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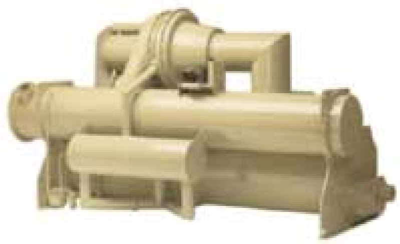

# Maintaining Low Pressure Chillers

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Low pressure chillers are typically centrifugal chillers charged with R-11 or R-123 refrigerants, operating under a vacuum in the cooler section and a discharge pressure of approximately 0.75 $kg/cm^2$ (11psig). Any leaks will suck in atmospheric air and moisture and hence such chillers are factory fitted as a standard with a purge unit that collects and purges these contaminants back to the atmosphere.

R-11 has been used as a refrigerant in centrifugal chillers for close to 70 years (the Metro and Regal cinemas in Mumbai and the Metro cinema in Kolkata were among the earliest users of R-11 centrifugal chillers in India around the mid 1930's). But it was only in the early 1980's that an international group of scientists became aware of the Ozone hole in the atmosphere that was the cause of severe health hazards to mankind. This hole was caused, the scientists determined, by the indiscriminate use and release of certain man-made chemicals into the atmosphere for many decades. R- 11 was one of the chemical culprits and the Montreal Protocol agreement signed by most countries of the world in 1987, decided to gradually phaseout the use of R-11 chillers and the manufacture of R-11 refrigerant itself. In the developed world (USA, Europe, Japan) R-11chillers are no longer manufactured and the production of R-11 totally stopped. The developing countries (India, China) were given some grace period and while the manufacture of R-11 chillers in India has already stopped, the phasing out of this refrigerant will begin in 2005 and be totally stopped by 2010.

R-123 (or HCFC 123) was developed, after the Montreal Protocol, as an alternative refrigerant to R-11, that could be safely used in place of R-11 in new centrifugal chillers and would not aggravate the reduction in the size of the Ozone hole, that was the ultimate objective of the Montreal Protocol.

It is estimated that about 2500 centrifugal chillers with R-11 are presently operating in India. The objective of this article is to provide such equipment owners *a refrigerant management strategy* including safe practices and procedures for servicing. If you do not feel comfortable in carrying out this strategy then you should consult with experienced professionals who can guide you to take the right decisions in the interest of environmental protection.

As the year 2010 approaches, the cost of R-11 will keep rising. If your present chiller is in good working condition and you are satisfied with its efficiency and your power bills, you will need to maintain your chillers much better than you have been doing so far, in order to reduce, if not totally eliminate the consumption of R-11 and its high cost. Remember, R-11 is consumed only when it is discharged or leaked into the air or contaminated by large amounts of water. As a responsible citizen of the world at large, we owe it to mankind to help in cutting down the release of R-11 to the atmosphere, by whatever means are available to us.

## Reducing the Entry of Air, Moisture and Dirt Into the System

If your purge unit operates very often and for long periods and if your discharge pressure is higher than normal, it is a sure sign that you have several leaks of air and moisture into the cooler section, because this is operating under a vacuum. Make it a routine daily practice to check for leaks from O' rings, gaskets, flare fittings, brazed joints and flanges. A leak source that is often overlooked is the rupture disc and motor terminals on which water will condense, being a cold surface and any leaks on the low pressure side will allow this moisture to be drawn in. On most systems the condenser water pressure exceeds the refrigerant pressure. Therefore if any leaks exists where the condenser tubes are rolled into the tube sheet, then water will be forced into the refrigerant circuit.

When water collects in the system, it usually ends up floating on top of the refrigerant in the cooler. This "free water" slowly reacts with the refrigerant producing Hydrochloric and Hydrofluoric acids. R-11 is particularly subject to chemical reaction with water to form acids. Of course, the acids produced are corrosive and attack the metals in the system, including the motor insulation. It can also cause rusting in the condenser shells and sticking of the guide vanes. So make it a practice to periodically remove the water boxes from the condenser and cooler to check that all the tubes are tight in the tube sheets.

## Reducing Possibility of Tube Failures

A tube failure can occur in any heat exchanger either in the cooler or in the condenser. In the cooler, a tube can fail due to water freezing and in the condenser due to foreign matter such as welding rods, (which are left behind through oversight at the time of initial installation and welding of the condenser water piping) stones and pebbles in the cooling tower.

To reduce the possibility of a freeze-up in the cooler tubes due to low water velocity, two precautions must be taken: keep the tubes clean by installing a good water strainer as close to the cooler water inlet as possible and installing a flow-switch at the cooler water outlet (either paddle type or differential pressure type – the differential pressure switch is normally recommended since the life of a paddle type switch is limited and tends to fail frequently).

To make sure the tubes are clean to start with, open the water heads and check every tube to ensure no stones or other foreign matter is partially or fully blocking any tubes. After running the water pumps for a few days, check again both the water strainer and the cooler tubes.

On the condensers make sure the tubes are clean to start with by opening the water heads and checking each tube. Also ensure that an efficient water strainer is installed at the cooling tower water outlet connection as well as near the suction of the condenser water pumps. Routine checking of the strainers and tubes is highly recommended.

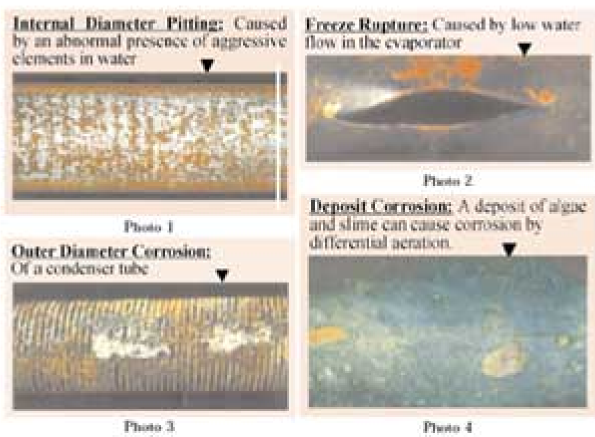
## Eddy Current Testing

To ensure that all tubes are in good condition and not susceptible to early failure an Eddy Current analysis should be carried out to test each tube. In performing an Eddy Current test the technician inserts a probe into each tube and pushes the probe the entire length of the tube. Eddy Current develops as a result of alternating current flowing through coils inside the probe. The Eddy Current flows in a circular motion forming a flux field outside of the coils. The current penetrates the entire wall of the tube and is sensitive to any variations in the tube wall. As the probe travels through the tube, any variables in the Eddy Current pattern are displayed on a small monitor. From the shape and direction of these signals, the technician can record the type of problem and its location anywhere within or on the tube. He can accurately determine the extent of the tube problems and whether or not the tube needs to be replaced. This sensitive type of equipment is capable of detecting upto four or five problems simultaneously.

With this kind of test equipment and an experienced technician it is possible to :

- detect ID (water side) corrosion, pitting, or erosion.
- detect OD (refrigerant side) corrosion, pitting, erosion, or support wear.
- detect longitudinal cracks in the tubes.

Here are a few images which give you an indication of the type of damage that can be caused to the tubes. Refer to ***Photos 1, 2, 3, and 4.***




An Eddy Current tube analysis can detect, identify, and locate potential tube failures before they actually become leaks. Eddy Current testing is about the only testing available to determine tube problems. If the tubes are fouled and if you are doing an Eddy Current test then the tubes will need to be cleaned first. Either mechanically clean the tubes or chemically clean depending on what is coating the tubes. Different corrosion on tubes will require different chemicals to clean. Excessive corrosion on tubes may hide some of this information. Once the tubes are clean so that the copper can be seen to be clean and free of foreign matter, the tubes can then be Eddy Current tested.

Do not use high pressure chemicals or water to clean the tubes as this will erode the tube surface and cause premature failure.

## What to Do if a Tube Does Fail

If in spite of all precautions, a tube does fail, either in the condenser or cooler, it is imperative to act **immediately** and not allow free water to lie inside the unit for an extended period. The main problem starts when quick action is not taken and air, moisture and water is allowed to lie in the units for extended periods. Once you have air, moisture and water in your machines then rusting begins to take place almost immediately.

The most serious problem caused by water and moisture in the system is corrosion. When moisture (water) combines with halogenated fluorocarbon refrigerants such as R-11 and R-123, the Hydrogen in the water combines with either the Fluorine or the Chlorine to form Hydrofluoric and/or Hydrochloric acid. Acid build up in the system attacks all mechanical parts like impellers, rotors and bearings. It mixes with oil to create sludge and once sludge is formed there is a total breakdown of the lubrication system.

The chiller that develops a leak will end up with two problems. One being the leak and the second being the contaminated refrigerant. Contaminated refrigerant will be the long-term problem. It is recommended that when a leak is detected, the refrigerant be removed using a Recovery Unit and stored in cylinders. Recovering refrigerant in cylinders other than those designated for the particular refrigerant will cause the refrigerant to mix with the residual oil which may be polyolester oil lying at the bottom of the cylinder, which is not used in a low pressure chiller. This contaminated refrigerant with oil mixed in it can be then charged into the chiller and cause contamination of the entire system. The oil mixture can cause a breakdown of the lubrication system.

Recovering refrigerant is the act of removing refrigerant from a refrigeration or air-conditioning system so that losses of that refrigerant to the atmosphere are minimized. A Recovery Unit is a mechanical device consisting of evaporator, oil separator, compressor, and condenser which draws the refrigerant out of the refrigeration system, purifies it and stores it in a storage cylinder. The equipment may employ replaceable core filter-dryers to remove moisture,acid, particulate and other contaminants. The reason you need to use a Recovery Unit is to facilitate high recovery rates for both low and high pressure units. It can eliminate CFC – leakage during service by recovering upto 99.95% of the total refrigerant. Refer to ***Photo 5***, which gives you an indication of what a Recovery Unit looks like.

Photo 5

While the refrigerant is being stored, purchase a standalone purge unit. A stand-alone purge unit is a device that removes air, moisture and non-condensibles from the unit and is independent of the chiller unit. It consists of its own tank, inlet and outlet valves, a refrigeration system and purge control system. The purge unit automatically detects air and non-condensibles from the refrigerant and purges them from the refrigerant to the atomsphere. As a result, the purge units removes the moisture from the refrigerant while the chiller is being repaired. This way when the refrigerant is charged back into the machine it will be free of moisture and contaminants.

## Determining the Location of the Leak

Now you need to identify the leak in order to repair it. Use Nitrogen plus a Trace gas. Never use compressed air, Oxygen or a flammable gas to pressurize the system! Refrigerant and air mixture should not be used due to the combustible nature of the mixture.

If an electronic leak detector is used it will be necessary to inject refrigerant into the chiller as a Trace gas. Use Dalton's law of Partial Pressures to calculate the amount of Trace gas required.

Dalton's law of Partial Pressure states : Total pressure = sum of all the partial pressures. Ten to twenty per cent of refrigerant is usually sufficient. The calculation for Trace gas is as follows:

Example used for high pressure chillers: 15% Trace gas = 15% refrigerant and 85% Nitrogen. Convert all gauge pressures to absolute for calculations. If you need to pressure test to 165 psig, add 14.7 to 165 psig (to convert to psia) = 179.7 psia. Now 15% of 179.7 psia is 26.95 psia. Subtract 14.7 from 26.95 psia to give you the pressure in psig, which is 12.26 psig. This is generally the method to find out the 15% of Trace gas required.

First break the vacuum or pressurize the system to 12.26 psig with HCFC-22. Next pressurize the system to 165 psig with Nitrogen. Always use a regulator when adding Nitrogen to a system.

When proper detection equipment is used, 1lb (0.5kg) of HCFC-22 Trace gas is sufficient to leak test all chillers, regardless of size. Don't use a CFC for a Trace gas. Add gas to both high and low sides. The maximum pressure the unit can be pressure tested to with the rupture disc installed is 5 psi. With the rupture disc removed the maximum pressure test pressure is 15 psi. Under controlled conditions the pressure can be increased to 20 psi. Pressure testing these machines on higher pressures may result in O-rings failing, tubes leaking or gaskets blowing out. If the vessels are rated as per ASME codes then the unit can be taken up to 25 psi. In the factory the units are normally pressure tested at higher pressures but this is done in a controlled and specially designed explosion room.

When pressurizing the unit you should never exceed the test pressure indicated on the manufacturer's nameplate. Always follow the name plate rating of the manufacturer prior to pressure testing. The maximum operating pressure of the condenser is normally 15 psi but if you exceed this pressure and test to 25 psi., then you are not looking for leaks but creating them !

A variety of leak-detection equipment is available, with electronic detectors being widely accepted. These devices are relatively easy to use. They can sense CFC, as well as HCFC and HFC and are accurate down to a leak-rate of one-half ounce per year.

Soap bubbles work well in leak-testing specific areas of the system such as flare fittings, service valves, Schraders and other small parts. No trace gas is needed. The bubble method may not detect very small leaks or leaks located in an inaccessible area. This method is also impractical for checking large areas such as coil faces.

To test if the leak is in the evaporator tubes, remove the water boxes and place rubber bungs (rubber plugs) in each tube and leak check with soapy water looking for bubbles. The leaks may be in the tubes or on the tube sheets. If rubber bungs are not available, coat the tube sheet with a fine layer of grease and cover with a light plastic sheet. A leak will cause the plastic sheet to bubble.

## Drawing a Vacuum

Once the leak has been found and rectified, the unit needs to be pressure tested again to ensure that no further leaks are found and the repairs are successful. Later the unit needs to be evacuated to remove all moisture and non-condensibles. Always make sure that you are using the right vacuum pump based on the size of the chiller. One way you can create the "ideal" conditions necessary for a very deep vacuum is by using a two-stage vacuum pump.

The single stage vacuum pump exhausts into atmospheric pressure. This is the limiting factor. The first stage of a two-stage pump exhausts into the second stage. The second stage inlet lowers the exhaust pressure of the first stage. The second stage begins pumping at a lower pressure, therefore, it can pull a deeper vacuum on the system than the first stage can by itself. For 60 tons to 200 tons, use a vacuum pump with a capacity of 5 CFM - 10 CFM (141 LPM - 283 LPM), for capacities above 200 tons, use a vacuum pump with a capacity of 10 CFM to 20 CFM. (283 LPM - 566 LPM). Using too small a pump will result in a much longer time being needed to evacuate the system. This leads to premature pump wear. On the other hand using a pump that is too big can result in the moisture freezing and consequently blocking the pump.

If the temperature around the unit is not at least 21°C (70°F) then the evacuation time could be dramatically increased. Increase the temperature around the unit using the method shown in **Figure 1**. Other means to create the ideal vacuum is to use the gas ballast, if your vacuum pump is fitted with one. 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 combines with the "wet" vapors passing through the pump from the refrigerant systems and 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. The gas ballast function should be used when the system being evacuated is contaminated with moisture.


Figure 1: If the temperature is too low....Add Heat.

It is recommended to evacuate the machine to less than 500 microns and a standing test of 24 hours may be required. Run the vacuum pump until an evacuation pressure is at a reading of 500 microns or less. If you do no reach this level, you might as well not evacuate the chiller. During this period the evacuation pull down should be checked. For example, if there is heavy contamination or a leak, then it will be difficult or impossible to pull the system down to 500 microns. In this respect, to connect the pump and then NOT check it for 12 hours or more, would be a waste of time. During this standing test, the vacuum should be measured each one hour to determine what is taking place inside the chiller. During the standing vacuum test, if the leak is less than 100 microns per hour to a maximum of 500 microns over 12 hours then the chiller can be charged. If not, the unit may require additional evacuation including flushing with dry Nitrogen or it may still have a leak. An electronic vacuum gauge is recommended for checking the vacuum. Like any job that you do, when you are evacuating an AC unit, if it is a small unitary split system or a large centrifugal machine, you should always keep a good record of what you are doing. The chart in **Figure 2** shows two typical trends and that can be observed.

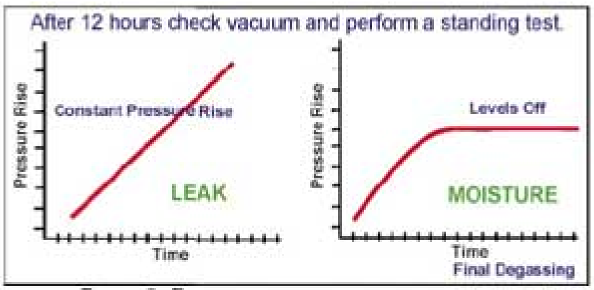


Figure 2: Evacuation guidelines – standing test.

- Leak trend indication
- Moisture trend indication

You should also use a record sheet to note down the readings and time as you take them. This is good practice in helping to provide excellent customer service too! By doing this you end up with a series of readings which can be analyzed to establish any trends such as moisture or a leak.

## Removing Rust From the Chiller "insides"

If chillers are full of rust, this is an issue that will take a long time to resolve. Rust in the machine indicates that a leak did exist and had been ignored. Rust is formed from running a machine exposed to high levels of moisture or non-condensibles for a long period of time.

Fit additional filters to the motor cooling lines if the chiller motor is refrigerant cooled. Add a bypass filter across the condenser to the evaporator, so that the refrigerant will be additionally filtered and moisture removed while the chiller is running. Change driers as required until the refrigerant and vessels are free of foreign material. This is good on-line kind of filtration and it works great. Also remember that CFC-11 refrigerant is a very good cleaning agent.

## What Does Surging Tell You

If you experience the chiller surging due to air or noncondensibles noncondensibles in the system then the most important device to check on the machine is the purge unit. This must be monitored looking for an increase in purge time. A correctly maintained machine will record zero purge time for months on end. When purge time starts to increase then you know you have a leak. The purge time should be monitored each week, when an increase is indicated. This is the NUMBER ONE indication that the system is leaking. Another strategy to adopt is to carry out frequent leak testing of the chiller. Do not wait until a leak is suspected, schedule leak testing at least quarterly.

Determine where the leak is coming from. If the chiller is running continuously and the purge is recording time the leak is on the low side. The side where the pressure is negative. If the unit is loosing refrigerant or only purging after the unit has been off, this would indicate the leak is on the high side and can be detected with a leak detector.

## Avoid Routine Oil Changes

Another step to take immediately toward refrigerant conservation is to avoid and discontinue routine scheduled chiller oil changes. Employ a reputable oil analysis program to analyze the oil quality and change the oil only if required.

## Conclusion

Establishing proper procedures for operation, routine maintenance, repairing, pressure testing and vacuumizing helps in preserving and obtaining efficiencies of a chiller resulting in low energy usage. It also reduces the generation of green house gase emissions at the power plant.

Following the right practices will help you to prevent losses and emissions of refrigerant resulting in conservation of the refrigerant, protection of our environment and protection of the ozone layer.

If you are the owner or the manager of a large centrifugal chiller facility, and if you are aware of the cost and uncertain supplies of CFC-11, the strategic approach will be to minimize the need for make up. The key will be to field test for leaks in all equipment, adhere to manufacturers recommendations for preventive maintenance and service practices, technician training and prompt responses to leak indicators. Recovery units must be budgeted, purchased and used. Operation and maintenance personnel must be trained in new maintenance and service procedures, refrigerant handling techniques, safety procedures and safety equipment use. We urge all service engineers and technicians working on any HVAC equipment to make sufficient effort to eliminate the release of CFC, HCFC and HFC refrigerant to the atmosphere resulting from installation, operation, routine maintenance or major service on equipment. Always act in a responsible manner to conserve refrigerants for continued use.