REBUILDING VS. REMANUFACTURING

OEMs have used independent compressor remanufacturers to build their products for years. City Compressor builds the A & B line for the Trane Company, and in the past was the supplier for Yorks' equipment that used Copeland compressors.

The compressor remanufacturing industry is made up of both very ethical, high quality shops, as well as companies that really give the industry a black eye.

Like anything else a Parts Center purchases for resale, you must do your homework before purchasing that product. Although cost is important, it does fall into a distant third place compared to quality and availability.

One may think that the quality depends solely on the parts that are installed in the machine, but if a shop does not have the ability to clean, machine to specs, and re-assemble correctly with proper torques, the quality of the parts installed have no worth. City Compressors' remanufacturing processes are ISO 9001:2000 certified, and can be viewed on the Virtual Tour of the website: www.citycompressor.com.

There are several companies that supply excellent aftermarket compressor parts. It is not surprising to know that these companies have also supplied their parts to the OEM. A majority of the new parts that City Compressor uses in our remanufacturing process are purchased from the same vendor that supplies to OEMs.

At City Compressor, we use the term "Remanufactured to ICRA specifications". For over 30 years, the International Compressor Remanufacturing Association has been compiling specifications that are available to its members. City Compressor follows the ICRA specifications which have been developed and tested over the years.

City Compressor is the oldest remanufacturer in the country (possibly the world), and has sold thousands of compressors to the Trane Company since our first agreement in 1992. We trust that we have earned your confidence in not only building a quality product, but also in our knowledge of this industry and our willingness to share that with you and your customers.

City Compressor Remanufacturers

RECIPROCATING COMPRESSORS
SERVICE DIAGNOSIS

THE TRANE COMPANY
COMMERCIAL AIR CONDITIONING DIV.
LA CROSSE, WISCONSIN 54601
ST-COM1-178

CONTENT

Reciprocating Compressors
Service Diagnosis

OBJECTIVE

The objective of this discussion is to acquaint the serviceman with the appearance of compressor parts that have been subjected to the effects of certain system malfunctions. This is aimed at improving diagnostic technique toward identifying and correcting system and application problems.

When viewing this presentation or studying the booklet, it must be remembered that even normally operating compressors and their systems are subjected to some of the same elements associated with failed systems. All systems are subjected to heat, varnish, discolored oil, and some normal wear which manifests itself as scratches or mild scoring. In addition, some contamination is always found in a system. It is physically impossible to eliminate elements that contribute to contamination.

What is needed by the serviceman is a developed sense of what is normal and what is not. This presentation shows the extremes of failure, but what about the system which has not failed or shown signs of failing? To what extent should you expect to see the elements of wear or abuse that are about to be described? This knowledge of the normal versus abnormal must come from experience and a developed serviceman's curious nature — that is, not to always accept the obvious clue as the only lead to the solution.

Most compressors are designed to be forgiving of minor system problems. As newer designs are introduced which take advantage of higher efficiencies, new challenges are placed on the servicemen in the form of closer system tuning, and system understanding. Cleanliness is more important now with systems designed with closer tolerances. Servicemen accustomed to taking small shortcuts on older systems and getting away with it, are now finding increased problems as a result of these methods or the methods of others. The compressor itself is seldom the problem in systems which have compressor failures. The key to servicing reciprocating compressor equipment today is based on a thorough understanding of the conditions and the sequence of events that lead to failures.

This discussion approaches compressor failure in a systematic manner. First, the affected parts are examined, then the conditions that led to failure and the possible cause or causes for the failure are explored.

The emphasis is placed on locating and correcting the basic cause for failure before any repair or replacement is attempted. If the basic cause goes uncorrected, it is only a matter of time before a repeat failure will occur.

PREVENTIVE MAINTENANCE — SYSTEM LOGGING

The best way to anticipate compressor problems is to initiate a preventive maintenance schedule that includes routine logging of system operating conditions. A record of the system's operating pressures, temperatures, etc., taken daily, provides a means for tracking system performance throughout the cooling season. With this type of data, it is possible to detect trends that might cause an operating condition to drift outside the acceptable limits.

Logging the system performance data not only provides a means for detecting impending problems but in the event of a failure, this information can be used to reconstruct the series of events that led up to it. At the conclusion of this presentation, some suggestions are discussed which can help in establishing a log system for your owner operators.

APPROACHING THE FAILED SYSTEM

When arriving at the cause of a system failure, use all of the possible data you can obtain from any and every source.

Talk to the owner's operating personnel and find out what you can about how the unit sounded immediately before the failure. Was the operation normal or erratic? At what time did the failure occur? If you know this, you may be able to determine the extent of system load at the time of failure. Did the operator keep a log as suggested above? If he did, your investigative work will be easier.

IDENTIFICATION AND CONDITION OF PARTS

When disassembling a damaged compressor, identify the parts as they are removed so that when they are to be examined, their relative positions within the machine can be determined. For permanency, mark the parts with either a metal scribe or permanent magic marker to prevent smudging when handled.

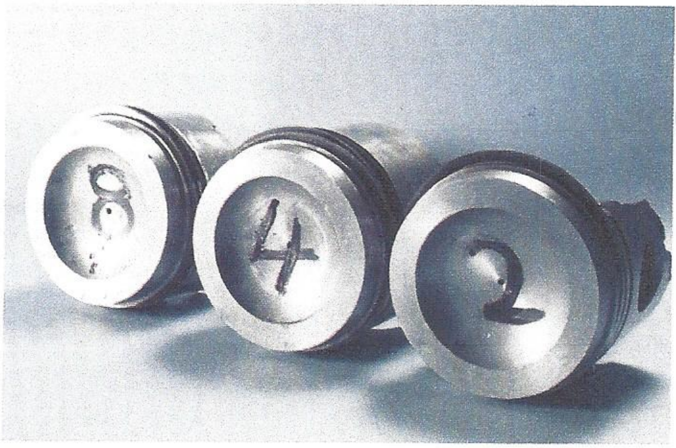

FIGURE 1

(Figure 1) Using a numbering system to identify piston and rod assemblies will indicate from which cylinder an assembly was removed and whether the cylinder is unloading or non-unloading. If, for this example, it is found that damage is confined to non-unloading cylinders only, the difficulty may have occurred while the compressor was fully unloaded.

This is the type of information that is helpful when reconstructing the conditions that led up to the failure.

In addition to identifying parts that are removed, look at the general condition of each part in the compressor. Are certain parts clean and undamaged? If so, make notes of this. If the general condition is dirty, what type of contamination are you looking at? Much can be determined at this point if you can identify soot, varnish, hard carbon, sludge, copper plating, rust, or powdered contaminants such as aluminum or flaked or rolled bits or metal and relate these findings to areas of the compressor or individual parts. Are the valves broken; if so, where and how? Even if extensive cleaning is needed to view the damage, the information obtained may be of extreme value when making the final analysis.

CATEGORIZING SYSTEM PROBLEMS

In dealing with compressor failures as a result of system problems, as we are doing with this presentation, we should first identify the various general system categories to which most system related compressor failures can be traced. Each of these general categories will then be discussed in terms of the damage they can cause and finally, a discussion of the solutions to each of these areas should help in leading toward identification of the system problem. This discussion is not intended as a system design manual and you should be prepared, following this discussion, to look to other sources (such as the Trane Reciprocating Refrigeration Manual) to further develop these design techniques and skills.

Now let us look at general system failure categories. Most compressor failures (with the exception of product defects) can be placed in the following general categories:

1) LIQUID SLUGGING — damage from hydrostatic pressure when a compressor attempts to compress a liquid (either oil or refrigerant or both)
2) LUBRICATION — excessive wear related problems caused by the lack of sufficient lubricating oil in essential areas.
3) SYSTEM CONTAMINATION — extraneous material resulting in excessive wear, mechanical motor damage, and heat.
4) ELECTRICAL — those electrical problems which can induce failure rather than those electrical problems caused by mechanical damage from # 1-3 (above). Our discussion will include some of the mechanical causes for electrical failures as well.

Let's take a closer look at each of these areas.

LIQUID SLUGGING DAMAGE

First, let's look at the mechanical damage that is associated typically with hydrostatic pressures from liquid slugging.

(Figure 2) The teardown of this Model M compressor revealed suction valve damage resulting from the attempt to compress liquid refrigerant or oil, or both.

Since a liquid is virtually non-compressible, the resulting hammering characteristically damages the suction valves of this machine. In this example, pieces of broken suction valve were wedged against the discharge valve and the side of the discharge gas passage.

This is a severe case. More often, the suction valves remain intact but crack radially or chip when subjected to liquid slugging.

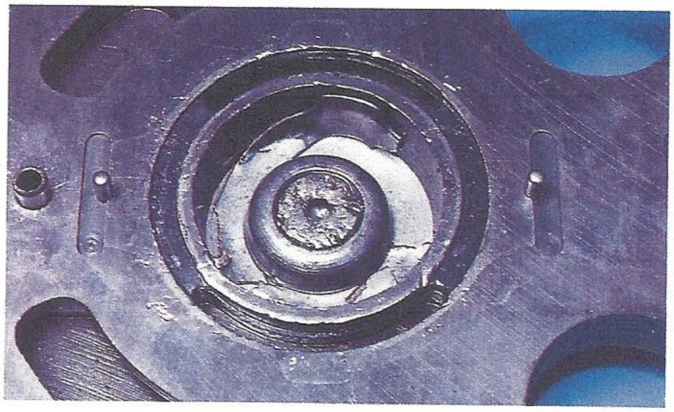

FIGURE 2

FIGURE 3

(Figure 3) This is the piston and rod assembly that was removed from the same compressor. The piston damage occurred when it contacted the broken valve parts.

When this type of damage is found, the cylinders are generally damaged to the point where they must be repaired.

Similarly, other compressors may show suction valve and spring damage when subjected to severe liquid slugging. The top of the piston will generally have marks caused by contact with spring or valve fragments.

Anytime valve or spring damage is observed, remove the motor and inspect it and the motor barrel carefully. It is possible that valve or spring fragments have lodged themselves in the motor barrel or stator windings where they can cause future spot burns. This is covered in greater detail under Electrical Problems, Page 12.

Causes of Liquid Slugging

Refrigerant Flood-Back From An Improper Expansion Valve

An improperly oversized expansion valve selection is one of the principal causes of liquid flood-back and the resultant slugging. While an oversized valve may perform well at full load, at part load it may lose control. The reason is, at part load the valve attempts to control at its superheat setting but its oversized port passes more liquid than is needed. This overfeeds the evaporator, causing a rapid reduction in the superheat of the leaving gas. In response, the valve closes until normal superheat is reestablished. At this point, the valve again opens to pass another slug of liquid. This "hunting" condition will allow liquid to flood through the evaporator and into the suction line from where it can enter the compressor to cause damage.

It is important to note that some manufactured packaged products are intentionally designed with expansion valves rated for larger tonnage. In this case, the valve has been carefully selected and tested to insure that it meets specific design objectives. Do not confuse this type of valve selection with a 'field' selected valve discussed above.

In many cases, field installed valves have been selected by inexperienced personnel. An experienced serviceman should always be suspicious of field selected and installed valves.

Refrigerant Flood-Back From Reduced Load

Reduced air flow across a direct expansion coil, resulting from dirty air filters, fan problems, air blockage, etc., can also result in liquid slugging.

The reduction in air flow reduces the load on the coil, resulting in coil frosting. Frost insulates the coil heat transfer surfaces which further reduces the load that the coil actually sees.

At this reduced coil load condition, the expansion valve is generally unable to control accurately. In a sense, it is oversized for the job it is attempting to do and will act in the same manner as described above for the improperly sized expansion valve. A water chiller will show the same symptoms when it is badly fouled or the water flow rate is low.

Refrigerant Flood-Back From Poor Air Distribution

A similar problem may be encountered when the air flow distribution across the face of an evaporator is not uniform. Poor air distribution causes unequal loading of the coil refrigerant circuits, resulting in an erratic suction temperature sensed by the expansion valve. This may cause even a properly designed valve to "hunt", resulting in possible flood-back of refrigerant through the lightly loaded circuits.

Poor air distribution may be evidenced by spot frosting or the appearance of spot condensation on the coil.

Refrigerant Migration

Migration is the result of refrigerant condensation in the coldest part of the system. Refrigerant which circulates as a vapor is trapped as a liquid when it condenses in the coolest place. Usually this is the compressor or the evaporator when outdoor ambient temperatures are warm. It causes no problem when it condenses in the condenser where it's supposed to. Certain types of systems lend themselves to migration problems because of the close association with other adjacent systems.

Refrigerant migration is a concern particularly with duplex water chillers. Since system water is usually pumped through the inactive chiller circuits as well as the active circuit, the temperature and pressure difference between the condenser and chiller of the idle circuit is considerable. And since the idle compressor may remain that way for days at a time, it is possible for large amounts of refrigerant to migrate from the condenser to the chiller idle circuit through any small leak and condense. Such leakage can take place through the liquid line solenoid valve or compressor valves which normally do not have an absolutely tight shutoff. This means that, in time, a large percentage of the total refrigerant charge will end up in the low side of the system.

Of course, when the idle circuit is finally put into service, large amounts of refrigerant will flood-back through the suction line and this will result in slugging and oil dilution.

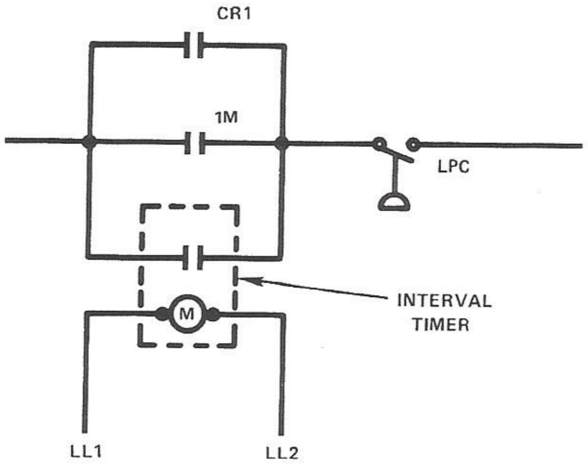

FIGURE 4

(Figure 4) The best solution to this problem is to install a Trane Timed Periodic Pump-out in parallel with the auxiliary pumpdown contacts of the compressor starter (1M) and the non-recycle relay (CR1). The control is adjusted to close at timed intervals (generally 30 minutes). If when the timer contacts close the contacts of the low pressure control are also closed, indicating the presence of refrigerant, a pumpdown cycle is started.

This timed pumpdown cycle keeps the low pressure side clear of excessive amounts of liquid refrigerant, preventing flood-back problems at compressor startup. It is important to note that migration to the evaporator will not be prevented by the availability of an oil sump heater. The quantity of refrigerant involved will overwhelm the sump heater.

Oil Flood-Back

The flood-back of oil can be equally as damaging as the flood-back of liquid refrigerant in terms of liquid slugging only. A well designed piping system will promote a uniform movement of oil, preventing the accumulation of damaging oil slugs.

System piping is particularly critical, for instance, with systems that must operate for extended periods of time at minimum load when the gas velocities required for oil movement may be marginal. If an improper piping design permits large amounts of oil to be trapped at minimum load, the oil may return as a slug when a compressor returns to higher capacity operation.

To avoid gas velocity problems associated with minimum capacity operation, it is absolutely necessary that accepted piping design and sizing practices be strictly adhered to.

If it is found that a piping design is allowing excessive amounts of oil to be trapped in the lines at minimum load, the problem may be solved temporarily by preventing the compressor from unloading to less than the part load rating where the velocities become marginal. However, when this is done, the compressor can be expected to cycle frequently. This may create a new problem of motor overheating and may require the addition of anti-cycle protection to prevent nuisance motor shutdown during this temporary period.

It must be understood that this is only a temporary solution to a piping problem. The piping design must be corrected at the earliest opportunity and the compressor returned to its full range of capacity control to properly correct the problem.

LUBRICATION PROBLEMS

Among the common categories of compressor lubrication problems are oil dilution, oil loss and reduced oil viscosity due to compressor overheating.

Oil Dilution

Probably the most common lubrication problem is oil dilution. Since oil has a strong affinity for refrigerant, it can be easily understood how oil can become excessively diluted by the refrigerant during prolonged shutdown, causing it to lose much of its lubricating qualities. And within certain normal temperature ranges, depending upon the oil type, it is possible for an oil-refrigerant mixture to saturate, causing a separation of the two fluids. The more dense refrigerant-rich mixture seeks the bottom of the crankcase while the less dense oil-rich mixture seeks the top. In addition, any refrigerant which has migrated and condensed in the evaporator further dilutes the oil on startup.

When a compressor is started with excess refrigerant in the crankcase, a refrigerant-rich mixture is drawn by the oil pump. Being an excellent solvent, the refrigerant washes oil from the bearings. In addition, heavily diluted oil foams excessively and may cause the oil pump to actually lose its ability to pump for a time after the crankcase pressure is reduced at startup. Add to this mixture, a secondary slug of migrated refrigerant from the evaporator and the stage is set for a mechanical failure because of severe oil dilution and refrigerant washing. The marginal lubricating qualities of the foamy oil, coupled with little or no oil flow from the pump and the washing action of the liquid refrigerant from dilution, results in the scoring of bearing and cylinder surfaces. The degree of scoring that takes place during any one startup depends upon the amount of refrigerant present, the time required to purge the refrigerant from the oil, the time required to "reprime" the oil pump, and the extent of compressor loading while all this is occurring

The bearing damage which results from excessive oil dilution is usually confined to the rod bearings that are closest to the oil pump. The remaining bearings may not show damage because the refrigerant portion of the mixture may escape or flash through the closest rod bearings before it reaches the extreme end of the lubrication loop which will allow adequate lubrication in these sections.

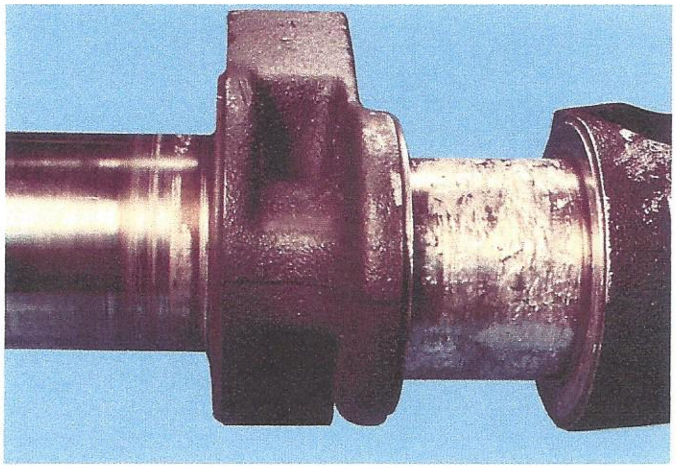

FIGURE 5

(Figure 5) This is a crankshaft that was subjected to a refrigerant washout. The key to this observation is the way the metal from the aluminum rods is literally smeared onto the crank bearing surfaces. The crank throws do not show any particular discoloration from temperature because the failure occurred almost instantly and the evaporating refrigerant within the crankcase and lubrication passages absorbed most of the heat of friction. With a rapid failure such as this, the crankshaft will not heat up.

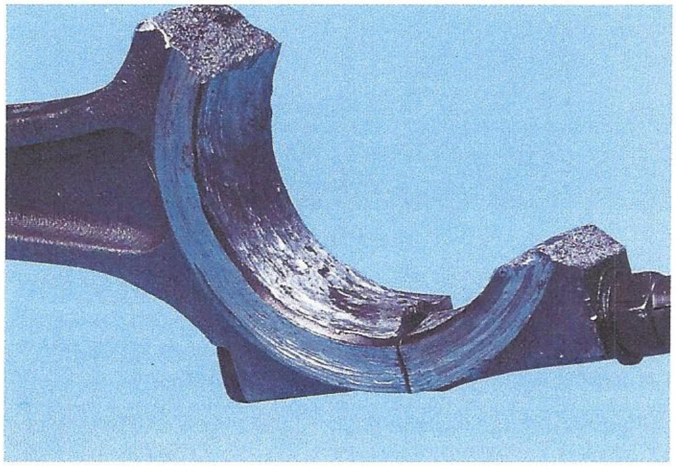

FIGURE 6

(Figure 6) A rod from the same machine shows a similar smearing of the aluminum of the bearing surfaces. Again, the rod shows little or no discoloration from heat.

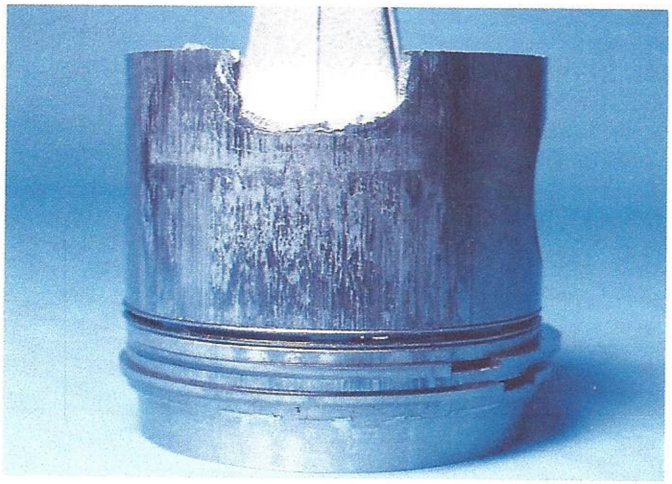

FIGURE 7

(Figure 7) Scoring of the piston in both the ring land and skirt areas is not uncommon when excessive oil dilution and refrigerant slugging occur. This failure mode results because if heavy dilution is occuring from a washout with migrated refrigerant, the upper cylinder walls and rings are being washed with refrigerant and are receiving virtually no lubrication. The rings and cylinder walls begin scoring initially and this scoring results in galling of the piston skirts and ring lands and the eventual piston seizure and breakup within the liner.

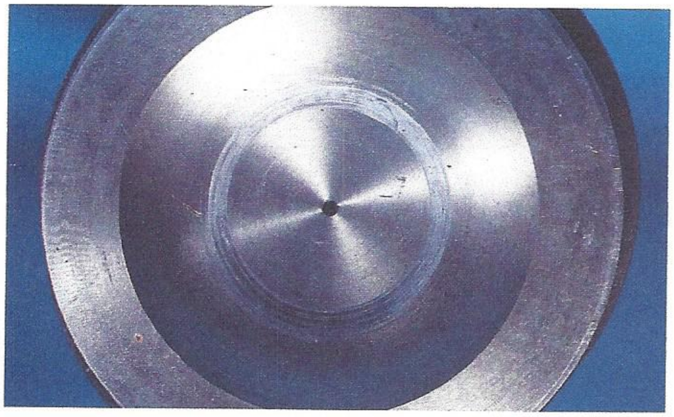

FIGURE 8

(Figure 8) The top of this piston was scarred when the loss of rod bearing material produced sufficient clearance for the piston to strike the discharge valve cage retaining bolt.

(Figure 9) The pump-end bearing and (Figure 10) the motor-end bearing show similar smearing of the babbitt bearing material.

From this discussion, it becomes apparent that failures produced by excessive oil dilution are such that the metal of the opposing bearing surfaces attempt to weld, producing the smeared appearance with very little indication of excessive heat beyond the point of failure.

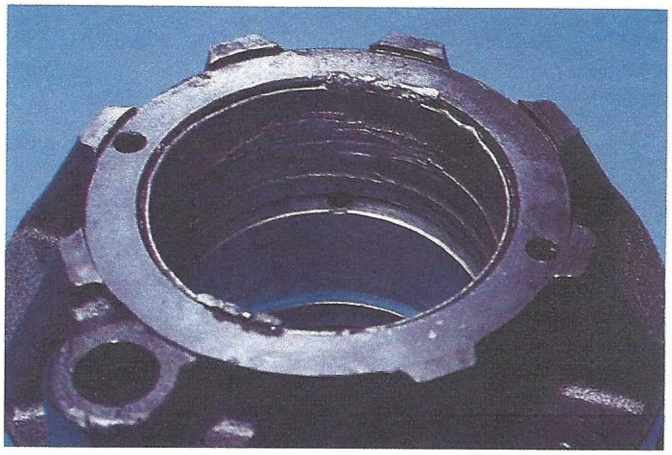

FIGURE 9

FIGURE 10

Causes Of Oil Dilution

Migration of refrigerant within an idle refrigeration circuit is one of the principal causes of oil dilution. As discussed previously, refrigerant vapor migrates to the coolest part of the system where it eventually condenses. This will continue until the pressure-temperature relationship of the refrigerant is equalized throughout the system. This migration to the compressor is aided by the oil-refrigerant affinity discussed earlier.

Since the compressor is constructed of a large mass of cast iron, it is the last thing to cool at shutdown and it is typically the last component of the refrigerant system to warm as the ambient temperature rises. Therefore, it is frequently the coolest part of the system after several hours of shutdown. In the compressor, the motor barrel is one place where the migrating refrigerant may collect and condense. In addition, since all commonly used refrigerant oils have an affinity for refrigerant, dilution takes place readily unless some preventive device is used to reduce oil/refrigerant affinity.

To counteract this occurrence, most compressors are now equipped with crankcase heaters. This preventive device functions to maintain an oil temperature 20-40F above ambient to reduce its affinity for refrigerant, thereby discouraging the migration of vapor to the compressor.

It is **not** the function of the heater to prevent refrigerant dilution of oil resulting from migration to other parts of the system or to vaporize quantities of refrigerant already in dilution in the compressor. The migration problem can be solved by installing an interval timer to periodically pump down the system. This is discussed under "Refrigerant Migration", page 4.

Oil Loss

The loss of oil robs a compressor of bearing lubrication and cooling, resulting in the generation of an excessive amount of heat, bearing scoring and rod seizure.

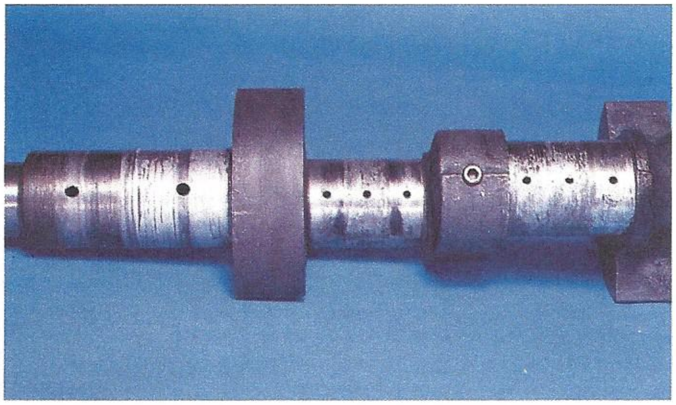

FIGURE 11

(Figure 11) Compare this crankshaft with the previous one, Figure 5. Note the color difference. The dark color of the throws and counterweights is due to the heat of friction resulting from the loss of lubrication. Also notice the appearance of the bearing surfaces. These surfaces show fine grooving instead of the smeared aluminum that typlifies the refrigerant washout. Although the fine grooving can also be the result of dirt in the system, the real key to the differences in these two crankshafts is the discoloration from heat and the longer time before failure.

Causes Of Oil Loss

There are several causes of compressor oil loss. Some of the common causes are short cycling, excessive oil foaming, leaking hydraulic unloaders and long periods of minimum load operation coupled with a poor piping design.

During extended periods of short cycling, it is possible for the compressor to pump oil into the system at a greater rate than it is being returned. This, of course, results in a reduced oil level.

Short cycling may be caused by a low refrigerant charge which is causing the compressor to cycle on the low pressure control, differential setting of the controlling thermostat set too narrow, minimum load conditions, etc. These conditions are all accompanied by a low mass flow of refrigerant which in turn, results in low gas velocities.

If the system is subjected to rapid load fluctuations which cause frequent stopping and starting, the cycling can be eliminated through the application of a hot gas bypass system.

Excessive foaming within the compressor crankcase is another cause of oil loss. When oil foams up within the crankcase it enters the suction passage where it is entrained by the refrigerant gas and is pumped out into the system. If foaming persists, it is possible that the oil level may drop severely.

A certain amount of foaming is expected when a compressor is started. However, once the excess refrigerant is boiled from the oil, the foaming will subside if system refrigerant flow control is proper and the proper oil recommended by the manufacturer is being used.

Persistent foaming has two main causes. Either an improper oil is being used or the crankcase oil is being diluted with liquid refrigerant. The cause of liquid refrigerant return to the compressor is discussed under "Causes of Liquid Flood-back", or "Migration", page 4.

Hydraulic cylinder unloaders, of the type used with the Trane Model E and F compressors can be a source of oil loss. When pressurized oil is fed to the cylinder unloader to load the cylinder, it is possible for oil to leak past worn "O" rings into the suction gas passage of the compressor. From there it is entrained by the suction gas and is pumped into the system.

If an equilibrium condition, where the oil loss and oil return are equalized, is not established within a short time, the sump oil level will be dropped to a level where oil pressure cannot be maintained.

If the refrigerant piping is assumed to be correct, the "O" rings can be checked by loading the compressor fully and observing the oil level sight glass. If the oil level drops from sight, the compressor should be unloaded manually to its minimum stage of loading. If after a period of time the oil returns to the normal running level, it can be assumed that the unloader "O" rings are leaking.

If the machine is electrically unloaded (Trane models 'F' and 'E' only), the unloaders can be checked for leakage by energizing the unloader valves individually. If when a valve is energized, the oil level and useable oil pressure drop, the cylinder unloaders controlled by that valve are the ones that are leaking.

Compressor Overheating

Compressor overheating and the resulting heating of the oil causes the oil to lose its viscosity. At reduced viscosity, the oil is less capable of properly lubricating the moving parts. Loss of lubrication, in turn, may cause the bearing surfaces to heat excessively resulting in extensive wear, binding and carbonizing of the oil.

An occurrence that typically accompanies compressor overheating is the scoring of the piston skirt. Since the thermal expansion rate of the aluminum piston is greater than that of the steel or cast iron cylinder, the piston virtually outgrows the inside diameter of the cylinder at high temperatures, causing the skirt to score and the piston to seize. In many cases, the ring lands are not damaged because the piston seizure occurs before ring land damage can result.

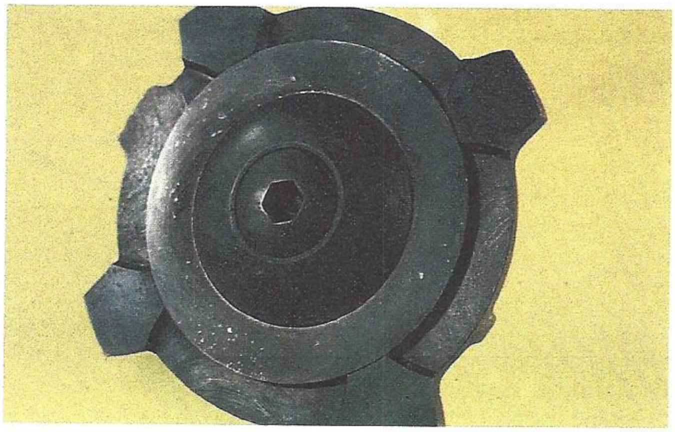

FIGURE 12

(Figure 12) This illustrates very early stages of carbonizing on the valve. Severe carbonizing more typically will give the valve and valve cage assembly a heavily coked appearance. High discharge temperature can cause oil to carbonize on the discharge valve cage assembly. In extreme cases the carbonized oil can restrict valve movement causing it to leak discharge gas back on to the surface of the piston. This places a constant downward pressure on the piston on the intake as well as the compression strokes.

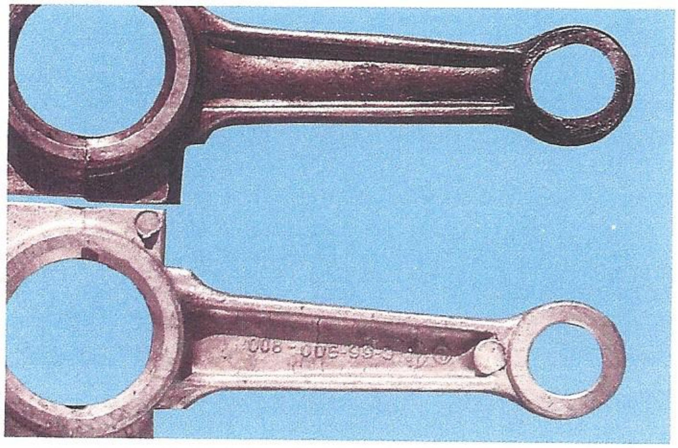

FIGURE 13

(Figure 13) The piston of the upper connecting rod, for example, was subjected to this type of constant downward pressure. The lower portion of the piston pin bearing surface was robbed of lubrication, resulting in the extreme wear.

Piston pin lubrication depends upon load reversal on the pin. On the compression stroke, the lower bearing surface is loaded, allowing oil mist to enter the clearance between the pin and the upper bearing surface. After the piston reverses direction, the load transfers to the upper bearing surface, allowing oil to enter the clearance between the pin and the lower bearing surface.

When a piston is under constant downward pressure, this transfer of load to the upper bearing surface does not take place and the lower bearing surface does not receive adequate lubrication.

FIGURE 14

(Figure 14) This piston and rod assembly was removed from a compressor in which the oil pump was intact and was apparently in reasonable operating condition.

The dark color of the rod is evidently due to heat in the compressor resulting from the poor lubricating qualities of overheated oil with its resultant discoloration or from another heat source. The rod was broken when it seized on the crankshaft. Once the rod broke free of the shaft, the upper portion was thrown into the piston, breaking off a piece of the skirt.

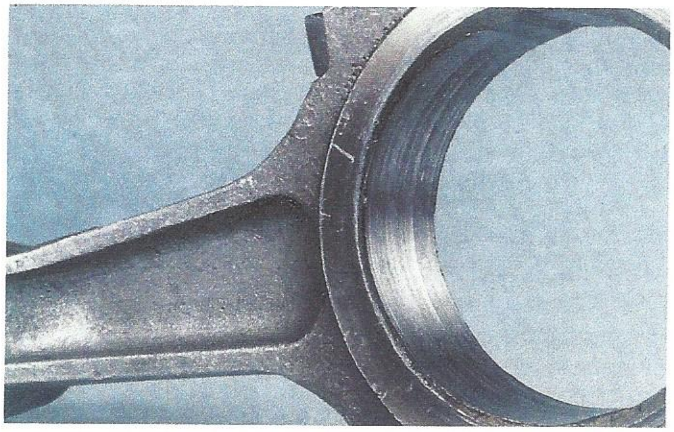

FIGURE 15

(Figure 15) This is a rod that was removed from the same machine. Notice the nature of the bearing surface. The surface shows fine grooving, unlike the smeared appearance that is characteristic of a washout. The extreme heat that accompanied this failure is evidenced by the darkening of the rod in the area adjacent to the bearing surface.

Causes Of Compressor Overheating

Among the common causes for compressor overheating are a high compression ratio (low suction and high discharge pressures), low refrigerant charge and unloading the compressor below its design unloading limits. Each of these conditions produce the same thing — low refrigerant mass flow. Since the motor heat and heat of friction produced by a compressor are always present, any condition that reduces the flow of refrigerant gas below the design minimum requirement deprives the compressor of needed cooling, resulting in an overheated condition.

When overheating is suspected, it is confirmed by checking both the oil and discharge temperatures. The oil temperature is taken on the outside surface of the oil sump at the discharge end of the compressor. Similarly, the discharge temperature is taken on the surface of the discharge line approximately six pipe diameters from the compressor.

These temperatures are to be taken on smooth, clean surfaces which are free of paint, corrosion, etc. The thermometer or thermistor is to be attached tightly to the surface and insulated to obtain the best possible reading. The readings obtained will not be precise due to heat conduction losses through the metal and this is an important consideration when using the temperature guidelines given below.

Since the oil viscosity becomes marginal at temperatures between 190 F and 200 F, any oil temperature reading within this range is approaching the point where oil films can breakdown, resulting in metal-to-metal contact and eventual mechanical failure.

The discharge temperature, on the other hand, should not exceed 275 F. If the discharge temperature is 275 F, the temperature in the area of the compressor valves is approaching a temperature that can be injurious to the oil.

This temperature range should not be thought of as a strict dividing line between good and bad. The oil breakdown process extends over a wide temperature range and in the ranges mentioned, this process is in an area of accelerated breakdown. This is why this range of temperatures is critical but still subject to many other variables.

A high compression ratio is generally attributed to condenser problems, evaporator problems, improper system control, or a combination of all three problems. The solution to this problem is to check the cleanliness of the evaporator and condenser, the condenser and evaporator air or water flow rate and the entering and leaving water or air temperatures. In addition, operation and control of the system must be monitored closely to identify any other operating mode which could contribute to low refrigerant mass flow.

A low refrigerant charge, on the other hand, is characterized by the appearance of flash gas in the sight glass at the expansion valve, low suction pressure and highly superheated suction gas. Of course, adding refrigerant to the system is the solution to this problem. Obviously, before doing this the source of the leaking refrigerant should be determined.

Finally, the unloading of a compressor below the minimum capacity specified by the manufacturer for certain ranges of suction and discharge temperature difference, can cause a refrigerant mass flow that is less than that required for adequate compressor cooling. The solution is to limit the unloading of the compressor to that specified by the manufacturer for the existing system design conditions.

SYSTEM CONTAMINATION PROBLEMS

Some of the contaminants most frequently found in refrigeration systems are moisture, copper oxide, dirt, flux, and flaked or powdered aluminum. While the filter-drier will usually trap these materials, this is not always the case.

Moisture

Water in a system can lead to further contamination due to formation of rust, corrosion, refrigerant decomposition, oil sludging, or general deterioration. By coupling each of these failure components with the resultant damage which can occur with their presence, further areas of failure become obvious. Excessive heat from friction, copper plating, and unnecessary wear of precision bearing surfaces all could be connected to this contaminant. In addition, ice formed (usually only in R-12 systems) in the expansion valve will restrict refrigerant flow or stop it completely.

One way to detect moisture in a system is with the use of liquid-line indicators. Sufficient time should be allowed for the indicator to reach a point of equilibrium and to indicate the proper color. It should be located ahead of the expansion valve and any driers (if present).

In an installation that has been properly installed and dehydrated there is virtually no way that moisture should be an initial problem in any reciprocating system. If a leak is present in a chiller so that water enters a refrigeration system, the resultant refrigerant leak would be apparent long before the moisture could become a problem.

Causes Of Moisture

The main cause or source of moisture contamination is from air introduced into the system during piping installation of any of the refrigerant lines. Another source of moisture introduced to the system is improperly handled refrigerant oils used as service replacement to the compressor. This can be remedied by closely following recommended oil handling techniques.

Without proper evacuation procedures, sufficient water can remain in refrigerant lines to induce corrosion and accelerate formation of other forms of contamination described earlier. Moisture is usually detected by use of a "dry-eye" moisture indicator located in the liquid line.

A common field procedure used to evacuate moisture and air from a system is the triple evacuation or "blotting" method. Alternately, evacuating to a 1mm Hg absolute pressure and then breaking the vacuum with dry nitrogen or refrigerant will normally minimize the time required to properly dehydrate a system. It is important to remember that removal of standing water in a system will require a lengthy evacuation process. At 50mm Hg absolute pressure, water boils at approximately 100F. It is obviously impractical to heat the entire system to over 100F. The only practical way to effectively dehydrate a system contaminated with standing water is with a vacuum pump capable of producing a blank off pressure of less than 1mm Hg absolute. Most deep vacuum pumps will go far below this blank off pressure and this ability will assure satisfactory dehydration.

The time factor for water removal is often ignored; it takes time to boil off water trapped in a system using only the heat derived from room ambient temperatures. Remember that the water is changing state and that a latent load is present in boiling the water.

Another important consideration is vacuum pump size. A pump which is too large may reduce the pressure fast enough to actually freeze the water making it almost impossible to remove. The possibility also exists that damage can result to portions of a coil or the piping if freezing takes place.

Dirt And Air Contamination

Foreign matter such as dirt, solder flux, or chemicals can, along with air, result in chemical inbalances which can cause oil molecules to break up. This situation combined with the heat from higher system discharge temperatures and friction temperatures, can result in the formation of acids, sludge, or combinations of the two.

Coupled with the increasing friction which this whole process can produce, the whole system begins a process of self-destruction. In addition to the basic problems induced, more complex chemical reactions result in the formation of oxides and the elements needed for copper plating.

Causes Of Dirt And Air Contamination

In addition to moisture, dirt and air from poor installation practice can result in severe problems after the system is put into operation. Dirt can be prevented from entering the system by insuring that only clean tubing is being used on field constructed system piping. Proper evacuation and purging of the system with oil pumped dry nitrogen while making brazed piping joints will prevent air induced problems.

A source of dirt and air (along with moisture in the air) in a normal service operation may occur while adding oil to the compressor. Since oil has strong oxidizing characteristics and can quickly entrain air and water, care must be taken when transferring oils to the compressor. Oil should always be stored so that air is displaced by an inert gas above the oil level.

Oxides

Oxides can appear in the form of:

1. Red iron oxide (Fe_2O_3)
2. Black iron oxide (Fe_2O_4)
3. Red copper oxide (Cu_2O)
4. Black copper oxide (CuO)

No attempt should be made by the serviceman to determine, by color, the exact contaminant. This must be done by chemical analysis. In addition, due to the combination of contaminants, the basic black color of the resultant product which you will see will give few clues as to the origin.

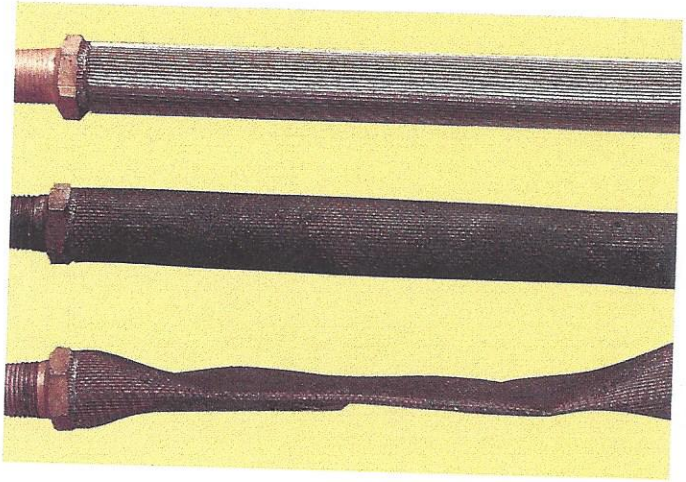

FIGURE 16

(Figure 16) This picture compares the condition of three oil strainers. The upper strainer is clean, while the center and lower ones are contaminated. The contaminant is an oxide which was wiped from the tubing walls or from within the compressor by the refrigerant and carried to the oil sump where it was deposited on the surface of the strainers. In fact, the lower strainer became so thoroughly plugged that the pressure drop across the strainer screen caused it to collapse.

Of course, a plugged strainer robs the compressor main and rod bearings of lubrication, causing scoring. The nature of the scoring is similar to that caused by oil loss, Figure 11, or overheated oil, Figure 15. In addition, many times it is possible to see fragments of the oxidized material imbedded in the softer bearing surfaces.

The extent of the damage depends upon the oil flow reduction. The bearings at the extreme end of the oil passage will be affected first. Since the cylinder walls are splash lubricated, the piston skirts should show no particular wear.

Causes Of Oxides

The formation of oxides on the interior walls of refrigerant piping takes place when the heat required to sweat high temperature silver solder joints is applied to the pipe in the presence of air.

Oxidation is prevented by displacing the air within the pipe with an inert gas, such as oil pumped dry nitrogen, before heat is applied. A nitrogen-rich atmosphere within a pipe is obtained by placing a piece of tape over the open pipe end opposite the nitrogen connection. A small hole is pierced in the tape and the flow of nitrogen is adjusted until escaping gas can be felt at the hole.

If oxides should be discovered in the oil, they may be cleared from the system by installing a suction line strainer or filter-drier to trap the material before it can enter the compressor. The oil is then changed, as necessary, until it remains clean.

Copper Plating

The parts where copper plating is most frequently found are close tolerance parts that operate at the higher temperatures, such as the compressor valves, bearing journals and the oil pump. The source of the plated copper is the system piping.

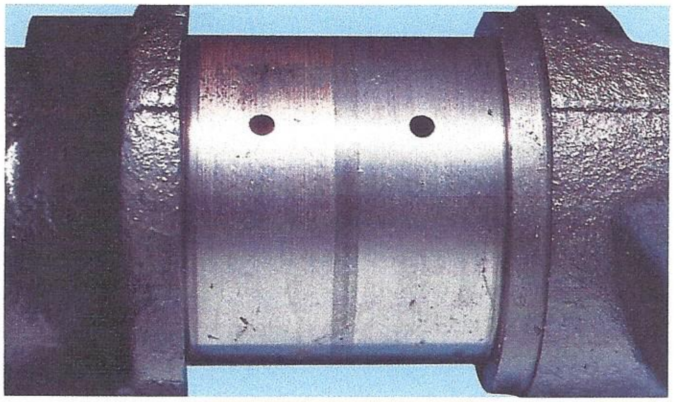

FIGURE 17

(Figure 17) The crank bearing surface on the left shows copper plating. The reason this particular bearing surface was plated is the rod was probably a little tighter than the others, causing it to operate at a higher temperature.

When copper plates out on a crank journal bearing, it is generally flaked-off and rolled into balls by the rod, causing severe scoring of aluminum. In addition, flaked-off copper will affect the life of open compressor crankshaft seals by reducing their sealing efficiency when the copper flakes become imbedded in the seal carbon face.

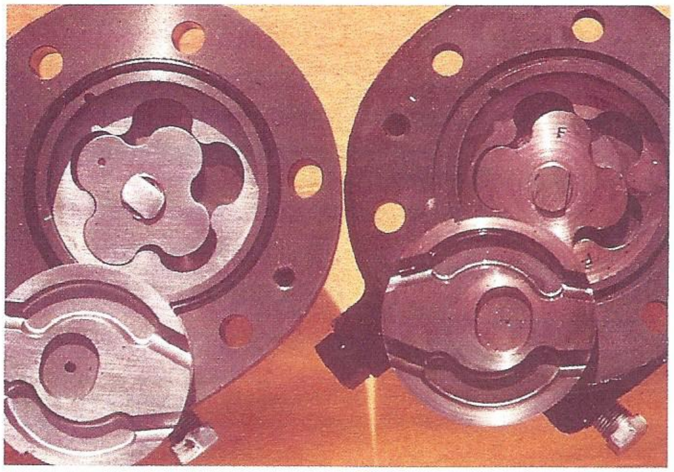

FIGURE 18

(Figure 18) In this illustration, the oil pump at the right is heavily plated with copper. To perform properly, a gear pump such as this must be built to very close tolerance. Consequently, a deposit of metal on the pump parts can close the fine clearances, resulting in dragging and binding of the pump gear and eventual shaft breakage. Once this occurs, there is a high probability that additional main and rod bearing damage will result even though the compressor shuts down on oil failure within a short time.

Typically, additional damage occurs when operators, or service personnel reset the OPC (oil pressure control) to restart the machine without realizing that there has been a complete loss of forced lubrication within the compressor.

Causes Of Copper Plating

Copper plating takes place in two steps. First, copper is dissolved in the by-products of an oil-refrigerant reaction. The quantity of copper dissolved is established by the nature of the oil, the temperature and the presence of impurities. As the second step, the dissolved copper is deposited on metal parts in a subsequent electrochemical reaction.

The common denominator in both the dissolving and depositing of the copper is high temperature. A second contributor to copper plating is the use of an improper oil. Certain oils react with refrigerants more readily than others under high temperature conditions to produce by-products that dissolve copper. Finally, the presence of air, moisture and other contaminants all hasten the depositing of the copper.

To prevent repeat failure due to copper plating, investigate and correct the cause or causes of high operating temperatures, use only the oils recommended by the compressor manufacturer and double or triple evacuate the system to assure the removal of air and moisture.

Incorrect Oils

The selection of compressor oils by the manufacturer is a far more detailed procedure than most servicemen may be aware of. Oils are selected in accordance with their analytical components to meet objectives of proper lubricity in certain temperature ranges with chemical stability. Other properties such as the analine point which affect seal and 'O' ring swelling, and those which limit the oil/refrigerant stratification at lower system temperature operating ranges must also be considered.

Only those oils tested and recommended by the manufacturer or their exact replacement may be used with the full knowledge that they are satisfactory for long term, trouble free use. Other oils may also be used successfully, but it is not practical for any manufacturer to test all of the available oils to determine their suitability for extended use.

ELECTRICAL PROBLEMS

The first reaction of all servicemen when first viewing a motor burnout in a hermetic compressor is to assume that the motor or some component of the electrical system was at fault. Although it is sometimes difficult to prove, this is usually not the case. The majority of motor burnouts have resulted from damage to the compressor and motor from system related causes, such as the areas previously discussed. All attempts should be made to determine the mode of failure before assuming that the motor was bad. If the motor protection circuit and control is functioning properly it is extremely difficult for a catastophic failure to occur purely from electrical means.

The problems in this section are discussed to include mechanical and specific motor and electrical problems.

Some of the common electrical-related compressor problems stem from the loss of power in one of the three phases (single-phasing), low voltage, shorted motor windings, overheating, dragging rotor and electrical control problems.

When a motor fails, it is strongly recommended that the windings be cleaned for inspection. Their appearance will generally lead to the **apparent** cause of the failure.

Before proceeding, the stator windings of a three-phase, four-pole motor will be examined. The identification of the windings of each of the three phases is important when diagnosing a motor problem.

Motors are available with 3, 6, 9 and 12 leads. However, regardless of the number of leads, the general appearance of the stator winding of these motors is the same.

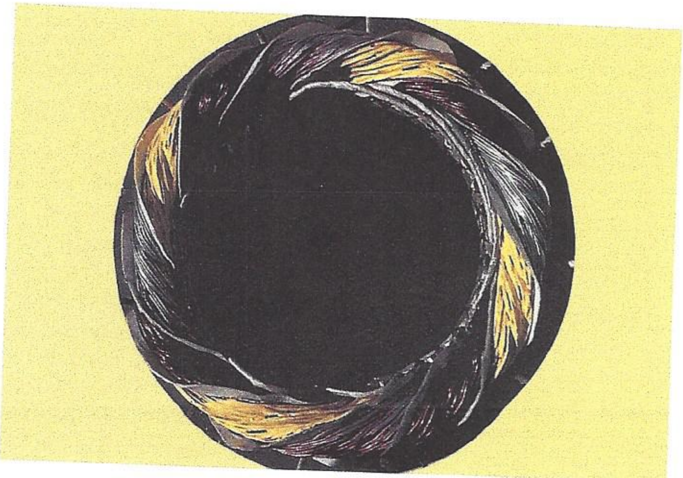

FIGURE 19

(Figure 19) This illustrates the stator coil arrangement of a three-phase, four-pole motor. For this purpose, the four coils, or poles, of each of the three phases are the same color for easy identification.

Note that the coils of the three phases appear in the color series yellow, which represents a phase; silver, which represents a phase; and copper, which represents a phase and that this series is repeated at each 90 degree interval.

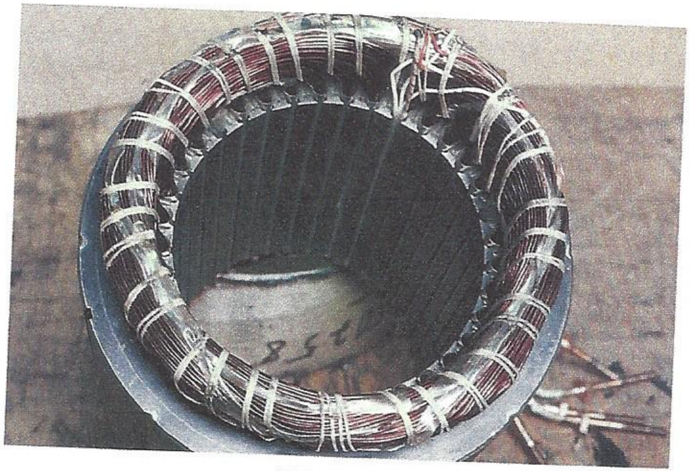

FIGURE 20

(Figure 20) The phase windings of a typical motor are also easily identified because each winding is separated from the others by an insulating barrier.

Complete Burnout

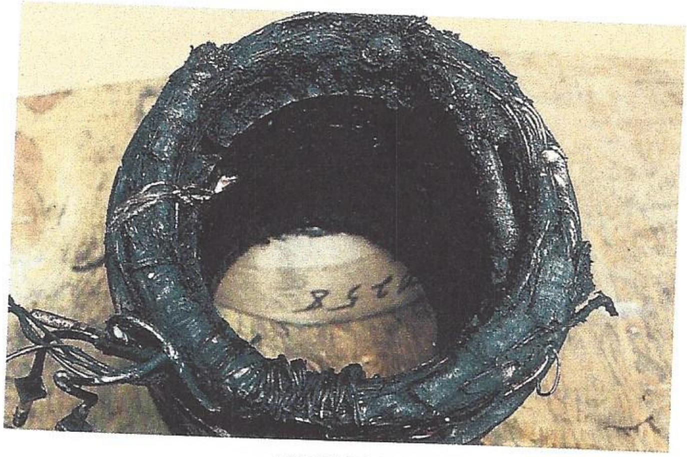

FIGURE 21

(Figure 21) A complete motor burnout is most apt to occur when the motor is in the stalled position. At the moment the motor is energized, the electrical and physical stresses on the windings are the greatest. If at this time the voltage is low or the compressor is mechanically locked up, the motor will burn unless the overloads are tripped within a very short time. When a motor burns in the stalled position, the soot and other by-products of the burn are confined to the suction side of the system. This may help with your diagnosis.

With the absence of proper motor protection, another cause for burnout is inadequate motor cooling due to reduced flow or no flow of suction gas. Since this type of burn takes place when the compressor is operating, the by-products of the burn are frequently carried to the discharge side of the system.

Causes Of Complete Burnouts

When all phases of the motor are burned, check the compressor to see if it is free. If the mechanical parts are seized, it can be assumed that the cause of the motor burnout and compressor failure is mechanical. When this is the case, further investigation is required to determine the source of the mechanical failure.

If, on the other hand, the compressor is free and appears to be in reasonable operating condition, the source of the problem could be electrical. The electrical analysis should start with a voltage and phase balance check. The voltage should be within plus or minus 10 percent of the nameplate rating and the phase imbalance should not exceed two percent.

Another source of the problem may be low suction gas flow or no flow. Check the condition of the contactor. If the contacts are welded, it is possible that the compressor pumped down the system and then failed to stop. Continued operation with no gas flow over the motor caused it heat and eventually burnout.

Compressor short cycle operation to meet the small needs of a weekend load, for example, can also cause motor overheating. The repeat starts with the corresponding in-rush current coupled with the reduced flow of suction gas over the motor during the brief operating cycles results in motor heating that can ultimately cause a burnout.

The mechanical evidence of the lack of compressor cooling is the scoring of the piston skirts with no apparent rod or main bearing damage. Since the suction gas cools other working parts of the compressor as well as the motor, a reduced gas flow or loss of flow causes the pistons and cylinder to heat. And since the thermal expansion rate of aluminum is greater than that of the cylinders, the pistons bind within the cylinders, causing the scoring.

When a motor fails, regardless of cause, always check the condition of the contactor. The high current that accompanies a burnout will frequently damage or weld the contacts.

If the system is subject to extended periods of minimum load operation or load fluctuations that cause it to cycle frequently, a recycle timer should be installed to limit the starts to four or five an hour.

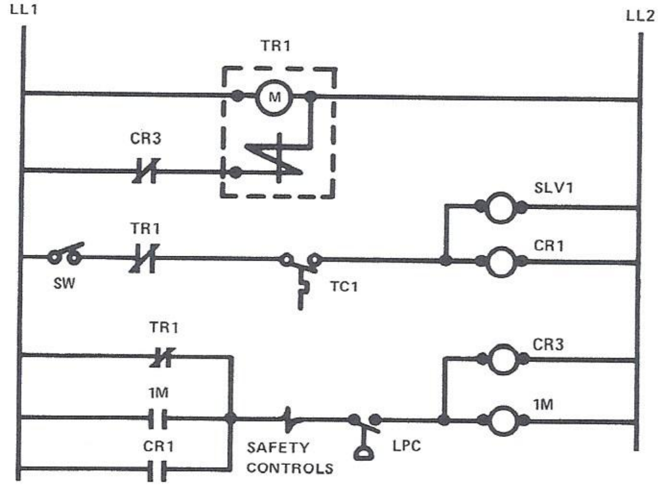

FIGURE 22

(Figure 22) The recycle timer contacts (TR1) are wired in series with the chilled water or conditioned air thermostat (TC1) and in parallel with the non-recycling relay (CR1) and the auxiliary contacts of the compressor motor contact (1M). This arrangement provides both a time delay between successive starts plus a timed pumpdown cycle.

The timer is controlled by a control relay (CR3). A compressor startup energizes CR3 which, in turn, opens its contacts. This de-energizes the timer clutch, resetting the timer to zero.

After the controlling thermostat (TC1) is satisfied and the pumpdown cycle is completed, control relay CR3 is de-energized, closing its contacts. This energizes the timer clutch which opens contacts TR1 and holds them open for the duration of the time-out period. After the time-out period has elapsed, contacts TR1 close. If at this time TC1 is again calling for cooling, the system is restarted. Or, if TC1 is open however the low pressure control (LPC) is closed, indicating a buildup of low side pressure, a pumpdown cycle is started.

Each time the compressor is started CR3 is energized, resetting the timer to zero. When the compressor is stopped, it cannot be restarted until the timer again times-out.

Spot Burns

Metal fragments resulting from a mechanical failure can become lodged in the motor windings. Here they can act like cutting tools, causing damage to the motor insulation.

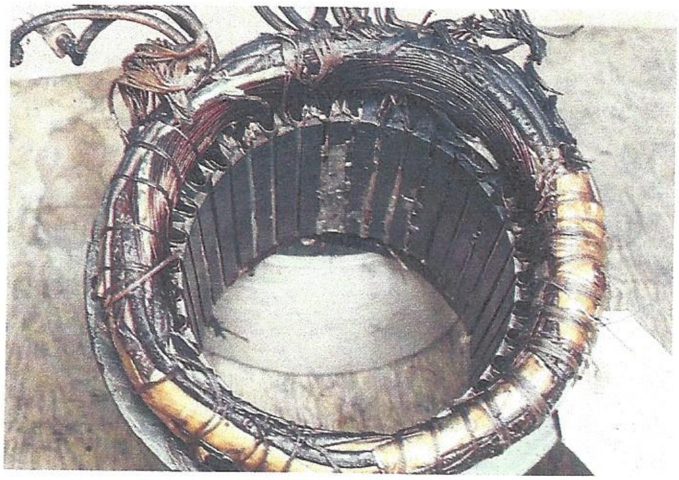

FIGURE 23

(Figure 23) The stator illustrated was subjected to such damage. In this example a piece of valve became lodged between the rotor and stator where it cut through both the winding and slot insulation, causing several windings to burn.

A spot burn, such as this, may take place weeks or months after a repaired compressor has been returned to service. The metal particles lie in the motor until they are worked into a position to cause damage. Consequently, it is always good practice to remove and inspect the motor and the motor barrel after a failure that involves broken parts.

FIGURE 24

(Figure 24) A spot burn can also be caused by relative movement between the individual turns of a coil. When a motor is started, the coil ends flex slightly, causing the wire turns to rub against one another. In time, this may cause a breakdown of the insulation, resulting in a turn-to-turn short. The heat from this short will burn away the insulation of adjacent wire turns, resulting in an eventual phase-to-phase or phase-to-ground short.

Notice that the short originated where the end portion of the coil enters the motor slot. A pressure point between the turns may have existed here or a metal fragment may have been imbedded between the turns which accelerated the wearing away of the insulation.

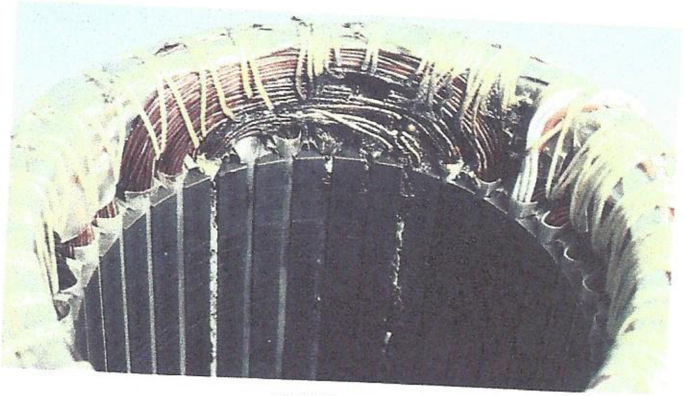

FIGURE 25

(Figure 25) A similar spot burn can take place within the slot for the same reasons as listed above.

To repeat, anytime a spot burn occurs, always remove the motor and examine the motor barrel and the windings for evidence of metal fragments.

It is absolutely necessary that all such material be removed before any motor replacement is attempted.

Causes Of Spot Burns

When a compressor valve fails, it is possible for a piece of valve or valve spring to be forced into the suction side of the compressor where it can become lodged in the motor windings. Here it can cause a short between the motor turns, resulting in a spot burn.

A spot burn may also be caused by stresses on the motor. If examination of a spot burned motor reveals no evidence of metallic particles, either imbedded in the windings or in the motor barrel, it may be suspected that the insulation breakdown resulted from normal stress.

Single Phasing and Causes

The loss of power in one of the phases causes a three-phase motor to single phase. This causes the remaining two phases to draw excessive current. If the overloads do not take the motor off the line quickly, these two phases will burn.

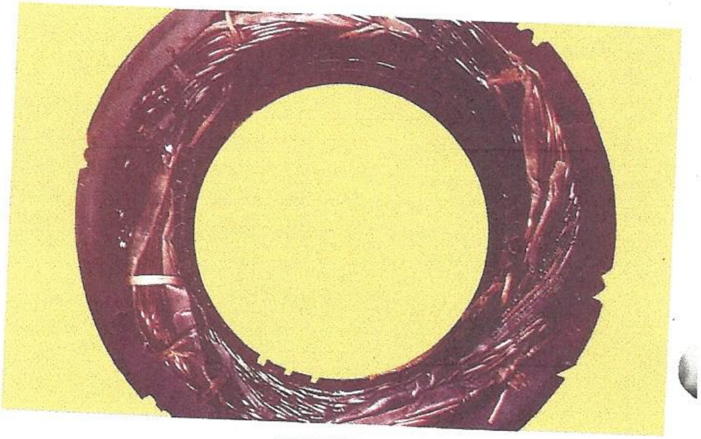

FIGURE 26

(Figure 26) This is the appearance of a motor that was subjected to single phasing. Note that the windings of two phases are burned while the four poles of the remaining phase are unburned.

The configuration is two windings burned — one unburned, two windings burned — one unburned, etc. When this is observed, the motor has undoubtedly been single phased.

The situation just described is a typical single phasing burnout. However, in a single phasing condition, it is possible for one phase to heat faster than the other causing only one phase to burn. When one phase is burned, check the windings of the remaining two phases. If one shows heat damage, it can be assumed that single phasing was the cause for the burnout.

Dragging Rotor

A dragging rotor is another cause for motor electrical problems. Since the rotor-to-stator spacing is extremely close, bearing wear can cause the rotor to dip sufficiently to drag on the stator.

(Figure 27) The stator illustrated shows signs of grooving caused by a dragging rotor. The rotor dragged the laminations causing a failure of the slot insulation, resulting in a phase-to-ground short. Note that two or three windings are burned, not the entire motor. The rotor that was removed from this motor showed similar grooving.

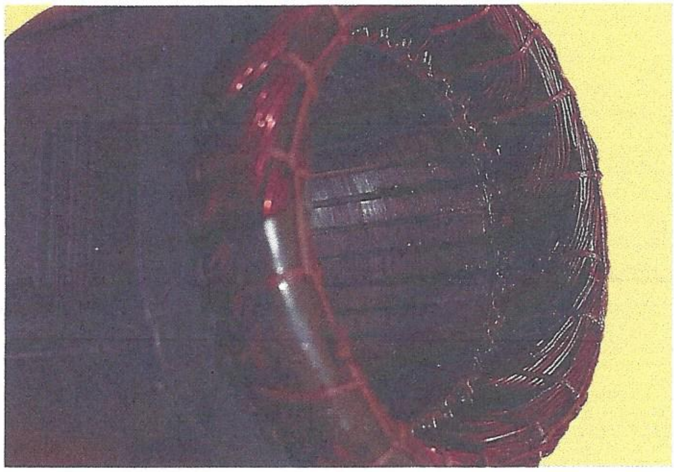

FIGURE 27

Causes Of Dragging Rotor

Bearing wear that is severe enough to cause rotor drag must be investigated. Some of the possibilities are oil dilution or oil that is contaminated by dirt or other abrasives.

Bearing surfaces that show smearing, similar to Figure 10, page 6 , indicates an oil dilution problem. See "Oil Dilution:, page 5.

Cloudy oil which contains suspended particles coupled with a dirty oil strainer screen, on the other hand, signals the presence of dirt, moisture or other contaminating materials.

After the replacement compressor is started, it is wise to periodically check the color and clarity of the oil. If it becomes discolored by suspended material shortly after startup, change the oil, as necessary, until it remains clean. In some cases it may be desirable to install a suction filter to trap contaminates prior to entering the compressor. Obviously, if the oil continues to indicate a continual build up of suspended material **after** installation of a suction filter, there is a good possibility that the particles are the result of another mechanical failure taking place.

UNDETERMINED COMPRESSOR FAILURES

Up to this point, we have assumed that by careful analysis the serviceman should be able to trace back through failed compressor parts and determine the real cause for failure. This may not always be the case.

In the real world, time, shop space, and the freedom to explore causes for system failures are not usually ideal. In addition, some compressor 'scrambles' are beyond the point of determining which mode of failure came first. Even with extensive cleaning of damaged parts, the baked-on varnish, carbon, and sludge may be so extensive that you wonder how the compressor lasted as long as it did.

In these situations you must simply explore all probable system causes based on a conclusion that more than one factor was involved in the actual failure.

The conditions that lead to a catastrophic compressor failure have probably come through a long and involved path. Combining all of the ideas from the earlier discussion in this presentation, start now in an attempt to avoid a repeat of the same sequence of events that caused the first failure.

While performing the necessary clean up operations that are described in the next step, use what time you have to check the electrical system for such things as inadequate wire sizes, burned motor contacts, and loose terminals. Check to see that the motor protection circuit is not bypassed and that pressure safety controls are working and wired properly. Is the expansion valve sensing bulb installed properly and is the valve in good working order? Even these simple and obvious items can be overlooked in the haste of installation and start up.

Finally, take extreme care to be sure that the system is cleaned and put back on line properly. When it is restarted you will be able to monitor the pressures and temperatures that may give you your final answers on the original failure.

SYSTEM CLEANUP

After a compressor motor failure or a failure resulting from the presence of contaminants within the system, the life of the repaired or replacement compressor is dependent upon the care exercised in system cleanup.

To reduce the amount of contaminants to be removed from the system, inspect the suction and discharge piping adjacent to the compressor. If either contain soot or other by-products of a motor failure, clean the line with a refrigerant parts cleaner before the compressor is installed.

Note: Cleaners that contain chlorine should **not** be used.

When installing or rebuilding a compressor in a system which has experienced an electrical failure, install a suction line filter-drier of an appropriate size.

After the leak test has been completed and the test pressure released, replace the liquid line drier, and evacuate to 1mm Hg absolute pressure. Break the vacuum with oil pumped dry nitrogen and again establish the 1mm absolute pressure. Allow the system to remain under vacuum for 12 hours. If the vacuum reading remains unchanged, the system is leak and moisture free and ready to receive its charge of refrigerant.

Charge the system and perform the following checks before the system is put into continuous service.

PRE-STARTUP CHECKS

Electrical System

1. First, inspect **all** wiring connections for tightness. Properly tightened connections are very important since loose wire connections will cause voltage drops which can be instrumental as a primary cause for various electrical failure.
2. Check the condition of all contactors. If the contacts are in poor condition, replace them. Specific information is available from manufacturers on how to determine if the contacts are past their service life.

3. The voltage at the compressor contactor should be checked to make sure it is within plus or minus 10 percent of the compressor nameplate rating.
4. The voltage balance between the phases should be tested. Voltage imbalance, in percent, is found by determining the sum of the three voltage differences from the average, dividing this figure by twice the average and then multiplying the result by 100.

   For example:

   Voltage readings = 220, 230 and 225 volts.

   $$\text{The average} = \frac{220 + 230 + 225}{3} = 225 \text{ volts.}$$

   The percent imbalance is:

   $$\frac{(225 - 220) + (230 - 225) + (225 - 225)}{2 \times 225} \times 100 = 2.22\%$$

   Since the maximum acceptable phase voltage unbalance is two percent, this 2.22 percent is not acceptable. When such a condition exists or the voltage to the contactor is not within plus or minus 10 percent of the nameplate rating, the local power company should be notified and the condition corrected before the compressor is started.
5. Check the overloads for proper adjustment. If equipment is available, it is a good idea to actually load and trip the overloads to confirm their calibration setpoint.

Refrigeration System

Air Cooled Condenser

1. Coil clean and unobstructed.
2. Fan and drive rotate freely.
3. Fan motor disconnect switch closed.

Water Cooled Condenser

1. All water valves positioned for operation.
2. Cooling tower fan motor disconnect switch closed.
3. Condenser water pump motor disconnect switch closed.

Direct Expansion Coil

1. Air filters clean and in place.
2. Coil clean.
3. Outdoor air dampers positioned properly.
4. Conditioned air fan motor disconnect switch closed.

Water Chiller

1. All chilled water valves positioned for operation.
2. Chilled water pump motor disconnect switch closed.

Refrigerant Circuit

1. Compressor suction and discharge valves back seated.
2. Liquid line shutoff valve open.
3. Other refrigerant valves in operating position.

Control System

To permit testing of the control system without starting the compressor, remove the leads from the compressor contactor. Close the compressor disconnect switch.

1. Energize the control system by starting the chilled water pump or conditioned air fan.
2. If necessary, lower the setting of the chilled water or conditioning air thermostat to energize the remainder of the control system.
3. Using a system wiring diagram, check the sequence of operation of the electrically interlocked controls and systems.

   Since the compressor is not operating, the compressor contactor should be dropped out in approximately 90 or 120 seconds by the oil pressure control. The time period will depend upon the type of controller used.

   Note: Above all, make sure that the operating and safety controls are wired into the control circuit.

   This is easily done by simulating the action of the individual controls to confirm fail-safe shut-down of the compressor.

START UP

1. Reconnect the compressor leads to the contactor.
2. With gauges installed, start the system.
3. During this run-in period, log the following system temperatures and pressures at hourly intervals:

Oil Analysis

After the system has operated for approximately four to eight hours following a motor failure, pump it down and draw an oil sample. Check the acidity of the oil sample using one of the oil test kits which are commercially available. If the oil test shows an unsatisfactory acid level, change the cores of the liquid line and suction line filter-driers, restart the system and allow it to operate for an additional eight hours. Repeat this procedure until the oil test is satisfactory.

Finally, replace the core of the liquid line filter-drier and, to reduce suction line pressure drop, remove the core of the suction line filter-drier or remove the entire assembly from the line and replace it with a straight length of pipe.

The system is now ready to be returned to full time service.

RUN-IN LOG

HOUR		1	2	3	4	5	6	7	8
DISCHARGE PRESS.									
SUCTION PRESS.									
OIL PRESS.	MODEL E & F	NORMAL 75 PSI							
	MODEL M & R	NORMAL 30 PSI							
OIL SUMP TEMP.*		MAXIMUM 200 F							
DISCHARGE GAS TEMP.**		MAXIMUM 275 F							
LIQUID SUBCOOLING		NORMAL 12-15 F							
SUCTION SUPERHEAT		NORMAL 12-15 F							
CONDENSING AIR OR WATER TEMP.***	IN								
	OUT								
DX COIL AIR TEMP.	IN DB/WB								
	OUT DB/WB								
CHILLED WATER TEMP.	IN								
	OUT								

* Temperature taken on surface of sump at discharge end.

** Temperature taken on surface of discharge line 6 pipe diameters from compressor.

*** Condensing temp. should be: A/C — approx. 30 F above ambient temp.; W/C — approx. 10 F above leaving water temp.

REVIEW

From these discussions, it can be seen that the mere treatment of symptom is not enough. Sufficient failure diagnosis must be done to reconstruct the entire sequence of events in order to identify and correct the primary cause for the failure.

For example, on the surface, a motor burnout may appear to be an electrical problem. However, this is not necessarily the case. The basic cause of the problem could originate elsewhere within the system or it could be the result of the system operating conditions.

Assume that a direct expansion system, which is slightly oversized to begin with, is operated on weekends to serve the air conditioning needs of a small work force. Since, in this example, most of the lights are turned off and only a part of the other load producing devices are in use, the building internal cooling load is a fraction of normal. This set of conditions causes the system to be grossly oversized for the job it is attempting to do.

To satisfy this reduced load, the compressor starts repeatedly, runs at minimum capacity for a short period of time and then stops. The small mass flow of refrigerant required by the load is not sufficient to properly cool the compressor and motor during the brief periods of operation, causing both to heat. Eventually, the motor temperature rises to the point where the insulation breaks down, causing a burnout.

Inspection of the electrical system reveals that the fuses are blown and the motor overloads are open, both caused by an overcurrent condition resulting from a short.

The teardown of the compressor reveals, in addition to the burned motor, soot on the inside surface of the cylinder head of the cylinders without unloaders and the skirts of the loaded cylinder pistons to be scored but no apparent damage to the rod bearings.

The evidence points to (1) an overheated compressor, (2) the compressor was running fully unloaded when the burnout occurred and (3) the motor thermal protection system failed to function. This, coupled with the fact that the failure took place on a weekend when the system was lightly loaded, provides an indication of the conditions that existed at the time of the failure.

This is the type of analysis that should be performed on any compressor that has failed. The information gained will indicate the corrective steps to be taken to prevent a repeat failure.

In this case, an anti-recycle timer will solve the basic short cycle problem and a thorough checkout and correction of the motor thermal protection circuit will provide this protection to the replacement compressor.