



Unicla

THE IMPORTANCE OF SUCTION LINES

**Analysis and connection
to compressors**



Unicla

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Table of Contents

| | |
|----------------------------------|---|
| Introduction | 1 |
| Suction line analysis | 1 |
| Suction line pressure drop | 2 |
| Hose selection | 3 |
| Hose fitting selection..... | 5 |
| A fault in the line | 6 |
| Improper line routing | 7 |
| Oil flow | 8 |

Introduction

The correct hose and pipe size connecting the main components in any mobile or transport air-conditioning system is important, however it is in the suction line where extreme care should be taken in the design and size, to ensure adequate flow of refrigerant is present in the system at all times.

Pressure and temperature conditions in the suction line can be used as excellent diagnosis tools for system performance. By analysing the suction line properly, correct refrigerant levels, systems faults and capacity can be determined quite easily. Low refrigerant level is the most common fault causing adverse conditions in the line and system, including incorrect sizing and design of the line itself. This booklet will cover the main system features adversely affected by poor suction line performance.

Suction line analysis

A suction line analysis is completed by taking both pressure and temperature measurements between the two points A and B as shown in diagram 1. In this normal healthy suction line the pressure is the same at both points (1.82 bar or -1°C), and the temperature is 8°C at point A and 9°C at point B. This means only 1°C additional temperature (or super heat) has been picked up in the line during operation, which is very typical and normal for most systems.

The super heat at any particular point is calculated by taking the actual line temperature and deducting the saturation temperature of the refrigerant (Refer to R134a Pressure and Temperature Chart) at the same point.

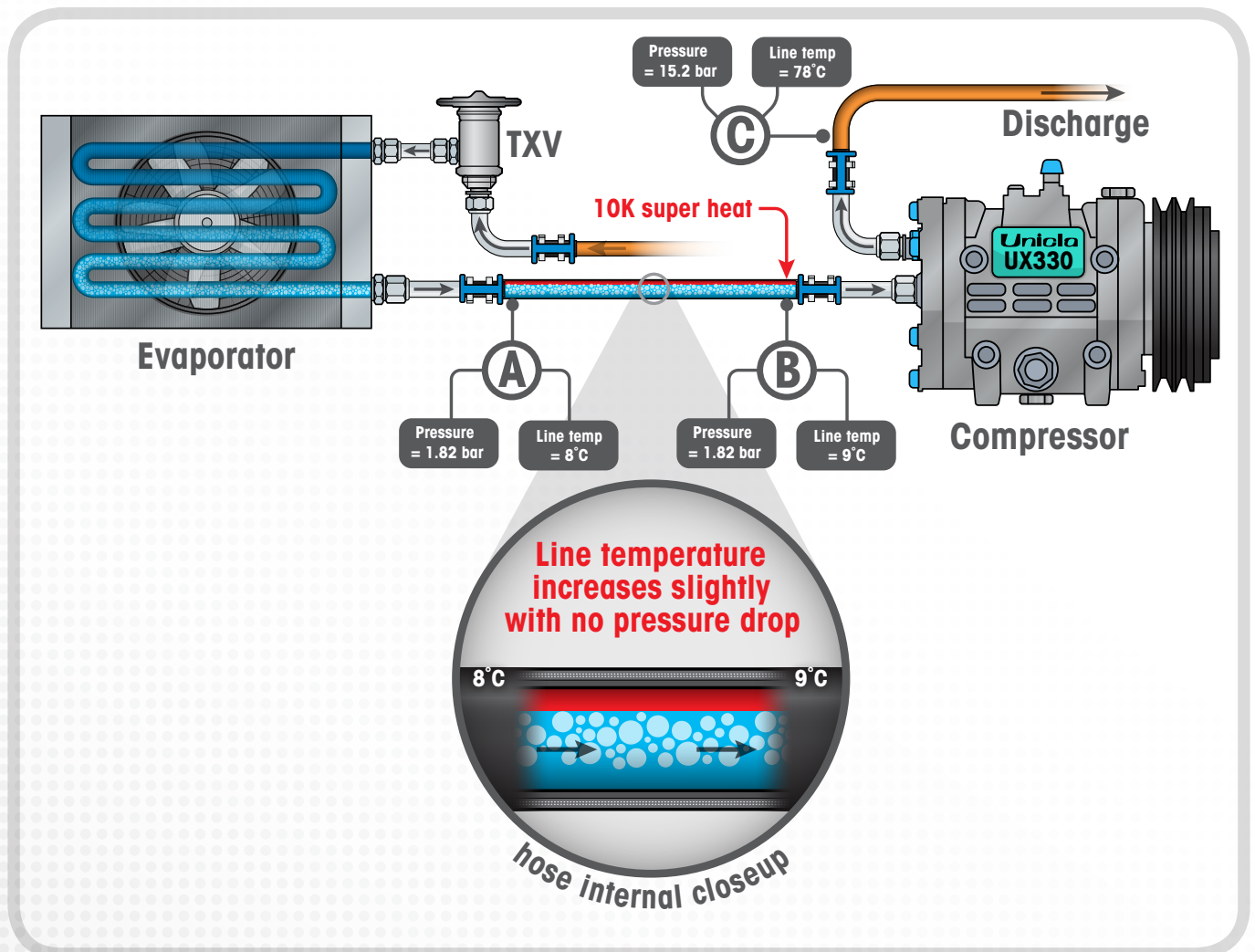


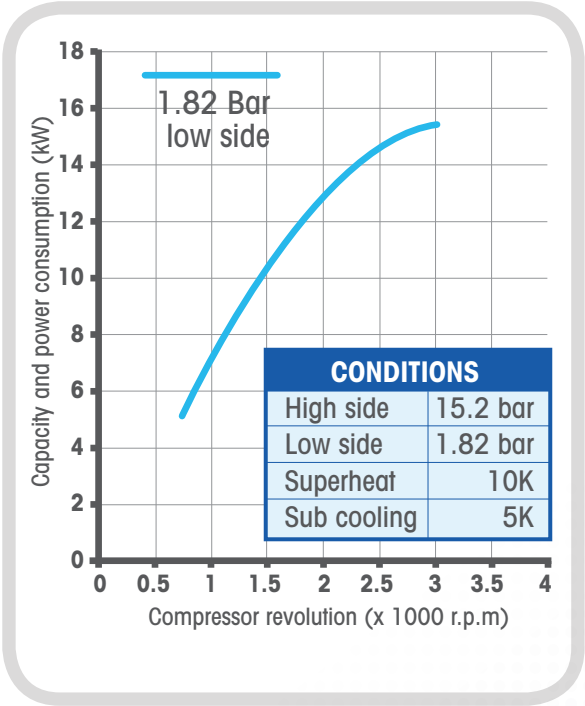
Diagram 1.

System operating normally with Uniola UX330 operating at 2000 rpm, High side 15.2 bar. Low side 1.82 bar. Superheat 10K. Sub-cooling 5K. Compressor capacity is 12.8 kW.

| Measuring point | Position | Pressure | Pressure drop | Refrigerant temp* | Line temp | Superheat and pressure drop | Diagnosis |
|-----------------|----------------------|----------|---------------|-------------------|-----------|-----------------------------|-----------|
| A | Evaporator outlet | 1.82 bar | Nil | -1°C | 8°C | 9K | Normal |
| B | Compressor suction | 1.82 bar | Nil | -1°C | 9°C | 10K | Normal |
| C | Compressor discharge | 15.2 bar | Nil | 58°C | 78°C | 20K | Normal |

*From R134a pressure and temperature chart.
†Degrees Kelvin or K is the primary unit of temperature measurement in the physical sciences, and is often used in conjunction with degrees Celsius and whenever reference is made to super heat in a refrigeration system. Both K and °C have the same magnitude.

Table 1. Suction line and discharge line analysis of normal system shown in diagram 1.



Graph 1.

Suction line pressure drop

The most prominent feature of poor refrigerant flow in the suction line is the decrease in compressor capacity and cooling. This poor refrigerant flow can easily be diagnosed by analysing the line for pressure drop between point A and B as shown in diagrams 1 and 2. No difference in pressure between these two points

indicates a healthy functional line (diagram 1), however if excessive pressure drop is present, an investigation should be undertaken to determine the cause. The most common is low refrigerant level, which should be discounted first by removing the refrigerant from the system and measuring the quantity

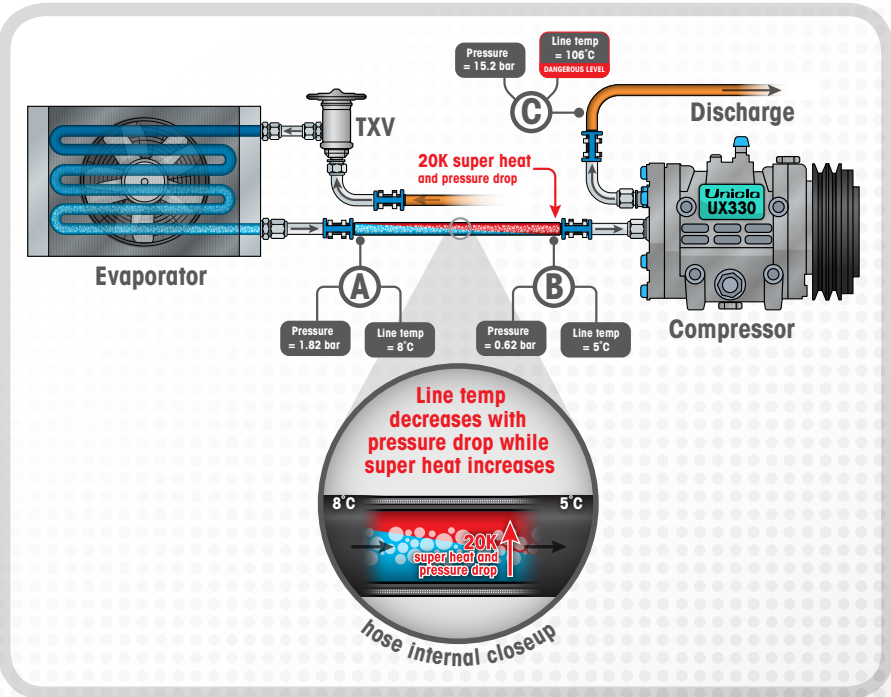
to ensure the correct level is present according to the system requirement.

Once the correct refrigerant level is determined, and the pressure drop is still present, then an investigation into the line itself is required.

The following diagram 2 shows the reduction in cooling capacity of the same Unicla UX330 compressor (shown in diagram 1) operating in typical conditions on a system with a suction line pressure drop of 1.2 bar. Capacity reduction is a hefty 65%.

Note:
This capacity reduction of 65% is assumed without considering further adverse effects on the condenser performance which would increase capacity reduction even further.

Diagram 2. Unicla UX330 compressor is operating at 2000 rpm, high side 15.2 bar. Low side 0.62 bar at the compressor and 1.82 bar at the evaporator. Superheat and pressure drop is 20K. Sub-cooling 5K. Compressor capacity is 4.5 kW which is a reduction of 65% from 8 kW shown in diagram 1.



Technicians and engineers should be aware when a pressure drop is present in a suction line, the line temperature at the compressor is almost always lower than the line at the evaporator (see points A and B in diagram 2), which is commonly mis-diagnosed as a healthy condition with cool refrigerant returning to the compressor. This actual condition is quite the opposite because the pressure is down and quantity or mass flow of refrigerant is severely reduced.

The complete analysis of the suction line with pressure drop, and its relationship to the discharge line is shown in the table 2 below. The effect on the compressor is quite dramatic, the combination of the pressure drop and even more superheat accumulation in line amounts to a total of 20K.

Calculated as follows:

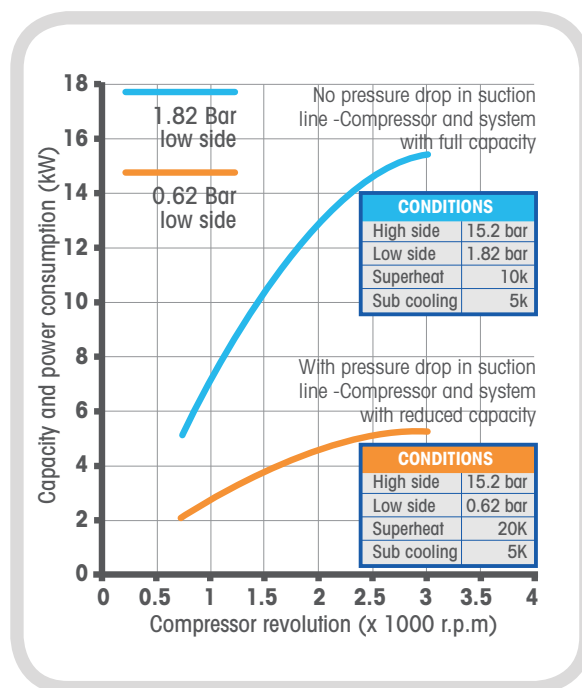
7K (pressure drop) + 4K (extra superheat in the line)
+ 9K (original superheat in evaporator) = 20K

| Measuring point | Position | Pressure | Pressure drop | Refrigerant temp* | Line temp | Superheat and pressure drop | Diagnosis |
|-----------------|----------------------|----------|---------------|-------------------|-----------|-----------------------------|------------------------|
| A | Evaporator outlet | 1.82 bar | Nil | -1°C | 8°C | 9K | Normal |
| B | Compressor suction | 0.62 bar | Nil | -15°C | 5°C | 20K | Reduced capacity |
| C | Compressor discharge | 15.2 bar | Nil | 58°C | 106°C | 48K | Compressor overheating |

*From R134a pressure and temperature chart.

†Degrees Kelvin or K is the primary unit of temperature measurement in the physical sciences, and is often used in conjunction with degrees Celsius and whenever reference is made to super heat in a refrigeration system. Both K and °C have the same magnitude.

Table 2. Suction line and discharge line analysis of system with suction line pressure drop as shown in diagram 2.



Graph 2.

This high level of superheat in the suction line reveals the lack of proper refrigerant flow and reduction of capacity at the compressor and system (as shown in graph 2). It also reduces the cooling of the compressor which is evident by the high discharge line temperature of 106°C, which places the compressor and its lubricant in the danger zone for a breakdown or complete failure.

A tip to remember is at 2000 rpm, systems with Unicla 45 cc to 330 cc compressors will produce discharge line superheat levels equal to approximately double the level of combined suction line temperature and pressure drop. In this example $2 \times 20^\circ\text{C} = 40^\circ\text{C}$, as compared to actual discharge line temperature of 48°C.

In most cases, any discharge line with super heat levels in excess of 40°C, is not only placing the compressor in danger, but is also an indication of possible pressure drop or restriction in the suction line causing capacity reduction. In these situations, both symptoms are undesirable and corrective action is required by repairing or replacing the suction to the correct size or condition.

Hose selection

To secure good suction line performance, it is imperative the correct hose or pipe size is implemented in the system. Suction line pressure drop is commonly caused by under sizing of the hose or pipe diameter as it relates to the refrigerant flow required for the system. The basic principle of this is, larger diameter hose is required as the length of the suction line increases, or when refrigerant flow demand increases in the line from higher compressor capacity and rpm.

The rules used by Unicla and Burgaflex for suction line size calculations are outlined in the ASHRAE Hand Book, Refrigeration Volume, 2006 Edition. This provides for suction line hose or pipe size recommendations so any pressure drop from friction is no greater than approximately 1 K change in saturation temperature in the line when operating at 0°C.

As an example, the system operating as shown in diagram 1 would require a suction line diameter of 22 mm (7/8") if the length was 3 to 6 metres, or 28 mm (1,1/8") diameter if the length was 10 to 12 metres .

The following diagram shows different suction hose sizes applicable to a system operating with a Unicla UX330 compressor running at 2000 rpm with hose lengths varying from 2 metres to 18 metres.

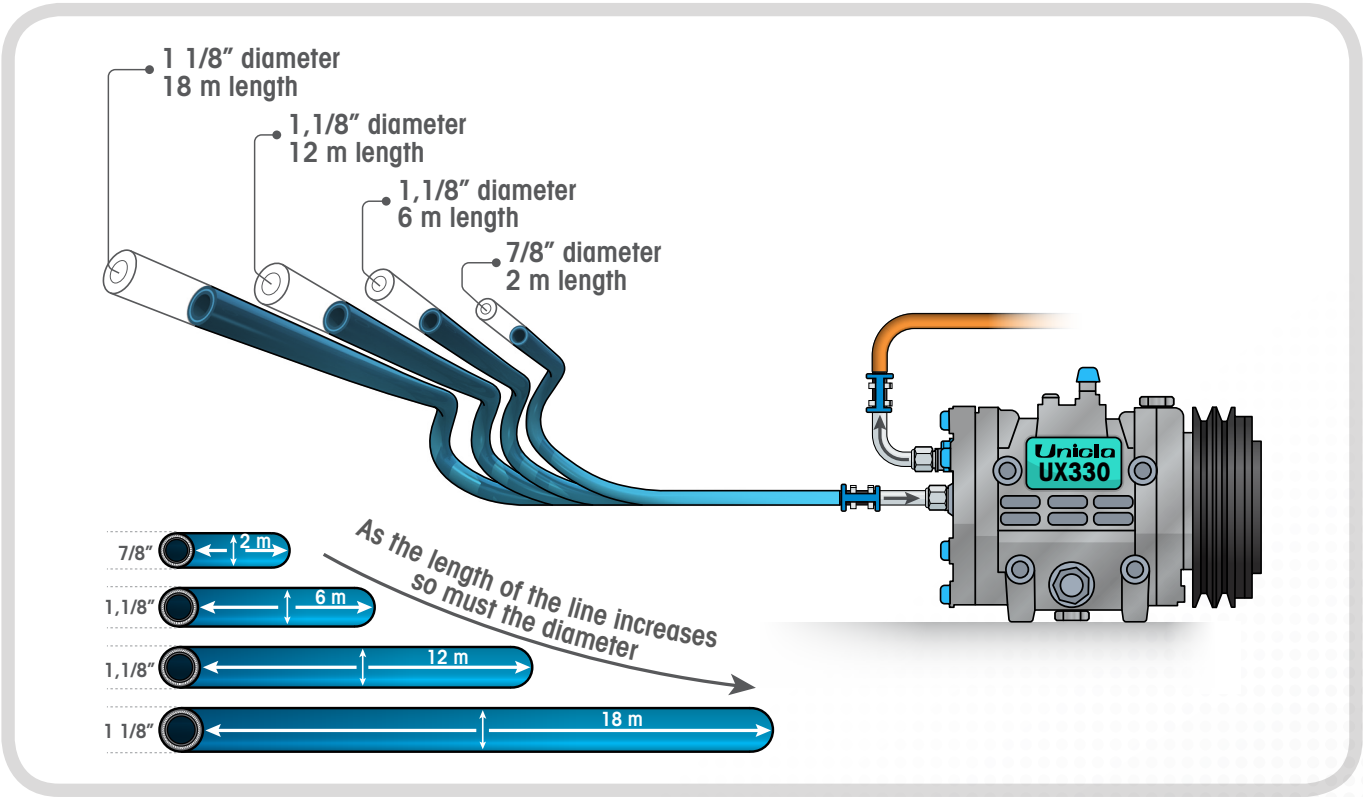


Diagram 3. A system with a 330 cc compressor operating at 2000 rpm will require different size diameter suction lines as the length of the line increases.

Mobile and transport air-conditioning applications are challenged by variable compressor speeds due to the same variable speed from the vehicle engine driving the actual compressor. System designers should take into account the optimum speed of operation for the compressor when calculating the suction line size for the system. Or alternatively, if the system is regularly reaching a particular over-speed point or 'maximum continuous' rpm levels, then the suction line capacity and size should be calculated around this. The following table shows further examples of various hose size requirements for a Unicla 330 cc compressor operating at different rpm levels.

Unicla 330 series compressors

| | | 3m pipe length | | | 6m pipe length | | | 10m pipe length | | | 12m pipe length | | | 18m pipe length | | |
|------|----------|----------------|------------------|---------------------|----------------|------------------|---------------------|-----------------|------------------|---------------------|-----------------|------------------|---------------------|-----------------|------------------|---------------------|
| RPM | RPM (kW) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) |
| 1000 | 6.25 | 0.46 | 7.7 | 19 (3/4) | 0.92 | 9.4 | 19 (3/4) | 0.71 | 7.3 | 22 (7/8) | 0.86 | 8.8 | 22 (7/8) | 0.34 | 3.5 | 28 (1,1/8) |
| 1500 | 9.25 | 0.94 | 9.6 | 19 (3/4) | 0.87 | 8.9 | 22 (7/8) | 0.38 | 3.9 | 28 (1,1/8) | 0.45 | 4.6 | 28 (1,1/8) | 0.68 | 7 | 28 (1,1/8) |
| 2000 | 11.2 | 0.70 | 7.1 | 22 (7/8) | 0.36 | 3.7 | 28 (1,1/8) | 0.6 | 6.2 | 28 (1,1/8) | 0.73 | 7.5 | 28 (1,1/8) | 1.1 | 11.2 | 28 (1,1/8) |
| 2500 | 12.9 | 0.89 | 9.1 | 22 (7/8) | 0.46 | 4.7 | 28 (1,1/8) | 0.77 | 7.9 | 28 (1,1/8) | 0.93 | 9.5 | 28 (1,1/8) | 0.48 | 5 | 35 (1,3/8) |
| 3000 | 13.25 | 0.99 | 10.1 | 22 (7/8) | 0.51 | 5.2 | 28 (1,1/8) | 0.85 | 8.7 | 28 (1,1/8) | 10.5 | 10.6 | 28 (1,1/8) | 0.54 | 5.5 | 35 (1,3/8) |

Table 3.

Hose fitting selection

The most common mistake made by system designers and technicians in the field is determining the suction hose size based on the dimensions or size of the connection points on the evaporator or the compressor. As an example, if a system has #10 fittings at both the compressor and evaporator, and the correct hose requirement is to utilise a #12 line, the correct course of action is to use single step up fittings (#10 - #12) at each end so the #12 hose can be used.

It is a complete mis-conception to assume the advantages of using step-up fittings and #12 hose in this example, are negated by the fact only #10 connection points are at each end. The most ideal situation would be to have #12 sizes over the complete suction line, however the effect of simply having #10 connection points at the ends is minimal, whereas the effects of total pressure drop in the line from using #10 over the complete line could be quite serious.

To take this point even further, the requirement to step up the hose size from the available connection point can sometimes necessitate going to the next size again. So to achieve this, 'double step up' Burgaclip fittings are now available from Burgaflex as shown in the following diagram.

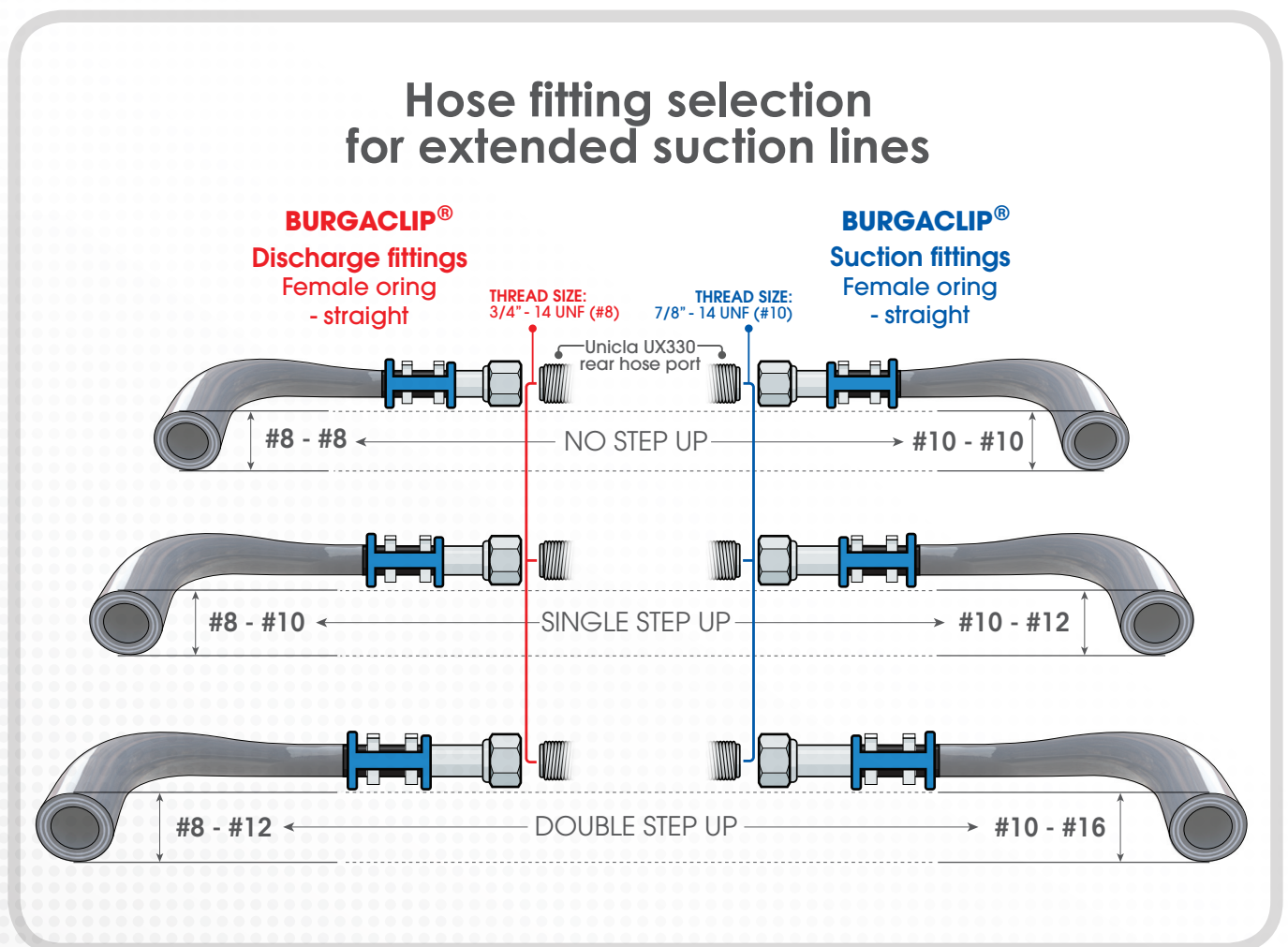


Diagram 4. Burgaclip female oring (FOR) step up fittings available across #8 to #16 hose and fitting range.

A fault in the line

Pressure drop in the suction line can also be caused by a fault or restriction in the line. In the case of a rubber hose suction line, this can be a kink caused by a sharp bend, or the hose delaminating or swelling from excessive thermal fatigue, contamination or old age. A metal line could also have a kink from a sharp bend, or a simple dent caused from an impact on the outside of the pipe.

Diagram 5 shows how such a fault causes a restriction in the line which results in an undesirable pressure drop. The effects of this are the same as described in diagram 2 where system capacity is reduced.

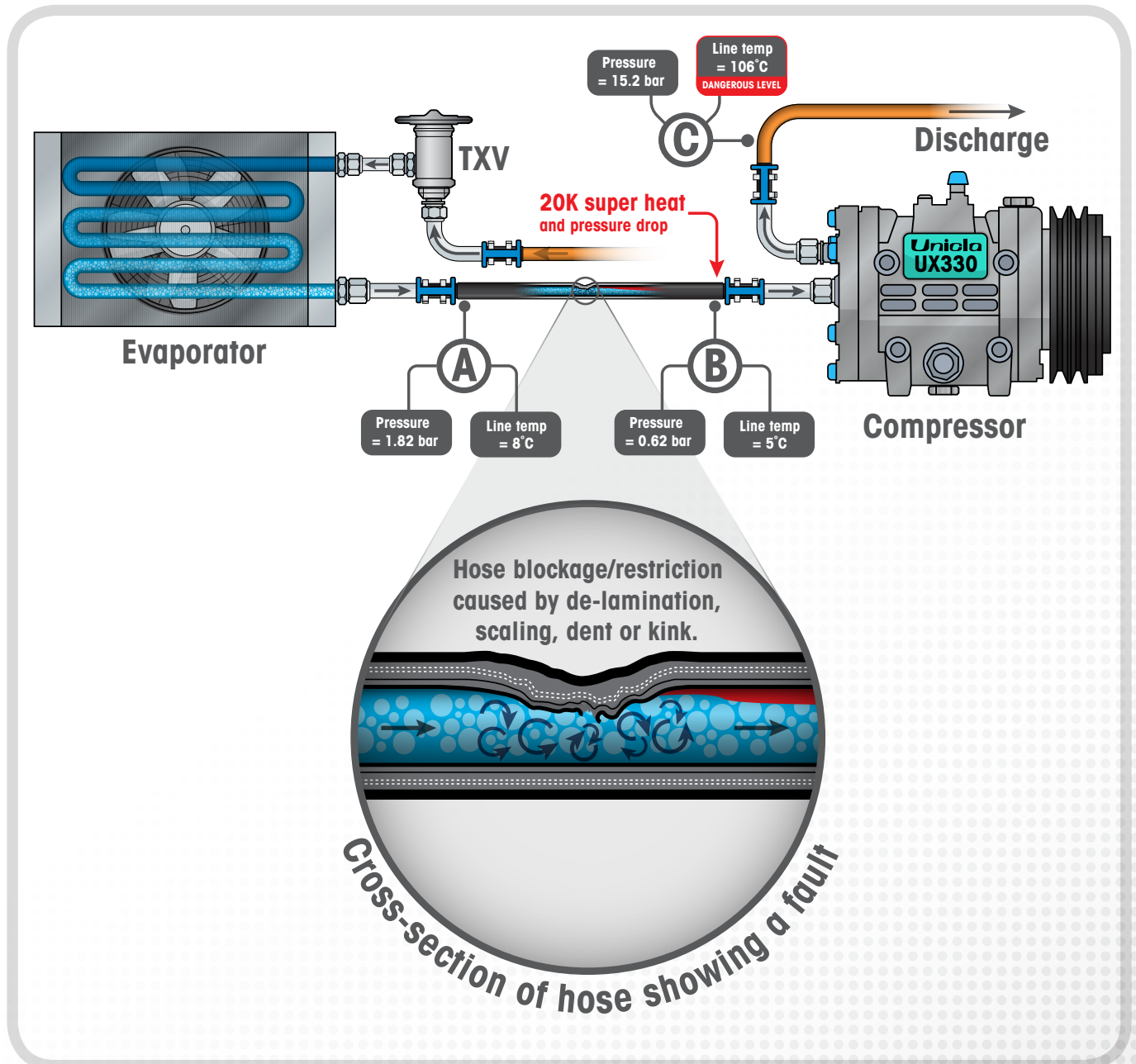


Diagram 5. Unicla compressor operating with a fault in the suction line causing the same consequences as an undersized line as shown in diagram 2.

Improper line routing

Pressure drop in the suction line can also be caused by improper routing which is commonly caused by installation of the hose or pipe over a complex or extended circuit between the evaporator and compressor, particularly as seen on many heavy machinery and large transport vehicles.

The most significant influence on pressure drop in these applications is the number of sharp turns in the line, or when an upward slope before the compressor is introduced. When both of these design events occur at the same time, Unicla engineers refer to this as the 'staircase effect'.

An example of this is shown in diagram 6 below. System capacity reduction as shown in diagram 2 also occurs in this situation if the hose size is not sufficient to compensate for the method of routing.

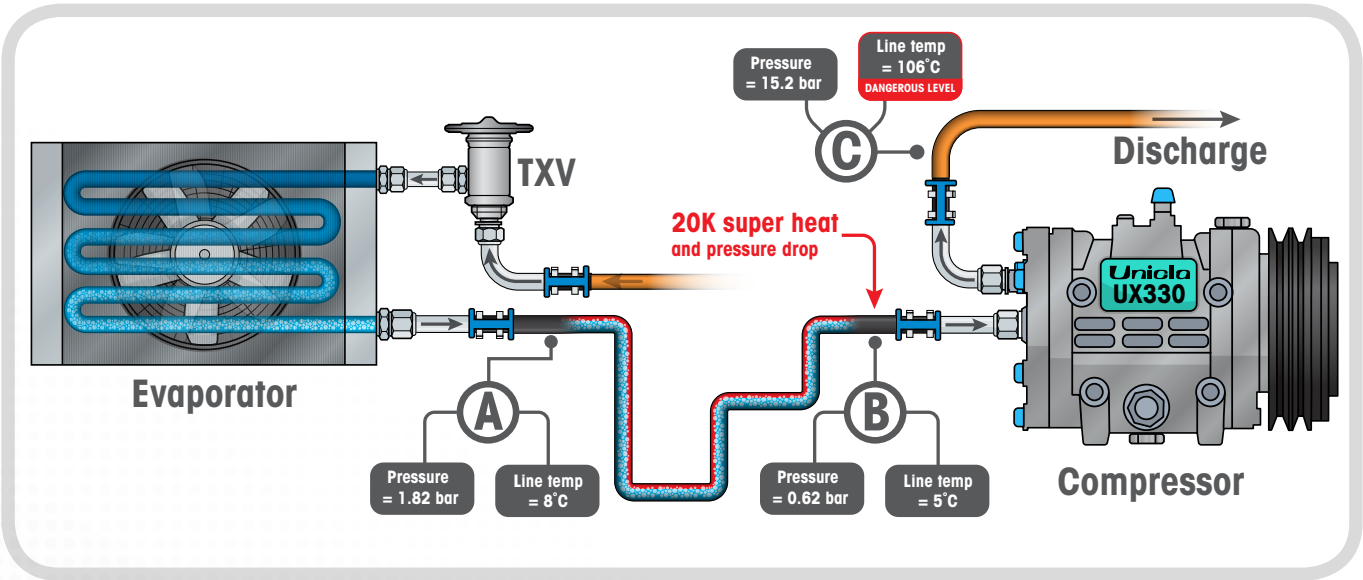


Diagram 6. Unicla compressor operating with with multiple bends and upward slope in the suction line.

System designers should avoid routing the suction line in this way wherever possible, however when multiple sharp turns cannot be avoided, then particular attention must made to the suction line size. The following Unicla table, as previously mentioned in this booklet, is an excellent guideline for this purpose. Each suction line size shown in this table assumes two bends in the line $\geq 90^\circ$ are allowed if the pressure difference is to be $< 1K$, and for every two additional bends $\geq 90^\circ$, the line must be increased by one size as shown in the table. The system as shown in diagram 6 above has 6 bends, which means two size steps are required. Therefore assuming the line is 6 metres in length and compressor optimum capacity requirement is at 1500 rpm, the line size must increase from 7/8" (22 mm) to 1 1/8" (28 mm). The effects of the upward slope would require further analysis and another step in size may be needed which is best done under practical test during system validation.

Unicla 330 series compressors

| | | 3m pipe length | | | 6m pipe length | | | 10m pipe length | | | 12m pipe length | | | 18m pipe length | | |
|------|----------|----------------|------------------|---------------------|----------------|------------------|---------------------|-----------------|------------------|---------------------|-----------------|------------------|---------------------|-----------------|------------------|---------------------|
| RPM | RPM (kW) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) | Temp diff (K) | Press diff (kpa) | Pipe size mm (inch) |
| 1000 | 6.25 | 0.46 | 7.7 | 19 (3/4) | 0.92 | 9.4 | 19 (3/4) | 0.71 | 7.3 | 22 (7/8) | 0.86 | 8.8 | 22 (7/8) | 0.34 | 3.5 | 28 (1 1/8) |
| 1500 | 9.25 | 0.94 | 9.6 | 19 (3/4) | 0.87 | 8.9 | 22 (7/8) | 0.38 | 3.9 | 28 (1 1/8) | 0.45 | 4.6 | 28 (1 1/8) | 0.68 | 7 | 28 (1 1/8) |
| 2000 | 11.2 | 0.70 | 7.1 | 22 (7/8) | 0.36 | 3.7 | 28 (1 1/8) | 0.6 | 6.2 | 28 (1 1/8) | 0.73 | 7.5 | 28 (1 1/8) | 1.1 | 11.2 | 28 (1 1/8) |
| 2500 | 12.9 | 0.89 | 9.1 | 22 (7/8) | 0.46 | 4.7 | 28 (1 1/8) | 0.77 | 7.9 | 28 (1 1/8) | 0.93 | 9.5 | 28 (1 1/8) | 0.48 | 5 | 35 (1 3/8) |
| 3000 | 13.25 | 0.99 | 10.1 | 22 (7/8) | 0.51 | 5.2 | 28 (1 1/8) | 0.85 | 8.7 | 28 (1 1/8) | 10.5 | 10.6 | 28 (1 1/8) | 0.54 | 5.5 | 35 (1 3/8) |

6 metre line size with 2 or less bends $\geq 90^\circ$ = 7/8" (22 mm)

6 metre line size with 6 bends $\geq 90^\circ$ = 1,1/8" (28 mm)

Oil flow

A well designed R134a air-conditioning system will have an adequate balance of oil quantity to refrigerant level in the system, which is referred to by Unicla engineers as the System Oil Quantity (SOQ). As a general rule this is recommended to be a minimum of 20% of oil to refrigerant ratio, calculated by volume. For example a system with 4000 grams of R134a refrigerant should have 800 cc of oil ($4000 \times 20/100 = 800 \text{ cc}$).

It should be noted different systems are able to operate with different 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 the components in the compressor receive adequate lubrication at all times.

In normal refrigeration and air-conditioning circuits there is always a percentage of this oil discharged from the compressor as part of the compression process, and 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 the refrigerant (miscible oil) and oil accumulating in various system components other than the compressor. This is different to the oil circulation ratio (OCR), which is the mass flow rate of oil, usually shown as grams/sec, expressed as a percentage or fraction of the total refrigerant and oil flow rate.

Different systems will have varying levels of OCR and OIC, however for this booklet only OIC will be studied for the purposes of showing the effects of the suction line on oil and refrigerant flow. A typical heavy vehicle air-conditioning system as shown in diagram 7 will be used as an example.

This system is a 12 kW system operating with a Unicla UX330 compressor and a R134a refrigerant charge of 4 kg. It has normal oil level behaviour, correct hose sizes and good refrigerant flow.

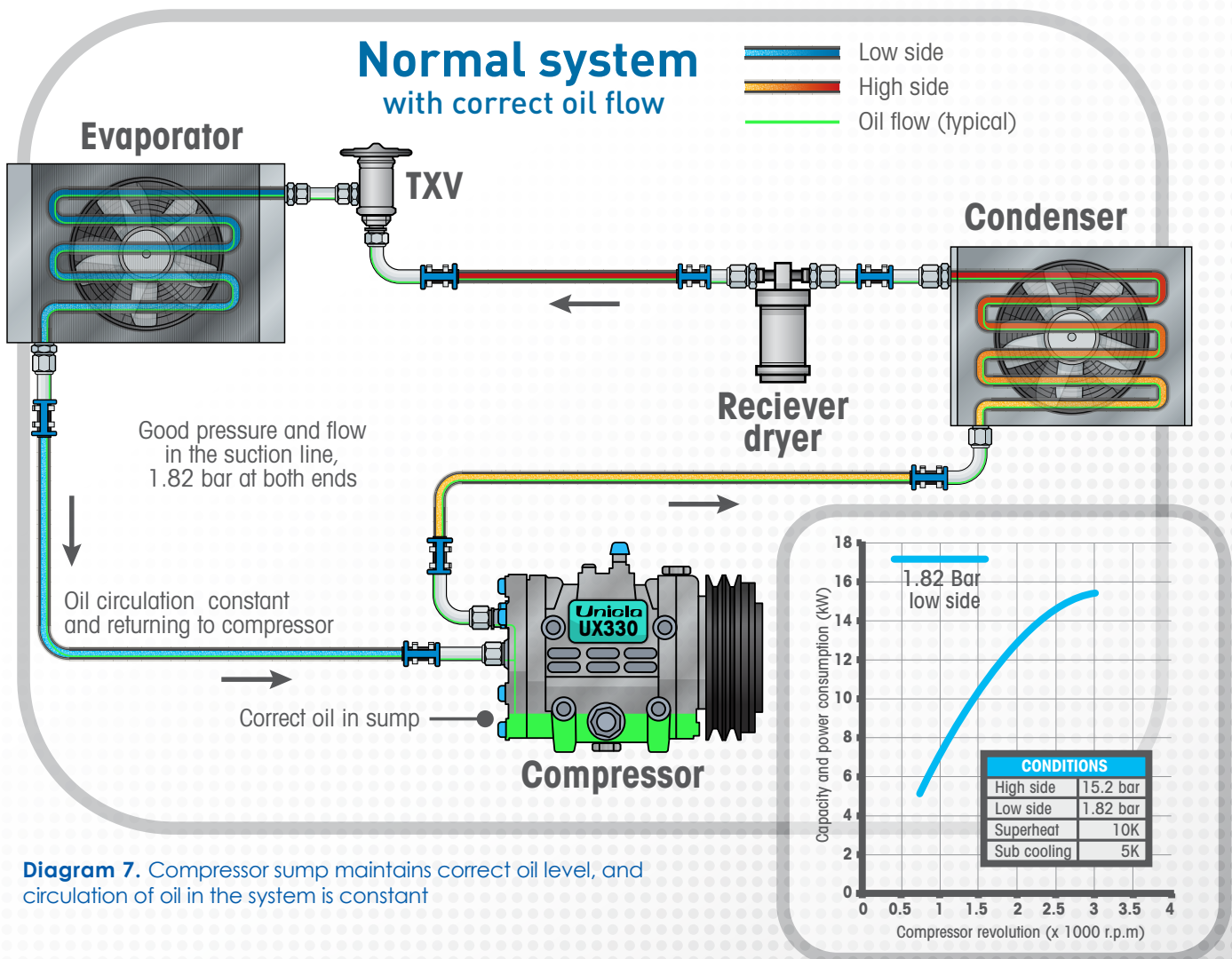


Diagram 7. Compressor sump maintains correct oil level, and circulation of oil in the system is constant

The normal system oil flow as shown in diagram 6 will stabilise at various points to approximate levels as shown in table 4 and illustrated in diagram 8. This occurs after commissioning, and operation of the system for an extended period, and includes oil soaking which is the amount of oil soaked into the system components such as hoses, receiver drier, pipes and inner walls of heat exchangers.

| System Capacity | 12 kW |
|---------------------------|--|
| Refrigerant | 4 kg R134a |
| SOQ (system oil quantity) | 800 cc (20% of refrigerant charge) |
| OIC (oil in circulation) | 576-672 cc (72-84% of SOQ, or 12-14% of total system refrigerant and oil-4800 grams) |
| Oil soaking | 8-40 cc (1-5% of SOQ) |
| Oil in the compressor | 120-240 cc (15-30% of SOQ) |

Table 4. Oil levels and circulation at various points in the system after commissioning and extended operation

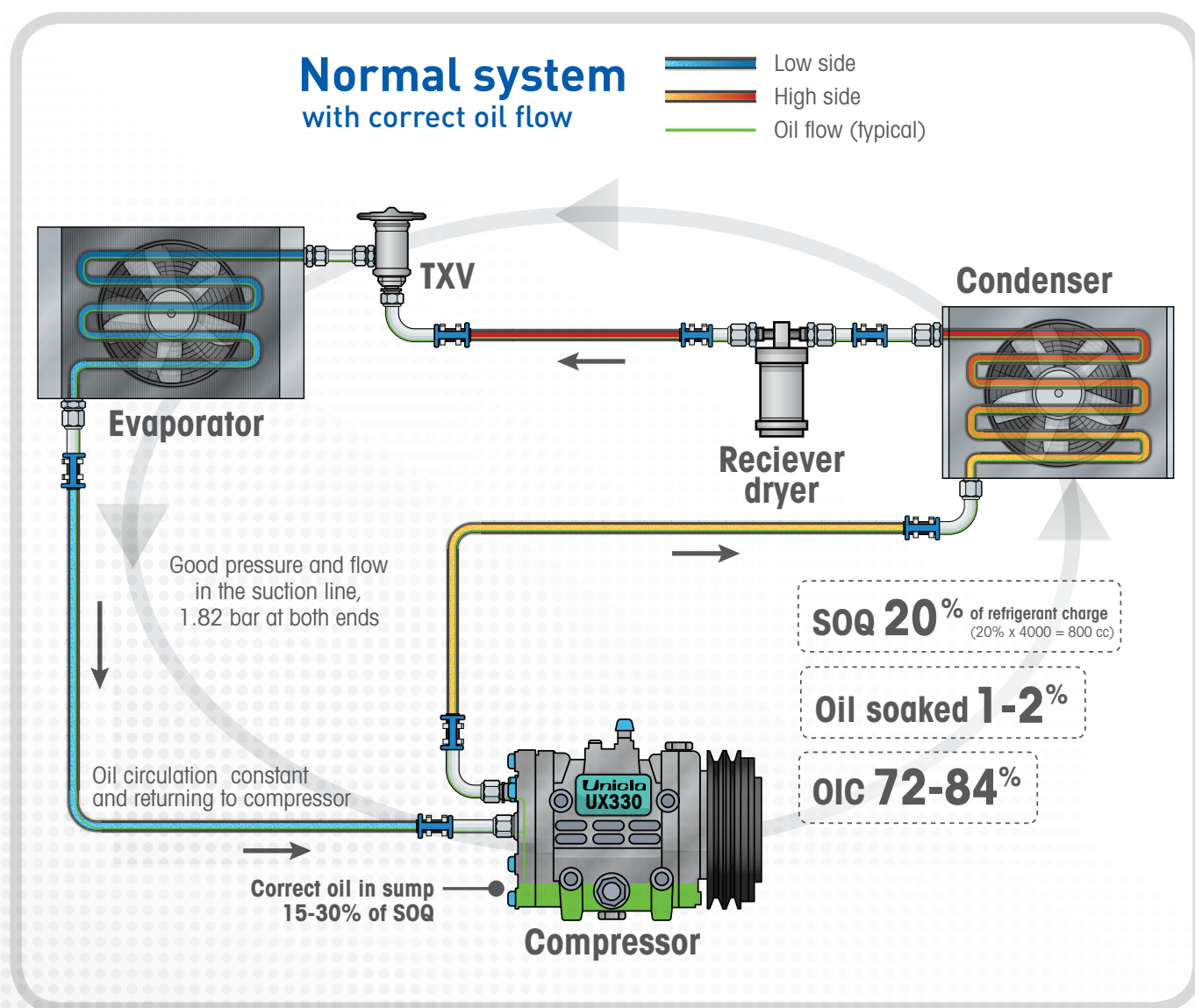


Diagram 8. Oil circulation and soaking levels after commissioning and stabilisation of the system

However, if restricted flow in the suction line occurs from incorrect sizing or a fault, both refrigerant and oil return to the compressor is reduced. Diagram 9 shows some typical system oil levels when a normal system as shown in diagram 6 has this condition.

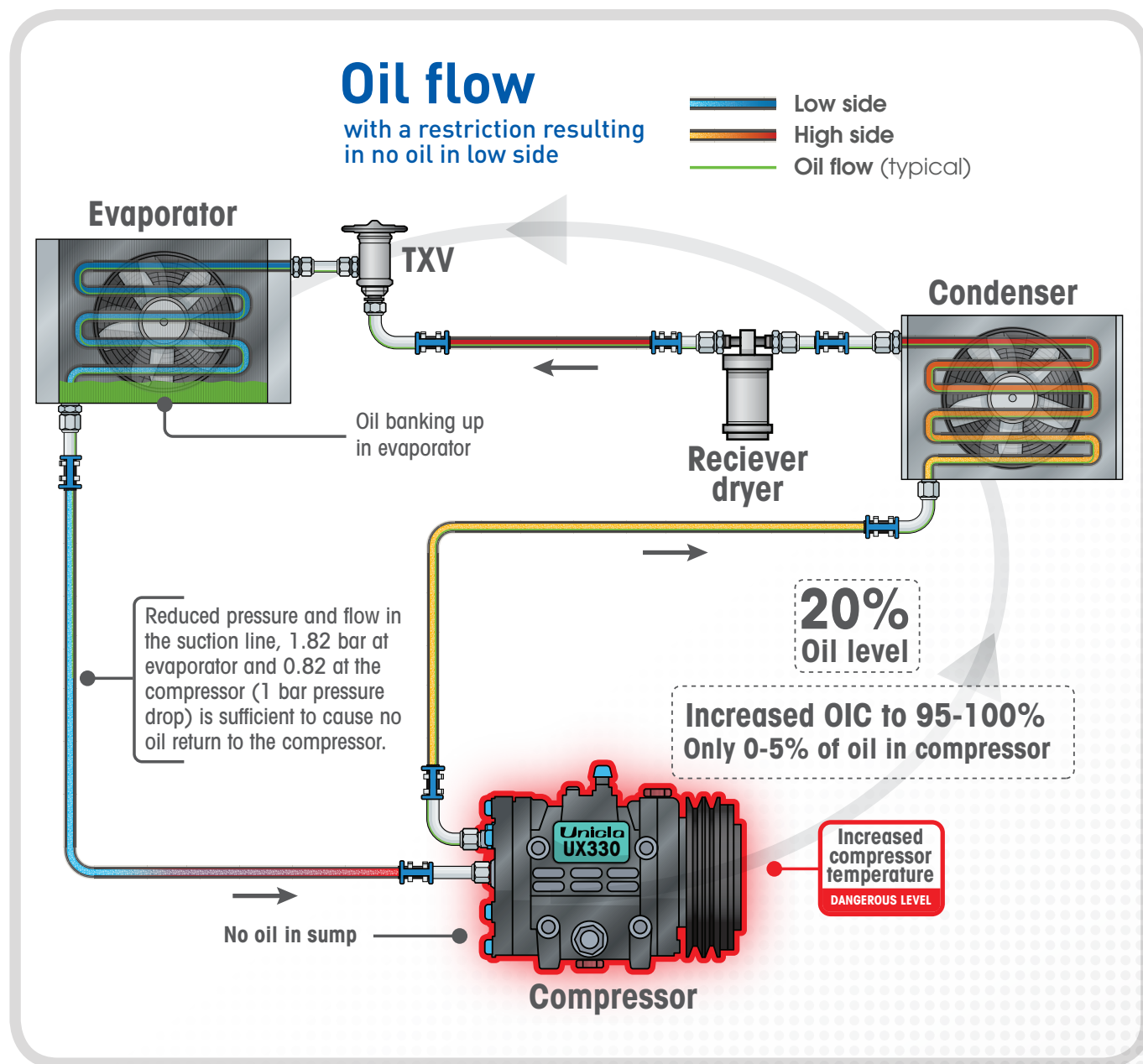


Diagram 9.

Diagram 9 shows the dangerous conditions placed on the compressor from lack of oil return caused by a simple pressure drop in the suction line of 1 bar. This compressor will eventually fail due to insufficient lubrication and cooling. Also OIC has increased with additional oil accumulating in the evaporator which further reduces the system capacity and efficiency.

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Notes

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