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Why Compressors Fail

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In the refrigeration and air conditioning industry, compressor failure is one of the major causes of worry. Commonly heard comments are :

- Compressors are not built as they used to be.
- Imported compressors are much better and can withstand more rigorous duty.
- Why does nobody build compressors which are "fitand - forget type".

- Why is compressor design so delicate that they break down even if a little bit of liquid or moisture enters.
- Manufacturers are making the designs more delicate to withstand competition and in the process sacrificing quality.

Installers and contractors continue to grumble, that there is no good or absolutely reliable compressor available in the market, and that every manufacturer, inserts several clauses about what should be done and what should not be done to protect himself, in case failure takes place. Also, he very rarely admits that the compressor is faulty.

It is understandable if newcomers in the industry, have these perceptions, but even those who claim to be experienced in handling plants, very rarely look inwards to find out whether they have done anything wrong that leads to compressor failure.

Having spent more than 36 years in this industry and been closely associated with compressor manufacturers of various types, being familiar with system design and installation, I thought it would be appropriate to share my experiences and knowledge as to why compressors fail and how to prevent such failures.

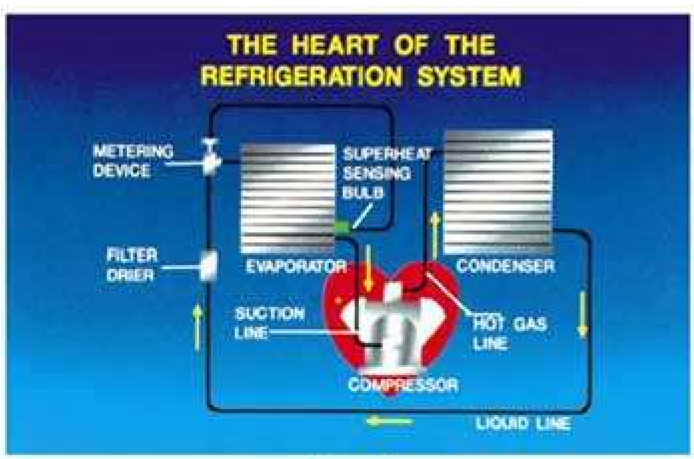

Figure 1

All of us know that a compressor is the only moving component in any refrigeration system and anything going wrong anywhere in the system will finally reflect on the compressor performance. It must be understood that related components and system malfunction initiate the compressor failure. Many times the compressor is therefore compared with the human heart

When a person suffers from a heart attack, it may be due to diabetes, hypertension, high cholesterol, mental tension or many other causes, which has finally resulted in heart failure. If proper diagnosis or preventive steps were taken at the appropriate time, the attack could have been avoided or at least delayed.

Similar is the problem when a compressor fails. The end result is the compressor failure, but the causes could be many, such as liquid entering the compressor, wrong design/application, incorrect piping, contaminants in the system, overheating or electrical problems and many more other reasons.

It is, therefore, essential to go to the root cause if the compressor fails, rather than simply replacing it with a new compressor, as the replaced compressor will also fail, if the root cause remains unattended.

We will therefore, get into the basics of what the refrigeration and air conditioning professional needs to know, to ensure that the compressor selected for a particular application gives satisfactory, trouble free and expected performance during its expected span of life.

It is my personal experience and also the experience of most of the world-class compressor manufacturers, with whom I have close interaction that more than 95% of compressor failures are not attributable to the compressor manufacturer and the problem lies elsewhere. It would also be incorrect to assume that compressor designers/ manufacturers never make mistakes, but statistics shows that these are very few, less than 5%.

I have come across the failure of a large number of compressors, utilized in one of the products manufactured in my previous company, procured from a forty-year-old, world class reputed supplier who produces these compressors in thousands and supplies them all over the world. Obviously, it would have been incorrect to assume that the compressor quality was bad and we had to look inwards as to what we, as system designers were doing that was wrong and which was leading to such failures. The reason why compressors were failing was that the lubrication was suffering. This was due to long pipe lengths to the evaporator located at the rear of the bus. A certain quantity of oil therefore was remaining in the system, as a coating of internal parts, and leading to starvation of oil in the compressor. When an additional quantity of oil was charged to compensate for the amount of oil remaining in the system, the problem was resolved.

There are various types of compressors and each has some peculiarities, but by and large, the basic precautions and understanding of the working of a refrigeration cycle is the same. It is therefore essential to know how each component operates in a system, what it is expected to do and compare it with what it is actually doing. This will enable the system designer to more accurately diagnose faults and avoid chances of repeat failures.

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Compressor Types

Refrigerant compressors fall into two categories:

A. Positive displacement compressors, where the increase of pressure is due to reduction of volume and which are:

- Reciprocating compressors with hermetic/semihermetic or open type designs
- Rotary compressors
- Scroll compressors
- Screw compressors

B. Non-positive displacement compressors like centrifugal compressors which work on the principle of kinetic energy getting converted into pressure head.

The study of each type of compressor, its design peculiarities and operation is not the purpose of this article, since irrespective of the type, the basic refrigeration cycle remains the same and it is therefore essential to understand what each component is supposed to do while working in close harmony with the rest of the components of the system.

In any closed mechanical-cycle refrigeration system, the basic components are

– compressor, condenser, evaporator and expansion device. All these components work in harmony with each other. Many technicians believe that just by replacing the compressor with a bigger compressor, the system performance will improve. However, this will not happen unless the other components are capable of shouldering this extra load. If the components are perfectly matched and if one component is replaced by a bigger component, instead of giving better results, it may lead to bigger problems.

The system is as strong as its weakest component or is as big as its smallest component. It is also worthwhile to remember that a single component, although it influences the performance of the overall system, it alone cannot determine the system capacity.

The problems leading to a compressor failure can be grouped in two categories:

- Mechanical, component/system-related problems
- Electrical problems, in case of hermetic/semihermetic designs

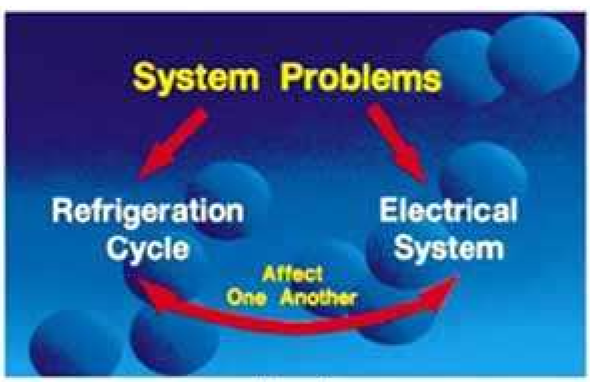

Figure 2

Problems covered in both these categories are interrelated and are overlapping and therefore need a more detailed and thorough analysis.

For example, a stuck up electrical contactor may lead to compressor on/off operation more frequently than recommended and can lead to oil starvation and thereby compressor failure.

Similarly, a contaminant in the system can get wedged in the motor winding, shorting it and leading to a motor burnout, or excessive moisture could weaken the motor windings, but in reality these are refrigeration-system related problems.

Also many defects of various types produce similar symptoms. Low capacity or insufficient cooling could be due to a number of reasons, like overcharging or under charging, non condensables, undersized piping or undersized heat exchangers, wrong expansion valves, choked coils or kinked /damaged piping and many more

such defects. All produce similar symptoms, therefore, a systematic troubleshooting approach in identifying the root cause is essential

Taking action based on the symptoms alone without proper analysis, therefore will not lead to a permanent solution, and thus one needs to go to the root cause if a permanent solution is to be implemented.

The reasons for compressor failure can be broadly classified as :

- Incorrect selection for the particular application
- Incorrect system design/installation/operation
- System accessories malfunction/or incorrect application
- Wrong selection of controls or their settings
- Wrong diagnosis
- Lack of maintenance/service
- Incorrect electrical wiring or other electrical problems

Normally a compressor manufacturer indicates the allowable limits for selection to ensure trouble-free operation. A system designer should not exceed these limits. If these are exceeded, the compressor may not fail immediately, but certainly will not give satisfactory performance over the period of its life.

The limits of operation to be taken into consideration are allowable saturated evaporating temperature for the operating saturated condensing temperature, allowable suction superheat and liquid sub-cooling, upper and lower speed limits, allowable compressor discharge temperature, voltage and frequency range, correct refrigerant, charge quantity etc.

In Ammonia compressors, it is recommended to limit allowable discharge gas temperature to a maximum 120°C. Normally, for Ammonia systems recommended temperature difference between the saturated condensing and evaporating temperatures should be limited to 50K. If the application calls for selection beyond this limit one should go for two-staging and for CFC/HCFC refrigerants this limit, could be 70K for single-stage application.

Many times, lubricating oils recommended by the manufacturer have to be changed to higher viscosity grades due to higher ambient temperatures encountered in our country and if not done the wear and tear could be higher, if we use the manufacturer's recommended lower viscosity oils.

In one of the low temperature Ammonia two-stage installations, where I was involved in designing, excessive cylinder liner wear was arrested, simply by changing the oil to a higher viscosity grade oil.

Besides proper selection and system design, the reasons for compressor failure can be classified as under:

- Loss of lubrication
- Liquid coming to compressor
    1. Flooded start
    2. Flooding
    3. Liquid or oil slugging
- Contaminants in the system
- Overheating
- Electrical problems

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Loss of Lubrication

Proper lubrication is essential to the life of a compressor. Most compressors, except welded hermetic, use a positive displacement oil pump to force feed oil to the various load bearing surfaces throughout the compressor.

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

Inadequate Oil Return

The absence of oil in the crankcase results due to lack of lubrication. During normal operation some oil will leave the crankcase. The piping system must be designed to return the oil to the compressor. Loss of lubrication is also caused by oil leaving the compressor at excessive rates. This rapid loss is usually associated with oil foaming which is easily observed in the compressor sight glass.

Figure 3

Figure 4

If oil leaves the compressor at an excessive rate, it is not likely to be returned at the same rate. The rate at which oil is pumped out by the compressor should be the same as the rate of oil return. If not, the oil quantity in the compressor will gradually reduce and lubrication will suffer.

Reasons for oil not returning at a satisfactory rate include:

- Low refrigerant velocity
- Short cycling

- Low load, excessive unloading
- Improperly designed or installed traps
- Piping errors
- Low refrigerant charge
- 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.

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 a suction riser. 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 vapour 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.

With regard to oil return and loss of lubrication, **the design and installation of the suction line** is the most critical 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.

Piping and oil return is also a consideration with systems using parallel compressors. When installing or servicing these compressor systems, the compressors are to be installed at the same level. Also, it is essential to install properly sized oil and gas equalizing lines on the crankcase of the compressors. This ensures equal oil level in each compressor and reduces chances of excessive or low oil level in any one compressor.

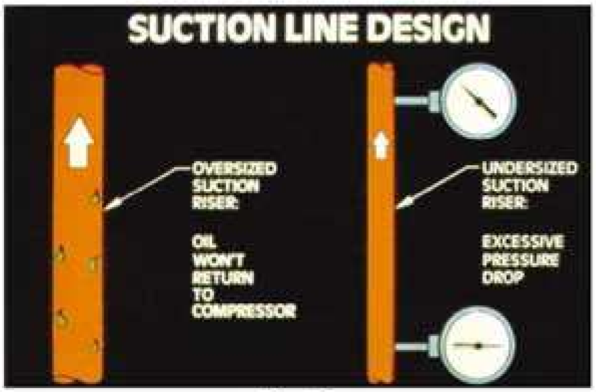

Figure 5

Oil return in flooded evaporators operating with HCFC/HFC refrigerants is one of the problems which the system designer has to address. An elaborate oil recovery system with proper controls must to be installed to get oil back to the compressors.

In centrifugal compressors using flooded evaporators, periodical gas distillation may be required to get rid of oil from the refrigerant.

In case of Ammonia systems, oil recovery is much simpler, since oil and Ammonia being immiscible, oil can be trapped from various points like condenser/receiver/ evaporator etc. and the piping design is not so critical.

Basically, oil is required only for the compressor lubrication and anywhere else in the system it is a nuisance. Effort should therefore be made to keep oil in a closed loop near the compressor rather than allowing it to go all over the system before returning to the compressor. A high efficiency oil separator is always a good investment to recover as much oil as possible. Oil does not have cooling properties and if excess oil goes into the system, cooling suffers. Also, it reduces heat transfer in the heat exchangers by coating the inner surfaces. Even for flooded HCFC-22 coolers for low temperature applications, an oil separator is recommended.

In screw compressor packages, compared to other types of compressors, much more quantity of oil is present and more efficient oil separator designs and bigger oil separators are required to prevent oil going into the system.

In smaller systems, it is always a good practice to maintain an oil inventory record. When the system is new, let us assume the compressor has 'X' quantity of oil. Once the system starts operating some oil is consumed in coating the internal surfaces of the heat exchangers, piping etc. The quantity of oil remaining in the compressor thus reduces to say 'X-Y'. If, for some reason the compressor needs to be changed and a new compressor, again having 'X' quantity oil is installed, the system will then have excess oil to the extent 'Y' quantity and the cooling performance suffers. It is therefore, good practice to measure oil quantity in the removed compressor and have the same quantity maintained in the new compressor by removing some quantity, so that the total system oil quantity remains the same and does not affect cooling performance. I have experienced this reduced cooling effect even after installing a brand new compressor, while servicing car air conditioning systems, where the quantity of refrigerant and oil charge is very important.

When inadequate cylinder bore lubrication takes place, discoloured(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.

The chain of events results from a lack of lubrication, which leads to poor oil film coverage of wearing parts, leading to mechanical damage and thereby, increased levels of contamination leading to electrical damage and finally system shutdown.

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Flooded Starts

This condition is not an operating condition. Liquid migrates to the crankcase during the "off" cycle and the problem shows up only when we restart the compressor.

During "off" cycle, oil in crankcase absorbs refrigerant. In some cases the refrigerant oil mixture will stratify with the refrigerant-rich-mixture at the bottom, unfortunately near the oil pump intake. During start up, the crank case pressure reduces and refrigerant boils off vigorously causing oil foaming. A crank case heater is normally provided to boil off this refrigerant liquid. The heater is switched on, much ahead of compressor start up. In Ammonia compressors, since the density of oil is higher than Ammonia refrigerant, oil settles at the bottom of the crankcase and Ammonia liquid floats on the top. The lubrication therefore, does not suffer; hence Ammonia compressors very rarely use crank case heaters.

A refrigerant is a poor lubricant and acts like 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 is greatly increased.

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 up in the crankcase. This pressure increase forces the oil and refrigerant mixture to enter the cylinders as a liquid slug.

It should be remembered that no compressor in the world is designed to compress liquid. A liquid is non compressible. Some compressors like a compliant scroll design can tolerate liquid better than others, but no compressor can handle liquid.

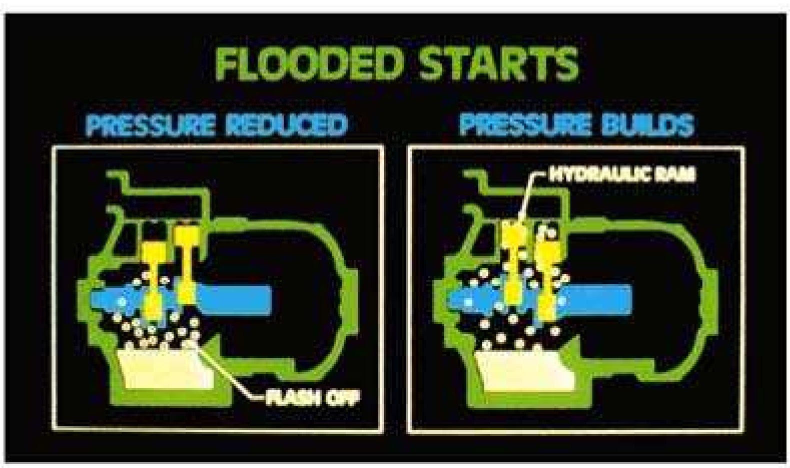

Figure 6

Long term, repeated mild slugging will also cause metal fatigue of internal and external parts, for example, discharge lines and stop valves.

Liquid Slug (short term)

Slugging is a short term return of a large quantity of liquid refrigerant or oil or both, to the compressor. Refrigerant can condense, during off cycles, within any part of the system where temperatures become low enough. This could be the evaporator coil, cooler, or compressor crankcase. On the next start up, this liquid will find its way as to the compressor cylinders as a slug, the same way as it does during a flooded-start condition. As mentioned earlier, providing a crankcase heater is one of the steps to reduce detrimental effects.

Trying to compress a slug of liquid results in pressures of over 1,000 psi., and such high pressures usually result in component failure since parts are not designed to withstand these abnormally high pressures.

Figure 7

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 continues 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 the conditions are severe enough, the internal cylinder head web between the suction and discharge side of the head may even break. Liquid slugging can have a disastrous effect of breaking connecting rods or even the crankshaft. The force that results when a compressor tries to compress liquid refrigerant or oil is tremendous and can even punch holes in the top of the piston. Valve plates, normally are the first casualty, though damage can range from dented valves to complete punctures at the ports.

I have come across a case, in a chemical/dyestuff plant installation, where a 12- cylinder compressor having a forged crankshaft of over 150 mm diameter was broken in two pieces as if it had been cut by a hack saw. Such a break down is possible only when a large amount of liquid has caused a liquid stroke.

Figure 8

In another cold storage application in a marine installation, using a 4-cylinder refrigeration compressor, when the liquid stroke took place, all the four connecting rods broke and the crankshaft was just rotating. The operators were puzzled, since the compressor operation was very smooth like a sewing machine, noiseless and no vibrations, but there was no cooling at all.

Where fixed orifice metering devices, such as capillary tubes are used, the refrigerant charge is often critical. For a given load, a specific amount of refrigerant is required to maintain the desired flow rate. An accumulator in the suction line is recommended to be installed, since during standstill conditions refrigerant will migrate from the high side to the low side in the evaporator, and during starting of the compressor, liquid stroke may take place.

A pump-down system with a solenoid valve installed in the liquid line is used to prevent refrigerant flow to the evaporator. The thermostat operates the solenoid valve.

Figure 9

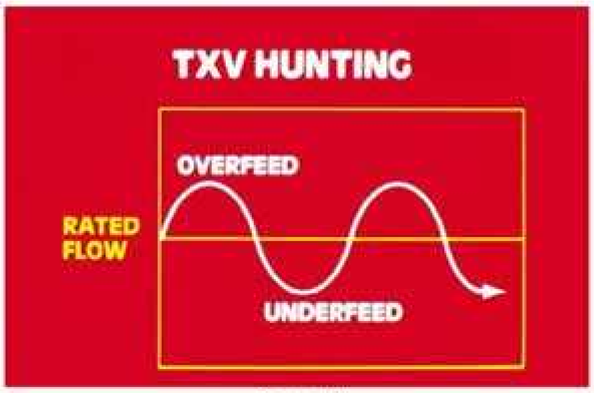

Figure 10

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, thus, decreasing the possibility of flooded starts or liquid slugging.

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Flooding (continuous)

Flooding is the continuous return of liquid refrigerant to the compressor, while the system is operating. Refrigerant flooding works in less obvious ways. Liquid refrigerant in the crankcase will act like a **detergent** to remove the oil from the piston assembly surfaces. 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. As the oil gets diluted with refrigerant, which does not possess lubricating properties, there is a continuous slow wear of parts and the compressor life reduces.

Reasons for flooding are normally associated with :

- Expansion valve-oversized – Check bulb and super heat setting
- Air side – Check evaporator fans and belts and evaporator coil and filters

An oversized expansion valve will cause hunting, and hunting causes intermittent flooding, and starving of the evaporator, leading to possible damage resulting from flooding itself, or from the potential flooded starts and slugging it can create. This gradually washes oil off the lubricated surfaces.

In case of TXV, also 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.

Figure 11

Figure 11 shows the bulb totally dislodged leading to liquid flooding.

Low Load Conditions

Insufficient load on the evaporator prevents all the liquid from vaporizing causing liquid flood back 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 blades, 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.

Contamination

Contamination is another cause of compressor wear and failure. Contaminants are any substances or materials other than refrigerant and compressor oil. All other foreign ingredients cause a chemical reaction or change the chemical composition of materials within the system.

Some of the contaminants found in the system are water, moisture, air, non-condensable, chips of copper, steel, or aluminum, copper or 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.

Figure 12

Figure 12 shows the difference between a new filter and a clogged filter. The contamination level is so high that the filter wire mesh has burst open due to abnormal pressure build up and contaminants have entered the compressor.

Many compressor manufacturers therefore recommend installation of a temporary cloth bag, in addition to the compressor's own filter, for a period of 24/48 hours of initial operation to trap the contaminants. It also serves to protect the main fine mesh filter. The important point to be noted is that, this cloth bag must be removed after its use. If left inside it can cause much more damage, as it will get torn and pieces and threads will enter the compressor.

Different contaminants can cause different types of failures. Air or other non condensable 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 iron in the valves, acting as a catalyst, promotes a chemical reaction between the refrigerant and oil soluble compounds. This results in a build up of film on the internal surfaces of the compressor. In time, the film will buildup to the point where valve leakage will occur.

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

Copper plating is a result of a combination of contaminants, the type of oil used, and high temperatures. The contaminants gradually eat away at the internal copper particles to travel through the system.

Figure 13

They become deposited on compressor surfaces within the compressor that are at elevated temperatures, such as bearing surfaces. The gradual build up 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.

Moisture, as a contaminant has two primary detrimental effects. First, it will react with the oil to form an acid; and second, it could cause a freezeup at the expansion valve. 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.

Figure 14

Figure 15

The table below gives guidelines as to how to get rid of contaminants

Contaminant	How to eliminate
Air	Evacuate/purge
Moisture	Dehydrate
Chips & dirt	Filter
Acid	Replace oil and drier
Burnout residue	Replace oil and drier

[top]

Overheating

Compressors generate heat. Heat of compression, thermal losses from motor windings, and frictional heat gain at load bearing surfaces are the main sources of 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. Although compressors are designed to handle normal thermal temperature gains, but when they operate outside design parameters, reduced life expectancy and potential damage results.

Reciprocating compressors need particular attention to limit discharge temperatures below 120°C. If the application indicates that the discharge temperature is likely to exceed this limit, then in such a case it is advisable to go in for two-staging. Normally in Ammonia refrigeration systems the critical design parameter to be considered is the compressor discharge temperature.

Laboratory tests show that with each 10°C 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 system.

To sum up, contaminants, liquid refrigerant and overheating can be called as the three most deadly enemies of the compressor.

System Accessories

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 wrongly applied or do not function as they should.

Improper Installation/Operation

Compressors will also give problems if the foundation is not made properly, the suction and discharge pipes are not aligned in line with compressor connections, leading to undue stresses on the compressor, when the flange bolts are tightened with force. The alignment of flywheel, motor pulley and 'V' belts or direct coupling has to be perfect on all three axes to avoid shaft seal leak.

Compressors also fail, if recommended starting and stopping sequences are not followed. I have experienced two compressor failures, one in India and other in Singapore, where operators forgot to open the compressor discharge valves before starting the compressor.

A periodical check of safety switches and their operation is essential. Many times I have observed that the capillary tubes connecting oil or discharge pressure safety switches are plugged with a glue-like substance, which is congealed oil, and thus renders operation of switches redundant.

Electrical Problems

Although a vast majority of motor burns are the result of mechanical breakdowns, electrical problems can also lead to compressor failure. In a three phase compressor, motor failure can occur because of voltage or /and current unbalance. These two types of problems cause increase in temperature that may go unnoticed for a long time.

The most probable cause for current unbalance is voltage unbalance. Current unbalance rises sharply with a small voltage unbalance. Thus, in any current unbalance problem the source which is voltage unbalance should be suspected. Voltage unbalance will cause a current unbalance, but a current unbalance does not mean that a voltage unbalance necessarily exists.

Figure 16

For example, in a three phase situation where there is a loose terminal connection on one leg, there is a buildup of carbon or dirt on one set of contacts. This will cause higher resistance on that leg than the other two legs. As the current follows a path of least resistance, higher current flows through the other two legs, which causes more heat to be generated in the windings. Under light load conditions, the current may not reach the trip current of the overload and the motor 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.

Another cause of overheating is too high or too low an incoming voltage. Finally, one of the causes of overheating often overlooked as a cause of compressor failure is rapid cycling. Each time the motor starts, it draws locked rotor amps and it takes a few minutes of running to get rid of the heat caused by the locked rotor current. Frequent cycling causes a buildup of heat because the heat from the previous start has not been dissipated.

The hermetic/semi-hermetic motor designs, provided by the collaborators need to be redesigned to withstand wide fluctuations of voltages in our country. My own experience has indicated that when we manufactured compressor motors exactly as per collaborator's design, the failure rate was very high, since the motors were designed to suit a very narrow voltage and frequency fluctuation encountered in their country.

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Current Situation

Since the opening up of the economy and reduction and rationalization of the duty structure, manufacturers now tend to build complete sets in the factory and reduce chances of site installation errors. This has certainly improved product quality and reduction in compressor failures. Earlier, most of the contractors purchased components from outside sources and delivered these directly to site. Many issues were therefore left to the imagination of field staff leading to more frequent break downs, compared to the current situation. Presently, factory-built and ready-to-use packages are available for most of the applications except for Ammonia systems where a plant still has to be erected piece by piece, and CFC/HCFC refrigerant systems for large cold rooms and special applications.

In this article, we have not covered troubleshooting techniques like oil analysis or tear down analysis of failed components, which are also vital tools to arrive at correct diagnosis.

Conclusion

In case of any compressor-related problem, identify the root clause, without jumping to the conclusion that the compressor is defective. If the compressor is replaced without attending to the root cause, the replaced compressor surely will also fail.

To conclude, it would be worth repeating that the compressor is the heart of the refrigeration system, and the most expensive component, and utmost care to protect the same should be taken.

References

1. Article by Carrier Corporation- *ACR News – Sept*. 1987.
2. Articles by Dick Snyder-*ACR News* -1992
3. Photographs courtesy Carrier training material.

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