Introduction

The refrigeration compressor is lubricated by an oil charge that resides in its crankcase. Unfortunately, due to the compression process, oil in an aerosol form can be carried by refrigerant out into the system and as a result not provide the required lubrication for the compressors components. The challenge for refrigeration system engineers is to keep this vital lubricant where it is required and to facilitate the return of any oil that have been released into the system.

The purpose of this document therefore is to highlight this oil's intimate working relationship with the systems refrigerant and how to best ensure that any oil that leaves the compressor during the compression process returns as quickly as possible to the crankcase. Although a well-designed piping system can facilitate the oil's successful passage through the entire system, one of the best answers to this challenge is to employ an oil separator.

Refrigerant & Oil – a close working relationship

The refrigeration systems refrigerant charge and its oil are miscible (the oil is soluble in the refrigerant). The miscibility ratio of refrigerant and oil is dependent on a number of factors such as:

- The actual refrigerant type.
- The oil type (Synthetic, Mineral and its associated Viscosity).
- The operating pressures and temperatures of that particular system.
- Overall system design including pipework and componentry play a significant role as well.

Often times the above items are somewhat 'fixed' being part of an existing system employed for a particular duty. The refrigerant type and its compatible oil are a product of the systems application. Also, the operating pressures / temperatures are governed by the duty in question and the means of condensing (air cooled or water cooled) available. The actual quantity of oil "carried over" into a refrigeration system is also dependent upon:

- The compressors design.
- The age (wear) of the compressor.
- The compressors configuration - a single unit as opposed to multiple units in parallel.

"Carried over" oil can lead to a shortage of the lubricant in the compressors crankcase. Any additional oil added to raise the level can lead to an undesirable situation upon the errant oils return. An acceleration of the quantity of "carry over" can also result as a consequence too.

Therefore the scope of this technical document will only focus upon the effects of 'free' oil that has been discharged into the systems pipework and componentry, its effects on the operation of a refrigeration system and conclude with how an oil separator can be of benefit in the management of oil return.

Oils & refrigeration: High pressure side challenges

When the compression process takes place, the discharged high pressure refrigerant exits the compressor with a fine oil mist entrained in it. The oil and refrigerant readily mix in the discharge line and condenser due to the high pressure / temperature of the refrigerant vapour. Unfortunately what happens next is the beginnings of the problem of oil "carry over" for a refrigeration system.

Firstly, the high pressures in the condenser cannot prevent an oil film from coating the inner walls of this heat exchanger and from commencing a new role as an effective insulator which reduces the overall rate of heat transfer; this increases both operating head pressures and the saturated condensing temperatures of the refrigerant, effectively reducing the capacity of the condenser. As a rule of thumb, for every 1K rise above the condensing units design condensing temperatures, the units overall refrigeration capacity drops by approximately 1%. As a result, you are getting far less efficiency out of the condenser.

Next, the oil's presence also reduces the condensers volumetric capacity too by reducing the amount of refrigerant present in the heat exchanger by the exact amount of its own volume. In other words, if 10% of the "miscible" refrigerant / oil solution is oil, this means only 90% of this mix is refrigerant. This will effectively reduce the capacity of the heat exchanger, retarding the 'heat of rejection' and consequently the systems"refrigeration effect". Longer running times are required in order to circulate the higher mass flow rates of refrigerant through the system to achieve the desired temperature. Therefore we can see that by acting as a catalyst, this oil film leads to an inefficient system that has a much greater electricity usage and associated running costs.

The higher head pressures generated as a result of an inefficient condenser quickly lead to the creation of unusually high discharge temperatures from the compressor, this heat will generate lubricant breakdown, which results in the creation of oil sludge, varnish and carbon deposits. Also as a refrigeration system can feature certain catalytic metals such as iron & copper, these elements can also further contribute to the lubricant's breakdown. Please refer to the Heldon Products technical document on Filter Driers / Drier Cores for further information on these topics.

From the condenser, through the liquid receiver and on to the refrigerant control, refrigeration oil finds itself soluble with the liquid refrigerant. This results in a positive movement of the oil towards the compressor.

Oils & refrigeration: Low pressure side challenges

The evaporator is also subjected to the inefficiencies created by this errant oil. The problem is compounded by the oil now being in the low pressure side of the refrigeration system. When the latent heat of vapourisation creates the phase change from a liquid refrigerant to a vapour, the effective movement of the oil is reduced significantly. The oil and vapour will not mix readily in the evaporator. This forces the oil to precipitate out of the solution and accumulate on the inner walls of this heat exchanger so affecting heat transfer to the refrigerant and interrupting the flow of lubricant back to the compressors crankcase.

The situation is even more serious than that previously encountered in the condenser as the oil is subjected to the effects of the expansion valve. When the oil / refrigerant mix exits this valve, the pressure drop that occurs causes the oil to foam.
This results in the generation of a film of oil bubbles that is of a even greater thickness than that experienced in the high side heat exchanger. The lower temperatures further complicate matters due to their affects on the refrigeration oils thickness or viscosity, making it much more difficult to move and consequently trapping the oil in the evaporator. Extreme cases of this condition can lead to an "oil logged" evaporator.

Volumetric capacity too is also reduced by the displacing effects of the oil on the systems refrigerant. The net result is a lower operating saturated suction temperature / pressure as the refrigerant fails to find adequate heat, 'starving' the rate of heat transfer, lowering the refrigeration capacity values for the compressor and producing longer motor running times in order to achieve temperature.

The refrigerant vapour's velocity is the only effective tool in returning the sluggish oil. It must strike the right balance of velocity between being high enough to facilitate a "rifling" effect of the oil droplets along the inner walls of the heat exchanger / suction line and not too high that troublesome noise and excessive pressure drops are created; this balancing act if correct will ensure good net oil return without penalising refrigeration capacity. Get it wrong and the result is a system that will have to work much harder and longer to achieve the required temperature, grossly affecting running costs and the energy usage of the plant. Operators must be acutely aware to avoid creating a system that has an oil logged evaporator with a high load demand.
The high refrigerant velocities created in this situation may return all the oil at once in a damaging "liquid slug" to the compressor. Such an "oil slug" can be as damaging to the compressor as that of a "slug" of liquid refrigerant.

Moving towards greater efficiency

In order to have the refrigeration system operating at its highest levels of efficiency we must:

- Make evaporator heat transfer area between low side refrigerant and the medium to be cooled as intimate as possible (so avoiding oil films that create an insulating effect), this will keep refrigerant mass flow rates at design ratings, "load" the evaporator correctly so keeping the saturated evaporating temperatures up and consequently raise the compressors refrigeration capacity. This results in less defrost cycles required to clear frost on refrigerant to air type evaporator coils as the temperature differences between the return air values and s.e.t's would be of a smaller value. This means a higher relative humidity figure.

- Make the condenser heat transfer area between high side refrigerant and the heat sink as intimate as possible again avoiding oil films that create an insulating effect. The temperature difference between the two will be at the lowest levels that the design dictates, resulting in the most efficient saturated condensing temperatures / pressures possible.

Our best course of action

Our best course of action is to be pro-active and install an Oil Separator to manage the collection and return of the oil carried over into the discharge line as a result of the compression process. Whilst not 100% efficient in their operation and not a substitute for a correctly designed system, their inclusion will satisfactorily protect the compressor from lubrication issues and "oil slugs".

Whilst originally designed to 'just' maintain the correct oil level in the compressor, the oil separator is now well recognised for its critical role in preventing the circulation of oil throughout the system. It also provides the advantage of an effective muffling action on the discharge vapour pulsations exiting reciprocating compressors, thereby reducing unwanted noise.
By installing an oil separator, it keeps the heat exchangers on both the low and high sides of the system free to do what they are designed for, without being penalised by insulating oil films. Higher efficiencies over the life of the plant will result in lower running costs and reduced emissions. The net result is a "win-win" situation, for both the "hip pocket" and for the environment.

The Oil Separator – an Introduction

As a rule of thumb, an oil separator should be employed on any system that may struggle with an adequate oil return. Whenever there is an excessive amount of oil in circulation or the risk of efficiency losses at the heat exchangers due to the effects of an oil film, it is good trade practice to install an oil separator. Specifically, oil separators are recommended with the following applications:

- Systems with long pipe runs and / or with long suction line / discharge line risers.
- Non oil returning evaporators such as the flooded types.
- Low saturated suction temperature / Low temperature systems.
- Systems employing capacity control or multiple compressors operating in parallel.
- Systems employing non-miscible refrigerants.
- DX coils or tube bundles that require bottom feed for good liquid distribution.
- Systems where off-cycle refrigerant condensation in the compressor oil is troublesome.

Oil separators use various modes of oil separation methods to remove the oil entrained in the discharge vapour that exits the compressor. These methods include the reduction of velocity, impingement, centrifugal force or coalescing elements. Oil separators vary in capacity and efficiency depending upon the mass flow that is being pumped through them. No oil separator is 100% efficient.

Again the scope of this document will focus upon the two styles of Oil Separators offered by Heldon Products Australia. These are:

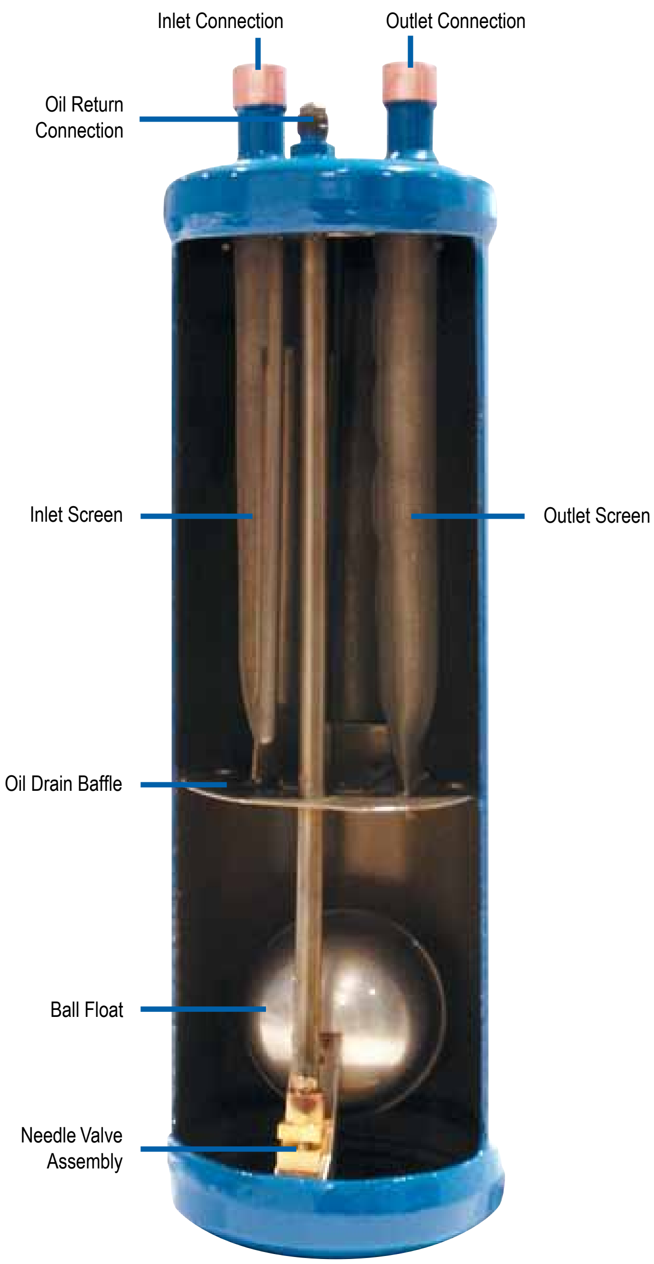
- The conventional (Impingement) type.
- The Helical (Centrifugal Force) type.

Conventional Oil Separator operation

As previously discussed, the high pressure, superheated discharged refrigerant vapour is laden with an oil mist. Upon entry to the oil separator the velocity of the mass flow is greatly reduced due to the larger volume of the vessel in relation to the discharge line. The oil particles having a greater momentum than the refrigerant vapour impinge on the mesh of the inlet screen. The refrigerant vapour exits the oil separator on its way to the condenser by passing through an outlet screen to further remove any residual oil particles. All the oil particles then combine in their relative screens and due to gravity, drain to the bottom of the separator.

A float operated needle valve is situated at this point and opens or closes based upon the level of oil in the separators sump, returning oil to either the compressors crankcase, or oil reservoir if an oil control system is being used. Only a small amount of the separated oil is required then to actuate the float mechanism. The oil flows quickly to the compressor due to the oil separator being at a higher pressure relative to the compressors crankcase. When the oil level has lowered to a pre-determined level, the needle reseats, closing off so ensuring that no high pressure vapour can exit into the compressor crankcase.

Conventional Oil Separator



Helical Oil Separators operation

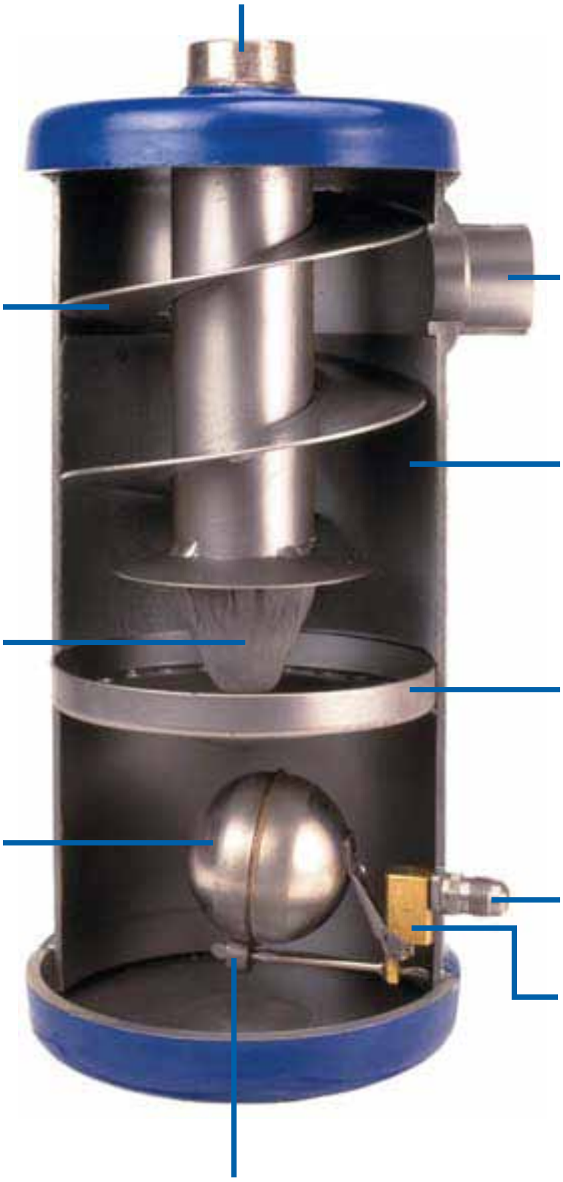
Upon separator entry, refrigerant vapour containing oil in aerosol form encounters the leading edge of the helical flighting. The vapour / oil mixture is centrifugally forced along the spiral path of the helix causing heavier oil particles to spin to the perimeter, where impingement with a screen layer occurs. The screen layer functions as both an oil stripping and draining medium. Separated oil flows downward along the boundary of the shell through a baffle and into an oil collection chamber at the bottom of the separator.

The specially engineered baffle isolates the oil chamber and eliminates oil re-entrapment by preventing turbulence. The virtually oil free refrigerant vapour then exits through a second screen fitting just below the lower edge of the helical flighting. A float activated oil return needle valve allows the separated oil to return to the compressor crankcase or oil reservoir. There is a permanent magnet positioned at the bottom of the oil collection chamber to capture any system metal debris, which could impair the operation of the needle valve. With proper selection, an oil separation efficiency of up to approximately 99% can be achieved.

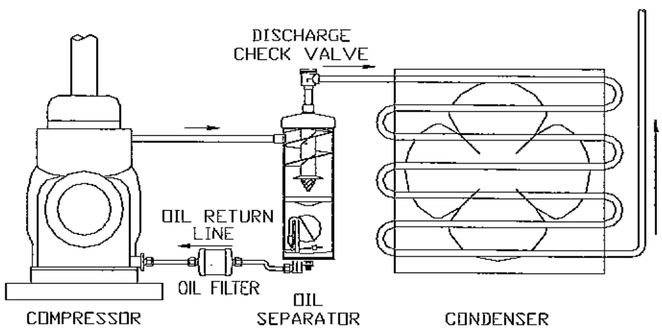
Oil Separator selection

By using the charts provided it is possible to compare the refrigeration capacity of the system to that of the oil separator. Data can include the capacity ratings for several refrigerants at various saturated suction temperatures. Another type of rating method can include the compressor displacement volume. Either way, if capacity control is featured on the compressor(s), an understanding of the system capacity in relation to the percentage of full load run time will assist in the selection process. Also as the compressor's refrigeration capacity value will increase with a raise in suction pressure or a lowering of condensing pressure, it is advisable that the oil separator selection be done employing figures gained from a refrigeration system operating at its lowest compression ratio figure.

Helical Oil Separator



Single Compressor System



Installation of an Oil Separator

When installing an oil separator to a system it must first be pre-charged with oil. This quantity of oil is held in the sump of the oil separator and is vital. If the oil separator is not pre-charged with the amount specified, (using oil of the same type as that of the compressor), damage can result to the oil return float mechanism. Further to this, if not pre-charged, the actual oil level in the compressor and its lubricating ability could be significantly affected due to any pumped-out oil getting 'stuck' in the oil separators sump and not being able to return until such time as the float mechanism is activated.

The oil separator should be installed close to the compressor, in the discharge line between compressor and condenser. It is recommended trade practice to install a check valve between the oil separator's outlet and the condenser in order to prevent refrigerant from 'migrating' to the oil separator and condensing there during the systems off cycle. As the internal float mechanism cannot differentiate between liquid refrigerant and 'liquid' oil there is the risk that the float could lift off its seat and return liquid refrigerant to the compressors crankcase. Any liquid refrigerant that enters the crankcase can produce a 'cooling effect' on the sump oil, chilling it in temperature, raising its viscosity and consequently reducing the lubricating ability of the oil. Liquid refrigerant may also wash out bearings leading to damage.

At the time of compressor start up the reduction of pressure inside the crankcase can cause any liquid refrigerant residing in the oil, to vigorously boil off, leading to the creation of oil 'foam'. Mechanical oil pumps can struggle to create the required oil pressure to provide adequate lubrication for the compressors internals when they attempt to pump this low quality oil. 'Splash feed' compressors can also suffer from the same malady.

One answer to minimise this problem is to connect the oil return line into the suction line. This line would be equipped with a shut off valve, an oil filter / strainer, a hand throttling valve, a solenoid valve and sight glass. The hand valve should be adjusted to provide a flow slightly greater in quantity than that of the 'rifled' oil return coming back down the suction line to the compressor. Normally, oil return lines are run from the oil return flare connection at the separator, to the compressor crankcase or to an oil reservoir if an oil control system is being used. The fitting of a sight glass to observe oil flow and an oil filter / strainer is recommended to be installed in the return line. Remember that Polyolester oils are a solvent and will scavenge debris from a system that mineral oils won't. Filtration must be taken seriously to avoid problematic blockages resulting.

Beware of locating the oil separator in a position where it is subjected to the cooling effects of air flow's that could produce condensation of the refrigerant during the off-cycle. If the separator is to be subjected to temperatures below that of the systems condensing temperatures, it is good practice to fit a low wattage electric heating 'band' around the base of the vessel to prevent the refrigerant vapour from condensing there. A 25 watt heating band would suffice for oil separator diameters of up to 100mm. If the condenser is located in a position which is effectively above the oil separator, the connection into the condenser should firstly rise above the condenser inlet by approximately 50mm before being pitched sloping downwards into the condenser. This will facilitate drainage into the condenser rather than into the oil separator during the off-cycle. Heldon oil separators are to be mounted in a secure vertical position and piped up employing proper trade practices. A vibration eliminator may be necessary to avoid the transmission of compressor vibration and motor start-up torque effects that could adversely affect the oil separators welded copper connections.

If installing an oil separator into an existing system be aware of the possibility of the crankcase over filling from existing oil that was previously 'trapped' in the system's components, upon the re-commissioning of the system. Monitor the compressors oil level over time and remove excess oil if required. After a compressor burnout, it is good trade practise to replace the oil separator. If one is to be installed on a system that has suffered a burnout where an oil separator was previously not fitted, make sure the system is clean and acid-free before its installation occurs.

Service / Trouble shooting tips

The Heldon oil separator is a fully welded type fitted with an internal ball float mechanism. As such it is unserviceable and if a fault is detected the entire vessel must be replaced. Note that the return oil line can provide good diagnostics in regards the refrigeration systems oil return 'health'.

In normal operation the oil return line will alternate a few times per hour between hot and cool as the float firstly feeds high pressure oil back to the crankcase then shuts off as the oil level is lowered to its pre-charged level. If a sight glass is present this will confirm whether it is oil or hot gas that is the cause of this heat source. As the separator's float mechanism opens the sight glass will display a sudden rush of oil and foam back to the compressor before reseating in the closed position.

If the oil return line is at ambient temperature at all times, this is an indication that there is a blockage of some sort at the float mechanism and no flow is occurring at all. Alternately, if the return oil line is constantly hot, this indicates a float mechanism which is stuck in the open position. This could be the result of a mechanical failure on the part of the float or needle and seat or it could even be the result of sludge and debris forcing the needle to stay off its seat. A compressor that is pumping excessive amounts of oil into the system or even an oil logged system will also display the symptoms of a constantly hot oil return line. But, if the return line is chilled this indicates liquid refrigerant is present and condensation is occurring in the oil separator.