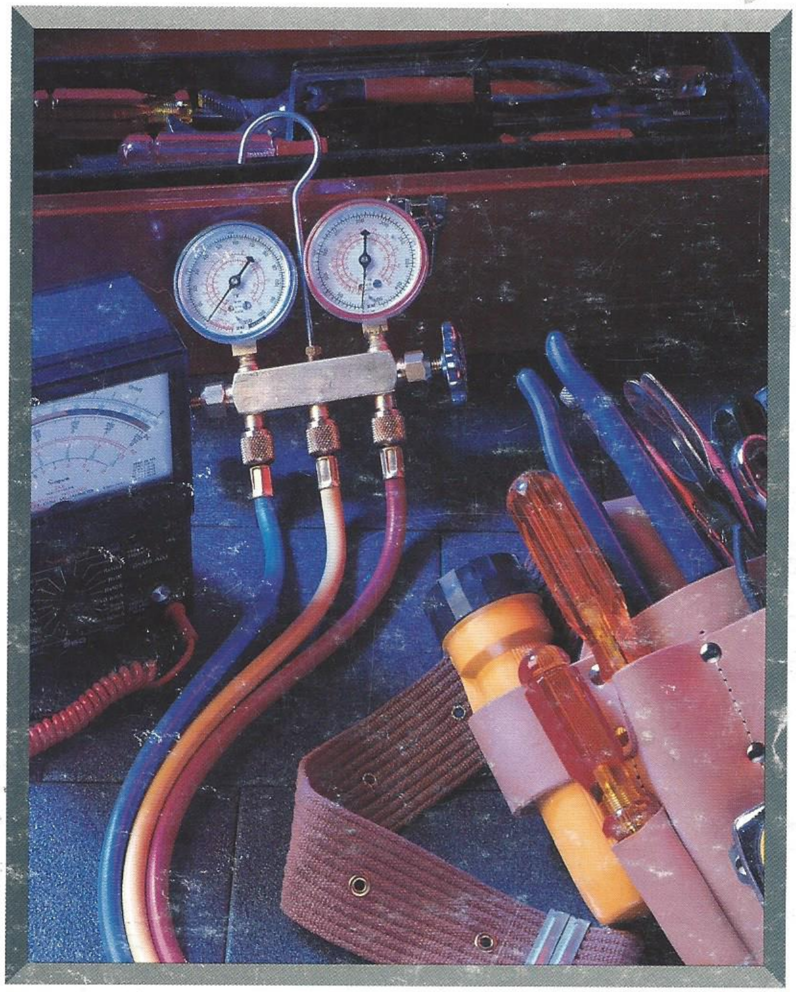
TECH
SERVICE
Training



WHY COMPRESSORS FAIL

FAMILIARIZATION • CAUSES OF FAILURE • SYSTEM ANALYSIS

GTC2-101A

020-345

WHY COMPRESSORS FAIL

Contents of the Why Compressors Fail packaged program, (Catalog No. 020-305) are: (104) 35mm slides, audio cassette and this workbook.

TABLE OF CONTENTS

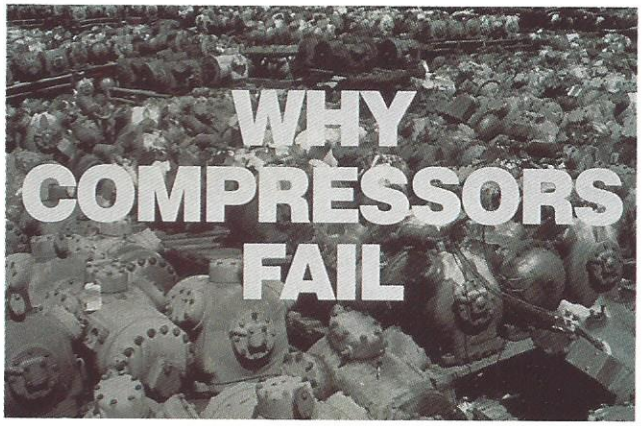
Objectives-
Upon completion of this training program, you will be familiar with the different causes of compressor failure, the symptoms associated with them, and those things which can be done to help limit the possibility of a repeat failure.

Presentation Instructions-
1. Obtain necessary audio visual equipment, service equipment, handout materials and program workbooks for each participant.
2. To run this slide/cassette program; project slide 1, focus, then start the tape. If your tape player does not have a built-in slide projector advance, there are audible "beeps" which signal that the slide should be advanced.
3. Show slides section by section. Review, discuss and ask questions at the end of each section highlighting topics of importance.
4. Distribute and review handout materials. (See suggested list of handout materials below.)
5. Administer quiz, then review using slide/page references as noted in the quiz key.

Handout Materials/Additional Training Materials-
1. Additional "Why Compressors Fail Workbooks" (Catalog No. 020-345).
2. See appendix for additional training materials.

Self Instruction-
When using this program for Self-Instruction, read the workbook and complete the quiz. The quiz is divided by section and may be completed by section or in its entirety upon completion of the program. Quiz answers with paragraph references are located in the quiz key.

INTRODUCTION

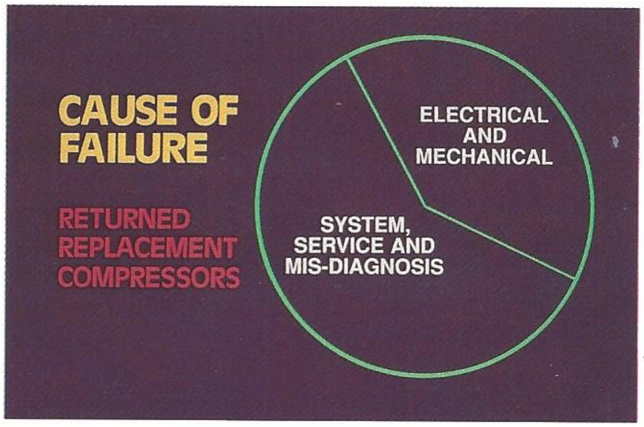


1. We in the HVAC industry have a common problem -- repeat compressor failures. This problem costs all of us time and money and inconveniences our customers. That is the bad news. The good news is that we can do something about it. Years of studying this problem have shown that it has two basic causes: Incorrect diagnosis and improper installation or servicing of the compressor or related components.

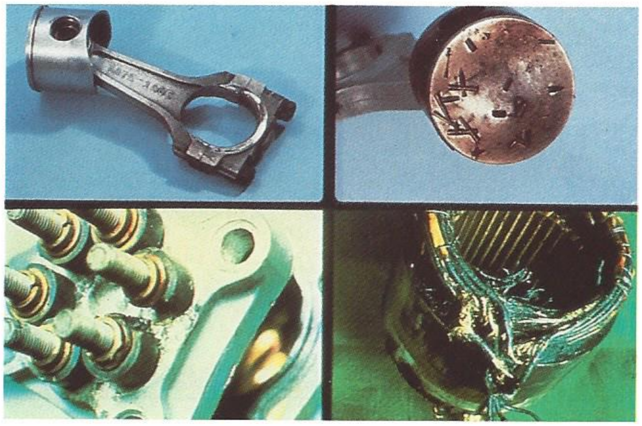
Very often, a compressor fails because of a problem outside the compressor. Yet more often than not, the compressor will be replaced without the service person determining the root cause of the failure. As you might expect, the new compressor will eventually fail as well. This program will examine the kinds of problems that can cause a compressor to fail and will give you insight on how to recognize and prevent these failures. The program will also review correct installation, servicing and trouble shooting techniques that will help you prevent repeat compressor failures.

As with any HVAC equipment, be sure to use proper safety practices and equipment as well as proper refrigerant handling and disposal techniques when working on this or other types of equipment. Also remember to lock and tag electrical circuits and be sure all power is off to the unit or system, including the crankcase heaters. In addition, be sure the compressors have been valved off from the unit or system. (Refer to the Appendix for additional training materials.)

FAMILIARIZATION

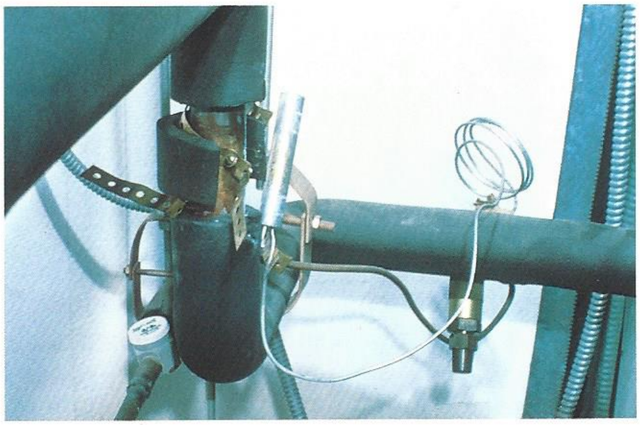


2. Repeat failure compressors have plagued the HVAC industry for many years. Documented statistics indicate that replacement compressors fail at a rate several times higher than first time installed compressors. Failure analysis of returned compressors indicates that 50% to 60% of the failures were caused by system and service related problems, or were returned as the result of mis-diagnosis. The others failed due to electrical and mechanical defects, mis-wiring, failing to open service valves during start-up, or improper service and maintenance procedures. Some were so badly damaged that the exact cause could not be identified.



3. The system and service related failures continue to show evidence of electrical or mechanical failure. These include broken valves, scored shafts, broken rods, and overheating. Electrical failures include single phasing, overheating, and

system control problems. In some cases, the evidence suggests that the compressors were misapplied, operated improperly, or not properly cleaned-up after a burnout.

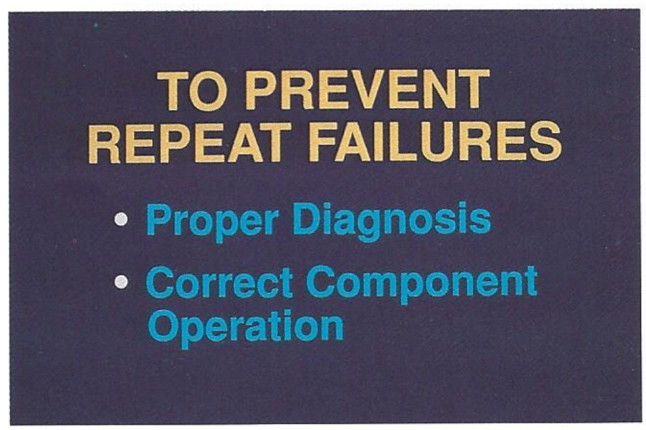


4. So, as you can see, the technician's job is much more than just replacing the compressor. It is finding the REAL cause of failure and making sure that it is corrected.

All too often results, such as burned motors, are treated as the cause of failure while the REAL problem remains undetected. Statistics show that 80% of the compressors returned as electrical failures were actually system caused mechanical failures that ultimately progressed to a motor failure and system shutdown. A loose TXV bulb caused flooding which resulted in flooded starts and the subsequent slugs broke the valve. A piece of the broken valve worked its way to the motor winding shorting it to ground. Worn bearings can allow the rotor to drop onto the stator shorting the windings. Such problems are often diagnosed as the primary cause of failure when in fact they were a result. Under circumstances like these, it is only a matter of time before a replacement compressor fails for the same reason the original did.

5. There are several things that can be done to help prevent repeat compressor failures. Among them are improving equipment maintenance and record keeping, using proper start-up procedures, improving systems and diagnostic skills, and inspecting the failed compressors. You can obtain information from equipment owners. Start by asking questions such as, "What has changed in or around this system since the last time it was serviced?" Information of this type can be very useful when diagnosing system-related problems.

SYSTEMS AND COMPONENTS



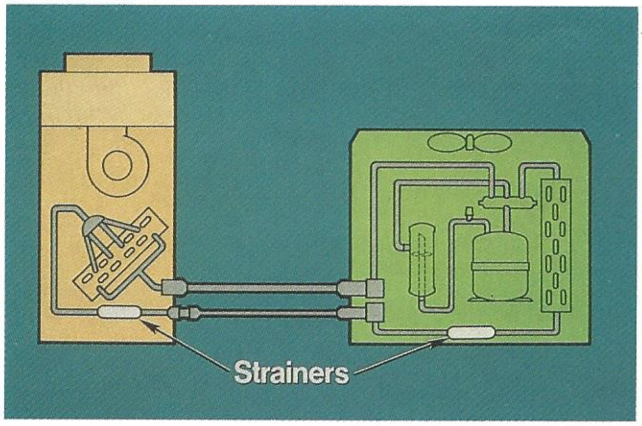
6. Preventing repeat compressor failures depends in part on proper diagnosis to determine what may have caused the failure. Even in standard cooling

systems, the major components if not properly maintained, can have an adverse effect on the compressor. Dirty coils or malfunctioning liquid flow control devices often create conditions which can lead to damage and/or ultimate failure of the compressor.

A dirty condenser coil or failed condenser fan motor allows heat to build in the coil rather than being rejected to the atmosphere. The compressor has to pump against excessive pressure which may cause it to overheat, resulting in accelerated component wear, damage, or complete failure.

Dirty evaporator coils or filters, failed indoor fans, or broken fan belts can lead to frosting of the coil. Liquid refrigerant will return to the compressor, again resulting in accelerated wear, damage, or complete failure.

Problems with liquid control devices can result in an overfeed or underfeed of liquid refrigerant to the evaporator coil. With overfeed the coil will not be able to boil off all the liquid refrigerant, again resulting in liquid return to the compressor. With underfeed, restricted flow causes high superheat and diminished oil return possibly leading to failure from overheating or loss of lubrication.

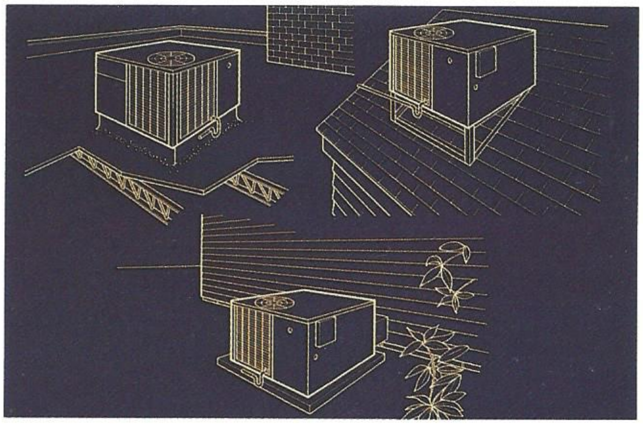


7. Heat pump systems possess the capability of creating several unique problems for compressors.

8. The more severe duty placed on a compressor in a heat pump must be considered. Because of its reverse cycle, there is additional load placed on the compressor when changing operating modes. When system problems do occur, this compounds the problem.

In this case, the liquid line strainer became plugged with contaminants. When the pressure became great enough, it literally blew the end out of the strainer.

Without the strainer to filter dirt and other particles, the compressor is more susceptible to damage from foreign particles.

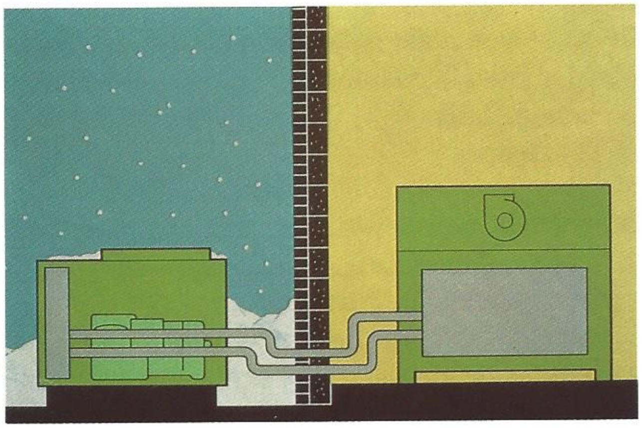


9. Packaged systems, although self-contained, require several additional considerations with respect to installation, equipment modifications, operating sequences, and controls.

When installing this equipment, unit position in relationship to prevailing winds and weather conditions must be taken into account. Incorrect positioning may effect operation of the air-conditioning system which directly effects the compressor.

Equipment modifications may also effect the compressor. For example, if an unloader is added, and the piping not checked to insure the oil will return at unloaded conditions, a lubrication failure could result.

Improper head pressure controls and not knowing correct operating sequences for the equipment being worked on can also lead to problems with compressors.

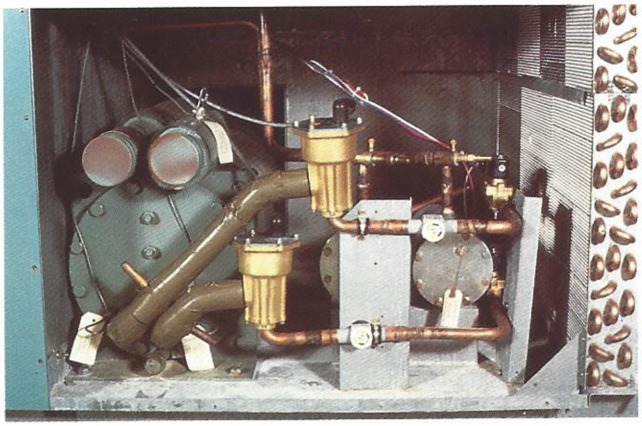


10. Split system applications present an additional set of problems. Compressors in these systems must deal with piping considerations, improper mixing and matching of components, additional oil return problems, duct work considerations, and ambient temperature variations.

11. Refrigeration applications must consider these items too, but must also take into account the colder temperatures at which they operate . These lower temperature conditions increase the likelihood of liquid return, and additional protective devices and/or accessories may be required to help protect the compressor.

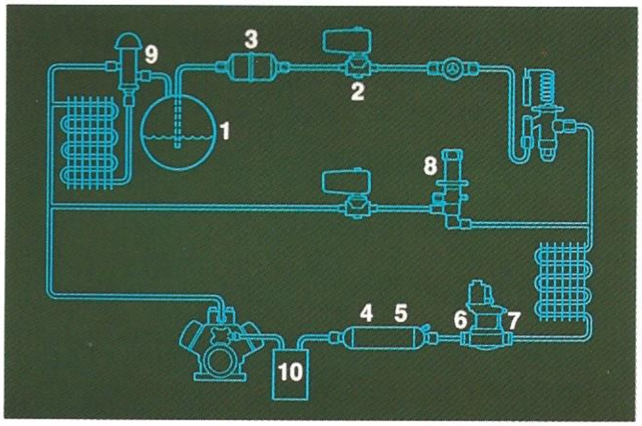
Shown here is the oil return hole of an accumulator tank. Due to its size, it does not take much to restrict or plug it. When this occurs, oil can not return to the compressor at a satisfactory rate.

SYSTEM ACCESSORIES



12. System accessories play an important part in most Air-Conditioning and Refrigeration equipment. Although generally installed with the intent

of providing specific functions and benefits to the system and/or compressor, they can also have negative effects when mis-applied or not functioning as they should. In this section we will look at several accessories and the effects they can have on a compressor.



13. **Receiver tanks** (item 1) are often installed to compensate for variations in the system's refrigerant charge due to operating loads, and will temporarily compensate for minor refrigerant leaks.

Receivers reduce or eliminate refrigerant subcooling and will increase the refrigerant charge and may increase the chance of a flooded start.

-**Liquid line solenoid valves** (item 2) are often installed to prevent refrigerant liquid migration to the low side during the off cycle, or as a refrigerant control device to pump the system down prior to cycling the compressor off. When used for this purpose these devices can provide great benefits to the system. They may also cause the compressor to operate in a vacuum if they fail to open.

Operating compressors in deep vacuums for extended periods of time can lead to internal arcing and shorting of the power terminals at the terminal block due to the reduced insulation effects normally created by the refrigerant vapor in the crankcase.

In circumstances such as this, motor failure would result as evidenced by discoloration and damage to the terminal block. Where this has occurred, check for restrictions in the liquid line and system low side by testing for excessive pressure drop and/or temperature drop across each component to determine where the restriction is located.

-**Liquid line filter driers** (item 3) remove contaminants such as moisture, dirt, acids, sludge, and varnish from the system. They also filter debris. If they are plugged, it will lead to lack of system capacity and the same types of problems associated with the malfunctioning liquid line solenoid valves just discussed. Be sure to check for excessive pressure and/or temperature drop across liquid line and low side components.

-**Suction line filters and filter driers** (items 4 and 5) should only be used for system clean-up purposes then should be removed before putting the unit back in service. Like most other accessories, they can create problems due to their close proximity to the compressors suction entry. If they become loose or break down, and portions of them enter the compressor, accelerated wear, contamination, and damage can result. If ignored or improperly maintained, they have also been known to completely plug with dirt and debris causing the compressor to run in a vacuum. This may lead to problems like the low side system problems just described.

-**Suction regulating valves** (items 6 and 7) such as Evaporator and Suction Pressure Regulators can also create problems for the compressor when they malfunction. Because they are regulating-type devices with moving parts, they are susceptible to normal physical wear.

If they become stuck closed, they will also cause the compressor to run in a vacuum, leading to damage. Once again, as with any system low side restriction, check for pressure and/or temperature drop across the components.

-**Hot Gas Bypass valves** (item 8) are designed to perform several functions: they maintain sufficient refrigerant flow for adequate compressor motor cooling during low loads; prevent evaporator coil frosting; maintain high enough refrigerant velocity to return oil; keep more coil surface active to better control humidity; and eliminate voltage fluctuations caused by compressor cycling. If this type of valve malfunctions in a system, the problems which the device is designed to prevent may happen anyway, resulting in compressor wear and potential damage.

-**Head pressure control devices** (item 9) such as: fan cycling, Motor Master® or head pressure control using a liquid line condensing pressure regulator, are often used to regulate compressor discharge pressure during specific operating conditions such as those encountered during cold ambients. A lack of pressure control when it is needed will cause low refrigerant flow, low suction, frosted coil and poor oil return leading to lubrication failures. A malfunction of a head pressure control may damage the compressor.

-**Suction Accumulators** (item 10) Often the cause of compressor failures are installed in systems where flooding or slugging conditions are suspected. The purpose of this device is to allow accumulated liquid refrigerant to return to the compressor as a vapor to prevent damage to the compressor. Although similar in appearance to receiver tanks, there are several significant internal differences. An accumulator has a tube with an opening at the top and a metering orifice (for oil return) at the bottom provides as the outlet path for refrigerant return to the compressor. Vapor is drawn off the top of the device and flows through the tube and out of the accumulator before returning to the compressor. This provides added protection from liquid control component (metering device) failure.

However, accumulators also have shortcomings when it comes to the compressor. As shown in the previous slide, the orifice in the bottom of the tube is small enough that it takes very little to restrict or plug it. With the orifice plugged, oil is prevented from returning to the compressor at an adequate rate. Oil continues to leave the compressor at a faster rate than it is returned. As a result, the oil remains out in the system leaving an inadequate amount in the sump of the compressor for lubrication.

The general tendency is to overlook this component when troubleshooting because of its apparent simplicity, but in fact it is a significant cause of compressor failures. If there is any doubt, replace or service the accumulator.

14. The major points covered in the Familiarization section were: Systems and Components, and System Accessories.

CAUSES OF COMPRESSOR FAILURE

15. As described at the beginning of this program, to effectively diagnose and troubleshoot an

air-conditioning or refrigeration system, it is first necessary to know how it should operate when functioning correctly.

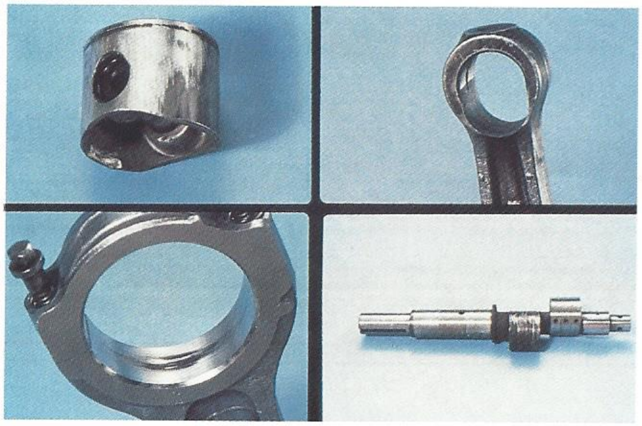
By knowing what the system or component should do, and comparing that to what it is actually doing you will be able to make a more accurate diagnosis, thus reducing chances of a repeat failure.

In this section we will look at the effects of various system problems on the compressor. We will cover things you should look for when replacing the compressor and make recommendations for prevention of repeat failures.

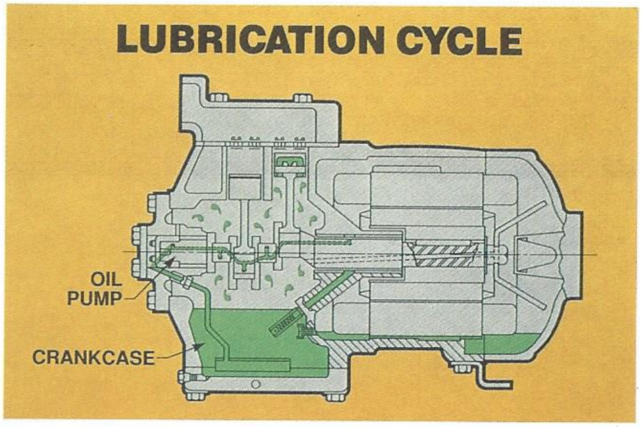
Compressors fail because of the following:

- Loss of Lubrication
- Flooding
- Flooded Starts
- Slugging
- Contamination
- Overheating
- Electrical Problems

LOSS OF LUBRICATION



16. Loss of lubrication can cause the kinds of problems illustrated here.



17. Proper lubrication is essential to the life of a compressor. To better understand how important this is, let's look at how the internal parts of the compressor are lubricated.

Most compressors, except welded hermetics, use a positive displacement oil pump to force feed oil to the various load bearing surfaces throughout the compressor. It is essential to have an oil film between these surfaces. The bearing clearances designed into the compressor and the oil pump maintain this film of oil and the lubrication it provides. When operating properly, the bearing surfaces will not even be in contact with one another, but will instead be separated by a film of oil.

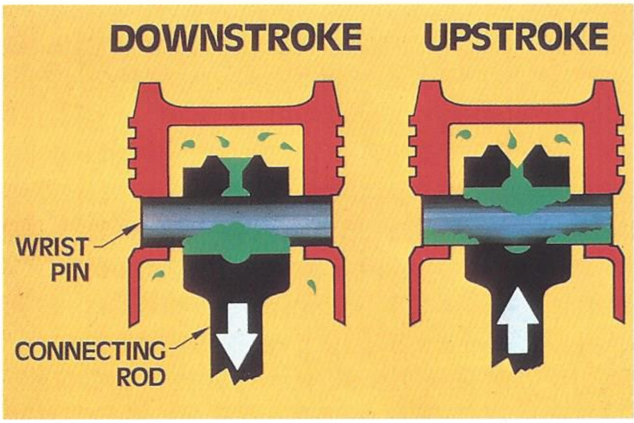
The oil pump picks up oil from the crankcase through an oil pick-up screen, pressurizes it, and forces it through passages in the crankshaft to lubricate the main bearings and connecting rod journals. An oil pressure regulator is installed to ensure that adequate oil pressure is maintained.

After completing the cycle, the oil is returned to the crankcase, where the cycle is repeated.

In addition to the pressure lubrication, pistons, wrist pins, and cylinder walls are lubricated by an oil mist that is present in the crankcase.

18. The wrist (piston) pin is lubricated by the refrigerant oil-vapor atmosphere (mist) in the crankcase. Oil collects on the different surfaces and components within the crankcase and lubricates them.

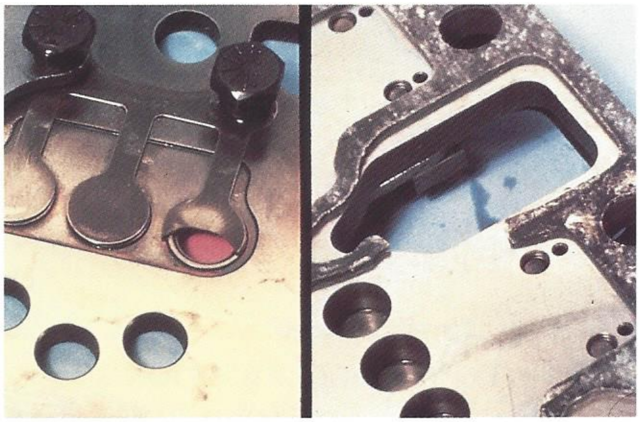
Shown above is the wrist-pin end of a connecting rod. On top is an oil reservoir with a hole that goes down to an oil groove that centers in the wrist pin hole.



19. This is the connecting rod and wrist pin in cross section with clearances exaggerated for illustration.

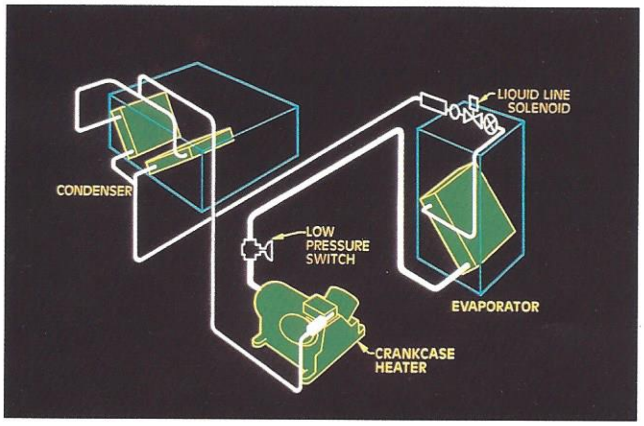
On the pistons downstroke, oil from the crankcase atmosphere (mist) collects in the reservoir. The connecting rod pulls the wrist pin down which allows the oil in the oil groove to flow around the wrist pin, lubricating the lower part of the pin.

On the piston's upstroke the forces reverse. The connecting rod pushes the wrist pin up, closing the clearance at the bottom of the pin and opening the gap at the top. This allows oil to drain down from the reservoir and flow around the **top** of the wrist-pin. Notice at the bottom that when the clearance is taken up, oil is forced laterally to lubricate the length of the wrist-pin.



20. When a discharge valve has failed or a cylinder head gasket has blown, the pressure on top of the piston remains high and the bottom of the wrist pin never gets lubricated. The friction causes the bottom of the wrist pin hole (bore) to wear.

21. The resulting damage looks like this. Because of this, the compressor will operate hotter than normal, the noise level will increase and the compressor will have a rattling sound. This wear contributes to problems on other components such as rods, cylinder walls, and bearing surfaces as well. This type of damage generally goes unnoticed until it can be heard.

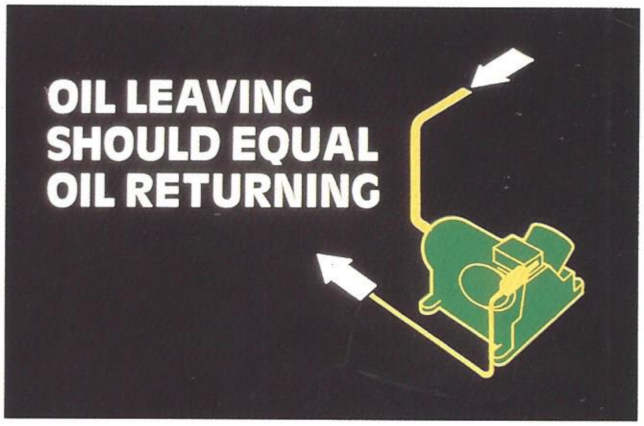


22. Another situation that leads to lubrication problems for compressors is refrigerant accumulation in the crankcase. When a compressor is started in this condition, the oil and refrigerant rapidly (violently) leave the compressor, creating a slug and a loss of lubrication.

This situation can be minimized by the addition of a crankcase heater. These resistance type elements raise the compressor oil temperature to prevent liquid refrigerant from accumulating in the crankcase during compressor off cycles. On larger split systems, "single pump-out" control may be used to keep the crankcase pressure low by limiting the amount of refrigerant available to the crankcase when the compressor is off. Crankcase heaters are typically used under these circumstances as well.

If liquid accumulation is suspected, be sure to check the crankcase heaters, operating sequences, and follow proper installation and start-up procedures when servicing or replacing a compressor.

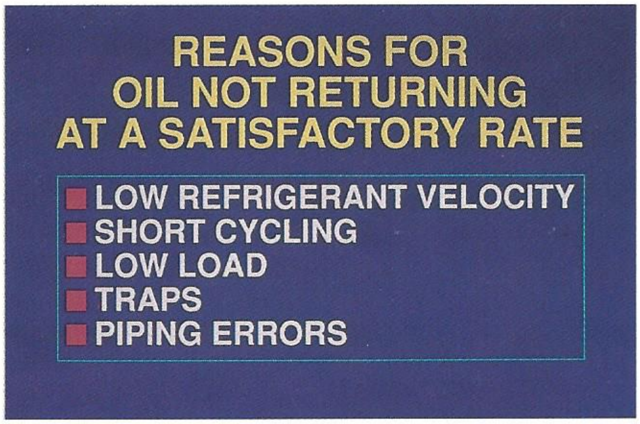
Also be sure to energize the crankcase heaters well before starting the compressor. Most manufacturers recommend energizing the heaters 24 hours before unit start-up.



23. Lack of lubrication can also result from the absence of oil in the crankcase.

As mentioned briefly in the system accessories section, some oil will leave the crankcase of a reciprocating compressor during normal operation. Note: When system accessories are installed, the piping must be designed to return oil to the compressor.

24. Loss of lubrication is also caused by oil leaving the compressor at excessive rates. This rapid loss of oil is usually associated with oil foaming which is easily observed in the compressor sight glass. If oil leaves the compressor at an excessive rate, it is not likely to be returned at the same rate.

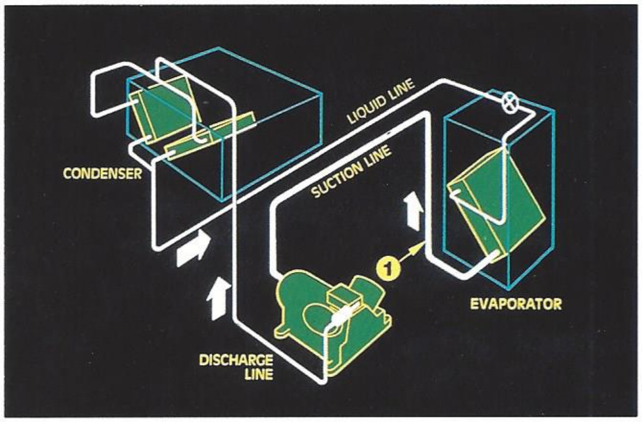


25. Reasons for oil not returning at a satisfactory rate include low refrigerant velocity, short cycling, low refrigerant charge, low load, excessive unloading, improperly designed or installed traps, piping errors, or plugged accumulator oil return holes.

- Low refrigerant velocity and short cycling may be caused by low refrigerant charge, broken fan belts, failed fan motors, dirty coils, or other factors which directly affect air flow.

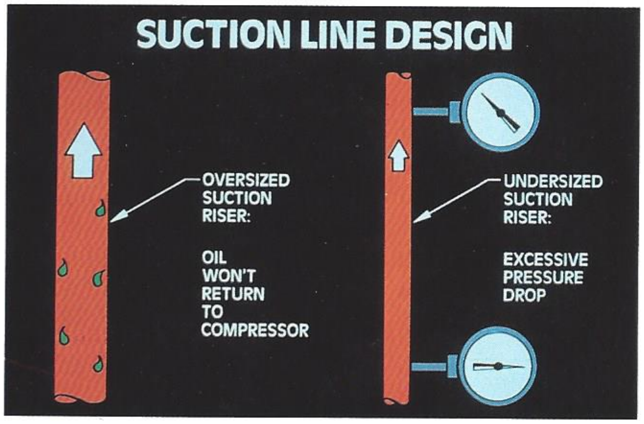
- Low load is often the result of inadequate heat load on the system such as that encountered during unoccupied periods. These loads can cause refrigerant flow controls to hunt and not control properly. Unloaded operation and resultant low refrigerant velocities will cause oil to pool in a system not designed for these flows.

- Difficulties with traps and accessories may often be the result of incorrect pipe sizing and improperly designed risers.

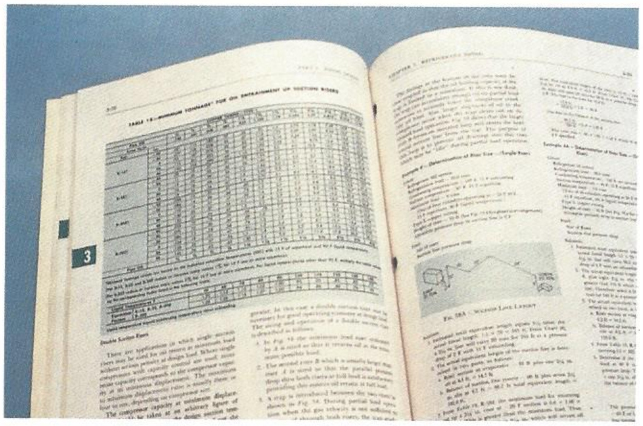


26. Loss of lubrication is also frequently the result of oil trapping, which occurs when the suction gas does not have enough velocity to return the oil to the compressor. This can occur in the suction riser shown at 1 on the diagram. The oil settles in the evaporator or in suction traps. This condition is most often found on systems using unloader equipped compressors where the compressor operates unloaded for extended periods of time. The reduced vapor flow caused by prolonged unloaded operation, and/or low suction pressures due to loss of charge, is a major cause of oil loss in compressors.

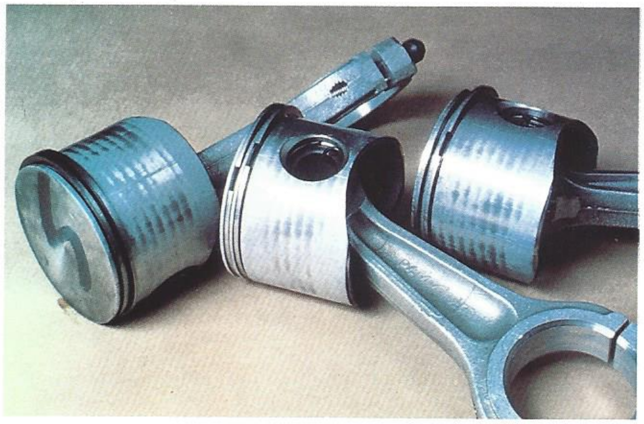
Piping and oil return is also a consideration with systems using parallel compressors. When installing or servicing these manifolded compressor systems, be sure the compressors are on the same level. This provides equal oil level in each compressor and reduces chances for excessive or low oil level in any one compressor.



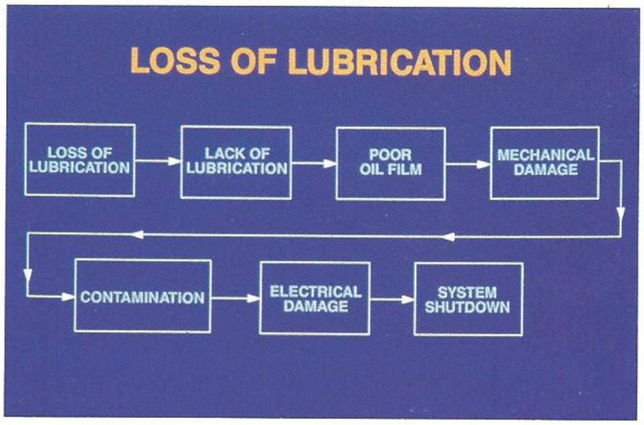
27. With regard to oil return and loss of lubrication, the design and installation of the suction line is the most critical line in the entire system. If a suction line is oversized, there will not be enough velocity to return the oil to the compressor. If undersized, there will be an excessive pressure drop in the line resulting in loss of capacity and an increase in superheat at the compressor.



28. When designing equipment, engineers use manufacturer's charts to design piping. The piping selected is based on the capacity of the system and the refrigerant used. Pressure drop is based on length and size of tubing and the number of fittings used. Operating conditions at full and minimum load are also taken into consideration.

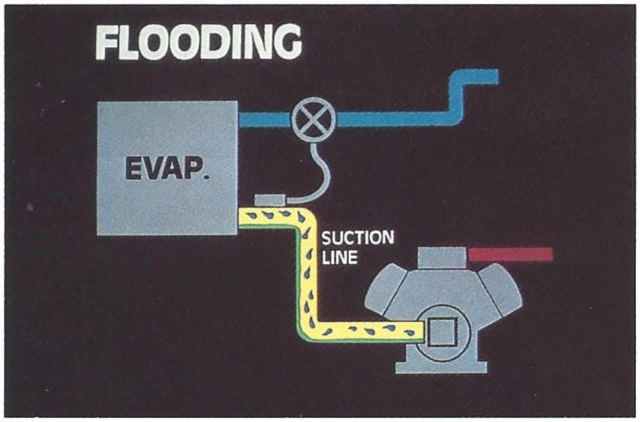


29. When inadequate cylinder bore lubrication takes place, discolored (grey) pistons, worn rings, and worn pistons result. This lack of lubrication is most frequently associated with lack of oil return during loss of charge or unloaded operating conditions, high but not necessarily extreme discharge temperatures due to loss of charge, or extreme floodback similar to what might be seen in split systems with large refrigerant charges.



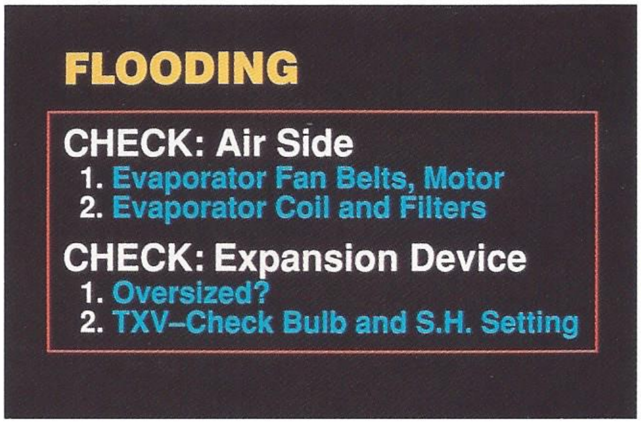
30. The chain of events resulting from a lack of lubrication leads to poor oil film coverage of wearing parts, mechanical damage, contamination leading to electrical damage and finally system shutdown.

FLOODING



31. Another cause of compressor failure is flooding. Flooding is the **continuous** return of liquid refrigerant or liquid droplets in the suction vapor returning to the compressor during operation. It is usually associated with improper refrigerant flow control.

32. The result of flooding is usually oil dilution, which results in crankcase foaming, a cold compressor and conditions which are ideal for liquid refrigerant accumulation in the crankcase.



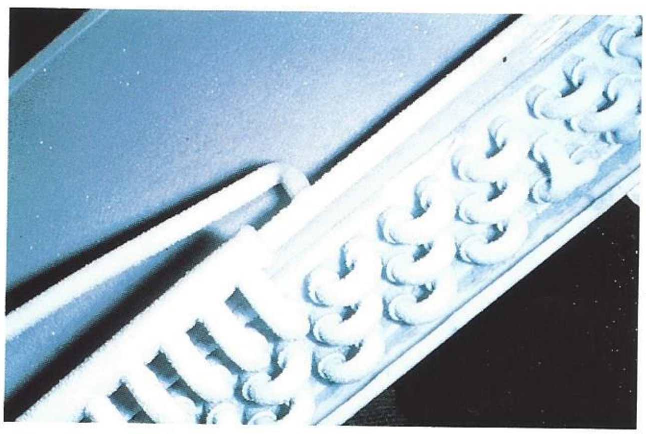
33. Air side problems are known to be a significant cause of flooding. These problems include broken evaporator fan belts, bad fan motors, dirty coils, and dirty filters. Although not often thought of as a real problem, their association with compressor failures is significant.

Inspect coils, fan blades, wheels, belts and pulleys on a regular basis to minimize potential problems.

An oversized metering device, or too low a superheat setting would allow more refrigerant to flow to the low side of the system than the load requires. The refrigerant may flow back to the compressor in a saturated state with entrained liquid droplets in the vapor. This gradually washes oil off the lubricated surfaces.

In the case of a TXV, check to see if the sensing bulb is properly located, free of dirt, grease, and oxidation, in good contact with the suction line, and properly insulated. After the sensing bulb is properly installed, perform a superheat check to confirm proper valve setting. Valve adjustment cannot compensate for poor installation practice.

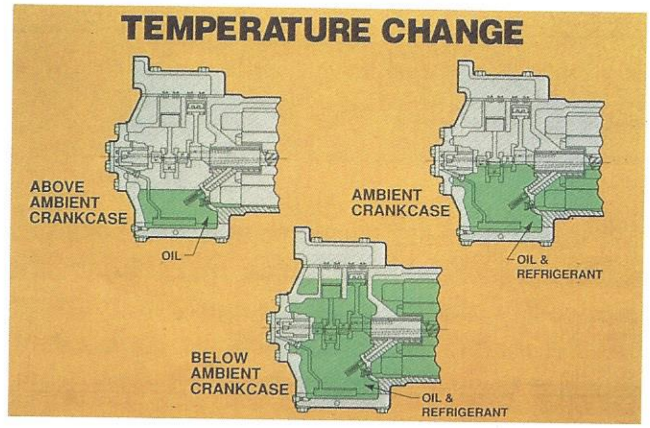
34. Where fixed orifice metering devices, such as capillary tubes or equivalent (Accurator™) are used, refrigerant charge is often critical. For a given load, a specific amount of refrigerant is required to maintain the designed flow rate. These devices do not react to load changes as a variable restriction device such as a TXV or EXV does and are therefore more sensitive to load change fluctuations.



35. Insufficient load on the evaporator prevents all the liquid from vaporizing causing liquid floodback unless an accumulator or other protective device is installed. There are many reasons for low load such as low or no air flow due to dirty filters, air restriction, air bypass, dirty fan wheels, loose or broken fan belts, and malfunctioning motors. Under these conditions the coil tends to frost and even a properly sized expansion device will tend to hunt.

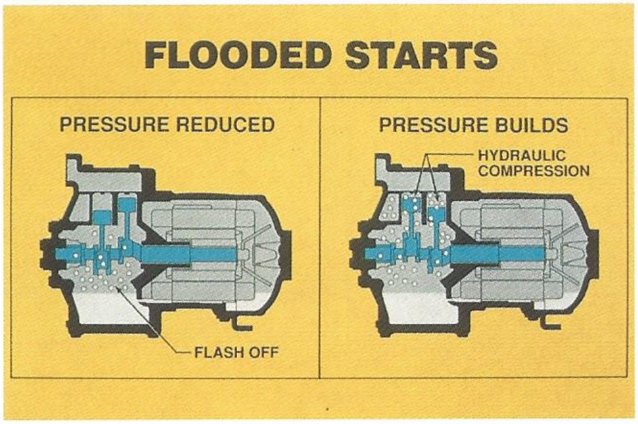
Low air quantity can cause low loads as well. Inspect and clean coils and be sure to straighten bent fins on a regular basis to maintain adequate air flow and heat transfer.

FLOODED STARTS

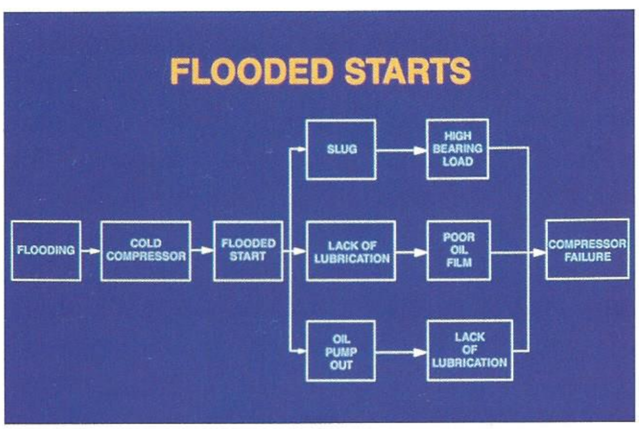


36. Flooded starts are another problem compressors must contend with. This condition differs from flooding in that it is not considered an operating condition. In this case, liquid migrates to the compressor during a compressor off cycle and the problem does not show up until the next compressor start. During these off cycles, oil in the crankcase will usually absorb refrigerant. This is especially true if the compressor was running in a flooded condition prior to shut off. The amount absorbed is a function of the temperature of the oil and the pressure in the crankcase. The lower the temperature and/or the higher the pressure, the more refrigerant absorbed. In some cases the refrigerant oil mixture will stratify with the refrigerant rich-mixture at the bottom, unfortunately near the oil pump intake.

The refrigerant is a poor lubricant and for practical purposes, could be considered a solvent. When the compressor starts again, the refrigerant rich oil will have reduced lubricating ability as it comes in contact with the various load bearing surfaces. As a result, wear and the potential for damage are greatly increased.

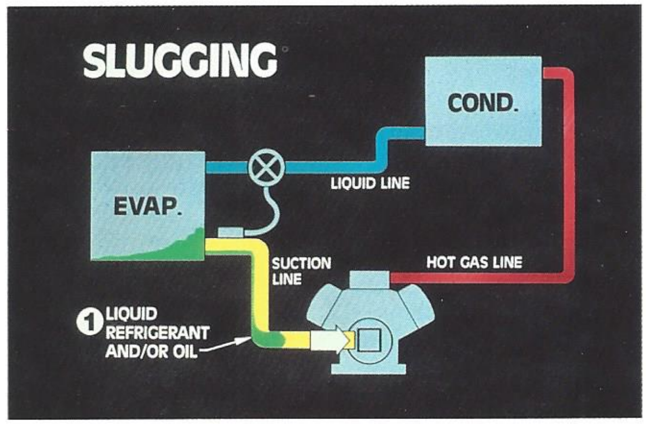


37. As previously mentioned, this condition usually occurs during shutdown. Lubrication received by the bearings during the next start-up will be marginal. In addition, as the crankcase pressure drops, the refrigerant will flash from a liquid to a gas causing foaming. This can cause restriction in the oil passages and will cause pressure to build in the crankcase. This pressure increase forces the oil and refrigerant mixture to enter the cylinders as a liquid slug.



38. Floodback to a running compressor causes an abnormally cold crankcase which leads to liquid migration at shutdown. This causes flooded starts resulting in severe pressure in the cylinder (slugging). This causes severe overload to valves, gaskets, and bearings occurring at a time of marginal lubrication. The usual result is component failure.

SLUGGING

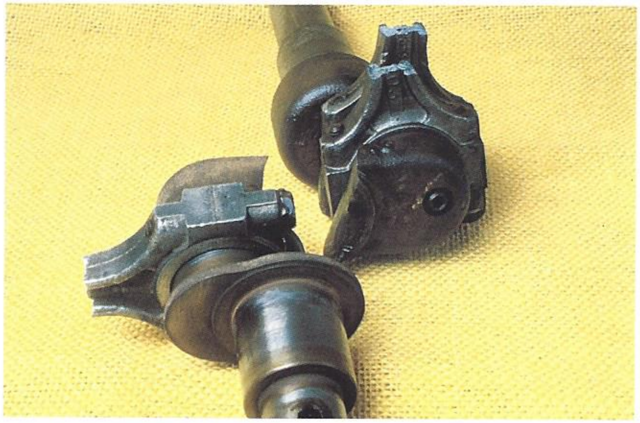


39. Slugging is a short-term return of a large quantity of liquid refrigerant, oil, or both to the compressor cylinders instead of a superheated gas. This can occur at start-up during a flooded start, or during a rapid change in system operating condition. It can sometimes be detected by a periodic "knocking" noise in the compressor. This is due to hydraulic compression, which occurs when the compressor is trying to compress a liquid. Compressors are designed as vapor pumps; and any attempt to compress something other than a vapor can lead to damage.

40. When parts, such as a suction valve break, the pieces may enter the cylinder. The clearance volume designed into the cylinder is not large enough to handle this "extra" material between the piston and valve plate.

41. A blown cylinder head gasket or valve plate gasket may also indicate a liquid slug. The gasket will blow on an internal partition between the high and low side of the head. If the compressor remained running, the particular head where the failure occurred would run hot compared to the others. Feel the underside of the suspected cylinder head for unusually warm temperatures.

If conditions are severe enough, the internal cylinder head web between the suction and discharge side of the head may even break.



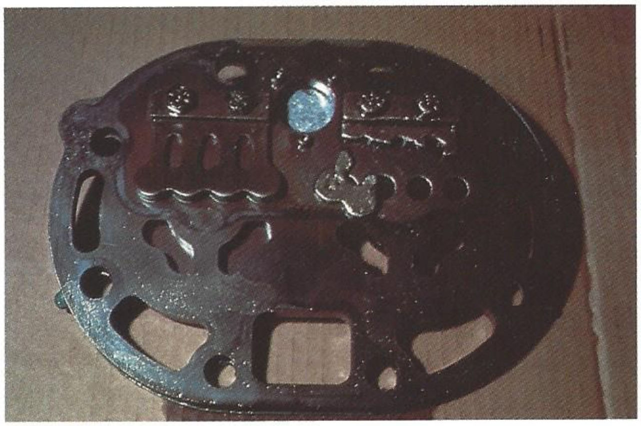
42. Liquid slugging can also have this disastrous effect. The connecting rods and even the crankshaft can break if the slug is significant enough. This type of failure would normally be caused by a tremendous slug at start-up.

43. The force that results when a compressor tries to compress liquid refrigerant or oil is tremendous. Pressures of well over a thousand psi can be reached in the cylinder.

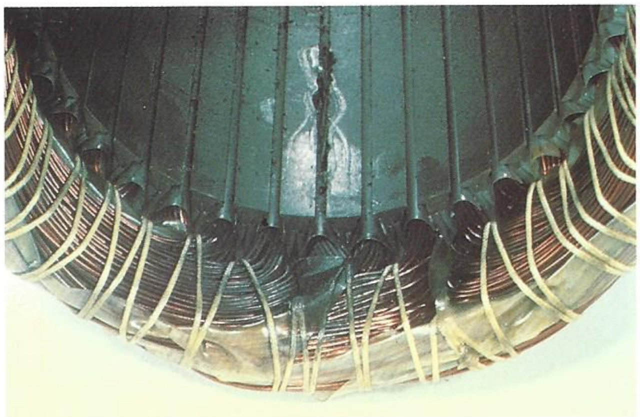
Among other damage which may occur, the liquid has the ability to punch holes in the top of the piston. This does not mean it happens in every liquid slug failure, but it is a possibility.

44. If the pistons survived a slug, the suction or discharge valves probably did not.

These slugs are capable of causing damage to the valves when they try to push them through the port. Damage can range from dented valves to complete punctures at the ports.

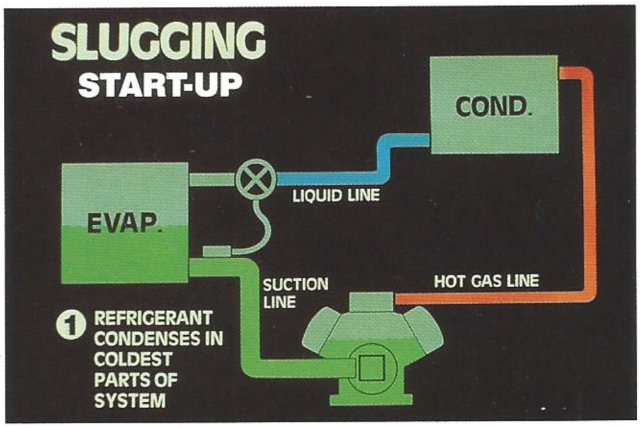


45. Long term, repeated mild slugging will cause metal fatigue of internal and external parts, for example, discharge lines and valve stops.

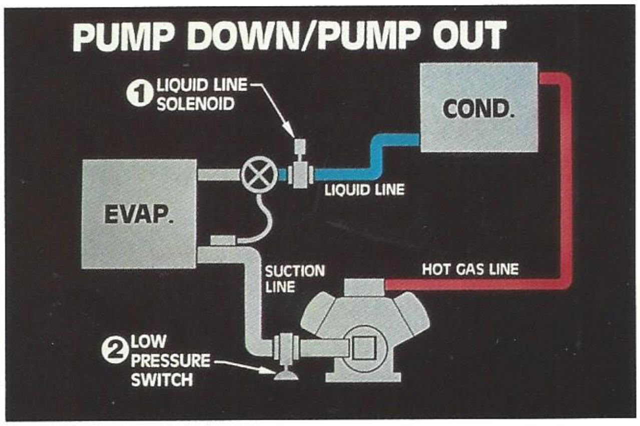


46. Whenever electrical damage is found in a semi-hermetic compressor, be sure to look for system problems which could cause mechanical damage to the compressor. Electrical failures are often blamed as the root cause of failure when they are not. The REAL cause may have been a refrigerant flow control problem or another less obvious problem, but are often not considered as a possibility because the immediate symptoms indicate a motor failure. Pieces of the compressor can become lodged in the stator or between the rotor and stator and eventually cause a motor failure. This may or may not be immediately obvious upon inspection. To summarize, mechanical failures cause electric failures, but electric failures do not cause mechanical failures.

SLUGGING (AT START-UP)

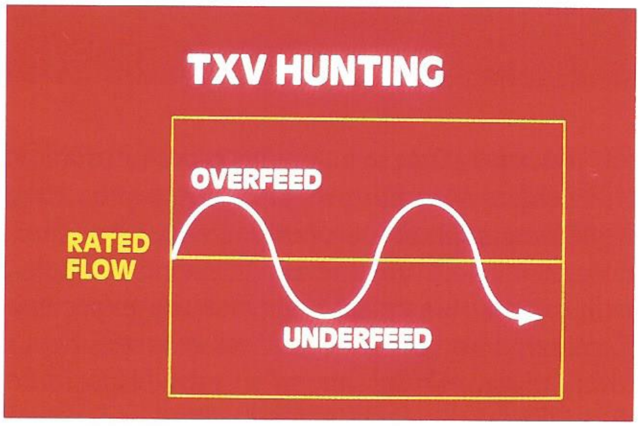


47. As described earlier, slugging is the return of a large quantity of liquid refrigerant or oil to the compressor. Refrigerant can condense during off cycles within any part of the system where temperatures become cold enough. This could be the evaporator coil, cooler, or compressor crankcase. On the next start-up, this liquid would find its way to the compressor cylinders as a slug the same way it does during a flooded start condition.

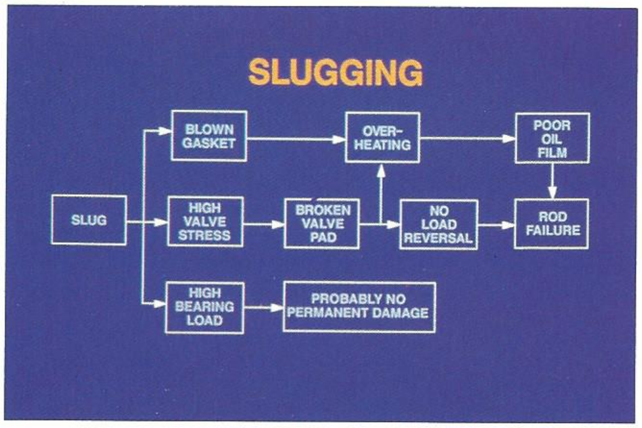


48. As mentioned earlier in the program, one method of minimizing refrigerant accumulation in the compressor is to incorporate a "single pump-out" control system. In this system a solenoid valve can be installed in the liquid line to prevent refrigerant flow to the evaporator. The thermostat operates the solenoid valve. The compressor pumps down the system and a low pressure switch stops the compressor after the refrigerant has been removed from the low side of the system.
The compressor restarts when the thermostat

energizes the solenoid valve again. "Solenoid drop" and "continuous pump-down" are other systems designed to decrease the possibility of flooded starts and/or slugging. Application of these methods depends on the design of the compressor and the system. Check with the manufacturer for recommendations.

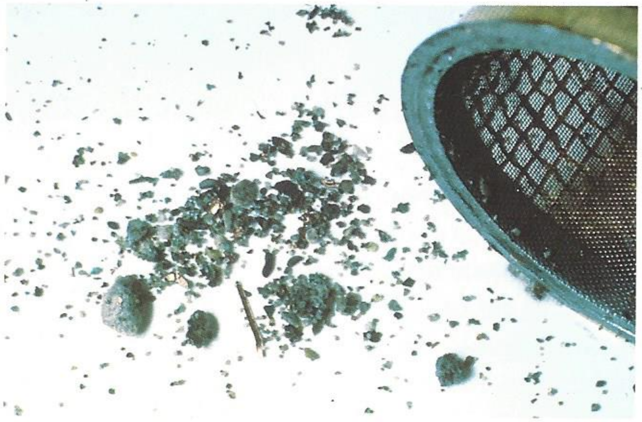


49. An oversized expansion valve will cause hunting, and hunting causes intermittent flooding, and starving of the evaporator, leading to possible damage resulting from the flooding itself, or from the potential flooded-starts and slugging it can create. This is especially true under light loads. In general, it is considered good practice to undersize rather than oversize an expansion valve.



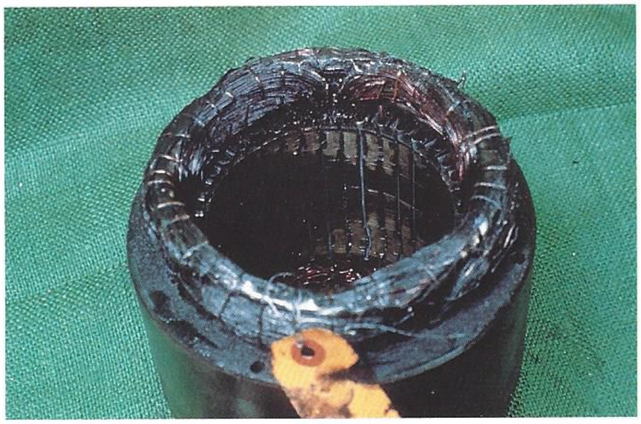
50. Slugging can lead to a blown gasket, high valve stress or high bearing loads. A blown gasket results in overheating, poor oil film coverage and eventual rod failure. High valve stress eventually leads to a broken valve pad and again to rod failure. High bearing loads will probably not result in immediate damage but repeated abuse of this nature will fatigue the bearings.

CONTAMINATION



51. Contamination is another cause of compressor wear and failure. Contaminants are any substance or material other than the specified refrigerant and compressor oil, which cause a chemical reaction, or change the chemical composition of materials within the system.

Some of the contaminants are: water, moisture, air, non-condensibles, chips of copper, steel, or aluminum, copper and iron oxide, copper and iron chloride, welding scale, brazing and soldering flux, and other types of dirt that might enter the system accidentally during installation, start-up, or servicing procedures.



CONTAMINANT	HOW TO ELIMINATE
AIR	EVACUATE
MOISTURE	DEHYDRATE
CHIPS & DIRT	FILTER
ACID	REPLACE OIL AND DRIER
BURNOUT RESIDUE	REPLACE OIL AND DRIER

52. Unless really obvious, contaminants are often overlooked as the cause of failure. They always seem to show up after the fact. Take this situation: the motor appears to have failed electrically, which it did. But, the REAL reason for the failure was the fact that solid contaminants (carbon and sludge) plugged the oil pick-up screen and lube passages to the main bearing preventing proper lubrication. The main bearing failed which caused the rotor to drop onto the stator. As the machine continued to operate, the metal filings from the rotor and stator rubbing, were forced into the slots in the stator. The filings then penetrated the insulation, shorting the windings to the stator, causing the motor to fail. What started as dirt or some other contaminant in the system ended up in motor failure.

The lesson to be learned here is to avoid bad habits when servicing equipment and be willing to take the extra step towards diagnosing the REAL problem. For example, when servicing compressors or other equipment, do not wipe replacement parts with a work rag. The rag is probably oily, the oil picked up dirt, and the dirt will end up in the system. Also, when possible and practical, inspect the failed compressor and ask yourself "What could have led to the symptoms seen in this failure?"

53. Because of these and other types of problems, it is necessary to use proper clean-up procedures. If a system is not properly cleaned-up after a failure, chances are the replacement compressor will have a shorter than normal life expectancy. Contaminants must be eliminated at the time of installation or at the time of service. Here is how to do this:

Air - evacuate
Moisture - dehydrate
Chips and dirt - work carefully and use strainers and filters
Acid - replace oil and/or the filter drier.
Burnout Residue - replace oil and/or the filter drier.

If uncertain of proper clean-up procedures, consult with the manufacturer. (Refer to appendix for additional training materials on this subject).

54. Different contaminants can cause different types of failures. Air or other non-condensibles displace the refrigerant in condensers resulting in higher than normal head pressures and temperatures. A typical result of high temperatures and contaminants in the system is the carbonization of oil on the discharge valves, guides, and cylinder heads. The hottest parts of the compressor are the valves and guides. The greater the build-up, the more likely that the compressor will fail. The iron in the valves, acting as a catalyst, promotes a chemical reaction between the refrigerant and oil-soluble compounds. This results in a buildup of film on the internal surfaces of the compressor. In time, the film will build to the point where valve leakage will occur.

The temperature of the valves and guides may be anywhere from 25° to 50° hotter than the discharge line temperature.

55. Copperplating is a phenomenon that is not clearly understood. It is a result of a combination of contaminants, the type of oil used, and high temperature. The contaminants gradually eat away at the internal copper surfaces throughout the system allowing the copper particles to travel through the system. They become deposited on compressor surfaces within the compressor that are at elevated temperatures, such as bearing surfaces. The gradual buildup of copper on these surfaces reduces the clearance for the oil film between the bearings. This in turn causes higher temperatures and decreases the life of the compressor.

56. Moisture, as a contaminant has two primary detrimental effects. First, it will react with the refrigerant to form acid; and second, it could cause

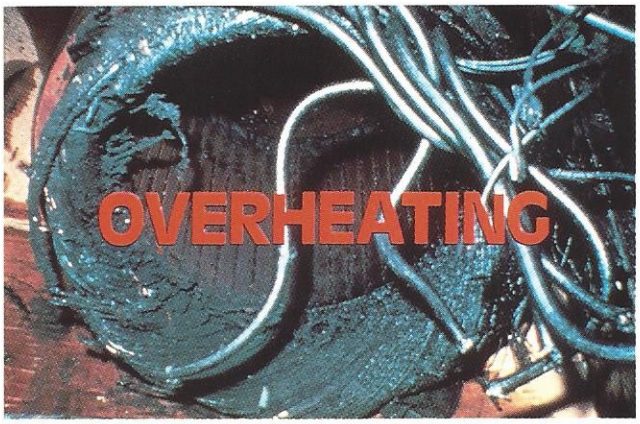
a freeze-up at the expansion device. This is a factor to be considered especially with heat pumps, which operate at lower temperatures than straight cooling systems. Low temperature refrigeration applications are affected in the same manner. The application of the compressor may be different, but the problems with acid are the same.

Acid may be a long range problem affecting different components of the system and may not show up right away. An example of this would be where the acids gradually eat away at a terminal block until the compressor fails electrically. Keep in mind, the cause of failure was due to moisture.

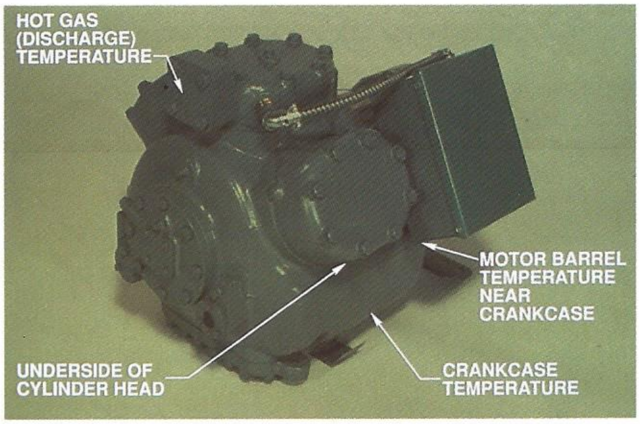
57. The oil in the compressor can be a dangerous substance as a result of acids. Compressor oil, although it may appear clear, should be tested for acidity. Use TOTALTEST® when contamination is suspected. This is especially true in the case of a compressor burn out.

You do not have to obtain an oil sample from the compressor because TOTALTEST® samples refrigerant gas. Complete instructions are provided with the kit.

OVERHEATING



58. Compressors generate heat. Heat of compression, thermal losses from motor windings, and frictional heat gain at load bearing surfaces are the normal source for heat, and all compressors are designed to tolerate these normal thermal gains. A few simple temperature measurements can provide useful information about the conditions under which a compressor is operating. They are also helpful in determining system operating conditions. A few minutes spent taking these readings may save a compressor, a lot of extra time and expense, and reduce the possibility of a call-back on a repeat failure.



59. As mentioned previously, compressors are designed to handle normal thermal temperature gains, but when they operate outside design parameters, reduced life expectancy and potential damage result.

Typical **normal operating** temperatures for semi-hermetic compressors are:

Oil Temperature
- Fully loaded 90° to 125°F
- Unloaded 90° to 135°F

Discharge Gas
- 60°to 100°F above saturated discharge temperature

Motor Barrel Temperature
- 60° to 105°F

Suction Gas Return Temperature
above saturated
- TXV = 15° to 25°F
- Fixed orifice and EXV = 0° to 10°F

Bottom of Cylinder Head
- 80°to 120°F

Obtaining this information during start-up procedures, or when problems are suspected, is helpful in determining how the system is operating. It will help you pinpoint those problems that are so often overlooked, or not even considered when a compressor failure occurs.

The highest temperature that you should read at the discharge line for most applications is 275°F. A reading of 275°F means the temperature at the discharge valves may be 300° to 325°F. At these temperatures refrigerant and oil start to break down and a failure is not far off. Operating temperatures should rarely reach these levels and are almost always a sign of system problems.

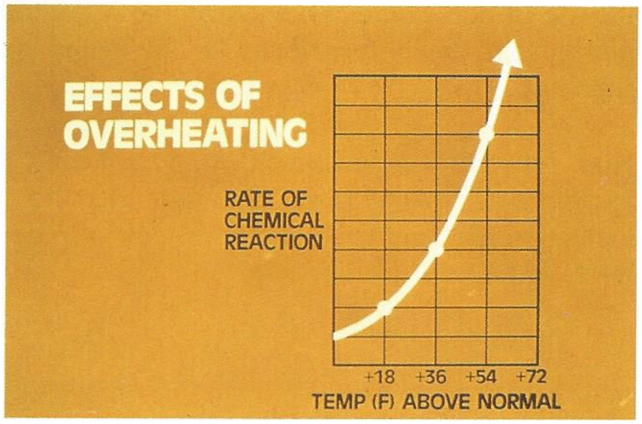
Motor barrel temperature provides the ability to determine potential problems before they become problems. Too warm a reading may indicate motor problems, lack of refrigerant cooling for the motor, or too much oil. Hot spots on the motor barrel may be caused by phase unbalance. Too cold a temperature may indicate refrigerant flow control problems and other cold suction return gas temperature problems.

Crankcase temperatures can be an indication of too high or too low a superheat, or the presence of a liquid return condition. If too high a temperature is present, check the high side for air flow restriction through the condenser coil, dirty fans, malfunctioning motors, and loose or broken fan belts.

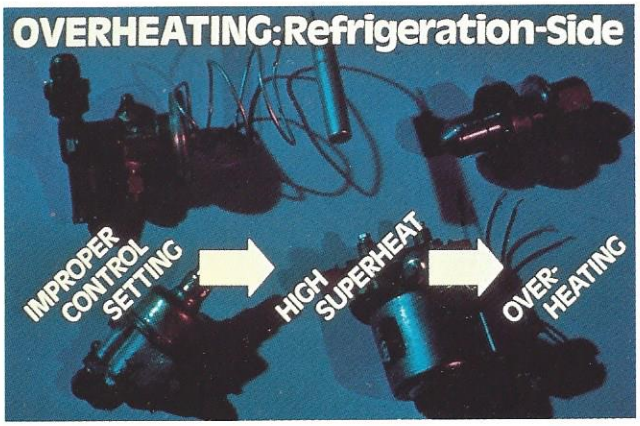
If too low a temperature is present, check the low side of the system for refrigerant flow control problems, dirty evaporator coils, loose or broken fan belts, dirty fans, dirty filters and malfunctioning motors.

Cylinder head temperatures outside their normal operating range can also be used to identify compressor problems. These readings should always be taken from the under side of the head. If the temperature is above the operating limit, blown gaskets and similar problems may be present.

If the temperature is below normal, liquid return problems may be indicated in which case further investigation is required.



60. Laboratory tests show that with each 18° F rise in discharge temperature above normal, the chemical reaction rate between refrigerant and moisture, acid and oxides, acid and oil, and refrigerant and oil doubles. Doubling the chemical reaction very quickly begins to damage the compressor. The harmful effects of the acids, however, do not just limit themselves to the compressor, but can cause harm to the entire system.



61. Reasons for overheating can be grouped into two basic categories: air-conditioning/refrigeration and electrical. On the A/C and refrigeration side, one of the most common causes of overheating is the improper setting of controls.

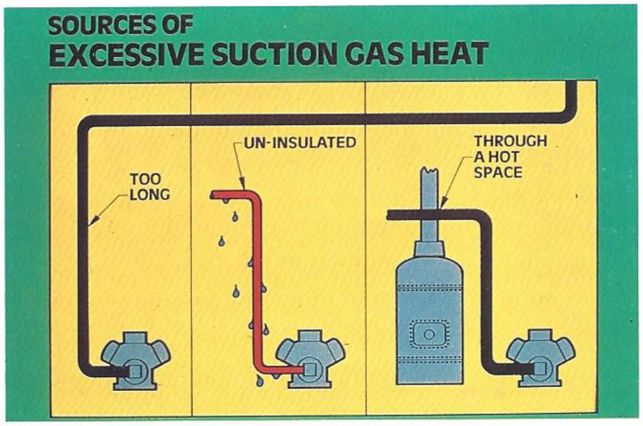
These controls could be a TXV, automatic expansion valve, evaporator pressure regulator, hot gas bypass, unloaders, pressure control switches, or the use of non-essential devices in the refrigerant piping that could contribute to the return gas superheat.

High return gas superheat is caused not only by improper control settings, but may also be an indication of a piping problem or lack of proper insulation on the suction line.

62. Hermetic compressors are cooled by suction gas. The ability of the suction gas to cool the windings is a function of the gas flow and the temperature of the gas entering the compressor.

Above normal suction return gas temperatures can reduce system capacity and may indicate inefficiencies or problems in the compressor if they become excessive. If the return gas temperature is below normal operating limits, flooding and its associated problems become possible and even slight changes in system load may become a problem.

Ideal return gas temperatures should be at 10° to 20°F. of superheat for air conditioning applications. For refrigeration duty with R-12 or 502 applications, the return gas temperature should be below 65°F.



63. Bear in mind that heat is added to the suction gas as it flows from the evaporator to the compressor. The amount of heat can be excessive if the suction line is too long, uninsulated, or runs through a hot space, such as an equipment room.

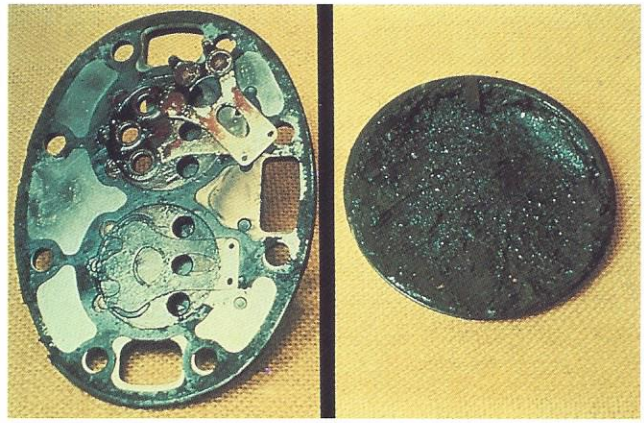
64. High discharge temperatures can cause worn or seized pistons, and piston rings, scored cylinder walls, and excessive wear on the wrist pin and pin bores.

COMPARATIVE COMPRESSION RATIOS

A/C TO REFRIGERATION DUTY

CONDITION	A/C DUTY (R-22)	REF. DUTY (R-502)
SST (F)	40	-30
SCT (F)	135	120
CR	4:1	12.4:1

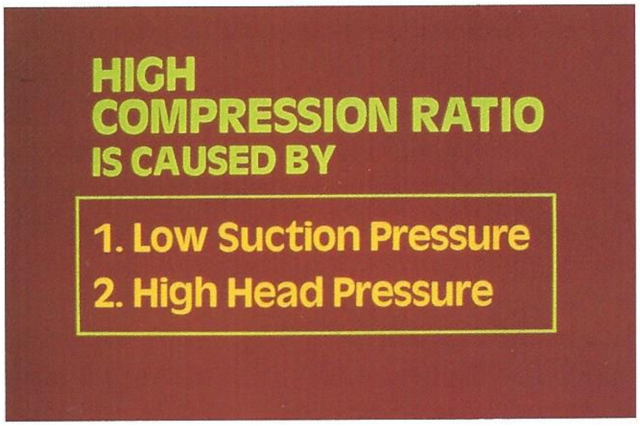
65. High compression ratios are also a cause of overheating. Compression ratio is the ratio of absolute discharge pressure to absolute suction pressure. Actual and maximum acceptable compression ratios are set by manufacturers and may vary from model to model and from refrigerant to refrigerant, depending on the application.



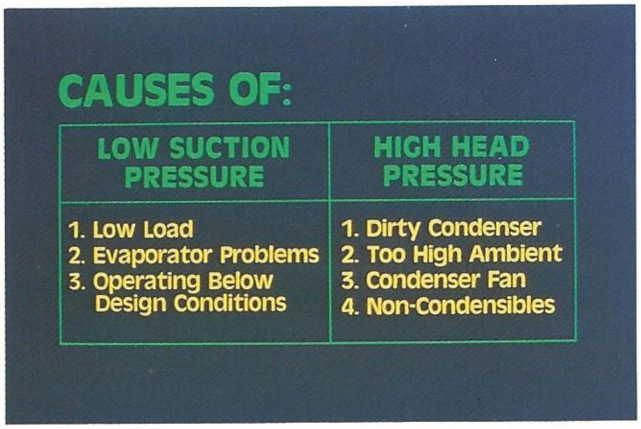
66. When the discharge line temperature approaches 300° F, system ingredients begin to break down. Oil will form sludge, which will coat the internal surfaces of the compressor with carbon as shown on the valve plate above. This sludge formation will collect in the oil pick-up screen in the compressor sump. This restriction makes proper lubrication nearly impossible. Damage under these circumstances is assured.

67. One component which suffers accelerated wear from the effects of high discharge pressures and temperatures is the suction valve. On the left you can see the outline of the suction port, which has worn into the valve. This wear has a tendency to stress the valve, making it more susceptible to failure.

During high discharge (head) pressure operation, the extra pressure forces the valve to flex more than it is designed to. This extra flex, combined with higher than normal temperatures, will exaggerate the wear pattern on the valve. Since this flexing is happening many times per minute, it is amazing the valve can take the abuse as long as it does.

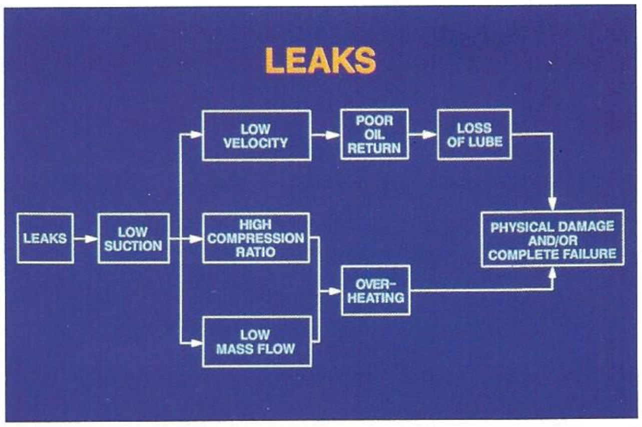


68. High compression ratio is caused by low suction pressure and high discharge pressure, or a combination of both.



69. Low suction pressure is the most likely cause of high compression ratios. Low suction pressure is caused by low load, evaporator coil problems, air flow problems, partial loss of charge, improper pressure switch settings, frosted coil, or by operating the compressor below design conditions.

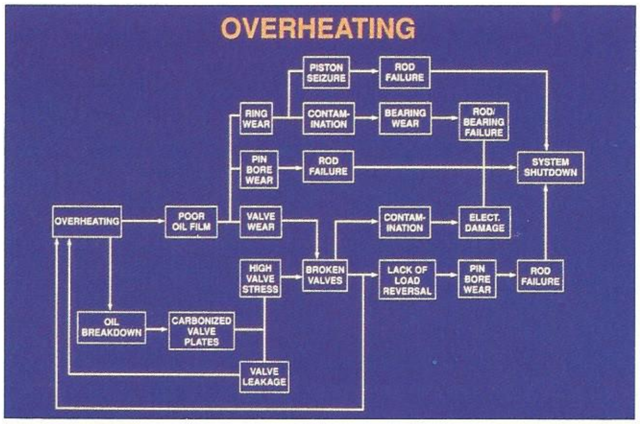
High discharge pressure may also cause high compression ratios. Look for things such as dirty condensers, high temperature ambient air, condenser fan problems, and non-condensibles. On water-cooled equipment also look for scaled condensers, high inlet water temperatures, and low water quantity.



70. Leaks within the system can also lead to overheating. As refrigerant is lost, suction pressure will decrease causing lower refrigerant velocity, and lower mass flow, at the same time the compression ratio will increase.

As a result of the lowered velocity, oil return decreases, causing loss of lube and ultimate failure.

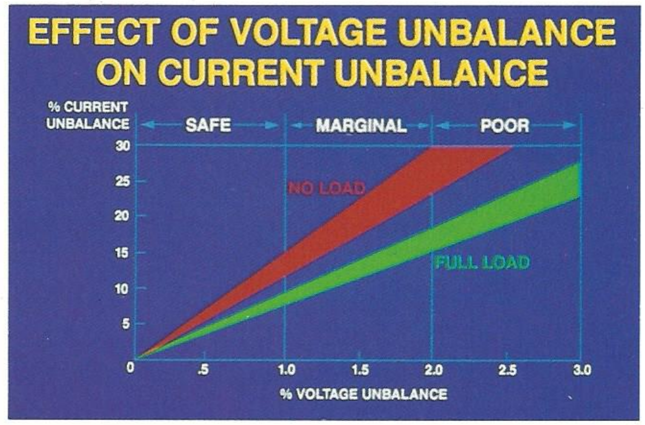
Lower mass flow, and the higher than normal compression ratios created by lowered suction pressure lead to overheating and its associated problems. These also lead to mechanical failure.



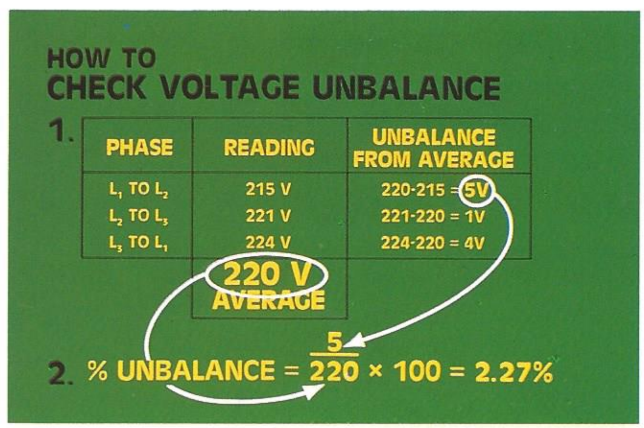
71. Overheating leads to thin oil and the resulting problems of accelerated wear. Severe overheating causes the oil to carbonize and contaminate. The resulting lubrication and contamination problems lead to mechanical damage and system shutdown.

ELECTRICAL

72. Electrical problems can also lead to compressor failure. In a three-phase compressor, motor failure can happen because of voltage and/or current unbalance. These are two types of problems which cause an increase in temperature that may go unnoticed for a long period of time.



73. The most probable cause of current unbalance on any induction motor is voltage unbalance. Current unbalance rises sharply with a small voltage unbalance. Thus, in any "current unbalance" problem, source voltage unbalance should be suspected. The maximum allowable voltage unbalance from winding to winding is 2%. This slide shows the effect of voltage unbalance on current unbalance for any type of three phase induction motor. The band indicates the spread that is likely to be encountered. Note that for a given voltage unbalance, the current unbalance will increase as load decreases.



74. To check voltage unbalance take the voltage readings between phases at the disconnect or the compressor contactor while the compressor is operating.

For example, if:

L1 to L2 = 215V
L2 to L3 = 221V
L3 to L1 = 224V

The average is 215 + 221 + 224 divided by 3, or 220V average.

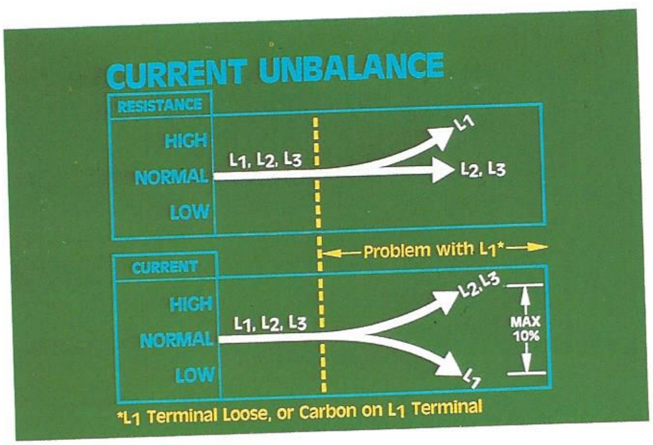
Next, figure the unbalance for each phase by getting the difference between the voltage reading and the average:

L1 to L2 = 220 - 215 = 5V
L2 to L3 = 221 - 220 = 1V
L3 to L1 = 224 - 220 = 4V

Five volts is the maximum unbalance. Use it in the formula: % Unbalance is the maximum unbalance divided by the average voltage times 100.

$$\% \text{ Unbalance} = \frac{5}{220} \times 100 - 2.27\%$$

This voltage unbalance is greater than 2% and therefore is not acceptable. The customer should be advised.



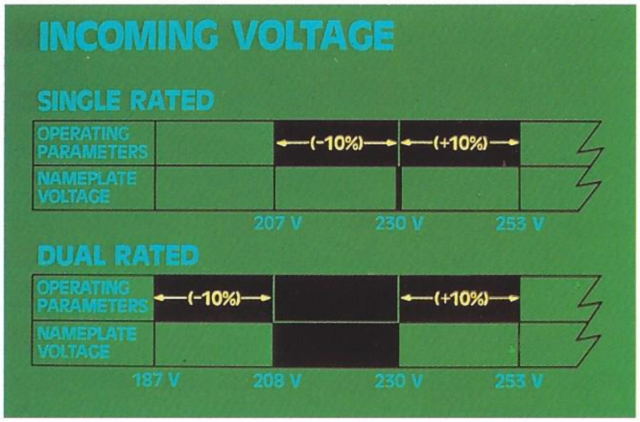
75. Voltage unbalance will cause a current unbalance but a current unbalance does not mean that a voltage unbalance necessarily exists. Take a three-phase situation where there is a loose terminal connection on one leg or where there is a buildup of carbon or dirt on one set of contacts. (Let's use L1 as our problem leg.) This would cause a higher resistance on that leg than on L_2 and L_3. Look at the lower chart. As we know, the current will follow the path of the least resistance. This causes the current to increase in the other legs. Higher current causes more heat to be generated in the windings. Percent of current unbalance is calculated like voltage.

Single-phasing, a condition where one leg of a three-phase system is lost, will react much the same as the conditions just described, but the motor failure may be more rapid.

76. When a three-phase motor single phases, one phase is unaffected but the others generally show signs of overheating. The pattern of failure shows up in this slide. One phase is bright and shiny and clearly unaffected. This was the open phase. The other two phases are burned.

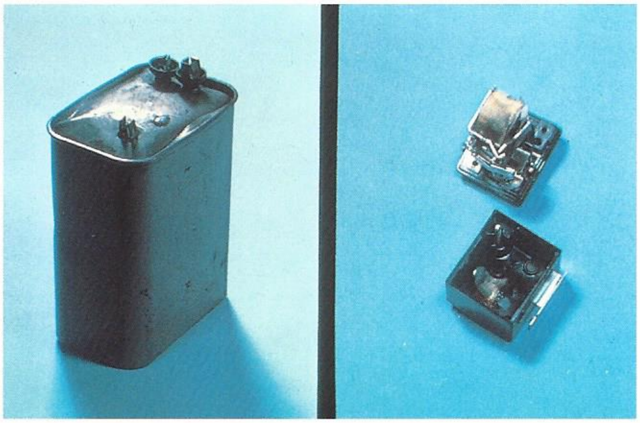
What happens in single phasing is that, if the compressor is operating and one phase of a three-phase motor opens, the motor may continue to run. The other two phases will attempt to pick-up the load that the lost phase was carrying. The current draw of the remaining two phases will increase to about 1-1/2 times normal. If the compressor is loaded, it will push the current draw of the motor beyond the "must-trip" current of the overload protection. Under light load conditions, the current may not reach the trip current of the overload and will remain running. The windings will run hot.

Once the motor stops, it generally cannot restart, tripping on the overload protectors again and again. This normally leads to motor failure.

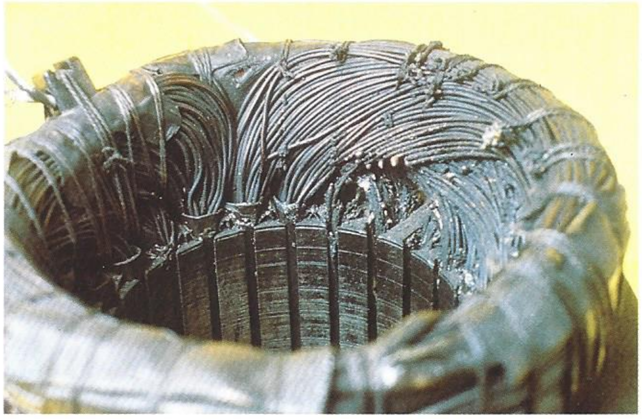


77. Another cause of overheating is too high or too low an incoming voltage. This is where the voltage is outside the maximum-minimum limits set by the manufacturer of the equipment. For a compressor with single rating of 230 volts, the operating limits are within $\pm$10% of 230 volts (207 to 253V).

On a dual-rated voltage unit, such as a 208/230 volt system, the operating parameters are within 10% below the 208 and 10% above the 230 nameplate voltage (187 to 253V).

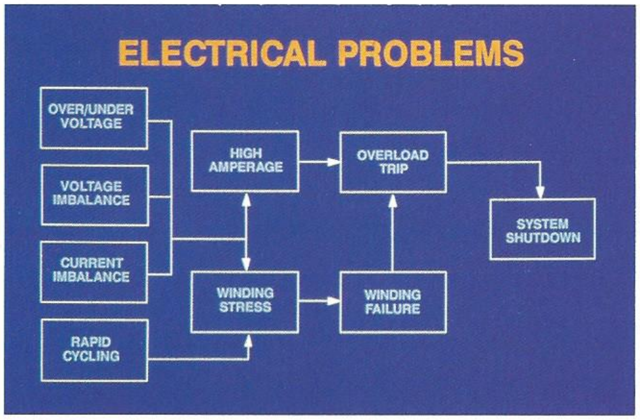


78. In a single-phase motor, another cause for overheating is faulty or improper start gear. It could be the start or run capacitor or any of the contactor-relay devices used in conjunction with the start gear. Without the proper voltage and microfarad rating, the compressor would not operate within the design tolerance, or might fail to start. If it fails to start, it could cause a locked-rotor situation which brings on overheating of the start windings and rapid failure.

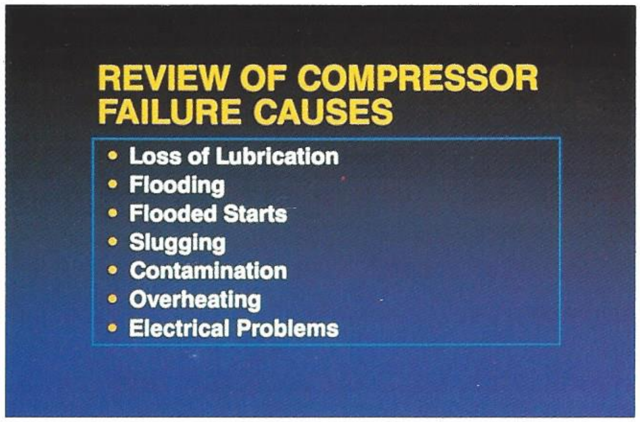


79. Finally, one of the causes of overheating often overlooked as a cause of compressor failure is rapid cycling. The start-stop cycling of controls and safety devices can result in shorted motor windings. Here is how it can happen:

Each time the motor starts, the current draws locked rotor amps. It takes a few minutes of running to get rid of the heat caused by locked rotor current. Frequent cycling causes a buildup of heat because the heat from the previous start has not been removed.



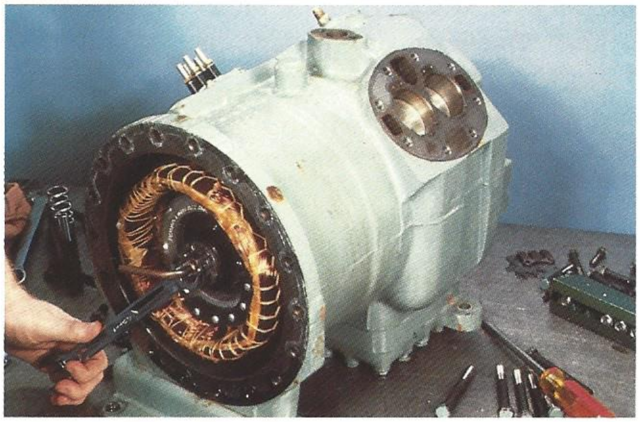
80. Electrical problems are usually caused by an electric supply imbalance or rapid compressor on-off cycling. All four typical electrical problems can lead to overheating and eventual burnout. In addition, rapid cycling can cause failure of the motor windings due to constant flexing of insulated turns and connections.



81. The major points covered in the causes of compressor failure section were:

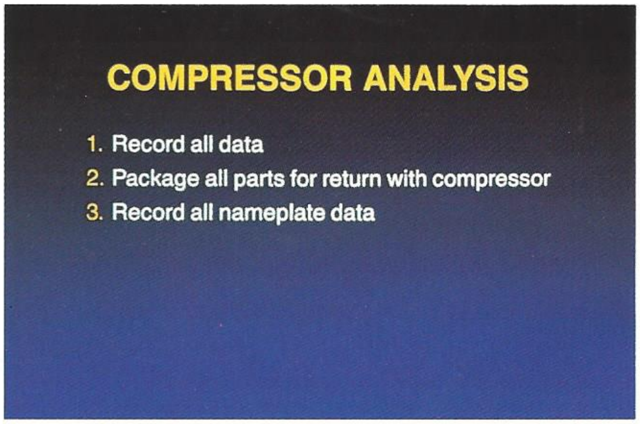
- Loss of lubrication
- Flooding
- Flooded starts
- Slugging
- Contamination
- Overheating
- Electrical Problems

COMPRESSOR ANALYSIS



82. As you can see, there are many things that can cause compressor damage. The responsibility of the technician replacing a failed compressor is not only to replace the compressor, but to diagnose and correct the root cause by further investigation.

There are certain physical damage characteristics associated with each of the different causes of compressor failure. Although they often overlap from one problem type to the next, looking at and confirming the existence of damage within the failed compressor gives us a reference point from which to work.



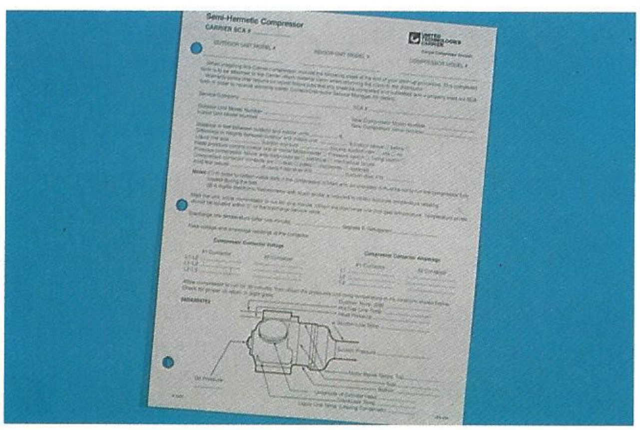
83. The best place to begin the investigation is in the failed compressor. In many cases compressors are replaced and started-up without this additional investigation. This all-too-common practice appears to be based on the assumption that, as

long as the replacement compressor operates after it is installed, the problem is solved. The first components to be inspected are the cylinder head, valve plate, and valves. If the compressor is still in the system, be sure that it has been isolated from the rest of the system and that any internal pressure has been relieved before removing the head bolts. Leave a couple of bolts loose in the head when breaking the seal to prevent the head from flying off and causing personnel injury if internal pressure still exists under the head. Once the head is removed, visually inspect the parts for mechanical damage. Any of the components may be damaged.

Removal of the base pan will provide additional information useful in determining the cause of failure. This allows easy identification of broken rods, piston damage, and crankshaft condition. On semi-hermetic compressors, inspection of the motor housing area is useful in determining bearing and motor damage.

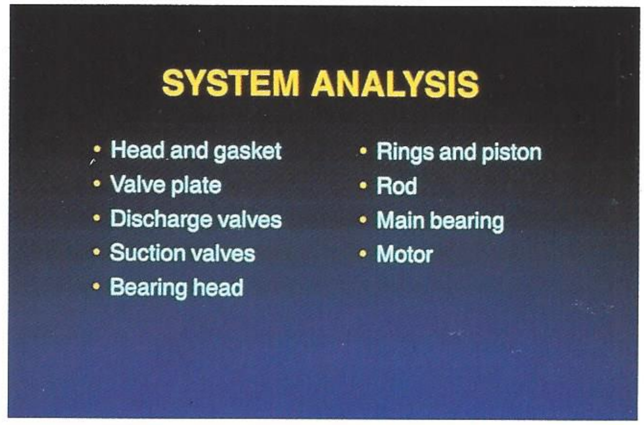
After you finish your inspection and have made a complete analysis:

1. Record all data.
2. Package all parts for return with the compressor.
3. Record all nameplate data.



84. Obtaining the information outlined in the above worksheet at the next start-up can help determine and eliminate future problems. (Refer to appendix for sample Compressor Service Worksheet.) This information is also valuable when calling for service assistance. Before starting the replacement compressor, be certain that a thorough system analysis has been performed and the appropriate corrective measures have been taken. Use the service worksheet provided with the replacement compressor.

SYSTEM ANALYSIS



85. The first step in compressor and system analysis is to inspect the compressor. You may follow any orderly procedure to do this.

86. A typical teardown inspection sequence might be as follows:

1. Cylinder head and valve train analysis.
2. Oil pump and bearing analysis.
3. Rod and piston analysis.
4. Shaft and main bearing analysis.
5. Motor and terminal plate analysis.

HEAD AND GASKET ANALYSIS

OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Blown Webb	– Severe high pressure	– Flooded start – Discharge service valve closed
Oily (non-unloading)	– Excess oil in circulation – Compressor defect	– Flooded start – Excess oil charge
Dry	– Oil return problem	– Piping design problem (oil traps) – Low refrigerant charge – Floodback
Blown Head or Valve Plate Gasket	– Slug	– Flooded start – Discharge service valve closed

87. The analysis of the head and gasket may show several possible symptoms from an oily surface to a blown web. By observing the exact condition of the disassembled parts you can usually determine a possible cause of failure. Then you must try to trace back to the system related malfunction which is the original trouble source.

VALVE PLATE ANALYSIS

OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Damaged	– Debris in cylinder	– Mechanical damage to piston or valves
Oily	– Excess oil circulation – Compressor defect	– Flooded start – Excess oil charge
Dry	– Oil return problem	– Piping design problem (oil traps) – Low refrigerant charge – Floodback
Black with carbonized oil	– Overheating	– Gasket blown – Valve broken – Low refrigerant charge – Low suction

88. After removing the valve plate, look for an oily, dry, discolored or damaged condition. Then follow through the possible cause until you relocate the system related malfunction that caused the problem initially.

DISCHARGE VALVE ANALYSIS

OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Broken at pad possibly dished	– Slug	– Flooded start – Discharge service valve closed at startup
Broken at pad valve and seat wear no dishing	– High compression ratio	– Low suction – High head
Break in finger no marks on backer, valve plate, or valve	– Defect in Swedish steel	
Break in finger marks on valve, valve plate, or backer at the break	– Foreign particle lodged between valve and plate or backer	– Mechanical damage in system

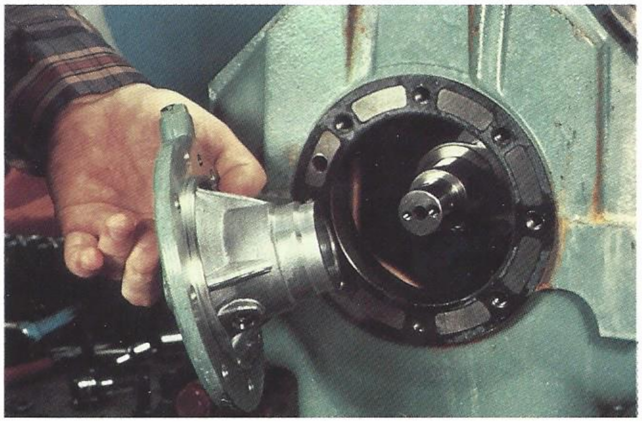
89. Broken discharge valves are usually caused by liquid slugging, or system contamination. It is rare but possible that defective valve material could be the cause of failure. Examine any broken valve carefully for signs of damage due to a liquid slug or dirt.

SUCTION VALVE ANALYSIS

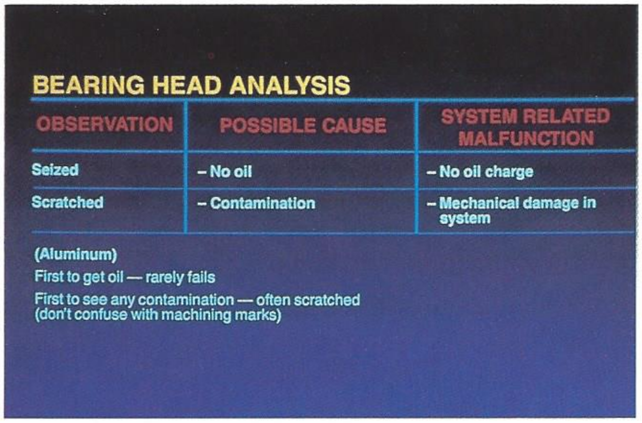
OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Broken seat area possibly dished no foreign particle marks	– Slug	– Flooded start – Discharge service valve closed at startup
Broken anywhere marks from foreign particle impact	– Contamination	– Mechanical damage in system
Broken at cylinder bore only	– Defect in Swedish steel	

NOTE: Broken piece frequently damages motor or discharge valve.

90. Suction valves will show damage similar to discharge valves.



91. Oil pump and bearing failures are rare since they are the first components to get oil. However, they are also the first components to see any system contamination. When examining the bearing for scratches, do not confuse abnormal marks with normal machining marks. Remove the oil pump cover from the compressor housing. After removing the oil pump cover, it is a good idea to rotate the compressor using an Allen wrench to see if the pistons move with normal resistance.

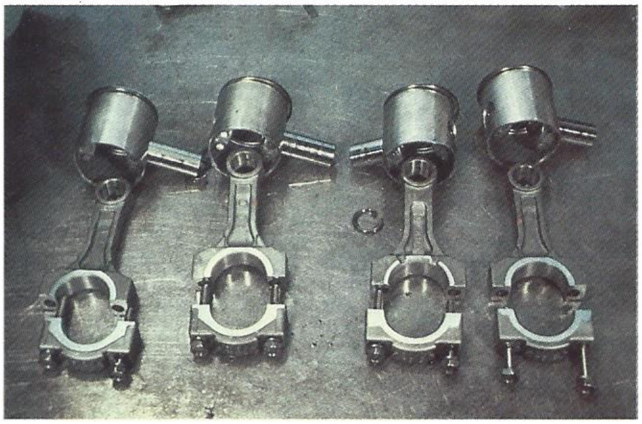


BEARING HEAD ANALYSIS

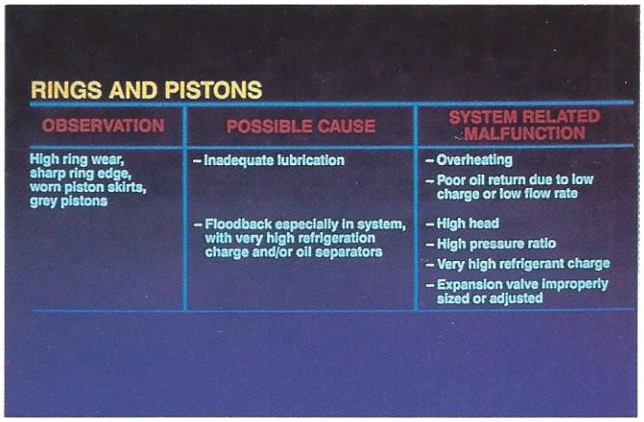
OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Seized	– No oil	– No oil charge
Scratched	– Contamination	– Mechanical damage in system

(Aluminum)
First to get oil — rarely fails
First to see any contamination — often scratched (don't confuse with machining marks)

92. Bearing head analysis will indicate either a seized or scratched bearing surface as a malfunction. Again, do not confuse normal machining marks with scratches due to contamination.



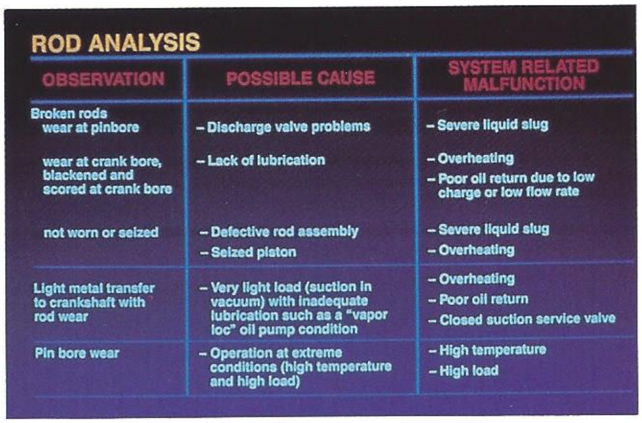
93. The pistons and connecting rods are removed from the cylinders and examined closely.



RINGS AND PISTONS

OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
High ring wear, sharp ring edge, worn piston skirts, grey pistons	– Inadequate lubrication	– Overheating – Poor oil return due to low charge or low flow rate
	– Floodback especially in system, with very high refrigeration charge and/or oil separators	– High head – High pressure ratio – Very high refrigerant charge – Expansion valve improperly sized or adjusted

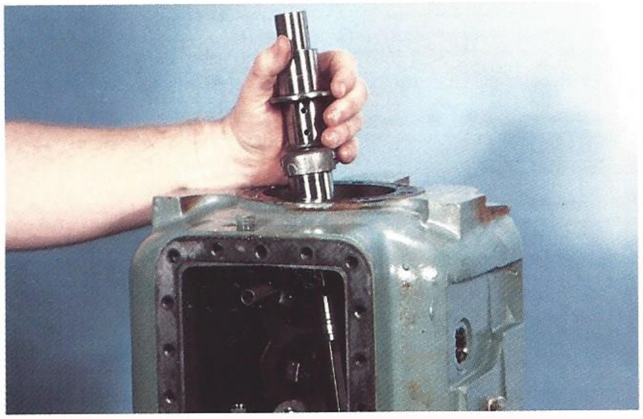
94. Extensive ring wear with sharp edges, and grey, discolored pistons usually are caused by poor lubrication due to refrigerant floodback. High compression ratio and discharge temperature will also cause accelerated piston and ring wear, but signs of overheating, such as discolored valves and valve plates, and pistons, are usually evident. Heavy suction valve wear will usually be evident if high discharge temperatures caused piston and ring wear.



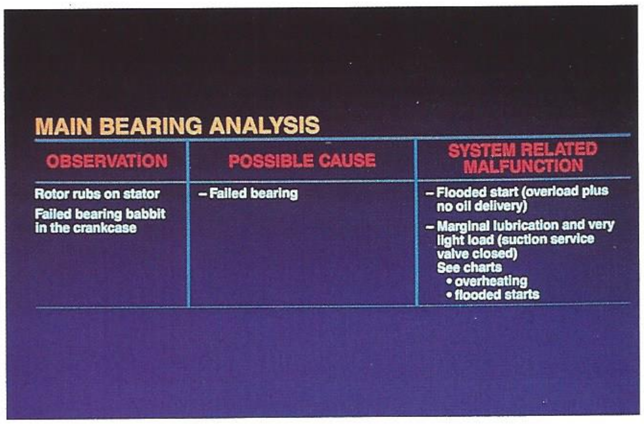
ROD ANALYSIS

OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Broken rods wear at pinbore	– Discharge valve problems	– Severe liquid slug
wear at crank bore, blackened and scored at crank bore	– Lack of lubrication	– Overheating – Poor oil return due to low charge or low flow rate
not worn or seized	– Defective rod assembly – Seized piston	– Severe liquid slug – Overheating
Light metal transfer to crankshaft with rod wear	– Very light load (suction in vacuum) with inadequate lubrication such as a "vapor loc" oil pump condition	– Overheating – Poor oil return – Closed suction service valve
Pin bore wear	– Operation at extreme conditions (high temperature and high load)	– High temperature – High load

95. Worn or even broken rods can be due to a number of problems. If these conditions are found there will be other indications of trouble in other compressor parts to help you tie down the exact system problem.



96. The next step is to remove the shaft from the compressor housing.

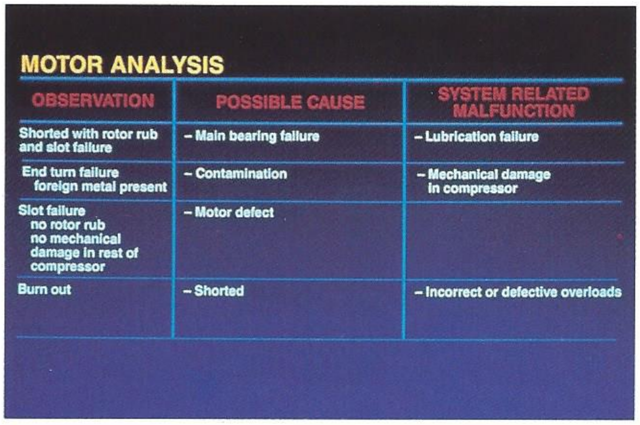


MAIN BEARING ANALYSIS

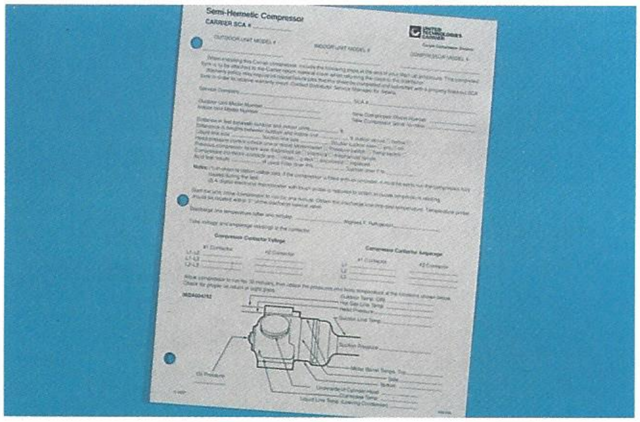
OBSERVATION	POSSIBLE CAUSE	SYSTEM RELATED MALFUNCTION
Rotor rubs on stator Failed bearing babbit in the crankcase	– Failed bearing	– Flooded start (overload plus no oil delivery) – Marginal lubrication and very light load (suction service valve closed) See charts • overheating • flooded starts

97. Indication of bearing failure such as the rotor rubbing on the stator is commonly caused in compressors by flooded start conditions.

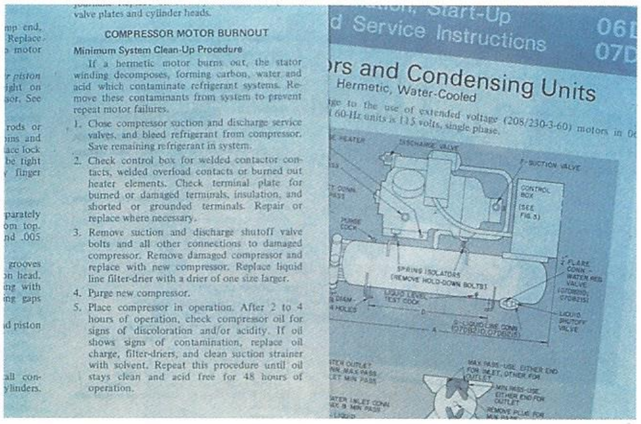
98. Next, remove the rotor from the compressor housing being careful not to damage the stator windings during disassembly. Any damage at disassembly will lead to a false analysis of the real problem.



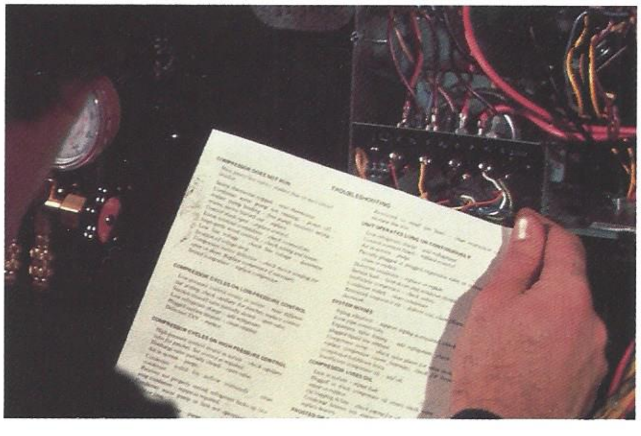
99. Look for signs of shorting, burnout, and single phasing. Most motor failures will be due to system causes while only a few are due to internal motor defects.



100. If it becomes necessary to call for assistance, be sure to have specific data such as compressor model and serial number, and system operating pressures and temperatures available before making the call. This information is necessary to effectively make a diagnosis.

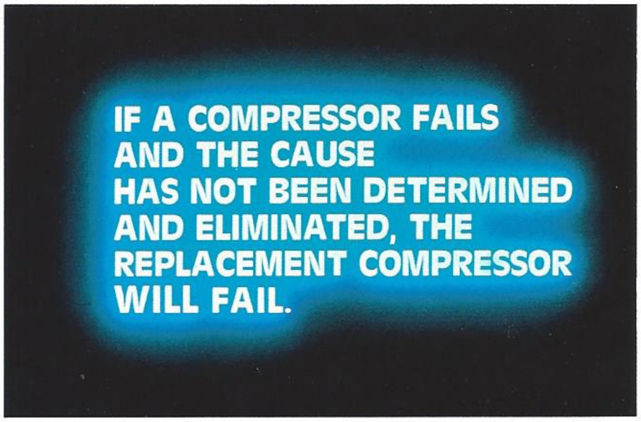


101. As a result of this investigation, let's say our diagnosis is correct. Once all problems are corrected, the replacement compressor may be installed. Be sure to follow recommended installation and start-up procedures to ensure a reliable installation. Complete proper system clean-up, evacuation, and dehydration procedures before charging the system. This is especially important when contamination has been identified. Taking short-cuts may allow you to get the system running, but increases the chance of a repeat failure. **Use the service worksheet provided with the replacement compressor.**



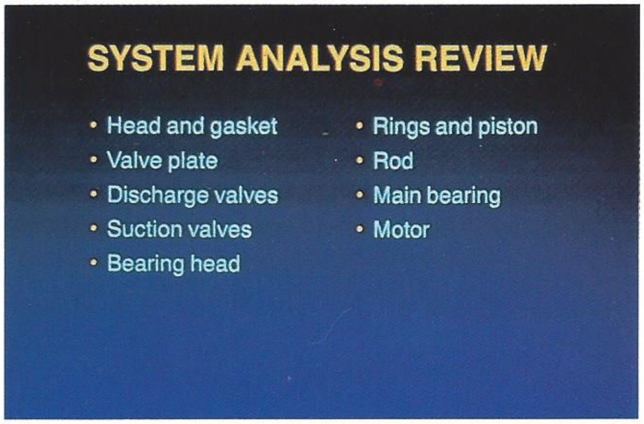
102. Before leaving the job site, take time to double check your work. Be sure to document all corrective actions taken, and notify the equipment owner of any additional recommendations that may

decrease the likelihood of a repeat failure. Replacing a compressor is a costly operation to all concerned. If not done properly, it can quickly lead to a repeat failure. Taking the time now may prevent an unnecessary call back.



103. It is a common pattern where the original compressor will last around 10 years then a series of replacement compressors will be used until the system problem is found.

Remember...If a compressor fails and the cause has not been determined and eliminated, the replacement compressor will fail.



104. The major points covered in the System Analysis section were:

- Head and Gasket
- Valve Plate
- Discharge Valves
- Suction Valves
- Bearing Head
- Rings and Pistons
- Connecting Rods
- Main Bearing
- Motor

APPENDIX

For additional information on Compressors and topics highlighted throughout this program, use this list in preparation of supplementary training sessions.

Title	Format	Form No.	Catalog No.
Compressors			
Carlyle 06D & 06E Semi-Hermetic Compressors	Slides	GTC-3	020-303
	Booklet	GTC3-101	020-343
Carlyle 5 Line Compressor Teardown and Rebuild	Slides	5F, H-02	020-503
	Booklet	5F, H-01	020-502
Capacity Control, Carlyle 5, 6 Line Compressors	Slides	GTC-1A	020-301
	Booklet	GTC1A-101	020-300
Preventing Compressor Failures	Video	GTC-4	020-491
	Booklet	GTC4-101	020-490
Clean-Up Procedures			
Clean-Up after Burnout	Slides	GTC-18	020-222
	Booklet	GTC18-101	020-262
Be Compressor Wise	Slides	GTC-19	020-217
	Booklet	GTC19-101	020-257
Safety			
Safety Training - It's Everyone's Responsibility	Video	GT32-02	020-456
	Booklet	GT32-01	020-455

Important - We have dozens of other product, theory and skills training programs to select from. For a free Service Training Materials (STM) Catalog, call 1 (800) 962-9212.

NOTES

WHY COMPRESSORS FAIL
QUIZ

Familiarization Section

1. Ways in which compressors fail may be attributed to....

   a. mechanical failures
   b. electrical problems
   c. mis-application
   d. all the above

2. When symptoms are treated as the cause of a compressor failure, the REAL cause remains undetected until a repeat failure occurs.

   a. true
   b. false

Systems and Components Section

3. Of the different types of systems a compressor must contend with, the one that places the most stress on the compressor because of it's reverse cycle heat is the:

   a. packaged system
   b. straight cooling system
   c. split system
   d. heat pump

4. Improper maintenance leading to dirty coils etc. can cause major system components to have adverse affects on compressors.

   a. true
   b. false

System Accessories Section

5. System accessories play an important role and provide specific functions within an HVAC system. They may also have negative affects if they are....

   a. misapplied
   b. not functioning properly
   c. both a and b
   d. none of the above

6. Components which can cause compressors to operate in deep vacuums leading to potential damage include....

   a. malfunctioning liquid line solenoid valves
   b. plugged liquid line filter driers
   c. suction line filter driers
   d. all the above

7. Accumulators are often added to systems where flooding or slugging conditions are suspected.

   a. true
   b. false

Causes of Compressor Failure Section

8. To effectively diagnose an HVAC system it is necessary to know what the system should do when it is operating correctly as well as being able to recognize when it is not.

   a. true
   b. false

9. Loss of lubrication due to insufficient oil return to the compressor may be caused by....

   a. low system load
   b. low refrigerant velocity
   c. short cycling
   d. all the above

10. Flooding is considered....

    a. the intermittent return of liquid to the compressor during the off cycle
    b. the continuous return of liquid to the compressor during the running cycle
    c. an intermittent condition only
    d. both a and b

11. Air side problems are known to be a significant cause of flooding. Among these problems are....

    a. broken fan belts
    b. inoperative fan motors
    c. dirty coils
    d. all the above

12. Wrist (piston) pin lubrication is accomplished by the oil-vapor collecting in the wrist-pin reservoir at the top end of the connecting rods.

    a. true
    b. false

System Analysis Section

18. During the compressor inspection, if broken discharge valves were found, some of the items to check would be the....

    a. liquid slugging
    b. system contamination
    c. defective valve material
    d. all the above

19. Discoloration of the valve plate and/or valves may indicate....

    a. a slugging condition
    b. a flooding condition
    c. low suction pressure
    d. contamination or overheating

20. After replacing a defective compressor and repairing the cause of failure, be sure to complete proper evacuation, dehydration, and start-up procedures.

    a. true
    b. false

INSTALLATION & START-UP CHECKLIST

SYSTEM DESIGN

- ☐ Heating and cooling loads properly calculated
- ☐ Equipment and supplemental heat sized in accordance with local utility and manufacturer directives (heat pump)
- ☐ Maximum thermal balance point in accordance with local utility standard (heat pump)
- ☐ Electric heat staging in accordance with local utility standard (heat pump)
- ☐ Outdoor thermostats set at proper balance points (heat pump)
- ☐ Circuit breakers, disconnects and wiring properly sized
- ☐ Properly designed ductwork to handle 400-500 CFM/ton of capacity
- ☐ Ductwork insulated and equipped with vapor barrier (if applicable)

NOTE: If system is a packaged unit, use the appropriate items in the following sections.

UNIT INSTALLATION

- ☐ Unit elevated for snow clearance and defrost water drainage (heat pump)
- ☐ Unit secured to pad or curb with correct clearance for airflow and service
- ☐ Curb installed per instructions
- ☐ Raintight disconnect(s) installed within sight of unit
- ☐ Wiring done in accordance to wiring diagram and codes
- ☐ Electrical connections and terminals tight
- ☐ Refrigerant lines trapped, insulated, secured and connected to service valves
- ☐ Correctly sized metering device installed
- ☐ Shipping brackets/compressor bolts removed and/or loosened per instructions
- ☐ Optional and field-supplied accessories installed properly
- ☐ Fan(s) rotate freely without binding or hitting
- ☐ Refrigerant lines properly connected
- ☐ Refrigerant lines and indoor coil evacuated to at least 500 microns
- ☐ Condensate drain installed per installation instructions
- ☐ Air filters clean and in place

ECONOMIZER/ AIR DISTRIBUTION SYSTEM

- ☐ Economizer outdoor air hood properly installed
- ☐ Economizer minimum position or outdoor air damper set per job specifications
- ☐ Economizer outdoor air thermostat or enthalpy control properly installed and adjusted for local climate conditions
- ☐ All supply and return air grilles open and unrestricted

UNIT START-UP

- ☐ Service valves opened
- ☐ All field-made refrigerant line connections checked for leaks
- ☐ Crankcase heater energized 24 hrs prior to start-up
- ☐ Compressor and outdoor fan(s) run on call for cooling and heating
- ☐ Refrigerant charge correct. Use superheat method for fixed restrictor metering devices or subcooling method for TXV equipped cooling coils.
  __________°F measured superheat
  __________°F measured subcooling
- ☐ Fan(s) rotation direction and rpm correct
- ☐ Condensate flows freely from drain
- ☐ No air leaks in system ductwork
- ☐ Air flows freely from all supply registers
- ☐ Test and balance of air flow

GENERAL

- ☐ Voltage and amperage imbalance for 3 phase units within accepted limits (2% voltage, 10% amperage)
- ☐ All thermostat functions operate correctly (heat, cool, fan)
- ☐ All accessory items operating correctly
- ☐ Outdoor unit/air handler/refrigerant lines checked for vibration
- ☐ Balancing dampers adjusted for correct air flow to each branch run
- ☐ All work areas cleaned up
- ☐ All packing materials removed from equipment
- ☐ System operation reviewed with customer and Owner's Manual presented

SAMPLE SYSTEM SERVICE WORKSHEET

DATE: ______________________

TECHNICIAN: ______________________

CUSTOMER
NAME: ______________________

ADDRESS: ______________________

PHONE: ______________________

– UNIT NAMEPLATE INFORMATION –

INDOOR SECTION	OUTDOOR SECTION	PACKAGED SYSTEM
MODEL NO.:	MODEL NO.:	MODEL NO.:
SERIAL NO.:	SERIAL NO.:	SERIAL NO.:
VOLTAGE – ϕ:	VOLTAGE – ϕ:	VOLTAGE – ϕ:

– UNIT DATA –

INDOOR SECTION	OUTDOOR SECTION	PACKAGED SYSTEM
VOLTAGE:	VOLTAGE:	VOLTAGE:
CURRENT:	CURRENT:	CURRENT:

– COMPRESSOR DATA –

FROM COMPRESSOR NAMEPLATE:

MODEL NO. ______________________

SERIAL NO. ______________________

	VOLTAGE	CURRENT	RESISTANCE CHECK
1ϕ	C-R:	C:	C-R:
	C-S:	R:	C-S:
	R-S:	S:	R-S:
3ϕ	L1-L2:	L1:	L1-L2:
	L1-L3:	L2:	L1-L3:
	L2-L3:	L3:	L2-L3:

– REFRIGERANT PRESSURE/TEMPERATURE –

	PSIG	SAT. TEMP.
COMPR. DISCH.		
L.L. SER. VLV:		
S.L. SER VLV:		
SUCTION		

	ACTUAL TEMP.	(Actual Temp. Minus Sat. Temp.) SUPERHEAT	(Sat. Temp. Minus Actual Temp.) SUB COOLING
DISCHARGE LINE			
LVG. O.D. COIL @ SER. VLV.			
ENTER METERING DEVICE			
LVG. INDOOR COIL			
ENTER SUCT. LINE SER. VLV.			
ENTER COMPRESSOR			

– AIR/WATER SYSTEM CAPACITY –

INDOOR COIL (EVAPORATOR)

	ENTERING	LEAVING	DIFFERENCE
D.B.			$\Delta T=$ °F
W.B.			$\Delta T=$ °F
*ENTHALPY			$\Delta h=$ Btu/LB

*Get from chart on page 21

‡EVAPORATOR CAPACITY

BTUH = 4.5 x CFM x Δh

‡Other methods for obtaining capacity are available.

OUTDOOR COIL (CONDENSER)

	ENTERING	LEAVING	DIFFERENCE
(AIR) D.B.			$\Delta T=$ °F

CONDENSER CAPACITY

BTUH = 1.10 x COND. CFM x ΔT

CHILLER

	ENTERING	LEAVING	DIFFERENCE
WATER TEMP.			$\Delta T=$ °F
WATER PSIG			$\Delta P=$ PSIG

CHILLER CAPACITY

BTUH = 500 x GPM x ΔT

CONDENSER (WATER)

	ENTERING	LEAVING	DIFFERENCE
WATER TEMP.			$\Delta T=$ °F
WATER PSIG			$\Delta P=$ PSIG

CONDENSER CAPACITY

BTUH = 500 x GPM x ΔT

TO MEASURE CFM (AIR FLOW)

CFM = FREE AREA (FT.^{2}) x VELOCITY (FT./MIN.)

Semi-Hermetic Compressor

CARRIER SCA # ____________

(SAMPLE WORKSHEET)

UNITED TECHNOLOGIES CARRIER
Carlyle Compressor Division

OUTDOOR UNIT MODEL #	INDOOR UNIT MODEL #	COMPRESSOR MODEL #
____________	____________	____________

When installing this Carrier compressor, include the following steps at the end of your start-up procedure. This completed form is to be attached to the Carrier return material claim when returning the claim to the distributor.

Warranty policy may require on repeat failure jobs that this sheet be completed and submitted with a properly filled out SCA form in order to receive warranty credit. Contact Distributor Service Manager for details.

Service Company ____________ SCA # ____________

Outdoor Unit Model Number ____________ New Compressor Model Number ____________
Indoor Unit Model Number ____________ New Compressor Serial Number ____________

Distance in feet between outdoor and indoor units ____________ ft.
Difference in heights between outdoor and indoor unit ____________ ft. Indoor above ☐ below ☐
Liquid line size ____________ Suction line size ____________ Double suction riser ☐ yes ☐ no
Head pressure control (check one or more) Motormaster ☐ Pressure switch ☐ Temp switch ☐
Previous compressor failure was diagnosed as ☐ electrical ☐ mechanical failure
Compressor contactor contacts are ☐ clean ☐ pitted ☐ discolored ☐ replaced
Acid test results ____________ (If used) Filter drier P.N. ____________ Suction drier P.N. ____________

Notes: (1) In order to obtain viable data, if the compressor is fitted with an unloader, it must be set to run the compressor fully loaded during the test.
(2) A digital electronic thermometer with touch probe is required to obtain accurate temperature reading.

Start the unit, allow compressor to run for one minute. Obtain the discharge line (hot gas) temperature. Temperature probe should be located within 3" of the discharge service valve.

Discharge line temperature (after one minute) ____________ degrees F. Refrigerant ____________

Take voltage and amperage readings at the contactor.

Compressor Contactor Voltage

	#1 Contactor	#2 Contactor
L1-L2		
L1-L3		
L2-L3		

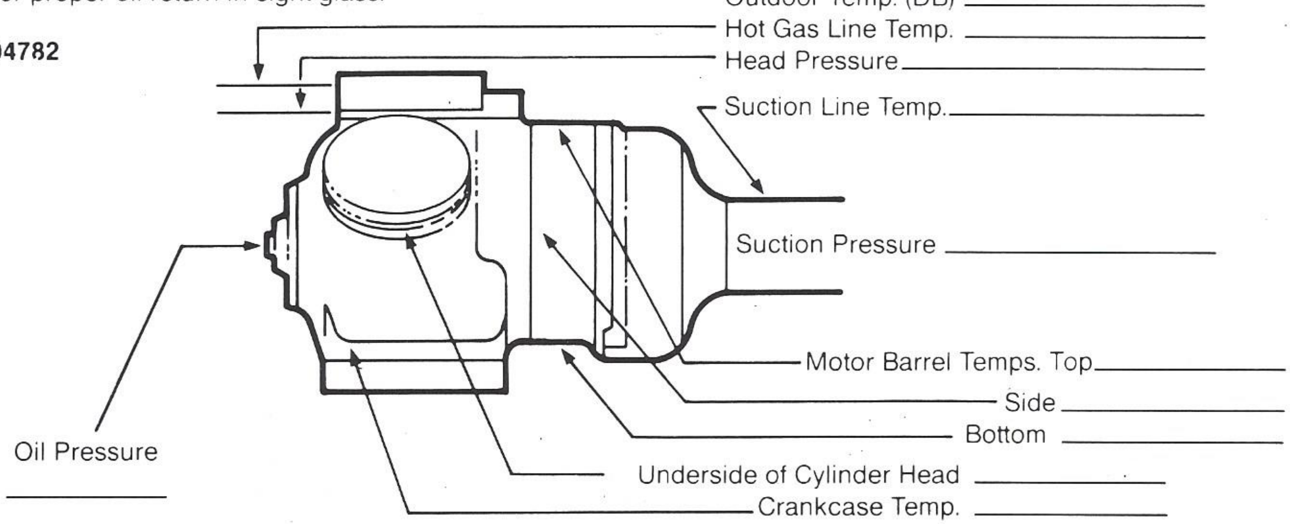
Compressor Contactor Amperage

	#1 Contactor	#2 Contactor
L1		
L2		
L3		

Allow compressor to run for 30 minutes, then obtain the pressures and body temperature at the locations shown below. Check for proper oil return in sight glass.

06DA604782

Outdoor Temp. (DB) ____________



Liquid Line Temp. (Leaving Condenser) ____________

Semi-Hermetic Compressors

The following procedure is Carrier's recommendation for clean-up after burnout for semi-hermetic compressors. The procedure is written for Carrier equipment as a generic approach to clean-up It has been written this way realizing that not all refrigerant systems have ideal accessibility to allow every step of the procedure to be performed the same way on every unit. (For a more detailed procedure, see Carrier Training Program GTC-18 available through Carrier. On specific units, see the product literature for that unit. Clean-up procedures will be listed under two failure causes.

Mild Burnout:
A non-running motor burn with the motor contaminants confined to the compressor.

Severe Burnout:
A running motor burn where the contaminants are pumped through the system. This type of failure accounts for 3 to 5% of all motor burnouts.

Procedure for Clean-up:
Observe all safety precautions while working on system. Avoid contact with refrigerant/oil mixture since acid burns may result. Wear safety glasses and work gloves.

Mild Burnout:

1. Shut off power, then remove refrigerant charge from compressor using suitable refrigerant recovery device (TotalClaim™ / TotalSave™). Do not blow charge to atmosphere.
2. Remove compressor, leaving service valves.
3. Replace compressor.
4. Verify crankcase heater condition with ohm meter.
5. Replace liquid line filter with one size larger in capacity than the unit worked on.
6. Triple evacuate down to 29 inches of mercury, breaking twice with refrigerant. Pull a deep vacuum of 500 microns before recharging.
7. Recharge unit compensating for larger liquid line filter.
8. Run a minimum of one hour and replace liquid line filter. If a heat pump, switch from heating to cooling a few times to verify component operation.
9. Acid check oil. If acid is present, change oil.

Severe Burnout:

1. Shut off power, then remove refrigerant charge from compressor using suitable refrigerant recovery device (TotalClaim™ / TotalSave™). Do not blow charge to the atmosphere.
2. Remove compressor.
3. Verify crankcase heater condition with ohm meter, replace if necessary.
4. Replace compressor.
5. Replace liquid line filter with one size larger than unit being worked on.
6. Add suction line filter of appropriate size, mounted vertically with pressure taps on both inlet and outlet.
7. Depending on the severity of the burnout, components may need to be changed out or cleaned.
8. Triple evacuate as discussed in the mild burnout procedure.
9. Recharge unit compensating for addition volume in larger liquid line filter drier.
10. Run 1 hour minimum, change liquid line and suction line filter plus oil.
11. Run a minimum of two more hours and change liquid filter again. Remove suction line filter entirely. Acid check oil and change. Depending on acid check, you may require an additional oil change.
12. On heat pumps, switch the four-way valve from heating to cooling a few times to verify component operation.

WHY COMPRESSORS FAIL
QUIZ ANSWERS

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