OIL AND COMPRESSOR LUBRICATION

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1. Introduction

The topic of oil and how it is used as a lubricant in Unicla compressors is a very important issue, and one which requires constant advice and support to both engineers designing new systems, and to service personnel in the field. This booklet will deal with the basics of understanding oil as a lubricant and its different properties when used in automotive air-conditioning and direct drive transport refrigeration systems (MVAC and TRAC/R). Additional Unicla booklets and information covering system servicing and repair tips can be found at the Unicla Technical Hub at **www.unicla.hk**.

The aim of this information is to provide technicians and engineers with some practical advice and suggestions that can be used in the field for general servicing, or when some 'on the job' system design challenges occur, especially in heavy equipment and special applications using larger capacity direct drive compressors.

There is some excellent and very detailed information available from SAE International (**www.sae.org**), Mobile Airconditioning Society (**www.macsw.org**) and ASHRAE (**www.ashrae.org**) regarding a range of topics covering oil and oil circulation in air-conditioning and refrigeration systems. These organisations have shown a long-term commitment to the research and testing of various subjects in this field, and we suggest any student studying this in detail should make these organisations a main source of information.

This booklet is dedicated to a practical approach to understanding oil performance and behaviour in MVAC and TRAC/R systems, and the actual oil itself.

2. Friction and how oil stops it

In very simple terms friction is defined as the action of one surface or object rubbing against another which creates force to oppose movement of the object. The function of any oil is to make sure friction does not occur by providing a lubricating film between the moving objects sufficient to separate them so that metal-to-metal contact does not occur, and movement-stopping force does not occur.

To achieve this, different surfaces require different types of oil. Rough metal surfaces are best lubricated by a thicker oil film, and smoother surfaces with thinner oil film as illustrated in *Diagram 1* below.

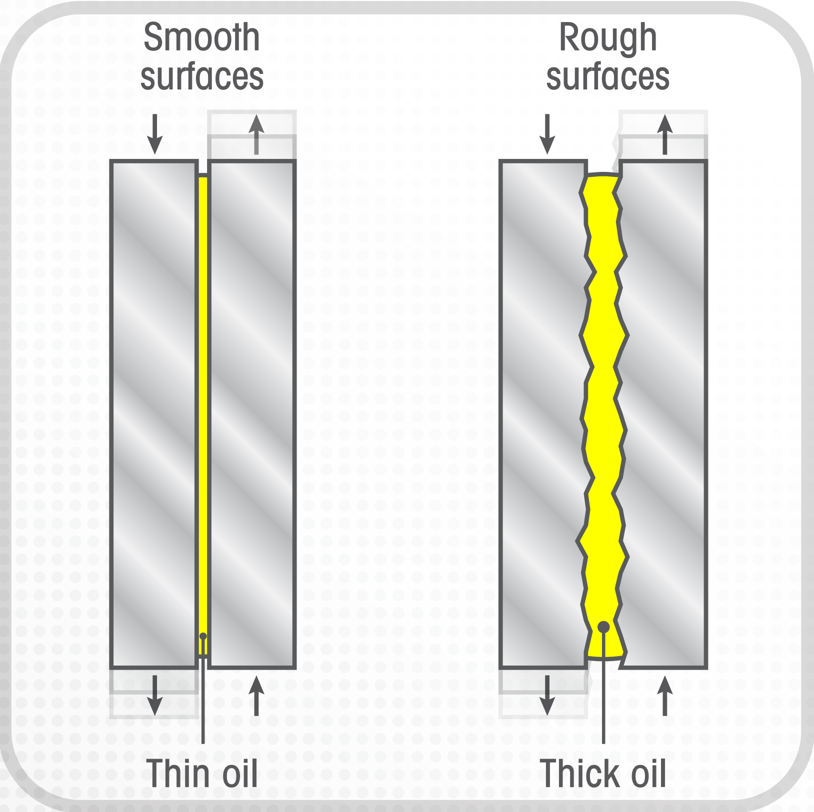


Diagram 1. Different surfaces require different thickness of oil film.

Other influences over whether an oil is providing the correct lubrication film also include temperature and force. An oil operating in extreme high temperatures will need different qualities to an oil required to do the same in sub-freezing conditions.

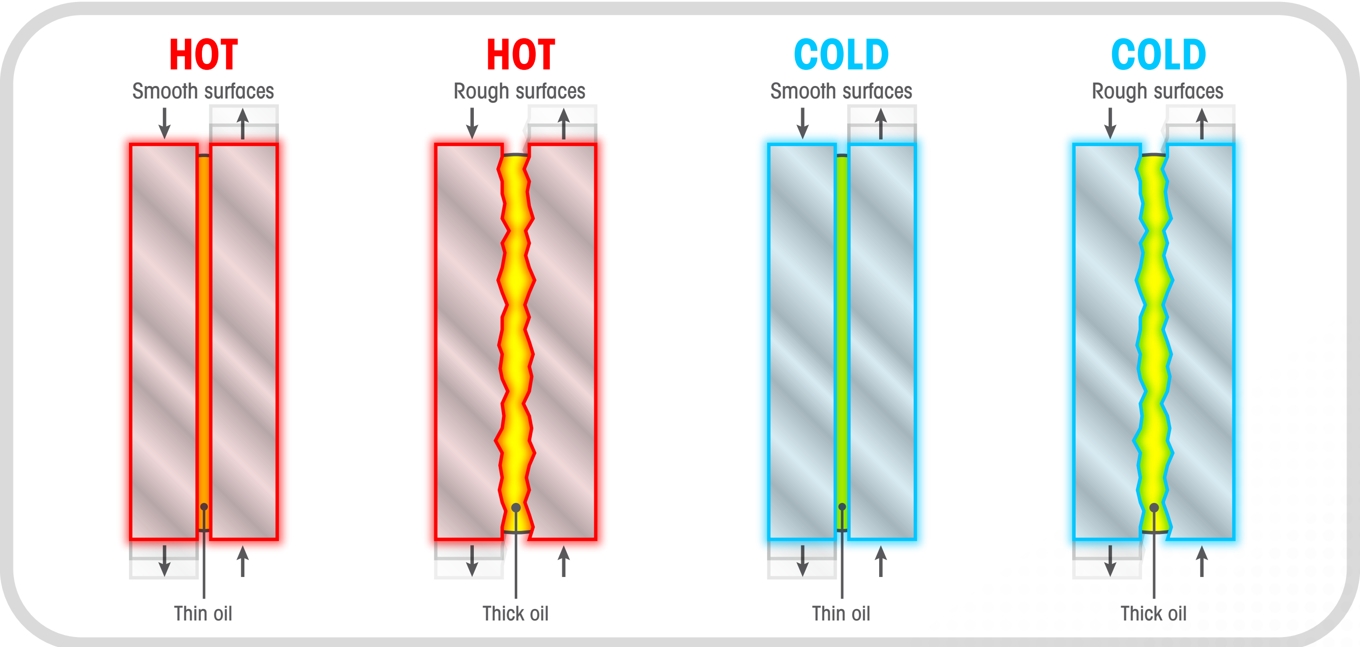


Diagram 2. Oil film must provide lubrication in high and low temperatures.

The same applies to an oil working under extreme force versus one under lighter loads as illustrated in *Diagram 3* below.

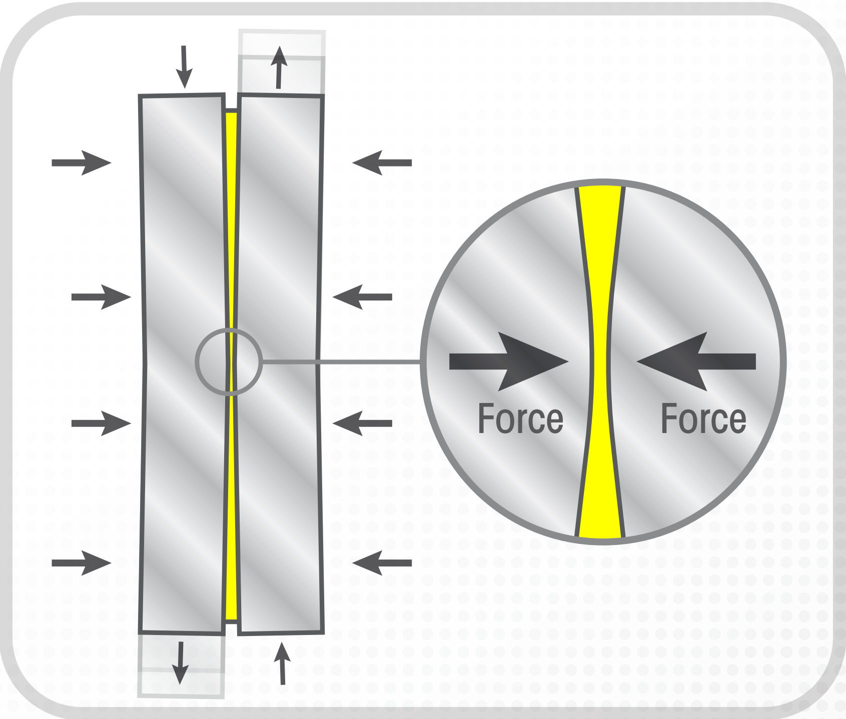


Diagram 3. Oil film must provide lubrication under force.

Modern oil technology provides manufacturers the ability to formulate oils capable of working within multiple conditions and requirements as shown above. This is particularly evident in gas compression cycle systems used in air-conditioning and refrigeration systems, and as necessary in Unicla compressors operating under different system conditions.

3. Boundary layer lubrication and when oil is not there

This is when the lubrication film deteriorates to such a point the surfaces of the components actually touch. Unicla compressors will not operate at this point and will most likely fail within a short time. Some Unicla compressor components can cope with thin oil films for short intervals of operation, but full film lubrication is required for the major part of compressor operation.

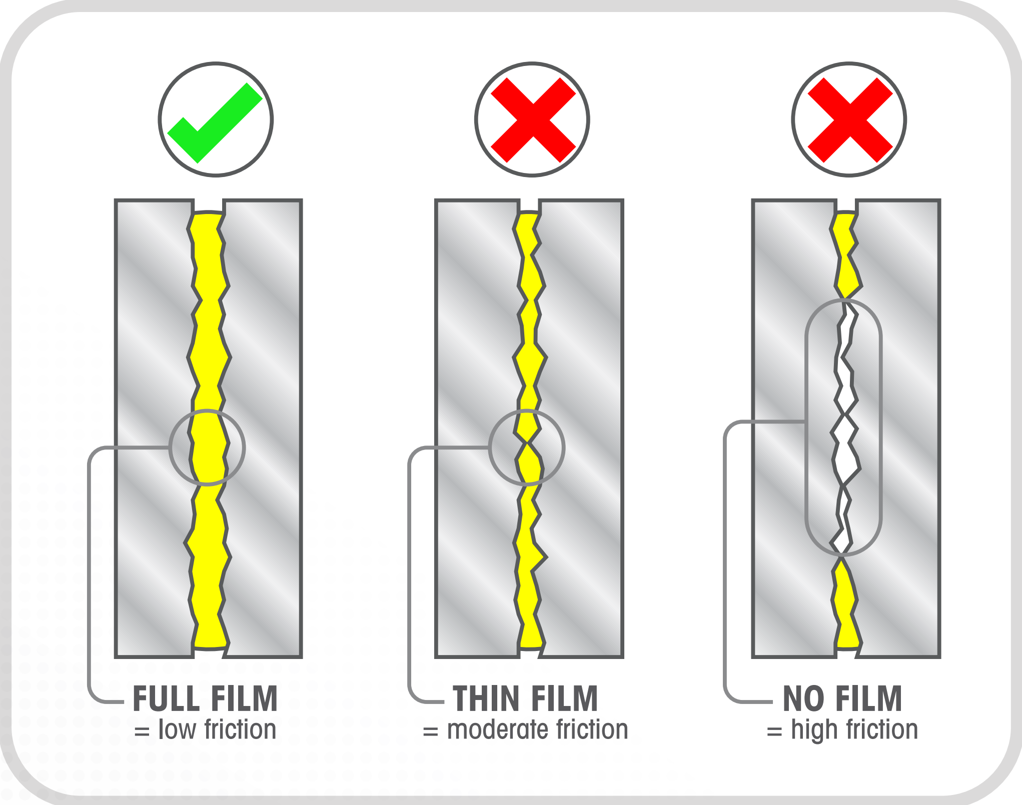


Diagram 4. Oil film must be at full extent to provide adequate lubrication.

4. Pour point and why oil moves

The pour point is the lowest temperature at which an oil still flows when it is cooled down under defined conditions, and describes the way in which oil moves from one point to another. The standards for pour point testing are well covered by all the major standards organisations, such as ASTM, SAE, DIN and ISO, and the methods used are all fundamentally based on cooling the oil at different temperatures in a flask, to determine at which temperature point the oil will not flow out of the flask when it is tipped on its side. When an oil reaches this point it is commonly referred to as being 'waxy'.

The following *Diagram 5* illustrates the fundamental difference between oils with high and low pour points, which is essentially how the test described above is conducted.

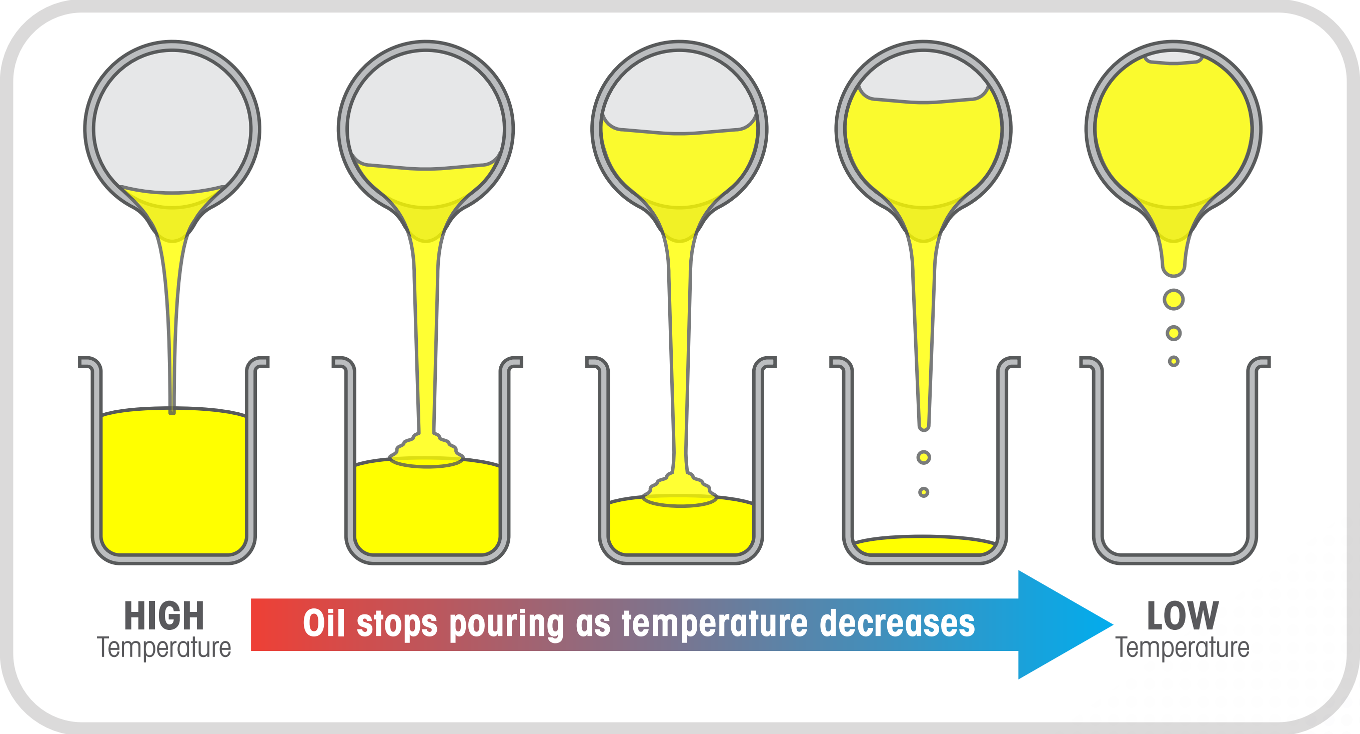


Diagram 5. Oils are rated and tested for pour point.

Pour point ratings usually follow the viscosity rating or index of the oil (described in the next *Section: Viscosity and the ability to lubricate* on page 5). A higher pour point temperature will mean a higher viscosity or thicker oil, and a lower pour point temperature will have a lower viscosity or thinner oil.

In refrigeration and air-conditioning systems, this feature is important to know due to the fact a certain amount of oil is always in circulation in the system, and it is critical for this oil to eventually return to the compressor and potentially continue to circulate. Refrigeration oils have low pour point levels ranging from -40°C to -60°C which is needed due to the low temperature zone the oil has to pass through in the evaporator when circulating in the system.

Even though most automotive and transport systems never reach these temperatures in the evaporator, the pour point temperature is still useful to know as an indicator of the oil behaviour in the low temperature ranges. For instance an oil with a low pour point of -56°C will perform and flow well in an evaporator operating with refrigerant temperatures of -20°C, as compared to an oil with a pour point temperature of -40°C. Both will flow satisfactorily due to neither having reached the relative pour point threshold, however the oil with the lowest pour point will perform the best in this situation.

However there are exceptions to this point when considering the miscibility characteristics of oil and flow rates with the refrigerant in the evaporator. Some oils have additives that change this behaviour to deliver other benefits while maintaining pour point levels. These features are examined in *Section 8: Miscibility and how oil moves* on page 10 of this booklet.

Unicla oil	Type	Pour point °C
Unicla Unidap 3	POE32	-56.00
Unicla Unidap 6	POE68	-47.00
Unicla Unidap 7	PAG56	-52.00
Unicla Unidap 8	PAG46	-54.00
Unicla Unidap 9	PAG46 HD	-25.00
Unicla Unidap 10	PAG100	-30.00

Table 1. Pour point ratings of Unidap oil range used in Unicla compressors.

5. Viscosity and the ability to lubricate

Viscosity is the measure of a fluid's resistance to flow which is measured quite differently to pour point. A simple example is to compare honey (high viscosity) and water (low viscosity). Honey is thick and sticky, and when placed between two surfaces it creates a resistive barrier. Whereas water is fluid and not sticky, and will not stay in place the same way as honey.

This ability to create a barrier between surfaces is called lubrication, and the viscosity of a fluid or oil is usually shown as an index or number to express the level or severity of this lubricating barrier in certain conditions. There are numerous definitions and measurement methods developed to express these viscosity numbers and indexes for different oils, and it becomes quite a detailed science if researched properly. However, the following will explain the viscosity of oil in simple terms as it relates to refrigeration and air-conditioning systems.

The are two main types of viscosity measurement;

Dynamic viscosity (*μ*) - also called absolute viscosity and it is a measure of a fluid's internal resistance to flow. It is measured by mechanical means using rotary or centrifugal force to obtain the resistance and shear capability of the oil at a specific level of force and temperature. It is usually reported in Centipoise (cP) or 'poise' which is taken from the name of French scientist Jean Louis Marie Poiseuille.

Kinematic viscosity (*v*) - also called momentum diffusivity and it is a measure of the resistive flow of a fluid under the weight of gravity, it is the ratio of the dynamic viscosity μ to the density of the fluid *p* (kg/m³). It is measured without additional force applied by noting the time taken of a fluid sample to travel through an orifice in a capillary under the force of gravity only. The time taken is noted and calculated into square metres per second (m²/s), then converted into units reported in Centistokes (cSt) which is taken from the name of Irish scientist George Stokes.

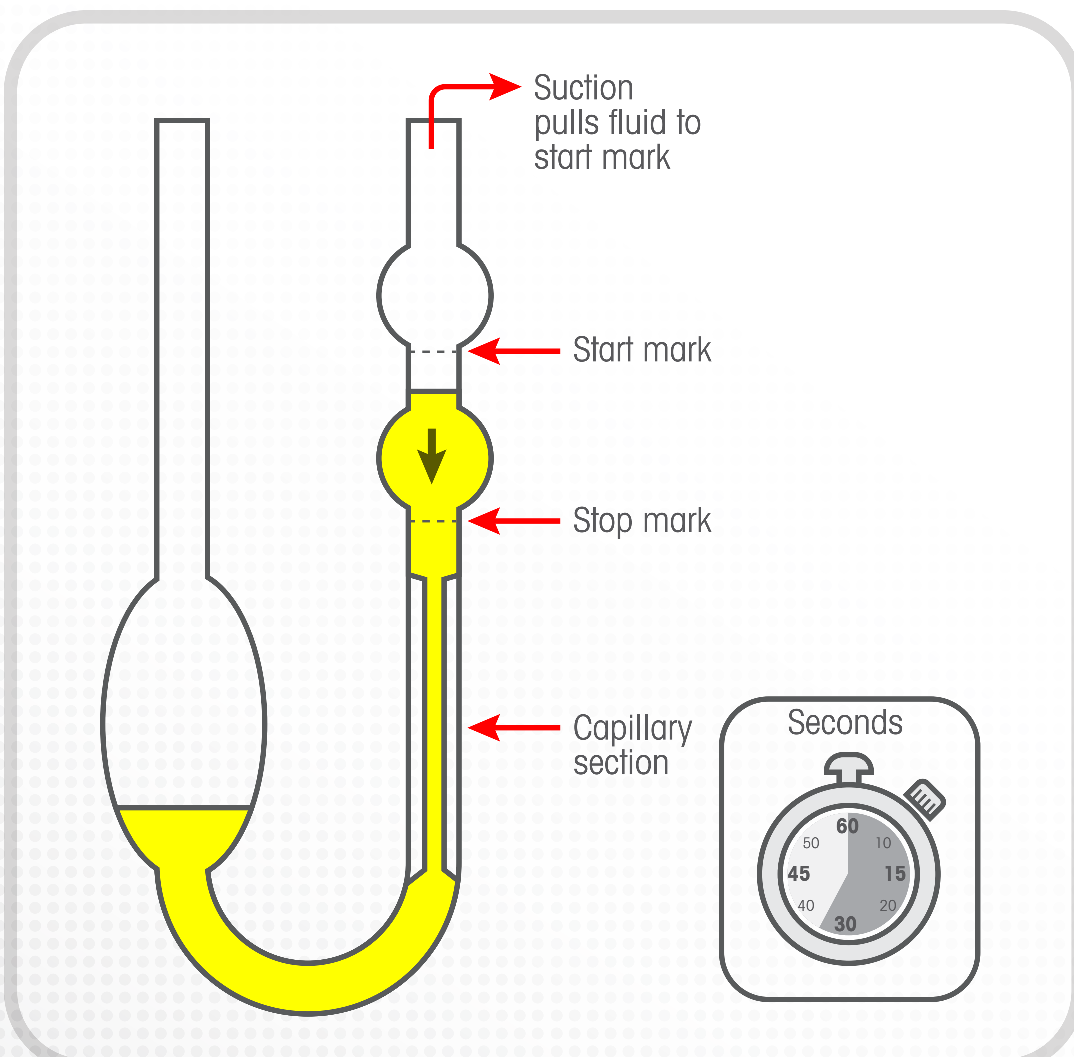


Diagram 6. Kinematic viscosity test apparatus measures the time taken for an oil to pass through an orifice.

So if the density of an oil is known in conjunction with one of these viscosity measurements, the following formula can be applied:

Dynamic Viscosity (cP) = Kinematic Viscosity (cSt) x Fluid Density (kg/m³) or **μ = vp**

Oil manufacturers for refrigeration and air-conditioning systems will quote the Kinematic viscosity at two temperature points, 40°C and 100°C as prescribed by international standards (ISO and others) and it is the 40°C number which is generally used to identify the oil model. As an example, *Table 2* below is the data from the Unicla Unidap oil chart:

Unicla oil	Type	Viscosity @ 40 °C	Viscosity @ 100 °C
Unicla Unidap 3	POE32	32.50	5.80
Unicla Unidap 6	POE68	65.50	9.30
Unicla Unidap 7	PAG56	56.00	10.85
Unicla Unidap 8	PAG46	48.01	10.51
Unicla Unidap 9	PAG46 HD	46.00	9.70
Unicla Unidap 10	PAG100	100.00	21.00

Table 2. Kinematic viscosity ratings of Unicla Unidap oil range.

Also when referring to the viscosity of refrigeration oils, other references are sometimes used such as the viscosity index and dynamic viscosity as used in automotive engine oils and usually measured at 100°C.

As an example Unicla Unidap 8 PAG46 oil @100°C:

Kinematic viscosity @100°C = 10.51
Viscosity index @100°C = 215
Dynamic viscosity @100°C = 9873

The density of Unicla Unidap8 at 100°C is 939.44 (kg/m³) so using formula above u=vp.

Dynamic viscosity(cP) = 10.51(cSt) x 939.44 (kg/m³) = 9873.5

These alternative references are rarely used by refrigeration engineers, and therefore Unicla recommends the kinematic viscosity at the dual points of 40°C and 100°C as the standard references for oil type and evaluation for systems.

The single kinematic viscosity number at 40°C helps to standardise and easily identify the type of oil, but it is important to remember the oil is made to be 'viscous' or to have lubricating properties over a range of temperature points, and in refrigeration and air-conditioning systems this becomes quite dynamic as a large percentage of the compressor oil moves around the system with the refrigerant.

For instance, when a R134a refrigerant changes state from the low side to the high side in an automotive AC system, the oil in circulation (OIC) can be subject to rapid temperatures changes from 0°C while in the low side, and up to 100 °C or more when reaching some points in the compressor high side. In a transport refrigeration system operating with R404a, this range is even higher from -25 °C to 120 °C.

The fact refrigeration oil has to do this multiple times during normal operation, is quite different to the operational temperature range requirement of petrol or diesel combustion engines, which generally stay in a constant high temperature condition once operating properly, and are not required to mix or become soluble with another substance, as does refrigeration oil.

Therefore, it is important to ensure the correct oil is chosen to best suit the application when it comes to the viscosity requirement. As a general rule, if the system is operating in high ambient conditions where the compressor discharge line temperature (CDT) is constantly in the higher range, then a higher viscosity oil is recommended. As an example, in situations where CDT levels exceed 85°C, and the duty cycle is severe, Unicla recommends oil with a kinematic viscosity of 100, instead of the standard 46 or 56.

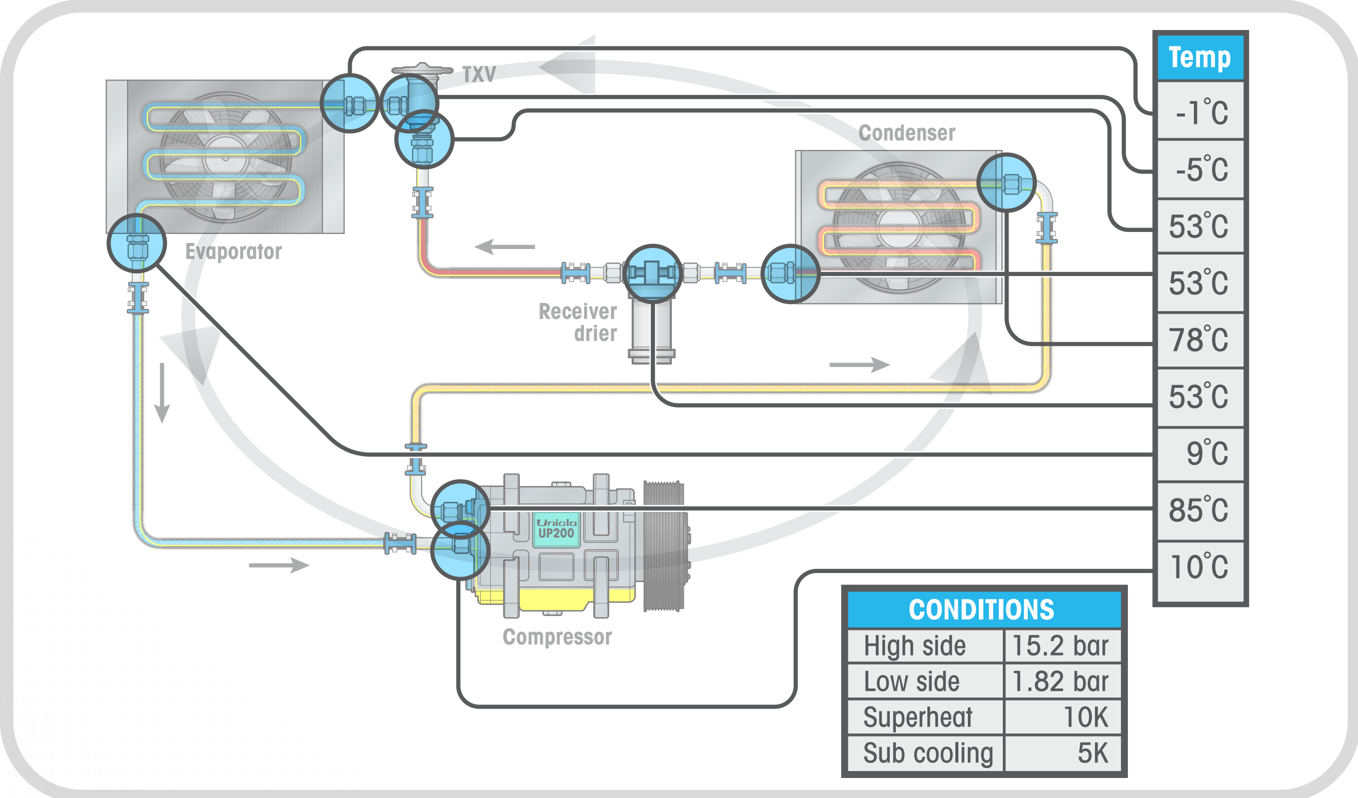


Diagram 7. A typical automotive air-conditioning circuit has multiple temperature points.

6. Choice of Oil

The decision for choosing the correct oil in modern transport and automotive systems is often over simplified as only a contest between species of oil, the most common of which are polyalkylene glycols (PAG) or polyol esters (POE). It is more complicated than just selecting an oil species when making the right choice, with numerous factors to be considered.

The standard oils in the Unicla range are from one of these types, PAG or POE, and as a compressor manufacturer Unicla has no generic favoritism to either. The combined and different features of these oil types provide system engineers with a much wider choice of lubrication than if only one type is considered.

As demonstrated later in this booklet, several factors in the system influence the choice of oil. The miscibility and viscosity is very important, so is moisture content, and performance at both high and low temperatures is critical.

It is quite difficult to have one oil do everything perfectly in a modern system and very often system designers have to make some compromises. However there are 10 common considerations for oil choice in Unicla compressors which take into account fundamental system features;

1. **Type of refrigerant**
   oils mix differently at various temperatures with different refrigerants
2. **Type of vehicle**
   this usually influences the type of system
3. **Size of vehicle**
   influences type of system, large or small
4. **Size and length of hoses**
   affects oil return to the compressor and choice of viscosity
5. **Evaporator temperature**
   affects oil return to the compressor and choice of viscosity
6. **Types and number of heat exchangers**
   fin, tube, and extrusion construction will affect oil circulation
7. **Type of controls and expansion device**
   consistency of refrigerant flow is important for oil return
8. **Ambient conditions**
   viscosity and miscibility of oil must suit consistent and fluctuating temperature
9. **System servicing**
   inspection and service intervals effect moisture ingress to system
10. **Oil separator**
    guarantees oil return to compressor

When all of these are applied properly to a vehicle and system design, and an oil is chosen to best suit all points, engineers can be confident of covering most of the issues necessary. As a general example of some typical vehicle and system types, *Table 3* below shows which type of oil is the most likely candidate when this is done.

System type	Refrigerant	Oil type	Viscosity	Features
Automotive - passenger car	R134a	PAG	Mid range	High temp viscosity and stability
Automotive - passenger car	R1234yf	PAG (HD)	Mid range	Miscibility and stability with HFO refrigerant
Transport - bus	R134a	POE	High	Resiliance to moisture contamination
Transport - refrigeration	R134a	POE	Mid range	Miscibility at mid temp
Transport - refrigeration	R404a	POE	Low	Miscibility at low temp
Heavy vehicle - large hose	R134a	PAG/ POE	Low - mid range	Miscibility with refrigerant
Heavy vehicle - high temp	R134a	PAG/ POE	Mid-high range	Viscosity at high temp

Table 3. Different vehicles and systems have variable selection criteria for correct oil type.

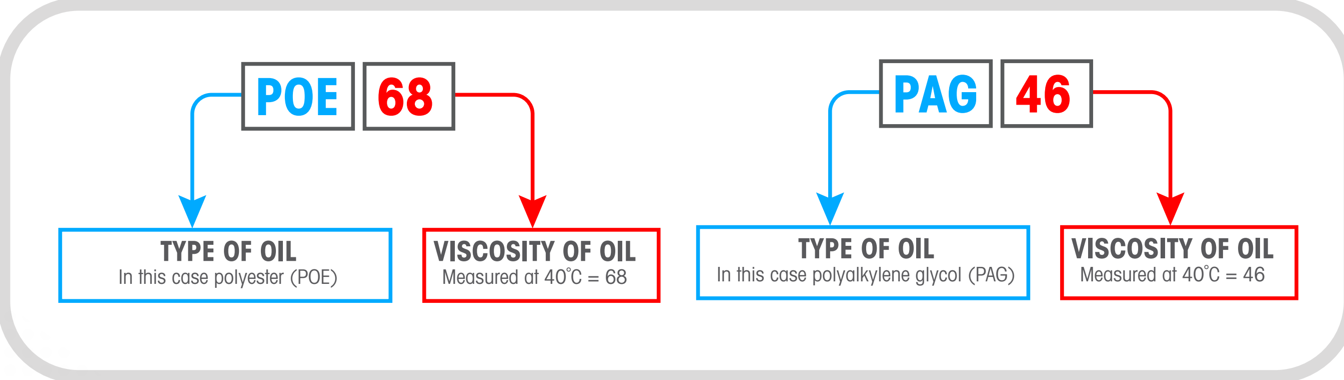
The temperature range of the oil must also allow for correct performance and lubrication within the system parameters. *Table 4* below provides a guideline for correct oil choice based on evaporator temperatures, which is critical to ensure oil return to the compressor.

Unicla model	Refrigerant	Oil type	Application	Low side saturation	Oil separator
All models	R134a	Unidap 7	Air-conditioning	> 0°C	Optional
	R134a	Unidap 6	Air-conditioning	> 0°C	Optional
All models	R134a	Unidap 6	Air-conditioning	≥ -10°C	Required
F series	R134a	Unidap 3	Refrigeration	≥ -10°C	Required
F series	R404a, R452a	Unidap 3	Refrigeration	≥ -15°C	Required
F series	R404a, R452a	Unidap 3	Refrigeration	≥ -35°C	Required
UWX with extended hose lengths	R134a	Unidap 7	Air-conditioning	> 0°C	Optional
	R134a	Unidap 6	Air-conditioning	> 0°C	Optional

Table 4. Unicla oil types and evaporator temperatures.

7. Labelling and identification

The labelling system and description of oils used by Unicla is shown below in *Diagram 8*.



Unicla Unidap 3	
Type	POE32
Viscosity @ 40˚C	32.50
Viscosity @ 100˚C	5.80

Unicla Unidap 6	
Type	POE68
Viscosity @ 40˚C	65.50
Viscosity @ 100˚C	9.30

Unicla Unidap 7	
Type	PAG56
Viscosity @ 40˚C	56.00
Viscosity @ 100˚C	10.85

Unicla Unidap 8	
Type	PAG46
Viscosity @ 40˚C	48.01
Viscosity @ 100˚C	10.51

Unicla Unidap 9	
Type	PAG46 HD
Viscosity @ 40˚C	46.00
Viscosity @ 100˚C	9.70

Unicla Unidap 10	
Type	PAG100
Viscosity @ 40˚C	100.00
Viscosity @ 100˚C	21.00

Diagram 8. Unicla oil tin and labelling configuration.

8. Miscibility and how oil moves

When referred to in refrigeration and air-conditioning terms, miscibility is the mixing characteristic of the oil with the refrigerant while they are both circulating in a system. All systems are different and have varying qualities when it comes to the level of oil circulation ratio (OCR) and oil in circulation (OIC) requirements and results. However, all systems have the one basic requirement when it comes to miscibility, and that is to not have too much oil mixing with the refrigerant so that excessive oil is not leaving the compressor. The oil must have sufficient properties to stay in circulation and remain sufficiently ‘miscible’ with the refrigerant so that it does not park itself in the system components.

The following *Diagram 9* is a typical example of a well-balanced system with the correct oil in circulation (OIC).

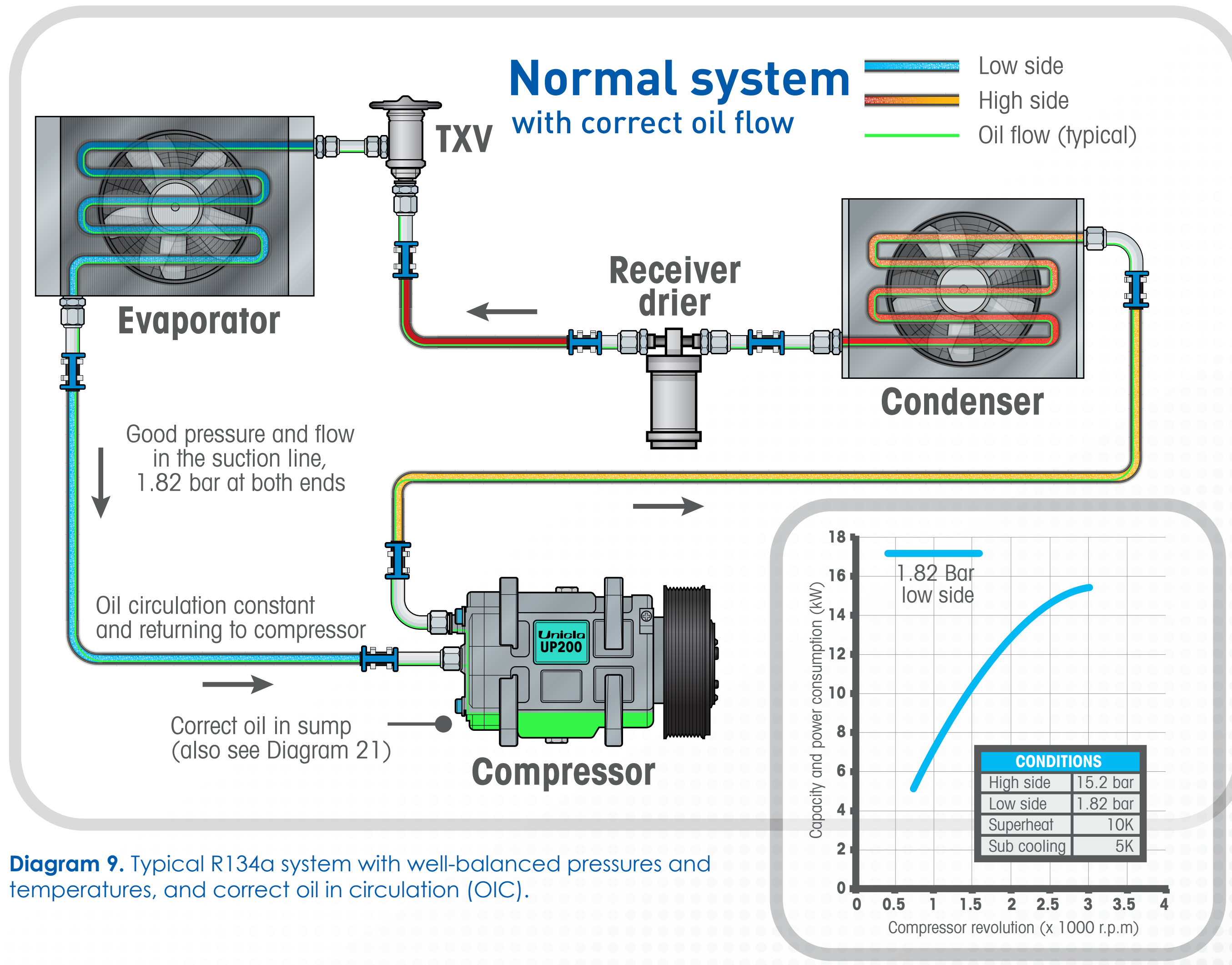


Diagram 9. Typical R134a system with well-balanced pressures and temperatures, and correct oil in circulation (OIC).

The undesirable situation to occur is to have oil leave the compressor into circulation to then park itself somewhere in the system and not stay in circulation. It is the miscibility and pour point quality or rating of the oil that determines the level of susceptibility of the oil to do this in a system.

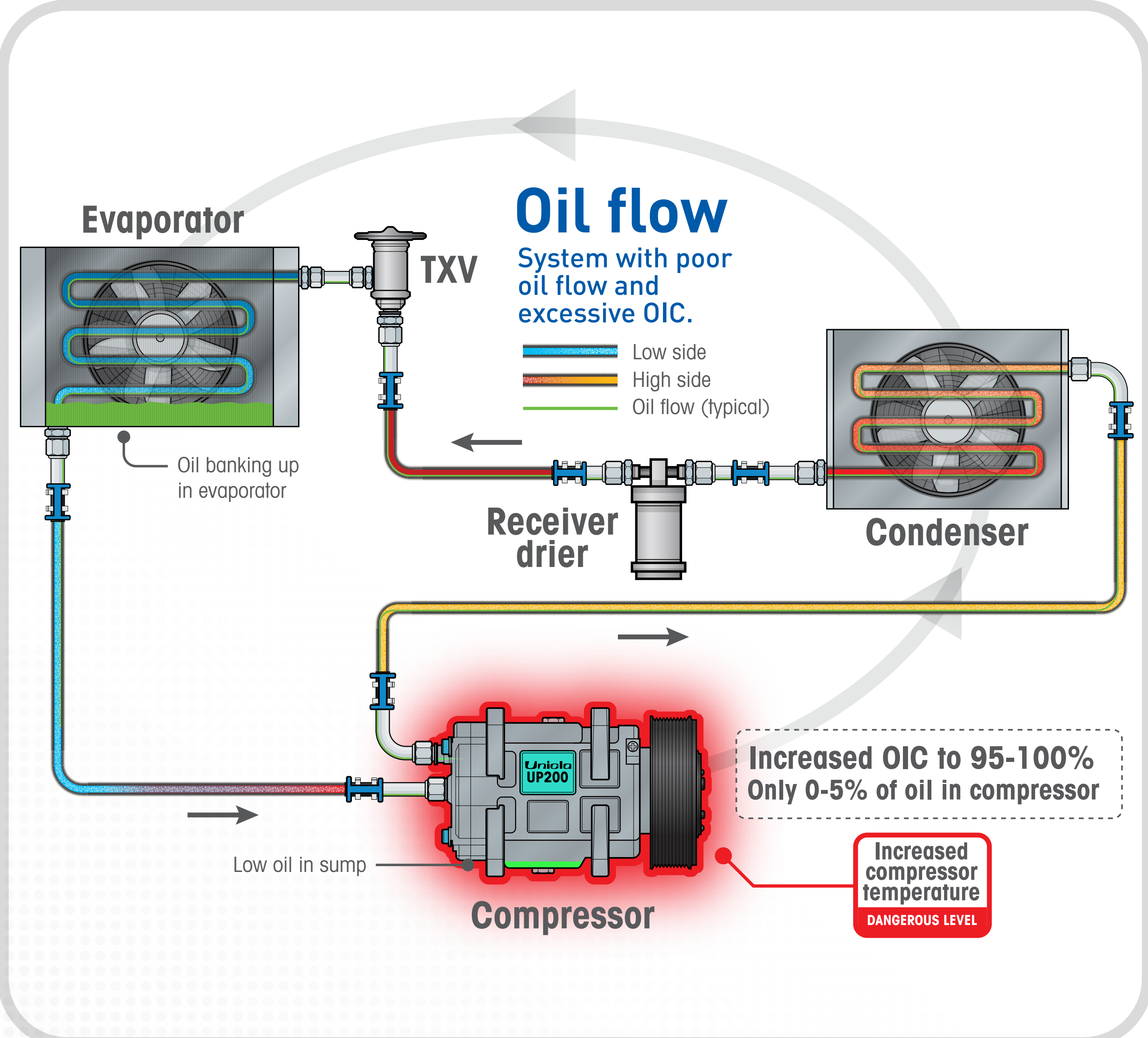


Diagram 10. R134a system with unbalanced pressures and temperatures, reduced oil in the compressor and excessive oil in circulation (OIC) which has banked up in th evaporator.

This behaviour has to be examined in conjunction with the type of refrigerant, operating conditions of the system and ratings of the oil (viscosity and pour point). When examining this miscibility behaviour it is essential to know at which point oil separates from the refrigerant when circulating in the system, which is commonly referred to as the 'miscibility gap' or the 'point of threshold solubility', or 'phase separation point'. The term 'phase change' is used to describe oil and refrigerant being as one phase (mixed together), or becoming two phases (separating).

This miscibility gap occurs at different points in the system depending on the relationship between refrigerant temperature and the oil circulation rate (OCR). It is best shown in a phase diagram commonly referred to as a miscibility - gap diagram. This is shown for Unicla Unidap8 oil in *Diagram 11*.

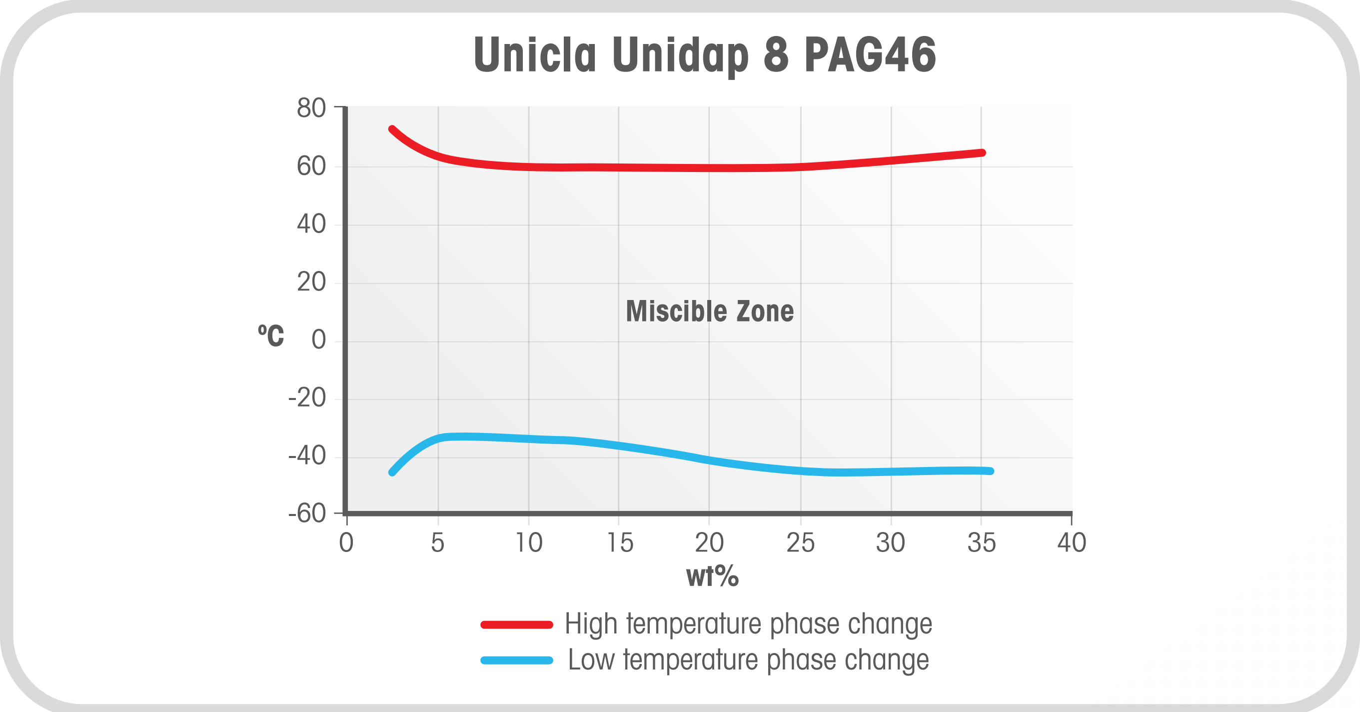


Diagram 11. Miscibility - gap diagram for Unicla Unidap8 oil (PAG46) with R134a.

To use this diagram in a practical manner, system designers and technicians can predict oil circulation problems in a particular system. For instance if a system had an OCR of 5-10%, and was operating in high ambient conditions or a refrigerant leak occurred in the system, it wouldn't be unusual to see higher than normal refrigerant temperatures in the condenser of > 65°C. At this temperature point in the high side, phase separation between the oil and refrigerant would occur as shown at point A in *Digram 12* below.

This temperature level of > 65°C can also easily occur in systems which are low on refrigerant.

Temperatures in the evaporator of -10°C to -20°C, will still allow miscibility of oil and refrigerant without phase separation as shown at point B in the *Diagram 12* below.

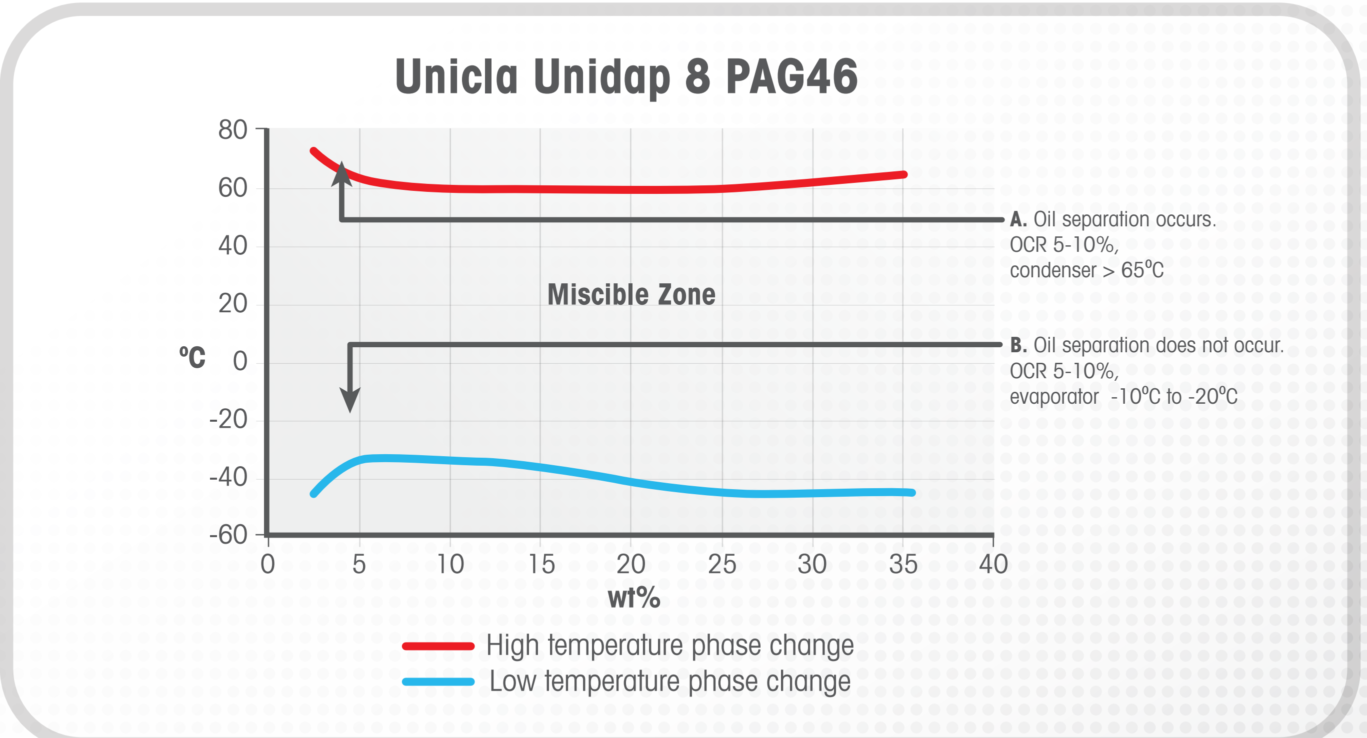


Diagram 12. Miscibility - gap diagram. Shows where oil separation occurs in a typical R134a system using Unidap 8 (PAG46) oil running high discharge temperatures >65°C from high ambient conditions, or low on refrigerant.

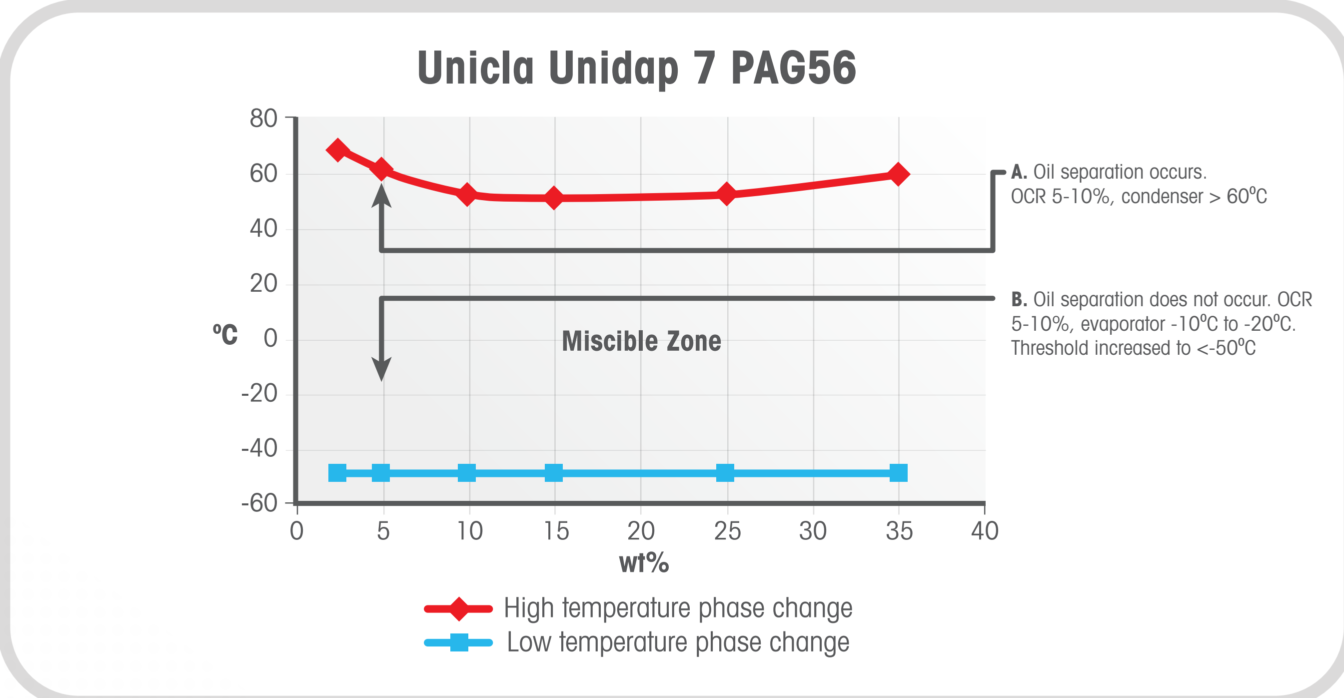


Diagram 13. Miscibility - gap diagram shows where oil separation occurs in a typical R134a system using Unidap 7 (PAG56) oil operating with high discharge temperatures >60°C from high ambient conditions or low refrigerant.

An important example to mention when balancing miscibility behaviour in a system is when the decision is made to use higher viscosity oil such as Unicla Unidap 10. This oil is a PAG100 and an option for system designers concerned about premature wear and deterioration on components in systems operating in very harsh conditions. This could be ambient conditions of continuous > 40°C, or heavy duty cycles of continuous daily running over long hours, or both.

Due to the viscosity of this oil (100 @ 40°C and 21 @ 100°C) superior lubrication is delivered to components provided the oil is in place and operating with sufficient volume. Therefore, careful consideration should be given to its miscibility in a system as shown in the *Diagram 14* below.

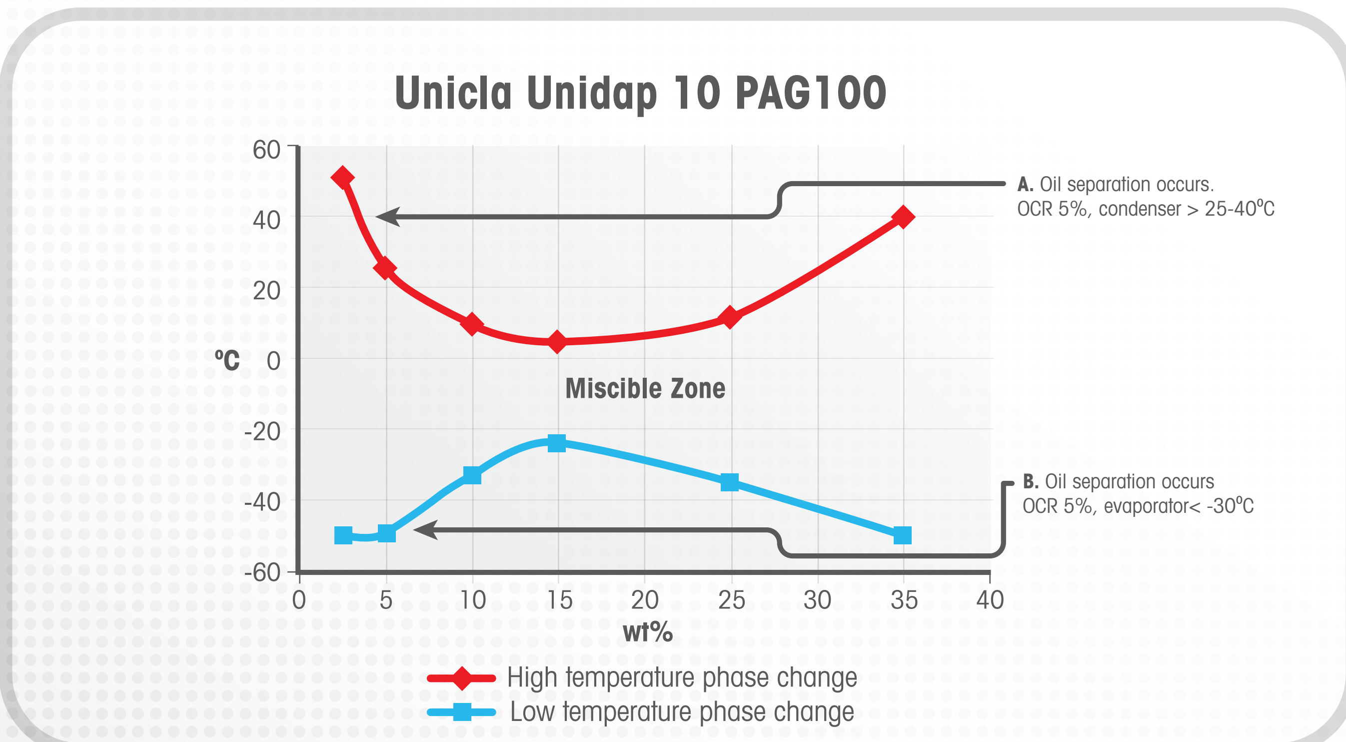


Diagram 14. Miscibility - gap diagram. Shows where oil separation occurs in a typical R134a system using Unidap 10 (PAG100) oil.

As shown in *Diagram 14* the phase change temperature point for Unidap 10 (PAG100) is quite low at 25-40°C when OCR is 5%, which means there is an increased risk of oil accumulating in the condenser when using this oil over an oil of lesser viscosity. Therefore, corrective action must be taken by introducing the use of an oil separator.

Unicla oil separators are installed into the discharge line connected to the compressor and designed to capture sufficient oil before it reaches the condenser and return it to the compressor. More details on this are covered in the oil separator section of this booklet, however it can easily be seen that any high viscosity oil in circulation such as Unidap 10 (PAG100) would drop out in most condensers when operating at normal temperatures, which would mostly be at all times above the phase change point of 25-40°C .

Further miscibility balancing must be considered with the new refrigerant R1234yf. Unicla engineers have worked extensively with refrigerant manufacturers Chemours and Honeywell during the development phase of this new refrigerant with a strong focus on compressor lubrication. The most suitable oil for this refrigerant in automotive applications is PAG46HD, which is a double end capped PAG oil badged as Unidap 9 by Unicla or Zerol HD46 by the manufacturer Shrieve. The validation by Unicla of this oil when used with R1234yf was undertaken by long term testing at Unicla's research and test centre in Australia, and with assistance from Shrieve Chemical (Shanghai) Ltd.

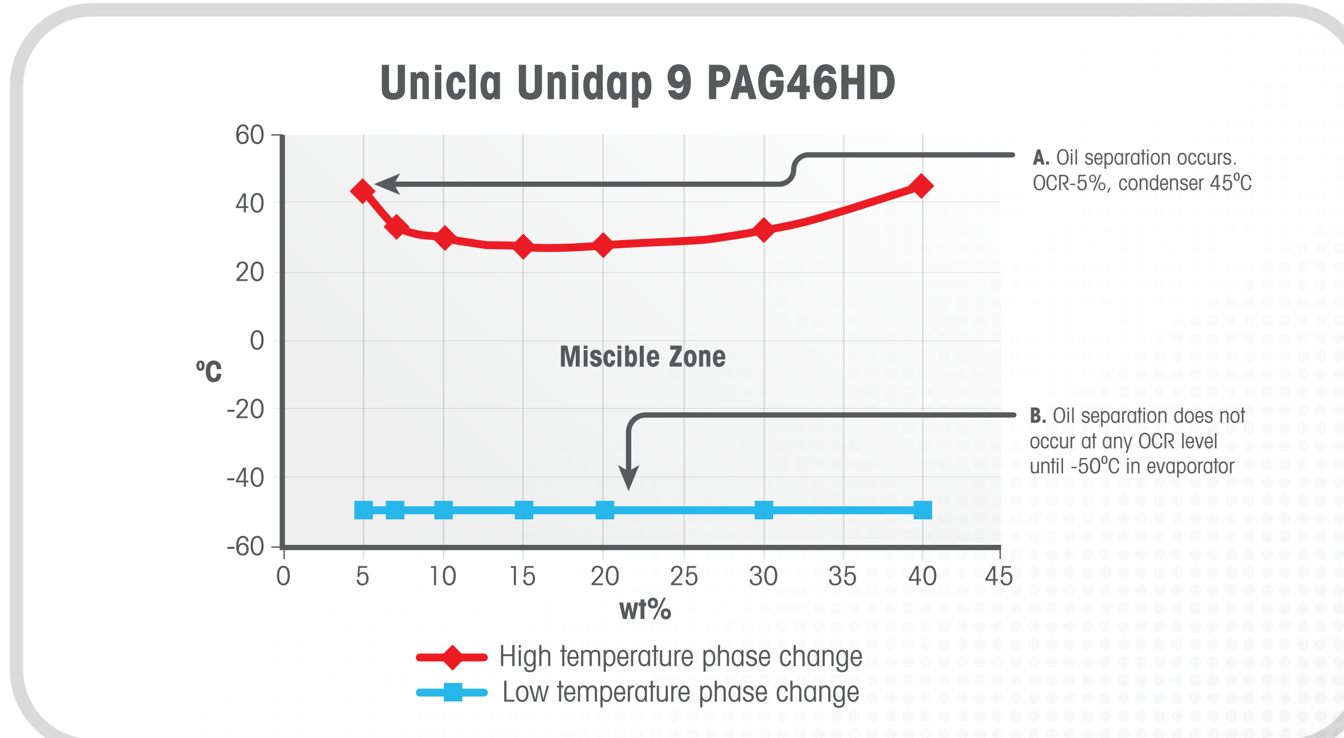


Diagram 15. Miscibility - gap diagram. Shows where oil separation occurs in a typical R1234yf system using Unidap 9 (PAG46HD) oil.

In this application, Unidap 9 (PAG46HD) oil has an excellent threshold of solubility in the low side, with the phase change point at -50°C across all OCR percentages. On the high side the phase change point is 45°C which is up to 20°C less than what the industry is accustomed to (Unidap 7 (PAG46) is 65°C) when comparing the performance of R1234yf systems to the traditional parameters found in R134a systems. It is also important to note that while R1234yf is very close to R134a in nearly every respect, it does operate at slightly higher temperatures for the same pressure in the high side when compared to R134a. See *Diagram 16* on the next page.

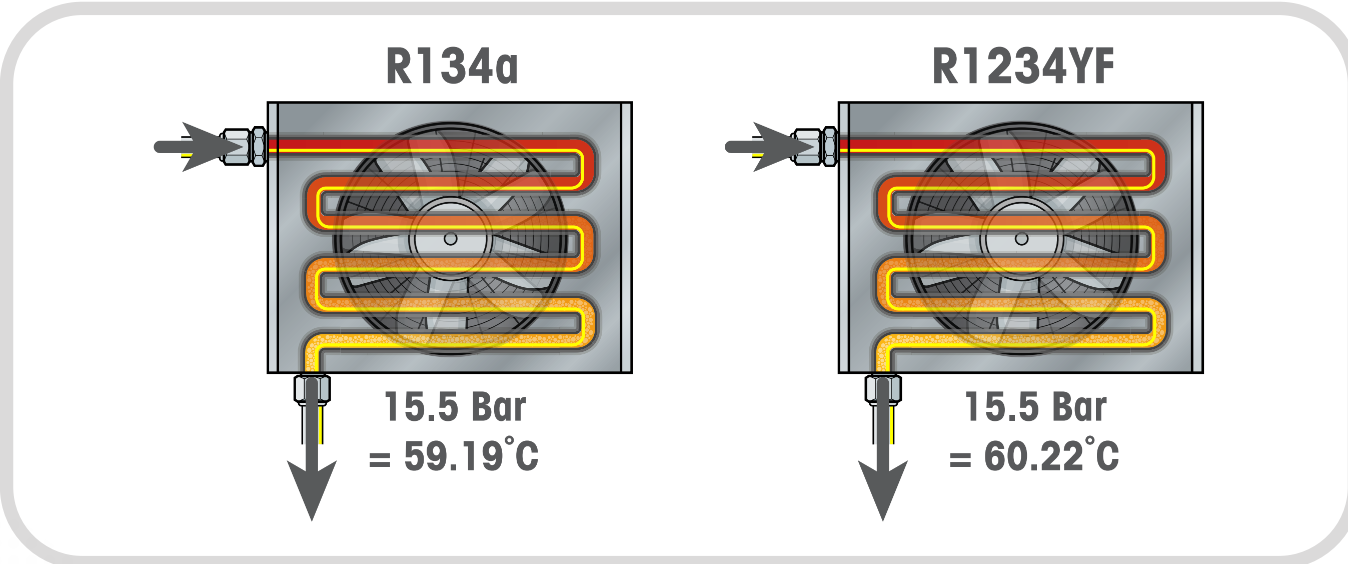


Diagram 16. Condenser temperatures at 15.5 Bar for R134a and R1234YF.

The cautionary action required of R1234yf system designers is to ensure discharge line and condenser temperatures are kept to a minimum, and the system oil quantity (SOQ) and oil in circulation (OIC) is balanced to ensure sufficient oil remains in the compressor.

The miscibility of POE oils can deliver excellent advantages in transport air-conditioning and refrigeration applications where it is necessary for the heat exchangers to have no compromise on performance without oil accumulating inside, and to have continual oil return back to the compressor. These requirements can be quite difficult to achieve in these systems which have additional features that impede adequate oil return, such as long hose runs, large heat exchangers, hot gas defrost cycles and condensers working at high pressures and temperatures.

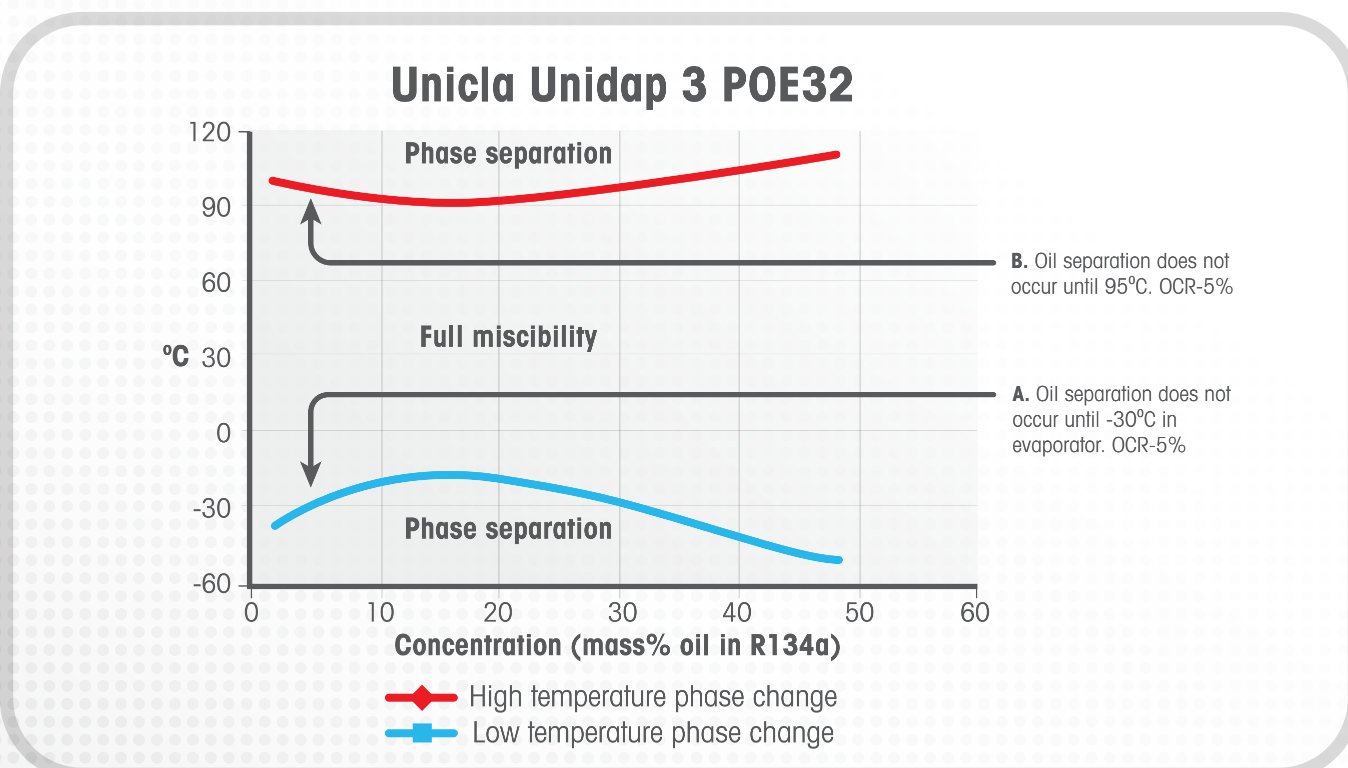


Diagram 17. Miscibility - gap diagram. Shows high range miscibility of Unidap 3 (POE32) oil.

Unidap 3 (POE32) oil is an excellent choice for systems with these features. It remains miscible at high and low temperatures, and even though the viscosity rating is not as high as others in the Unicla oil range, the principle is to keep the oil moving in the system so that components are always covered in lubricant.

To summarise miscibility of oil and refrigerant in a system, its much like a train full of passengers taking a round-trip journey. The refrigerant is the train, and the oil the passengers, and during the journey the passengers will get on and off the train at varying and random stops which also move location on the journey route depending on conditions.

Therefore, with these 'variable stops' for the oil to get on and off in the system, its important for designers and engineers to understand the application of the system, its measured capacity so it can be applied efficiently, and the compatibility of components so that optimum performance is achieved.

Another important point for engineers to remember is the switching on and off zones that create these oil stops. When a system is turned off and not running, all of the system oil is miscible with the refrigerant, which is a standard feature of the whole Unicla oil range and of most modern refrigeration oils. However, once the system is running, a completely different set of conditions is immediately created, and as *Diagrams 18 and 19* show below, these can be separated into eight different zones affecting oil miscibility and its movement around the system.

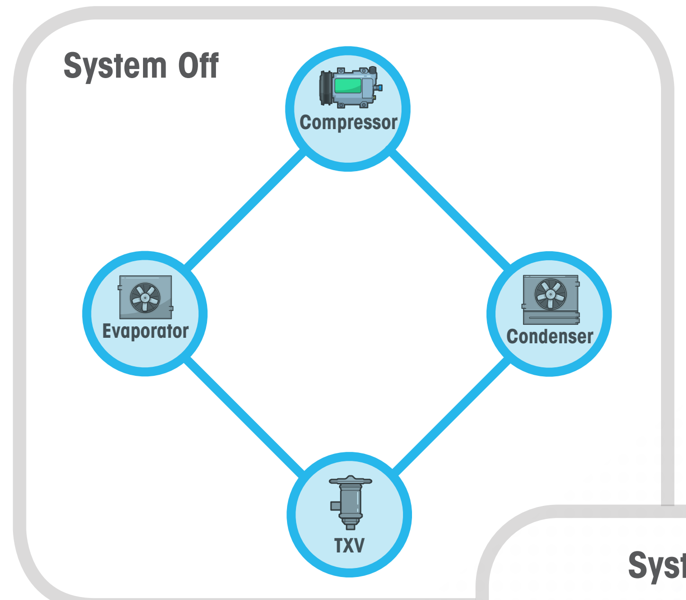
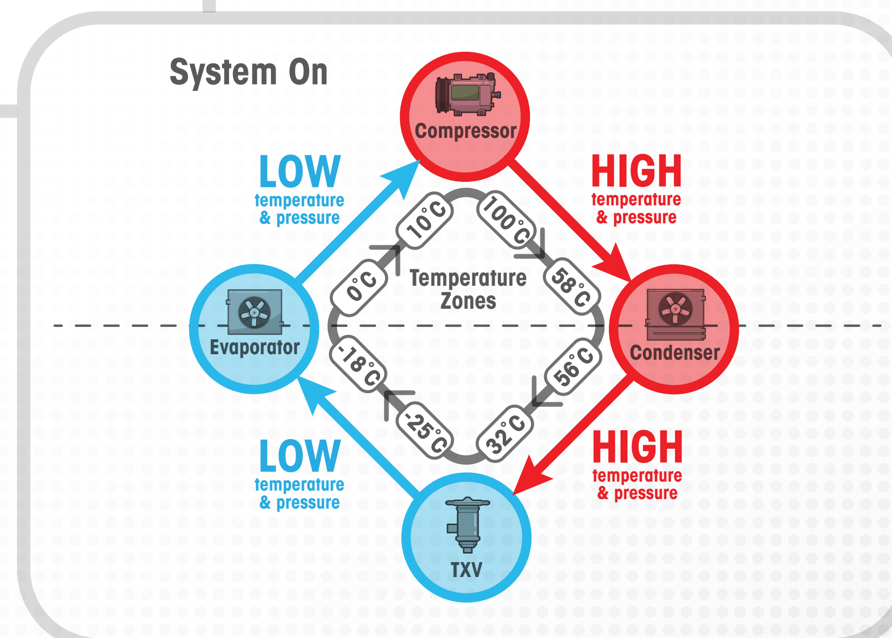


Diagram 18. Main components in a system turned off.

Diagram 19.
System is now turned on and different zones at variable pressures and temperatures are now created where oil stops occur.



For system design to achieve adequate oil and refrigerant miscibility, it has to take into account all these different zones in the system, and the fact they are constantly being switched on and off with variable pressures and temperatures dependent on ambient conditions.

9. Moisture

Every air-conditioning and refrigeration technician knows the impact of moisture in systems, and this is no different when it comes to oils. Refrigeration oil is hygroscopic, which means it will absorb moisture, as compared to petroleum oil which is hydroscopic and repels moisture.

All Unicla oil types are manufactured with the lowest possible levels of moisture, usually < 500 PPM and as low as ≥ 200 PPM. Metal containers are recommended as the best method of shipping and storage to ensure there is no moisture ingress into the oil, particularly after opening and storage in the workplace environment.

It is important to realise that significant levels of moisture can be introduced into refrigeration oil just from the simple task of decanting the oil from one container to another. In recent tests conducted by Unicla, new Unidap 6 (POE68) oil was poured from its metal container into another and back again. The ambient conditions were 31°C / 75% RH. The new oil was measured with 350PPM before decanting, and after decanting the moisture rose to 1000PPM which is considered unacceptable.

This is a key point which most technicians do not realise, and it's easy to see how moisture can be unknowingly introduced into the system from not understanding the hygroscopic nature of refrigeration oil.

Moisture also makes its way into systems from lack of proper evacuation and service procedures, and from non-replacement of receiver driers during system repairs and or servicing. Moisture is considered a system contaminate mainly due to causing internal corrosion of components and reduction of quality.

Technicians can also use the colour of oil as an indicator of the presence moisture and its effects on the oil quality. *Diagram 20* below shows the expected colour change that occurs in Unicla PAG and POE oils with different levels of contamination.

Diagram 20. Colour can be a good indicator of oil quality which darkens as moisture increases.

10. Oil quantity in systems

It is important for technicians to understand that the compressor oil level is different and separate to the oil quantity required for the complete air-conditioning or refrigeration system. While they are dependent on each other, the calculations for correct levels and their operational characteristics need to be examined separately.

Compressor oil level (COL)

Unicla compressors are manufactured with a shipping charge of oil. This oil level is not to be taken as an indicator or recommendation for the correct level of oil to be used in the system, it is only for the purpose of keeping the internal compressor components sufficiently lubricated during transport and storage prior to being placed into service. Once in service the system should have an adequate balance of oil to refrigerant ratio to ensure the correct COL is always maintained. Unicla COL is determined as follows:

1. Systems with no extra oil added to the system - which have smaller refrigerant levels requiring no extra oil added to the original Unicla ex-factory COL. These systems should keep 20-30% of the original oil in the sump during operation. An example is a UP200 compressor with its original factory oil of 180 cc operating in a system with <900 grams of refrigerant, which means no additional oil is required, and SOQ can remain at 180 cc *(see Unicla 20% rule described in System Oil Quantity (SOQ) Section below)*. Therefore COL should always be 36 - 54 cc.

2. Systems with extra oil added to the system - which have refrigerant levels sufficient to require more oil other than the original ex-factory level shipped with the compressor. These systems should maintain 15-30% of the total system oil quantity (SOQ) in the sump during operation (see *Table* 6 on page 21). An example is a UP200 compressor with its original factory oil of 180 cc operating in a system with <1200 grams of refrigerant, which means additional oil of 60 cc is required, and SOQ is 240 cc (*see Unicla 20% rule* described in System Oil Quantity (SOQ) section below). Therefore, COL should always be 36-72 cc.

As a typical example, the Unicla UP200 compressor as shown operating in *Diagram* 9 on page 10 has oil levels as follows;

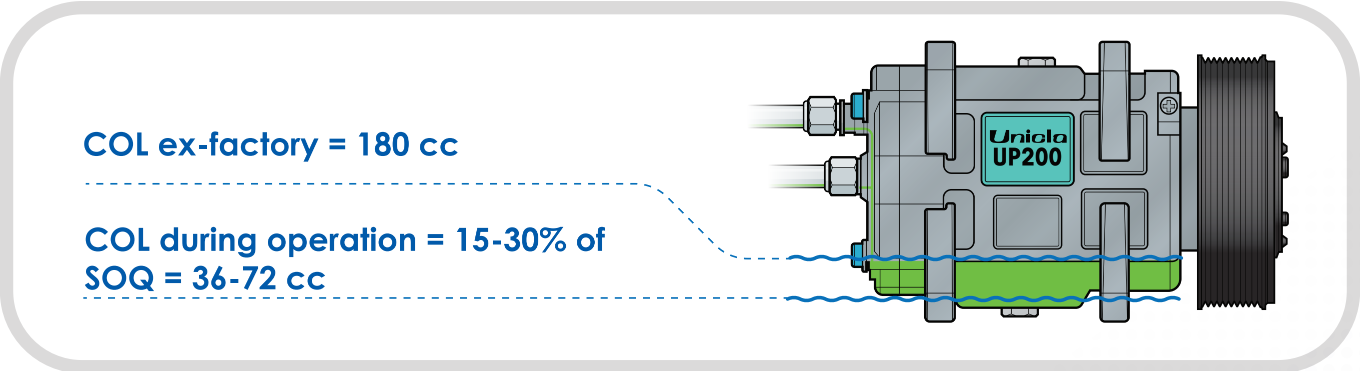


Diagram 21. UP200 as shown operating in *Diagram* 9 on page 10 with refrigerant of 1200 grams and SOQ of 240 cc. Oil level in sump is shipped from the factory with 180 cc, and during operation this reduces to 15-30% of SOQ = 36-72 cc.

System oil quantity (SOQ)

A well designed air-conditioning or refrigeration system will have an adequate balance of oil quantity to refrigerant level in the system, which is referred to by Unicla engineers as System Oil Quantity (SOQ). This is recommended to be a minimum of 20% of oil to refrigerant ratio, calculated by volume. For example a system with 1200 grams of R134a refrigerant should have 240cc oil (1200 x 20/100 = 240 cc).

Different systems are able to operate with alternative SOQ levels. Some systems may be capable of having less oil, which in theory promotes slightly better heat transfer in the system heat exchangers, whereas other systems may need more oil due to some design issue in the system circuit that compromises the oil return rate to the compressor.

The SOQ must be sufficient to ensure the compressor maintains the correct oil level so that all components in the compressor receive adequate lubrication at all times. Modern automotive and transport AC and refrigeration systems have in recent years increased oil levels in line with increasing variable compressor speeds and higher system efficiencies. It was once thought that any SOQ level higher than 10% was excessive, however *Table 5* below lists a sample of recent and popular vehicles with relative oil and refrigerant quantity data with average SOQ levels in the 20% region.

Vehicle	Oil type	Oil volume	Ref charge	SOQ%
Toyota Hilux KUN26R 1KD-FTV 3.0 Turbo Diesel (05-15)	PAG46	80 mL +/- 15 ml	450 g +/- 30 grams	17.78%
Hyundai FD i30 G4FC 1.6 Petrol (07-12)	PAG46	150 mL +/- 10 ml	500 g +/- 25 grams	30.00%
Mazda CX-7 ER L3 2.3 Turbo Petrol (06-12)	PAG46	120 mL	500 g +/- 25 grams	24.00%
Mitsubishi Mirage LA AO3 1.2 Petrol (13-Current)	PAG100	60 mL	270 g +/- 20 grams	22.22%
Toyota Camry ASV50R 2AR-FE 2.5 Petrol (11-17)	PAG46	100 mL +/- 15 ml	500 g +/- 50 grams	20.00%
Audi Q7 4 LB CASA 3.0 Turbo Diesel (07-10) Dual System	PAG46	245 mL +/- 15 ml	1050 g +/- 50 grams	23.33%

Table 5. Popular vehicles with refrigerant and oil quantity data, and SOQ%.

Oil in circulation (OIC)

In normal refrigeration and air-conditioning circuits there is always a percentage of oil discharged from the compressor as part of the compression process, which circulates in the system. This amount of oil circulating in the system is referred to as the oil in circulation (OIC), which includes the combination of oil mixed with refrigerant (miscible oil) and oil accumulating in various system components other than the compressor. OIC is also sometimes referred to as oil retention, however Unicla engineers prefer to use this term when considering the amount of oil in individual components of the system (referred to as 'oil retention' in the component such as the evaporator or condenser).

Calculating OIC

There are two equations used by Unicla engineers to calculate OIC:

Equation 1. $\mathbf{OIC_{Total} = SOQ - COL}$

Equation 2. $\mathbf{OIC_{Total} = OIC_{Component} + OIC_{Refrigerant}}$

Equation 1

Unicla recommends engineers and technicians should pay attention to OIC equation 1 (above) because it can be used as a useful and practical tool to determine if a system is sufficiently balanced to ensure proper lubrication is taking place, particularly for the compressor. This is simply done by knowing the original system oil quantity (SOQ) and deducting the compressor oil level (COL) immediately after system de-commissioning. To ensure the best 'snapshot' of COL is taken, the compressor should be isolated from the system immediately at the point of switching off the system,preferably after operation in balanced conditions as shown in diagram 9, so that any OIC remain separate to the compressor and does not migrate into the sump during system equalisation. It is also recommended the system is under load during this procedure as per *Section 15: Oil and compressor lubrication check list - step 6.*

Also the compressor speed should be recorded at the point of switching off and should be referenced against the OIC calculation. In depth OIC calculations require this to be done at various rpm levels if required.

A typical example calculation of a system operating with a Unicla UP200 compressor is shown in *Diagram 9* on page 10 and *Diagram 21* on page 18. The system has 1.2 kg of refrigerant and SOQ of 240 cc. As mentioned earlier, the compressor should have a minimum of 15-30% of the SOQ in the sump during operation. Different systems using a Unicla UP200 compressor will deliver results somewhere between these two minimum and maximum points depending on the variable rpm, temperature and pressure conditions, and the 20% rule *(see Unicla 20% rule described in System Oil Quantity (SOQ) Section)* will usually ensure the COL is kept in the region of these levels during operation. Therefore, OIC levels in this balanced system can be determined as follows:

Maximum $\mathbf{OIC_{Total} = SOQ - COL_{Minimum} = 240\ cc - 36\ cc = 204\ cc}$ or Minumum $\mathbf{OIC_{Total} = SOQ - COL_{Maximum} = 240\ cc\text{-}72\ cc = 168\ cc}$

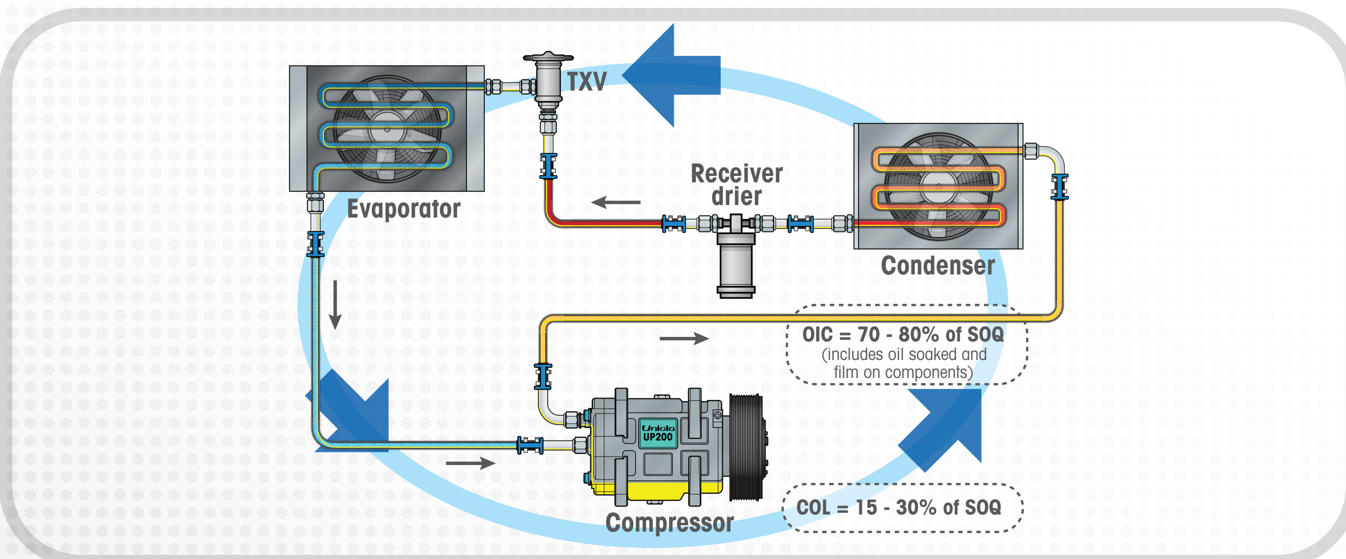


Diagram 22. Shows the clear relationship between OIC and COL as a percentage of SOQ. As an example, using the system shown in *Diagram 9*, COL = 36-72 cc and OIC = 168–204 cc.

Equation 2

This is much harder to determine and generally not very useful in the field due to the complexity associated with calculating the amount of oil miscible with the refrigerant at any given interval, and the necessity to analyse all the other components in the system to measure relative oil levels at the same interval. The method to do this requires laboratory conditions and the ability to weigh the components during system operation.

Types of OIC

When oil circulates in a system it takes on different characteristics causing it to stop and start in various forms and locations around the system. So total OIC can be separated into the categories shown in the following equation:

$$\mathbf{OIC_{Total} = OIC_{Refrigerant\ mist} + OIC_{Refrigerant\ droplets} + OIC_{Component\ pool} + OIC_{Component\ film}}$$

Diagrams 23 and 24 show a typical discharge line containing all the various types of OIC. This dynamic can occur in any of the system components, but for the purpose of illustration, a discharge line S bend is used.

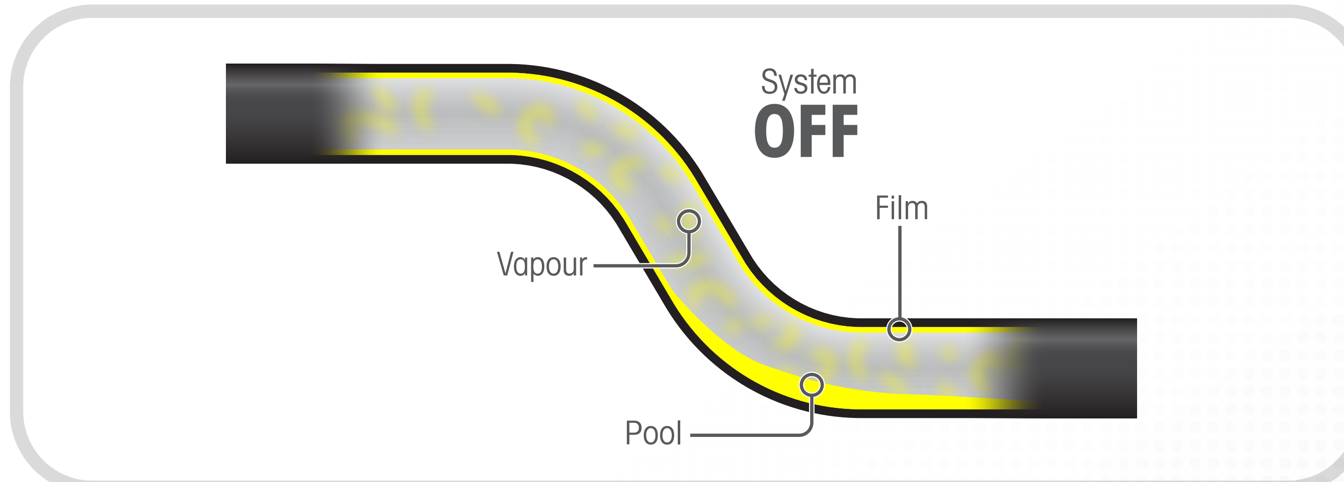


Diagram 23. The S bend of a discharge hose is typical section in a system that can have all types of OIC. In this example the system is off, so there is an oil pool, oil film and oil vaporised (miscible) in the refrigerant.

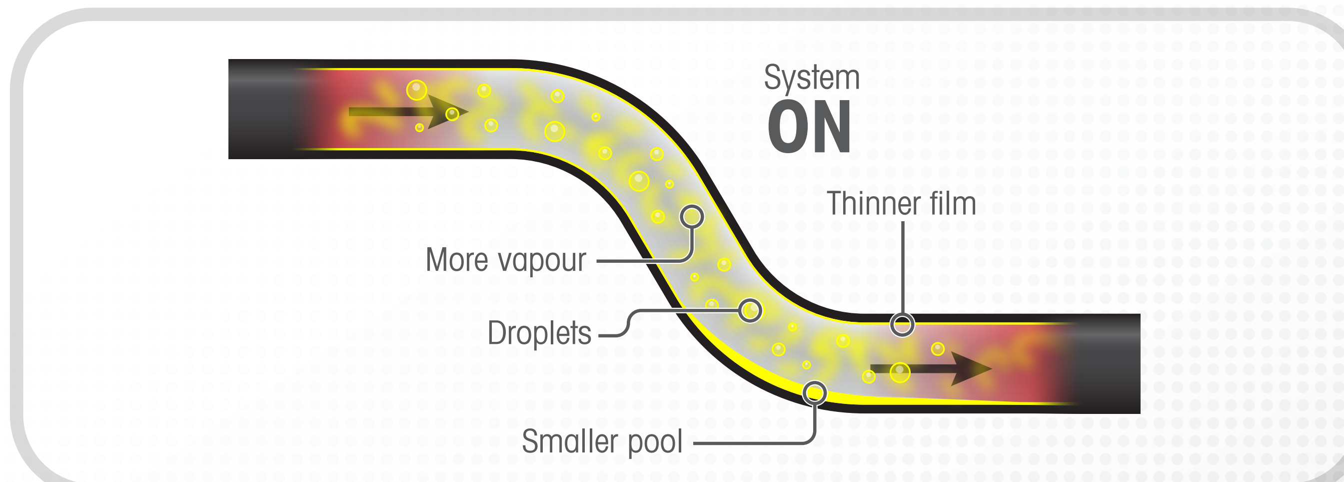


Diagram 24. The S bend in this Diagram is the same as *Diagram 22* except the system is now on, and the refrigerant is now flowing. The oil pool is smaller, the film is thinner, oil vapour (miscibility) has increased, and oil droplets are now moving in the refrigerant.

Technicians should also be aware the oil film shown in the above diagram forms part of the oil soaked in the system referred to earlier in this booklet. This is generally considered as the oil not possible to drain from the system during normal servicing and known as the 'soak amount'.

Distribution of OIC

The following *Table 6* provides a guideline of the oil quantities likely to be distributed from the total OIC in the system. This data was captured from from actual testing of a wide variety of air-conditioning and refrigeration systems operating with Unicla compressors.

The following example shown in *Table 7 and 8* and *Diagram 25* below is data from an actual system tested by Unicla engineers over a wide range of environmental conditions and heat loads. The measurements show how the OIC levels vary at different intervals depending on the conditions, and will stay within a certain range as listed *Table 6* above. Well-balanced systems performing properly will always behave consistently, and when set up properly, the OIC can always be relied on to stay within these parameters. The only time OIC will deviate from its normal behaviour is when the system develops a fault and is allowed to operate in adverse conditions or fault mode.

Component	Percentage (no oil separator)
Compressor	15-30%
Evaporator	10-20%
Condenser	10-20%
Hoses (system)	30-65%

Table 6. Distribution guideline of OIC as percentage of SOQ.

System capacity	8 kW
Refrigerant	**1.2 kg R134a**
SOQ (system oil quality)	240 cc (20% of refrigerant charge)
OIC (oil in circulation)	174-202 cc (72-84% of SOQ, or 12-14% of total system refrigerant and oil - 1440 grams)
Oil soaking	2-12 cc (1-5% of SOQ)
Oil in the compressor	36-54 cc (15-22.5% of SOQ or 20-30% of original compressor sump level)

Table 7. Oil levels and circulation measured from an actual system under test during extended operation in multiple conditions.

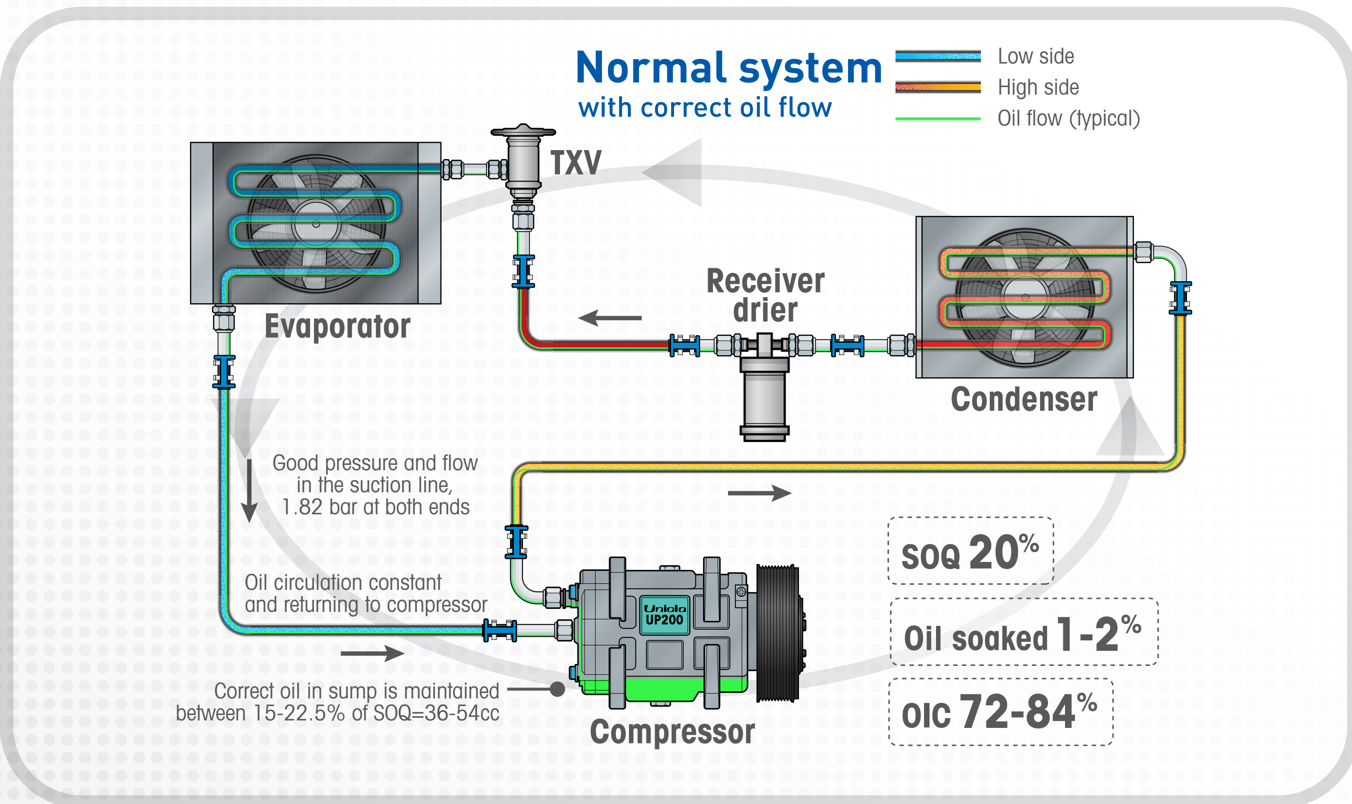


Diagram 25. Oil distribution circuit of actual 8 kW system under test with 1.2 kg of refrigerant R134a and connected to a Unicla UP200 compressor.

Oil circulation ratio (OCR)

Oil circulation ratio (OCR) is completely different to oil in circulation (OIC), however they are often confused by engineers and technicians by referring to them as the same. The fundamental difference is OCR is a rate of flow, and OIC is a mass of oil (as explained earlier). OCR is the flow rate of oil, usually shown as grams/sec, expressed as a percentage or fraction of the total refrigerant and oil flow rate.

To measure OCR accurately, very controlled and precise conditions are required which are generally not possible to achieve in the field or on a system installed on a vehicle. Techniques used can require the weighing of components during operation, refrigerant sampling from different locations in the system, or use of miniature in-line cameras focussed on passing refrigerant and oil mixtures.

The formula used for OCR calculation is;

$$OCR = \frac{\dot{m}_{oil}}{\dot{m}_{oil} + \dot{m}_{Refrigerant}}$$

An example test conducted by Unicla research and development centre in Australia using a weighing of components and refrigerant sampling method, revealed the approximate oil circulation ratio for a 200cc compressor running at 2000 rpm is 2.18%, calculated as below. The system was placed in the standard Unicla test conditions as described in *Diagram 24* on page 20, R134a refrigerant charge of 1.2 kg, and SOQ of 240 cc (20%).

Component	Percentage (no oil separator)
Compressor	22%
Evaporator	12.4%
Condenser	9.1%
Hoses (system)	56.5%

Table 8. Oil distribution of separate components in system as shown in *Diagram 24* on page 20 after one test interval.

$\dot{m}_{oil}$ = Oil mass flow rate (from the test results): 1.255 g/s. This was obtained by using a special test rig to enable the use of weighing scales under each heat exchanger during operation, and by conducting a 'system chop' (simultaneous system stopping with component isolation) to individually measure refrigerant and oil quantities in the lines.

$\dot{m}_{oil} + \dot{m}_{Refrigerant}$ = Refrigerant and Oil mass flow rate : 57.583 g/s. Measured from flow meter data.

$$OCR = \frac{1.255}{57.583} = 2.18\%$$

11. Oil separators

Oil separators are recommended in systems where the oil return to the compressor is potentially lower than it should be, at risk from a design feature in the system, or from adverse conditions created by system operation. These can include:

- Very long hose runs (> 6 metres), particularly in the suction line causing pressure drop and reduced refrigerant and oil flow
- Low evaporator temperatures as found in transport refrigeration systems, causing oil to pool in the evaporator coil
- Large or multiple heat exchangers providing locations for oil to pool, as found in bus and coach rooftop applications
- Air-conditioning systems where the condensing temperature is greater than 50°C and the evaporating temperature is lower than -5°C
- High-revving and continuous compressor operation causing excessive oil discharge from the compressor in relation to oil return

Oil separators are also recommended in systems where evaporator capacity is marginal and oil in the evaporator is affecting system efficiency. Reducing oil in the evaporator improves evaporator saturation temperatures by allowing optimum heat absorption in the refrigerant.

Unicla has three oil separator models available which are suited to different size compressors as shown in *Table 9* on page 23.

Pressure			Oil return rate		
MPA	PSI	KPA	A Type	B Type	D/F Type
3	435	3000	40 ml/min	60 ml/min	92 ml/min
2	290	2000	30 ml/min	40 ml/min	64 ml/min
1	143	1000	10 ml/min	13 ml/min	21 ml/min
0.75	108	750	8 ml/min	10 ml/min	16 ml/min

Table 9. Unicla oil separator models and specifications.

The oil separators are installed in the discharge line and are pressure operated. The picture and *Diagram 26* below shows the cross-section of the receiver section, mesh and collection coil inside the separator.

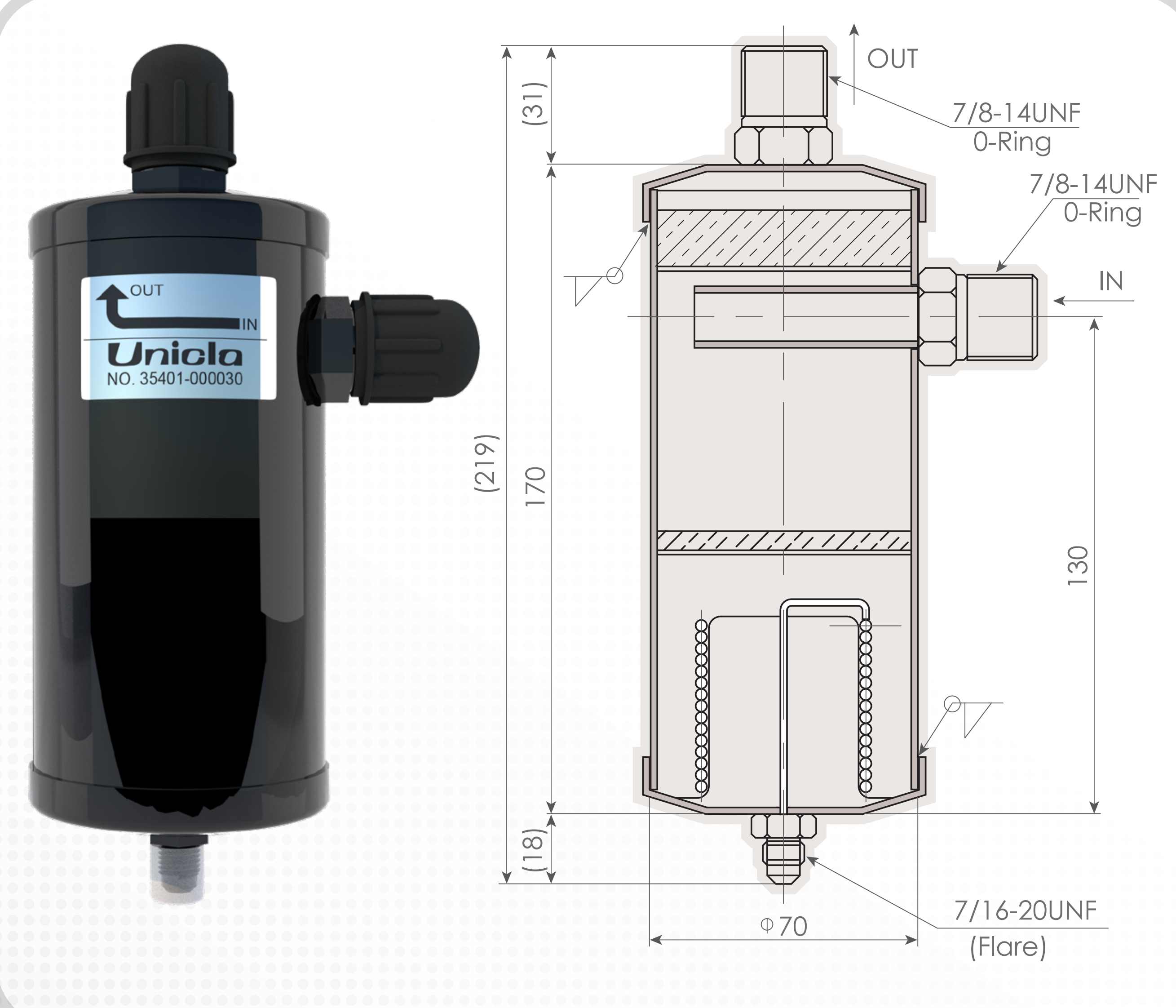


Diagram 26. Unicla 35401-000030 oil separator design and internal section.

The following *Diagram 27* shows a Unicla oil separator installed into the circuit. In this example the system is the standard system mentioned in *Diagram* 9 on page 10 except the oil separator fitted is showing how the more oil is retained in the compressor, COL is increased and OIC is reduced.

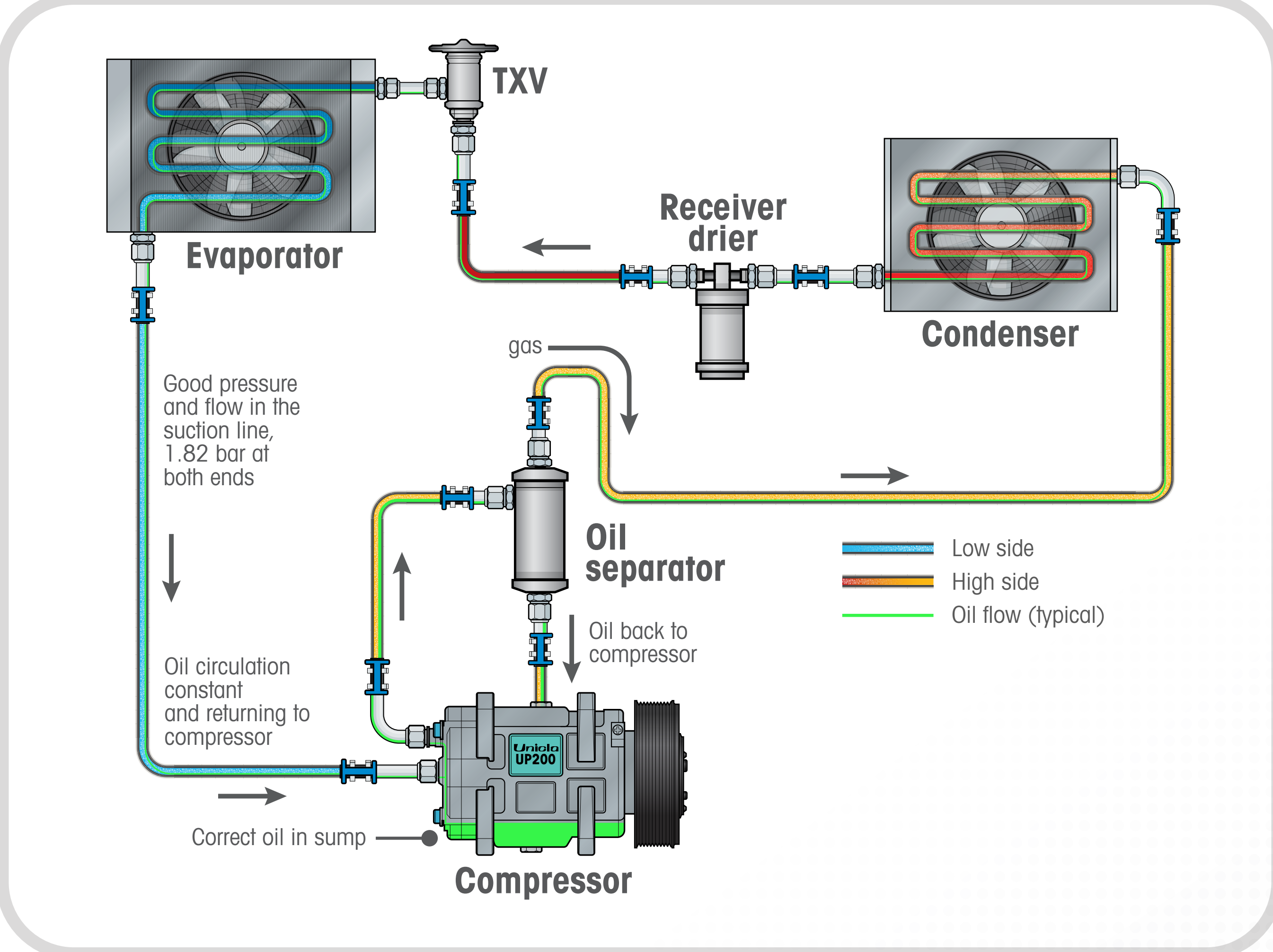


Diagram 27. 8 kW system with 1.2 kg of refrigerant R134a connected to a Unicla UP200 compressor and oil separator.

System capacity	8 kW
Refrigerant	**1.2 kg R134a**
SOQ (system oil quality)	240 cc (20% of refrigerant charge)
OIC (oil in circulation)	118-142 cc (50-60% less oil soaking)
Oil soaking (film)	2-12 cc (1-5%)
COL (compressor oil level)	96-120 cc (40-50%)

Table 10. Oil distribution circuit and components of actual 8kW system shown in *Diagram 27* under test with 1.2 kg of refrigerant R134a and connected to a Unicla UP200 compressor.

Unicla oil separators when used in systems with OCR of between 1-5% will retain compressor oil levels (COL) of 40-50% of system oil quantity (SOQ), as shown in the example above. OCR levels in system are affected by a wide range of system conditions and parameters, however as mentioned earlier Unicla compressors will consistently function within an OCR range of 1-5% when SOQ is ≤ 20% of the system refrigerant charge.

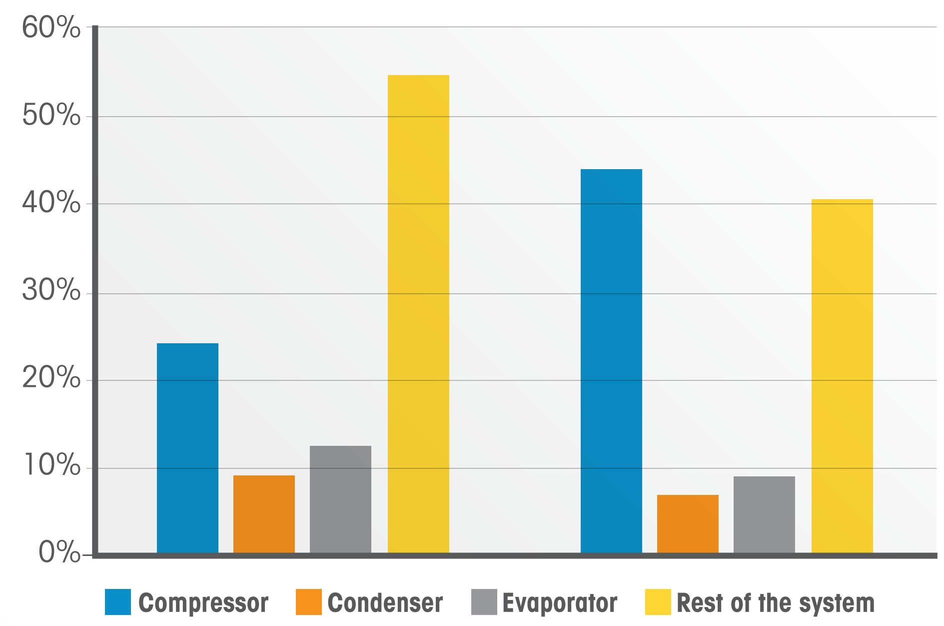


Diagram 28. Oil retention in separate components as shown in *Diagram 25* on page 21 (system with no oil separator) compared to system in *Diagram 27* on page 24 (system with oil separator) from total OIC.

Results from actual system testing by Unicla are shown in *Diagram 28*. When an oil separator is used there is a large reduction of OIC, particularly in the evaporator which as mentioned earlier, is sometimes very important in systems with marginal capacity or efficiency issues. The reduction in oil pooling in the evaporator is crucial in these circumstances.

	No oil separator		With oil separator	
Component	**Percentage**	**mL**	**Percentage**	**mL**
Compressor	24%	57.6	43.8%	105.6
Evaporator	12.4%	29.7	8.9%	21.8
Condenser	9.1%	21.8	6.8%	16.7
Hoses (system)	54.5%	130.9	39.9%	95.9
TOTAL	**240 mL**			

Table 11. Oil distribution of separate components as shown in *Diagram 25 (system with no oil separator)* compared to system in *Diagram 27 on page 24 (system with oil separator).*

Table 12 provides a general guideline comparison of SOQ percentages found in system components during normal operation and no fault in the system.

Component	Percentage (no oil separator)	Percentage (with oil separator)
Compressor	15-30%	40-50%
Evaporator	10-20%	5-10%
Condenser	10-20%	5-10%
Hoses (system)	30-65%	30-50%

Table 12. Oil distribution guideline comparison of SOQ percentages in separate system components when oil separators are used.

12. Contamination and breakdown

Compressor lubrication relies on pure oil being present during operation at all times, which only fails when the oil is insufficient in quantity (low), has something foreign added to it (contamination), or something is done to it to change its chemical structure (breakdown). Any of these situations will cause poor lubrication in a compressor, and it is important to know how and why his can happen in systems.

Foreign particles

Due to handling
Foreign materials such as dirt, metal, plastic and other solids, liquids and gasses can be introduced when careless practices are used to add lubricant to the compressor or when charging the system with refrigerant. Unicla recommends the following as mandatory service practices;

- Always use pure oil in the compressor which is preferably taken from a sealed metal tin (refer Unicla Unidap oil range)
- Use clean rags, hand gloves and tools
- Use recommended grade of oil suitable to the application
- Use pure refrigerant from a known source (cylinder), supplier and manufacturer.

Due to operation
All compressors and systems will over time generate foreign particles due to the wear and tear of the moving parts and continual flow of refrigerant in the system circuit. Refrigerants are excellent cleaners and eventually carry contaminants back to the compressor oil. Periodic service, oil and filter changes, ensure that the contaminants are removed before they can build up to a point of causing damage.

Common types of contamination:

- Chips from broken reed valves
- Particles from the casting process used for the compressor body, heads, and other cast alloy and iron components
- Moisture ingress via system components and seals
- Particles from rubber lines
- Green slime from copper lines
- Silcone or rubber material from flexible hoses.

Diagram 29. Pure oil can develop green slime or particle contamination during operation, or both.

Foreign particles

Due to sludge
Sludge is caused by chemical breakdown of the oil, most commonly due to operating temperatures which are higher than the oil rating, usually above 120°C.

High system temperatures occur in the discharge side and compressor which can be caused by:

- Poor condenser performance
- Low refrigerant levels
- Flow restriction in the system lines
- Pressure drop in the suction line
- Low compressor oil
- Extreme ambient conditions
- Moisture in the system

The most effective and obvious means of eliminating the creation of sludge is through regular system servicing which includes regular filter drier change, charging and evacuation procedures, leak check and sampling of oil condition and quantity.

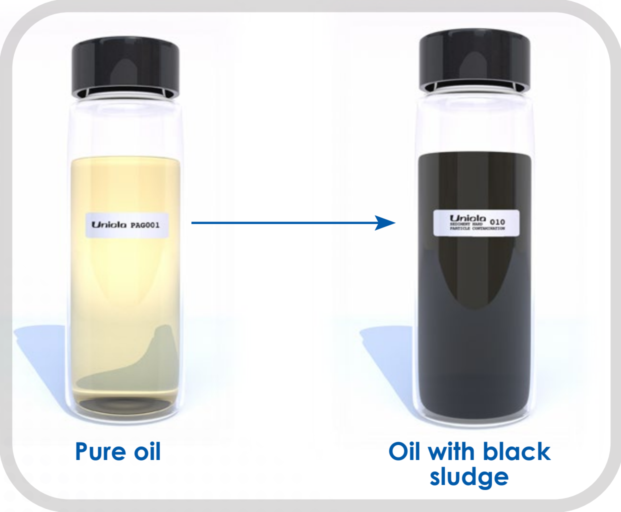


Diagram 30. Pure oil can develop black sludge or particle contamination during operation, or both.

Foreign particles

Due to low compressor oil level (COL)
If the COL reduces to a critically low level to the point where friction occurs, moving components create metal particles which immediately circulate into the oil further compounding the lack of lubrication and increasing friction. High temperatures also occur which affect oil quality.

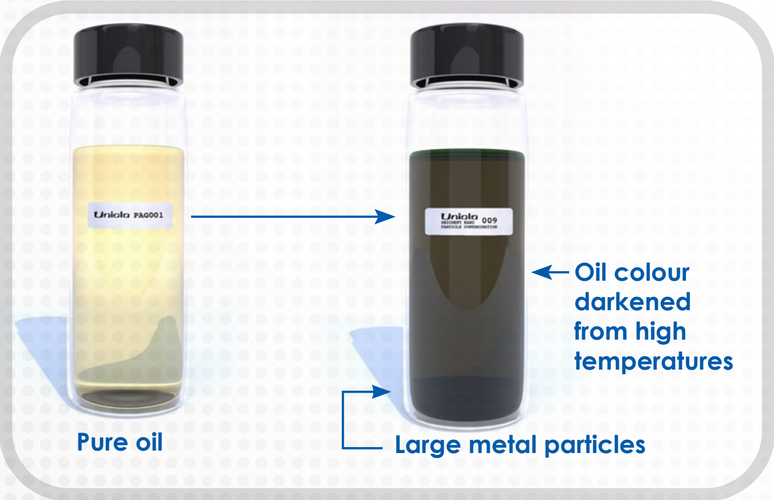


Diagram 31. Low COL causes friction between moving parts and high temperatures.

Chemical breakdown

Caused by acids
Acid formation is a significant cause of lubrication failure. Both organic and mineral acids are created depending on the refrigerant type and level of contamination and high temperature introduced to the system. Suction line leaks are particularly efficient at introducing air into the system, and the relative oxygen intake reacts with the refrigerant under high temperature to form these acids. The acid attacks any surface or component possible in the system, with copper and alloy piping being particularly vulnerable causing corrosion and producing particulates of copper and alloy salts.

Copper particulates plate onto the moving components and bearing surfaces, and form sludge in the oil channels of the crank shaft. The sludge restricts the flow of oil while the copper plating on the bearing surfaces decreases clearances, and operating temperatures rise. Once this cycle begins it is an ever-accelerating breakdown of the oil due to high temperature.

Caused by moisture
As mentioned in the previous section, moisture is introduced to systems from poor handling procedures (storage, pouring and decanting), inadequate filter drier replacement and evacuation during system servicing, and system leaks (most severe on the suction side). Once in the system, moisture contributes to acid formation and overall chemical degeneration of the oil.

Caused by excessive temperatures
Also mentioned earlier, excessive system operating temperatures cause oil breakdown as well as sludge, and accelerates other unwanted and negative impacts on the oil integrity.

13. Oil testing and colour

Laboratory oil testing is normally undertaken at the point of manufacture to validate the quality of the oil made, or when oil is returned from the field after use in a system and a breakdown or contamination issue has to be diagnosed. Responsible oil manufacturers will test oil quality and features by production batch to ensure the correct viscosity and pour point levels are achieved. Other tests conducted on both new and used oil are:

TAN - The total acid number (TAN) is a measurement of acidity that is determined by the amount of potassium hydroxide in milligrams that is needed to neutralise the acids in one gram of oil. It is used to estimate the amount of additive depletion, acidic contamination and oxidation of lubricant degradation.

The TAN value itself cannot be used to predict the corrosive nature of an oil, as the test only measures the amount of acid in a sample, not the specific quantities of different acidic compounds in the sample. Two samples might have the same TAN value, but one have high levels of corrosive acids while the other much lower levels of the same corrosive acids. An increase in viscosity and the formation of gums and resins are two other negative effects which can be attributed to an increased TAN value.

PQ Index - Particle Quantification (PQ Index) is the measurement of total ferrous (iron) particles present in the sample oil. PQ does not take into account size of particles. The ferrous is detected via magnetic fields and reports the total concentration of magnetic particles in the sample.

Wear metals - are the individual metal types present on the oil sample such as aluminium, chromium, copper, iron, lead manganese, nickel and tin. Laboratories use various different methods to measure these and all are reported as ppm.

Other contaminants - are any other type of substances present in the oil that should not be there. Silicon and sodium are commonly founded in contaminated refrigeration oil.

The colour of oil can be used to provide an indication of its quality or diagnose a system fault or condition. Below are some common oil conditions and colour indicators commonly found in systems using synthetic HFC and HFO refrigerants with POE and PAG oils.

Pale yellow to clear - Indicates pure unused and uncontaminated oil with zero metal particles (PQ index), TAN (total acid number) and low moisture levels. Typical lab analysis would be:

	Unidap POE	Unidap PAG
Moisture	<50 ppm	<500 ppm
TAN	<0.04	<0.10
PQ	0	0
Silicon	0 ppm	0 ppm
Wear metals	0 ppm	0 ppm

Table 13. Test data from pure Unidap PAG and POE oil samples.

Green - Green slime formation in the oil caused during high temperature operation and moisture in the system attacking the copper components. Copper compounds then become soluble with the oil and the moisture further hydrolyses the oil to form copper hydroxide. Oil viscosity is severely affected. Details from actual analysis;

	Unidap POE	Unidap PAG
Moisture	500 ppm	500 ppm
TAN	0.11	2.47
PQ	10	34
Silicon	16 ppm	171 ppm
Sodium	0 ppm	7 ppm
Wear metals		
Iron	1 ppm	12 ppm
Copper	3 ppm	5 ppm
Aluminium	16 ppm	28 ppm

Table 14. Test data from green slime infected Unidap PAG and POE oil samples.

Red - Indicates high temperature operation and the presence of moisture and acid causing a reaction with anti-wear additives such as phosphorous. Also high levels of silicon from rubber hose degradation under high temperature operation. Oil viscosity is severely affected. Details from actual analysis;

	Unidap POE	Unidap PAG
Moisture	500 ppm	500 ppm
TAN	0.48	0.23
PQ	10	17
Silicon	495 ppm	229 ppm
Sodium	1 ppm	2 ppm
Wear metals		
Iron	3 ppm	12 ppm
Copper	4 ppm	5 ppm
Aluminium	7 ppm	28 ppm

Table 15. Test data from red colour Unidap PAG and POE oil samples.

Black - Indicates high temperature operation and the presence of black sludge (also referred to as corrosive metallic salt), moisture, acid and metals which have formed part of the oil solution. Oil viscosity is severely affected. Details from actual analysis;

	Unidap POE	Unidap PAG
Moisture	500 ppm	500 ppm
TAN	0.45	0.52
PQ	67	10
Silicon	85 ppm	7 ppm
Sodium	1 ppm	1 ppm
Wear metals		
Iron	39 ppm	5 ppm
Copper	14 ppm	1 ppm
Aluminium	287 ppm	14 ppm
Lead	3 ppm	
Manganese	4 ppm	
Nickel	2 ppm	

Table 16. Test data from black colour Unidap PAG and POE oil samples.

Light orange or dark yellow - Indicates very slight presence of moisture with no other contamination of degradation of the oil quality and viscosity. Oil viscosity is unaffected. Details from actual analysis which also shows slight presence of silicon from rubber hoses used in the systems from these samples;

	Unidap POE	Unidap PAG
Moisture	≥350 ppm	≥750 ppm
TAN	<0.04	<0.10
PQ	0	0
Silicon	<5 ppm	<5 ppm
Wear metals	0 ppm	0 ppm

Table 17. Test data from light orange or dark yellow colour Unidap PAG and POE oil samples.

Dark orange or light red - Indicates a degradation of the anti-oxidant or anti-wear additives in the oil after long-term use or high temperature operation. Oil viscosity is unaffected. Details from actual analysis which also shows slight presence of silicon from rubber hoses used in the systems from these samples;

	Unidap POE	Unidap PAG
Moisture	<50 ppm	<500 ppm
TAN	<0.04	<0.10
PQ	0	0
Silicon	<5 ppm	<5 ppm
Wear metals	0 ppm	0 ppm

Table 18. Test data from black colour Unidap PAG and POE oil samples.

14. Oil examination and sampling

Oil quality should one of the main system items considered by technicians during servicing and repair in field. The can be done by taking a sample from the compressor after de-gassing and before evacuation begins, or if the compressor has sump sight glasses, an oil inspection can be done during operation.

Unicla B Group compressors (330 cc to 680 cc) have dual sight glasses so that cross-viewing can be conducted to check both oil quality and quantity. Technicians need to be aware that only oil quantity (level) can be determined (not quality) with compressors having a single sight glass due to the lack of light to illuminate the oil features as shown in *Diagram 30* below. When inspecting oil through a single sight glass without sufficient illumination, the oil will appear dark and contaminated, and oil foam during operation actually looks black, which is a false reading of the oil condition.

To obtain the best possible visual of the sight glass, it is recommend the rear sight glass is back lit with a good quality white light, preferably from an LED torch. This will produce good light through the centre of the compressor sump to allow accurate evaluation of the compressor level and quality.

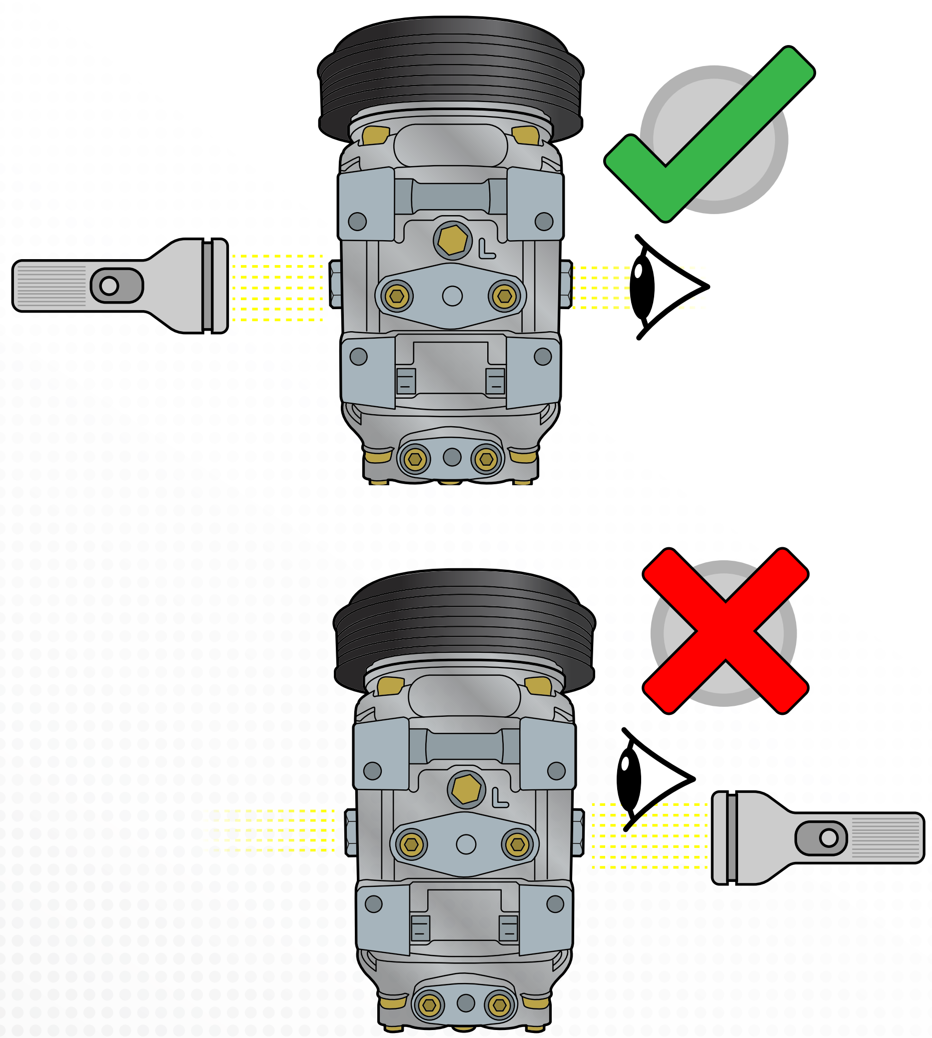


Diagram 32. Correct examination procedure of oil in a Unicla B Group compressors (330 cc to 680 cc) sight glass.

The following chart and images will assist the technician to check the sight glass of the compressor after commissioning of the system. Different operating conditions will present variable symptoms to appear at the sight glass, and Unicla recommends this must be checked immediately after commissioning and at future regular intervals during service.

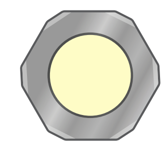
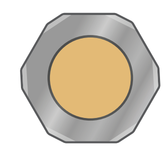
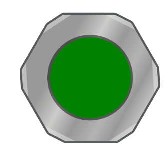
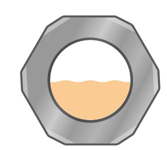
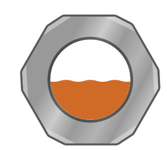
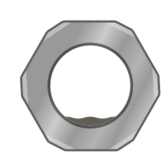
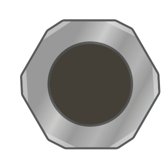
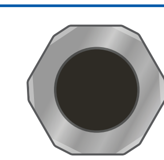
Visual	Sight glass	Oil	Operation	Recommendation
	Normal > high point	Normal - clear and transparent	OK	Nil
	Normal > high point	Possible slight moisture contamination, or high temperature operation	OK	Monitor oil condition and change if necessary
	Normal > high point	Green slime- copper hydroxide present	OK	Monitor oil condition and change if necessary
	Oil level low < half point	Normal- clean and transparent, dark sections is oil foam not contamination	Oil flow or level is low	Check suction pressure and system oil quantity
	Oil level low < half point	Normal-clean and slight orange or red colour	Oil flow or level is low and running at high temperature	Check suction pressure and system oil quantity
	Oil level < low point	Not visible	Oil flow or level is criticaly low - damage to compressor will occur Suction pressure is most likely at 1.0 bar (14 psi) or less and must be rectified	Cease system operation and check suction pressure and system oil quantity
	Normal > high point	Black and cloudy - severely contaminated	Compressor will fail	Cease system operation - clean and flush system, replace compressor oil
	Oil level < high point	Dark black-severely contaminated and has black sludge	Compressor will fail	Cease system operation - clean and flush system, replace compressor oil

Diagram 33. Compressor sight glass check table.

15. Oil and compressor lubrication check list

NEW SYSTEMS

01

ACTION
Calculate system oil quantity (SOQ) by using Unicla percentage rule, or HVAC system requirements, which ever is the greater. Minimum should be 15-20% of total system refrigerant charge.

REASON
System oil quantity (SOQ) needs to be sufficient to maintain compressor oil level (COL) during operation.

REFERENCE
Refer to *Section 10: Oil quantity in systems.*

02

ACTION
Check correct oil specification, type and viscosity.

REASON
Incorrect oil will affect or reduce lubrication and oil return to the compressor.

REFERENCE
Refer to *Section 6: Choice of oil.*

03

ACTION
Check oil quality (in compressor and oil being added) is clean and without moisture contamination.

REASON
Contaminated oil will not lubricate properly.

REFERENCE
Refer to *Section 9: Moisture, and Section 12: Contamination and breakdown.*

04

ACTION
Add oil to system to meet correct SOQ. Example as follows;
- System with 1.2kg refrigerant charge with Unicla UP200 compressor
- SOQ = 1.2kg refrigerant X 20% = 240cc
- Original compressor oil level (COL) = 180cc
- Oil to be added = SOQ (240cc) - original COL (180cc) = 60cc

REASON
Extra oil is nearly always required to meet correct SOQ, and can be added to system hoses before connection, or by injector during the evacuation and charging process.

REFERENCE
Refer to *Step 1 as explained in Section 10: Oil quantity in systems.*

05

ACTION
Evacuate and charge system to HVAC system manufacturer's requirements, or to SAE International/ASHRAE/ISO standards relevant to the system.

REASON
Proper evacuation will ensure moisture is removed from the system, and the oil will not be affected.

REFERENCE
Refer to *HVAC system manufacturer requirement and relevant standards.*

06

ACTION
Operate system under load, preferably according to the following conditions;
- Temperature of air entering evaporator side (return air) - 27°C dry bulb/ 19°C wet bulb*
- Temperature of air entering condenser side (air on) - 35°C dry bulb/ 24°C wet bulb*

Operate for a period of 20 minutes, or a time sufficient for the system to stabilise.

*Note these temperatures are referenced in Standard ISO 5151:2010 Testing and rating for performance of air conditioners and heat pumps.

REASON
Operation under load will ensure the oil will flow and behave as in real conditions.

REFERENCE
Refer to *Section 10: Calculating OIC - Equation 1.*

07

ACTION
At the completion of *Step 6*, turn off system while simultaneously isolating the compressor by using shut off valves already fitted to the compressor (for testing purposes only), or by using the hose clamping method (use vice grips or simple brake line clamps).

REASON
Simultaneous isolation of the compressor with system stopping (or system 'chop' as it is called) will capture the oil level in the compressor during operation.

REFERENCE
Refer to *Section 10: Calculating OIC - Equation 1.*

08

ACTION
Remove compressor from the system and drain oil.

09

ACTION
Oil quantity drained from compressor should be 15-30% of SOQ OR 20-30% of original factory COL.

REASON
This is the minimum oil level required in the compressor at all times for proper lubrication.

REFERENCE
Refer to *Section 10: Oil quantity in systems.*

10

ACTION
If COL is less than the required minimum, undertake Steps 1-7 (New systems) in Suction line validation check list.

REASON
Incorrect suction line size and design, and an incorrect refrigerant level are the most common causes of incorrect oil return to the compressor.

REFERENCE
Refer to *Unicla booklet B1801 - The Importance of Suction Lines.*

11

ACTION
If COL is still less than the required minimum, other components in the system need to be removed to locate the oil and determine the reason. Corrective measures may include changing oil viscosity, improving other hose design and size, increasing SOQ level, or installation of oil separator.

REASON
System components should not withhold excessive oil during operation sufficient enough to drain COL below this recommended level.

REFERENCE
Refer to *Section 11: Oil separators.*

12

ACTION
Once corrective measures in Step 10 are completed, drain and flush all system components of oil, and repeat Steps 1-9.

REASON
The system must re-start with correct SOQ.

13

ACTION
If COL is still incorrect, repeat step 11 followed by Step 12. Repeat until COL level is correct.

EXISTING SYSTEMS

If an existing system is under repair or service due to low oil in the compressor, the following action is required:

01

ACTION
Repair system to be free of faults.

REASON
Oil flow cannot be validated in a system with faults.

REFERENCE
Refer to *Section 10: Oil quantity in systems.*

02

ACTION
Drain or flush all system components of oil, including compressor.

REASON
Oil flow can only be analysed by starting at the correct SOQ.

REFERENCE
Refer to *Section 10: Oil quantity in systems.*

03

ACTION
Obtain HVAC system manufacturer's specification of oil type and level of SOQ and undertake remaining items in Steps 1-6 (New system oil flow validation).

REASON
System manufacturer's recommendations must be followed, or if not available consult compressor manufacturer (Unicla).

04

ACTION
During the operation of Step 6 (New system oil flow validation), conduct suction line analysis as in Steps 5-7 (Suction line validation check list).

REASON
The suction line plays an important part in oil flow to the compressor.

REFERENCE
Refer to *Unicla booklet B1801 - The Importance of Suction Lines.*

05

ACTION
Once suction line is validated, and all other steps followed, the system should now meet correct specifications. If manufacturer's specifications are in doubt, then undertake steps 7-12 (New system oil flow validation).

REASON
In the absence of manufacturer's correct recommendations, necessary checks and validations are required.

REFERENCE
Refer to *Section 10: Calculating OIC - Equation 1, and Section 11: Oil separators.*

Notes

Notes

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