the most variable and time consuming portion of the complete servicing procedure.

   With a gauge that registers from at least as high as 20 mm, and down to zero, the service engineer is like a doctor serving a sick patient. With the proper instrumentation he can at least hope to instantly diagnose the patient's illness and can continuously note his progress of recovery. In contrast, should the doctor be handicapped by using limited instrumentation, he would have to lose valuable time by guessing at the cause of the illness and probably have to wait until the patient was almost well before he could determine what caused the delay in the patient's recovery.

4. With such a wide range of pressure readings, starting at 20 mm Hg, the gauge can serve in a most valuable and time-saving manner as a leak and moisture indicator throughout the complete servicing cycle. This becomes true when your inlet gas line between your deep vacuum pump and the system contains properly arranged deep vacuum valves.

TWO-VALVE TEST MANIFOLD

To reap the maximum return from your investment in a deep vacuum pump and an electronic deep vacuum gauge, having a range from zero to at least 20 mm, you should construct, or purchase, a two-valve test manifold. It consists of two vacuum-tight valves between which is mounted the gauge tube. They are available for screwing directly into the inlet of the pump, thereby making a compact assembly for portability. The same principle of a vacuum test manifold should be incorporated in the manifold of a modern complete service station.

This two-valve test manifold, shown in Figure 16, combined with the 20 mm electronic deep vacuum gauge, will save hours of lost time by instantly recognizing the three commonly encountered reasons that delay the dehydrating of a system.

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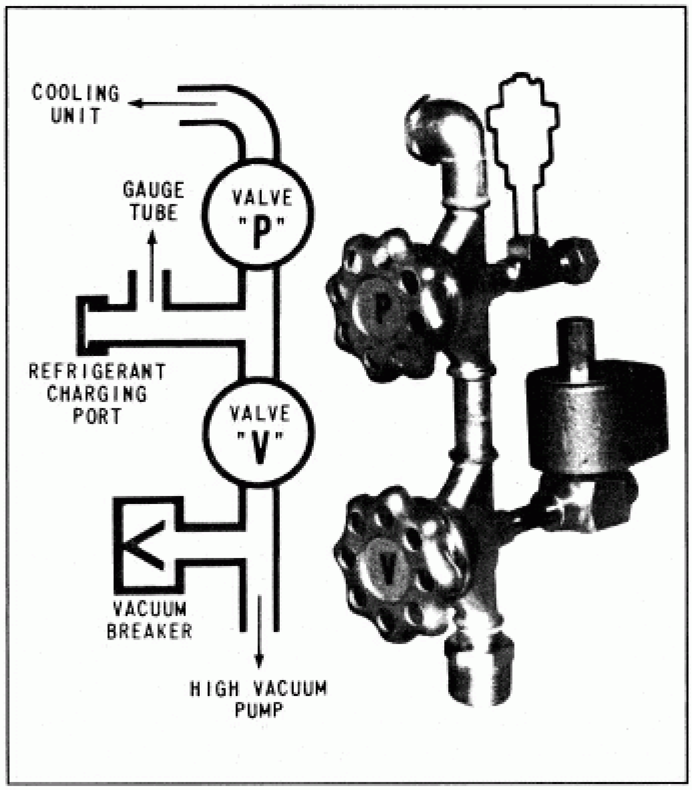

Figure 16

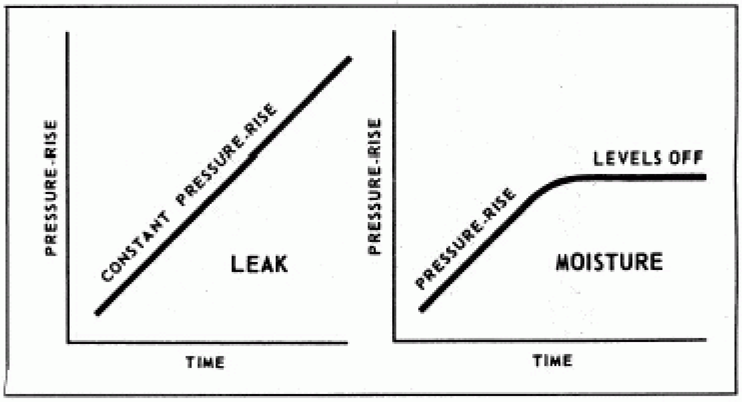

Figure 18

Two — Valve Test Manifold

1. Is the condition of the pump causing the delay? Close Valve P to isolate the system from the pump. (Figure 17.)

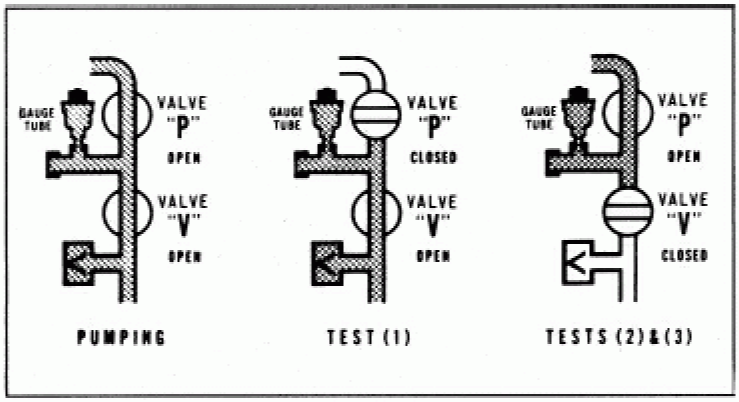

Figure 17

Valve Arrangement For Pressure Test To Determine Condition Of System Being Evacuated

If the gauge needle snaps down to a low blank-off pressure reading, you instantly know the pump is in perfect condition, hence not delaying the dehydrating cycle. Should the blank-off pressure reading not be satisfactory, change the oil in the pump until a satisfactory reading is attained.

2. Is the delay being caused by a leak? Reopen Valve P and pump down the unit to as low a pressure as is attainable, then close bottom Valve V. This isolates the pump from the system and holds the unit under vacuum. Observe the gauge. Note the pressure rise and, with a watch, the rate of pressure rise. (See Figure 18.)

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Should the pressure continue to rise quite consistently after a minute or so, be suspicious that a leak exists somewhere. Take plenty of time to confirm this suspicion before shutting down the pump to locate and eliminate the leak.

Is the unit still not adequately dry? Should the needle of the gauge show a pressure-rise but soon level off at some higher pressure, it indicates that the unit is still too wet and needs additional dehydrating or pumping time.

Open Valve "V" and resume pumping for a half hour or so, then close Valve "V" and again observe the magnitude and rate of pressure rise. You will note that both the magnitude and rate of pressure rise are not so great. This confirms that you have made progress in the dehydrating cycle. In other words, you KNOW that you haven't wasted any time. Instead of guess work, you proceeded in a logical and time saving manner.

You may repeat this leak and moisture indicating test as often as circumstances warrant until the unit has not only been exhausted to the desired finishing pressure but found to have an acceptably low pressure rise when Valve "V" is closed. This small pressure rise is proof that the unit is sufficiently "bone-dry" and ready to be charged.

This modern three-component pumping unit can quickly indicate whether a partial "freeze-up" exists in the unit which has to be defrosted before wasting further pumping time. From Figure 15 you can note that the vapor pressure of 32° ice is about 5 mm Hg. Consequently, should the gauge, during the pumpdown, hang up at about 5 mm, seek the existence of a cold spot in the system and defrost it.

CARE AND MAINTENANCE OF AN ELECTRONIC DEEP VACUUM GAUGE

Treat this gauge with the respect and care you would give any metered electrical instrument and you will enjoy years of profitable service from it without appreciable maintenance. Precautions must be taken to prevent the sensing element in the gauge tube from becoming contaminated by a deposit of oil, dirt, acids and condensable gummy vapors from the mixture of gases exhausted from the unit being evacuated.

Such a deposit not only affects the accuracy of the gauge reading, but if it cannot be dissolved by using a solvent, the tube is beyond repair.

Always connect a gauge tube in a vertical position in the top side of a manifold, or piping system. Always use a small wrench to prevent distortion of the internal sensing elements. Do not subject the tube to a sudden burst of pressure. Always have a spare tube at hand to serve as a master or "check" tube should you question the accuracy of the gauge reading.

The control unit of the gauge is guaranteed against defective materials and workmanship, but not against abuse or rough handling. Obviously, a gauge tube carries no warranty because the life depends upon the care taken by the user to prevent excessive contamination.

The electronic vacuum gauge is unlike any other gauge, such as the common Bourdon tube or low side compound service gauge, Mercury U tube manometer, or the McLeod gauge. These instruments read the pressure directly based on the weight of mercury and speed of the pump. The electronic micron gauge does not read in this manner. It is really a type of flow meter. Its sensing element located in its gauge tube exposed directly to the gases in the system is actually sensitive to temperature. The faster the molecules of gas move from the system being evacuated, the cooler the sensing element. As the gases become less dense or more rarified in the system there is less cooling effect and the sensor gets warmer. The meter scale in the cabinet is set to read lower as the temperature rises at the sensor and higher when the sensor is cooler.

This is an ideal detecting instrument for our trade when using a deep vacuum pump. For example, if the service technician uses an oversized vacuum pump and uses regular gauging equipment, he can easily be misled. The large pump can lower the pressure in the area of the pump so fast that all readings will be in error. This is common with the Bourdon tube gauge, the McLeod gauge, and Mercury Manometer, which read only pressure. The electronic instrument reads the flow of microns of gas passing by its sensor. It makes little difference if an oversized pump, the right sized pump, or an undersized pump is used.

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If the system is still forcing a large quantity of gas by the sensor it tells the technician the job is not finished. The electronic gauge can also confuse the technician. Always remember when reading the micron instrument that while the pump is running it is reading the flow of gas. As an example: With the pump running the meter reads 500 microns. When you close down the valve to the pump the micron reading will start to rise rather quickly. It might rise to 650 or 700 microns or higher in approximately one to three minutes before the indicator begins to settle down. This will be the true reading, telling you to pump the system lower if you are after a 500 micron reading. Remember that the gases throughout the system were still balancing in pressure by flow, even though the pump is shut off.

DEEP VACUUM SEALANT

To save exasperating hours of wasted time in testing for and eliminating those infinitesimal leaks so commonly encountered in assembling a deep vacuum line, or pump, use a sealant processed specially for deep vacuum. It must be a liquid that has a vapor pressure within 1 micron Hg pressure; thin enough to be painted over threads and joints; must remain plastic and, preferably, be colorless.

SIZE OF CONNECTING LINE

No matter how short or large in diameter the connecting line is that you install between your pump and the unit to be evacuated, it will offer an appreciable resistance to gas flow. This means loss of useful vacuum. Recall that we are involved in minute differences in pressure, such as 100 microns of mercury pressure which is about 2/1000ths of a pound per square inch. For the range of absolute pressures with which we are involved, the resistance of gas flow increases in direct proportion to the length of the line and the inside diameter raised to the fourth power! Consequently, install a line as short and as large in diameter as is feasible. Whenever it can be avoided never use tubing as small as 1/4”. Use at least 3/8” because, under vacuum conditions, its conductance capacity is 8 times greater than 1/4”. For large industrial systems the connecting line should be piping 1-1/4” size or larger to permit utilizing the fast pumping speed of an 8 cfm pump.

Do not use neoprene hose. It is not sufficiently vacuum tight for deep vacuum evacuation, or for pressure-rise testing in connection with an electronic deep vacuum gauge. Flexible seamless metal hose is very satisfactory.

A deep vacuum pump has such a low blank-off pressure that it can create the necessary differential in pressure to create a useful vacuum back deep in the system being evacuated.

A filter-drier is installed in the system to subsequently maintain the “bone-dry” condition of the dehydrated system, and pick up solid or gummy contaminants.

Modern operating conditions require that both the moisture and the air in a refrigeration system be evacuated, in field installations, more thoroughly than was acceptable a few years ago.

To most profitably accomplish this in a time-saving manner requires using a deep vacuum pump in connection with a deep vacuum two-valve test manifold and an electronic deep vacuum gauge having a range from 20 mm Hg down to the low micron pressure range.

With such a complete pumping unit, you will have continuous visual registration of the progress of the dehydrating and degassing cycle from start to finish. This will save you hours of delay due to uncertainty and permit you to evacuate a unit in a knowledgeable and organized manner, and will provide you with assurance of quality control with exacting repeatability.

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