Compressor Longevity

Original Draft Document of article printed in R A C magazine Spring 2000

November 1999

Compressor Longevity

Introduction

ThermaCom are often asked the simple question "Why compressors fail ?". Of the multitude of answers available one that rarely applies is "Old Age".

So what would constitute "Old Age" for a compressor ?

ThermaCom are not compressor designers, however, our knowledge of such a wide range of makes and models in all conditions of brokeness, places us in a unique position in regard to: the nature of failures, which machines seem to perform more effectively and also those that do not, in certain cases where use or re-use of certain parts is unwise, and ultimately when repair is simply not feasible.

We understand many manufacturers will normally reckon on around nine or ten years working operational life for the typical semi-hermetic compressor. Interestingly few manufacturers issue any servicing instructions for the actual compressor itself, therefore we presume they expect the compressor to meet it's service life without internal maintenance. This lifespan does require the compressor to operating in near perfect conditions through out it's life.

Principally this means the compressor should …

1. only ever pump a cool, but fully superheated gas of the design grade.
2. the suction and discharge must be kept within designed operating pressures and temperatures.
3. the lubrication system must never be degraded.
4. the electrical supply must be sound and correctly controlled.

Get these four conditions met all the time and the compressor should operate until the end of it's normal wear life without failure *(this statement obviously presumes the manufacturer has designed and constructed the compressor correctly in the first place)*.

Rationale for Reduction from Ideal to Actual Life Span

Actual service life will on average reduce from the nine to ten year ideal span according to the degree that any of the above four principle fault conditions occur. It must be borne in mind that it will be close to impossible to achieve perfect operating conditions through out a compressor's service, but the closer to this ideal actual conditions are, the longer the machine will last before breakdown.

The complications faced by a major owner or consumer of many compressors begin here.

Each of the four principle problems may manifest from almost innumerable causes. Some causes may affect more than one principle problem. Thus it becomes very difficult to analyse actual failures to use statistical trends to assist with premature failure reduction.

This task is further complicated by the fact that different examiners may have differing subjective conclusions from evidence presented when a compressor is dismantled. An examiner may not have intimate knowledge of the associated system, and certainly is unlikely to have any knowledge of it's history or other associated problems. This consideration is most important, the principle reason for this is that of all compressor failures we deal with, hardly any arise because the compressor has reached old age, and we believe there is no reason why a correctly designed and built compressor should fail of it's own volition unless it simply wears out.

So how long do they last ?

Ideal life scenario

This presumes the compressor will run for say 18 hours per day, 5 days per week, 52 weeks per year, for ten years.

Considering the actual technology employed this is quite a feat. Many bearings are simply of machined aluminium. The valve reeds open and close 1,450 times per minute.

Actual numbers for a machine lasting ten years under the above scenario are …

Running Hours	46,800
Revolutions / Valve flutters	4,071,600,000
Starts (say 1 each 2 hours running)	23,400

Compare this to a car engine for a typical company vehicle say 35,000 miles per year, which would probably need a new engine at 200,000 miles …

Running hours (say 30 mph average)	6,667
Revolutions (say 3,000 rpm average)	1,200,060,000
Starts (say 30 miles average journey)	6,667

Thus it can be seen these simple machines should with care give a very effective life. If the same longevity were expected from the car engine it would have to run the car at least for 1 million miles (not too many of these around!).

Is Short Compressor Life A New Problem

Several years ago we were involved in a study of longevity of the compressors used by a major supermarket chain. Our discussions with the engineering staff revealed little was known about how long their compressors were actually lasting.

Certainly they could tell us precisely when any machine failed within warranty, but you can imagine their horror to find that on average they were only getting around five years service. However, those compressors applied upon low temperature units considered on their own merit revealed average life down to about 3 years. The higher temperature applications were achieving better life spans and this improved the overall average.

What surprised us was the lack of knowledge of these trends by such major consumers. We then delved into what was causing such high usage trends. Simply put the principle reasons were poor system design together with poor level of effective maintenance.

This is not to say either the systems were always poorly designed to start with nor were the service companies tasked with the maintenance always at fault either. What was apparent was a high level of system alteration during service life. Alterations without the input of the original designers considerations cause a multitude of failures. Each time a supermarket decides to place the cabinets on the floor in a different place the system is modified. Even seemingly innocuous changes can have disastrous affects upon longevity, but as the life span reduction is often measured in terms of years, in very many cases no connection is made between a modification and the longer terms effect upon longevity.

Similarly maintenance contracts are relatively short term. Often the price agreed upon is simply insufficient to enable the work scope to be adequately undertaken, whilst still allowing the service company to produce an effective profit. Field service engineers themselves can be fickle in their attitude to routine maintenance. The upshot is that an inadequate contract price will ultimately lead to inadequate maintenance. However, when premature failure sets in at even three yearly intervals often the contractor will have moved on to pastures new, another will take his place, and any continuity of operational knowledge and history is lost.

Repetitive failures were often seen as the fault of the compressor supplier, commonly a re-manufacturer, and even if the apparent cause were found little was ever done to prevent this problem occurring elsewhere on similar systems.

Approach to Maximising Compressor Life

Diligent maintenance is the most crucial single factor to optimising compressor longevity. System modification work must be properly thought out, but if the maintenance is done correctly then longer running life will be the reward.

So What Goes Wrong ?

Principally all failures will fall in two broad camps …

Mechanical and Electrical

Bear in mind mechanical faults will often cause a secondary electrical fault. It is far rarer to find an electrical defect causing a mechanical fault, but they do happen.

Considering these two areas further the following is a common list (but by no means definitive) of root causes of internal failures ...

Mechanical	Loss of lubrication	Loss of oil level	
		Blocked filter / strainer	
		Oil viscosity reduced	Too hot
			Liquid refrigerant return
		Contamination present in oil	
		Worn moving parts	
		NB Wear may be a secondary condition of previous lubrication problems	

	Valve Reed Failure	Thermal Shock Hydraulic effect Fatigue
	Piston Seizure	Loss of bore lubrication Overheating
	Small End failure	Failure of discharge reed Fatigue Overheating
	Con rod failure	Hydraulic effect Fatigue
	Crank failure	Worn bearings causing crank to flex out of line Fatigue (rare) Hydraulic effect
	Bearing Failure	Loss of lubrication Wear
Electrical	Burnout	Single Phased supply Overheating Lack of cooling Overloading Too many starts Mechanical damage Tracking / Spiking Loose leads Degradation of insulation Over voltage Under voltage Loose connections

Many compressors will exhibit a mixture of the above symptoms and often damage found is secondary to the root failure. Often there is evidence of more than one root problem and severe failures may defy any positive conclusions.

Considering the above list consideration of the associated external refrigeration and control system can drastically reduce the frequency of failure …

Mechanical Faults will be drastically reduced if …

1 the refrigerant is correctly controlled

Liquid must never be allowed to gather in or enter the compressor whilst running. Attention to the following areas is essential

Correct charge level - do your engineers know how to measure sub cooling as this is the only true method of establishing charge condition. Low charge will cause the TEV to hunt, and this will lead to liquid slugging.

Does the liquid line solenoid shut properly during shut down. During shut down refrigerant will naturally condense in the coolest part of the system. The evaporator remains cooled by it's own surroundings, thus if liquid builds up here it can slug back to the compressor at the subsequent start up.

Bear in mind the principle is to reduce where at all possible anything which accelerates the wear of the compressor. Periodically starting with a heavily saturated suction may not kill the compressor straight away (a large belly full of liquid will) but each time it happens the bearings will be lubricated by diluted oil until the low pressure in the sump causes the liquid refrigerant to boil off. This could take several minutes.

Is the Thermostatic Expansion Valve (TEV) controlling the flow of refrigerant at <u>all</u> load conditions, and particularly during rapid changes of load condition. Remember the suction gas entering the compressor must be properly superheated, and not be carrying any particles of saturated vapour. The superheat level must <u>always</u> be above 5^{o} K.

Does the crank case heater work and does it switch off when the compressor starts.

2 the system Clean

Build up of acidic residues in the system will affect the compressor. Commonest of these is moisture leading to formation of copper plating on close running bearing surfaces.

Coppering is a complex chemical process in which moisture breaks down to form an acidic electrolyte. Electrolysis then causes transfer of copper ions from the system pipework to the hotter running areas of the machine. In severe cases the copper builds up to such levels that it will then break off and form a coppery powder in solution in the oil. In this form it is highly effective at blocking oil pick up strainers.

3 the refrigerant is pure

Build up of other gases such as air will have major detrimental effects upon the whole system. Air will cause excessive head pressure, plus all air contains trace levels of moisture.

Mixtures of other refrigerants may change the operating characteristics of the gas. The TEV is not designed to cope with unknown mixtures and it may allow excess quantities of liquid to flow back to the compressor.

4 the Oil rectification system functions correctly.

All compressors will pass oil from the discharge mixed with the hot gas as a vapour. It is essential that the system is adequately designed and maintained to allow the oil to circulate back to the compressor.

If a separate sub circuit is fitted for this then it must be correctly sized, and all components must work.

If during a previous failure excessive oil enters the system then it must be removed, otherwise oil slugging and hydraulic effect is highly likely.

5 the correct grade of oil in use.

With many systems now using refrigerants based upon R134a
system oil transportation requires use of Polyolester type lubricants.

If mineral type oil is filled by mistake then oil separation may take place in the evaporator. This can cause oil starvation at the compressor and may also lead to slugging and hydraulic effect.

6 the discharge pressure adequately controlled.

Excessive head pressures place undue load upon the compressor.

Condenser fans should work, and the condenser must be clean and clear.

7 What is the evaporator condition

If the evaporator becomes too warm then the compressor loading can become
immense.

Similarly Electrical faults will be reduced if …

8 the supply is clean and the voltage condition is stable

Other large loads local to the machine could cause transient spikes or large drops in the supply voltage. The voltage must be even and the supply system adequate to handle the load. No spikes should be present from equipment such as Power factor correction.

Even capacitors on nearby single phase motors can cause high voltage spikes on the supply. At many thousands of volts these spikes will try to find an earth and if successful a track line of burnt carbon will be formed. Subsequently the motor current will travel along this track and this may cause a direct burn out.

9 the Switchgear works correctly.

Loose or worn contacts will prevent the supply from passing current correctly to the motor.

In this condition a partial or full single phase condition may arise in the motor windings. Overheating to the temperature of insulation failure and then burnout can be remarkably brief.

Partial single phase conditions may also cause a lot of vibration and mechanical noise, incorrectly suggesting a mechanical problem.

10 the fuses or circuit breaker are sound

When any fuse fails apparently good fuses from the same set should also be rejected, as they certainly will be strained, otherwise they can actually precipitate a subsequent single phase condition.

Circuit Breakers also have contacts within them and these cannot easily be examined, but they can still fail.

11 all joints and connections along the supply right up to the compressor are clean and tight.

12 the compressor cannot start too often.

Overstarting can rapidly overheat any motor to the point of insulation failure.

Accelerated wear can also arise as the full lubrication is not effective until several hundred revolutions of the compressor have occurred.

13 ancillary controls are in good condition

Faulty contacts within a system ancillary control such as an LP switch can cause the control circuit to switch rapidly. This in turn makes the contactor 'buzz', leading to arcing at the points, rapid wear and once again phase loss.

14 the Suction Superheat is not too warm

Suction gas is used to cool the motor. Excessive running with highly superheated suction gas can allow the motor to run too hot.

Repeated heating of a motor may not cause it to fail immediately, but instead an insidious breakdown of the insulation can set in, and it may subsequently fail when the machine loading merely increases within it's normal range.

The above list is by no means definitive but gives a good guide to what kills compressors early.

Internal maintenance routines could also be adopted. For example renewing valve plates halfway through a machines life will eliminate the prime fatigue failure of broken valve reeds, and if combined with a compressor oil change any build up of loose contamination will also be removed.

Summary Statement

Compressor longevity should ideally be about nine or ten years.

Reductions to compressor life will be created by four principle factors …

1. Lack of control of refrigerant entering compressor suction as properly superheated, but cool gas.

2. Operation outside or continuously close to upper or lower suction and discharge parameters.

3. Any fault condition that in any way degrades the lubrication system.

4. Lack of control upon the electrical supply system.

Of these the two most notorious areas that will drastically affect the compressor longevity are, in our view, Liquid Refrigerant entering the compressor and full or partial Single Phasing of the power supply.

Attention to the key points in an objective ongoing manner will undoubtedly produce dividends in the longer term.

ThermaCom Ltd