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Application Engineering Europe

COPELAND SCROLL™ COMPRESSORS FOR REFRIGERATION IN PARALLEL

1 Introduction

Parallel operation is when several compressors are operating on one common refrigeration system. These installations require a special design to achieve a maximum possible operating capacity and reliability. Only the system design engineer can make the decision which configuration of installation is to be used in view of the particular requirements. The concept of scroll compressors for refrigeration in parallel operation brings several benefits:

- **Efficient capacity control**
  With several compressors in parallel, if one of the compressors is turned off, you achieve a simple method of capacity control combined with a maximum possible saving of energy. If the load or ambient conditions change, compressors can be switched on and off to match capacity requirements. This method of capacity control provides the advantage that the application limitations are not altered as when the plant is equipped with capacity control. The use of unequal compressors allow many capacity possibilities.
- **Standby operation**
  If one compressor cannot run for any reason the load can often be met by the remaining compressors. If the stoppage is caused by a compressor breakdown, the other compressors could be damaged as well. One has to take immediate action to protect the whole installation if acid/dirt is generated. The cause has to be detected in order to be able to decide on the urgency of repair. This is especially required on plants having oil and refrigerant vapour pressure equalization lines, and on plants having no oil level regulating system with filters in the suction and oil return lines.
- **Changing compressors**
  If a compressor needs to be changed for any reason, the small lightweight nature of the scroll makes this a much less costly operation and causes much less disruption. This is particularly true for the smaller models.
- **Matching several evaporating conditions**
  If there are two or more temperatures to be controlled, individual compressors can be matched to each evaporator while working on a single condenser circuit. This will give power savings compared with an alternative system working at the lowest suction pressure.

Scroll compressors have no positive displacement oil pump and therefore no oil pressure switch. The high performance Teflon® bearings provide protection for short periods in case of oil losses. However sustained running at high-pressure differences without lubricant will fail the bearings. In order to ensure adequate protection it is necessary to observe the following guidelines.

2 Parallel application considerations

If compressors are required to operate in parallel it is normally necessary to stop and start them independently for capacity control purposes. There are three major considerations in this type of application:

- **Oil return**
  With all capacity-controlled refrigeration plants the oil circulation has to be perfectly correct especially under part-load operation. This means that the maximum possible capacity reduction will be limited by the means of guaranteeing the correct oil circulation. An adequate oil level at all times is necessary to maintain lubrication of the bearings. Too much oil can result in inefficient operation and excessive oil carry over to the system.

- **Tubing stress**
  If compressors are mounted close together care must be taken to ensure that there is sufficient flexibility in the tubing. If this is not done the starting pulse may result in excess stress directed at the mounting positions and may give rise to a leak. Tube resonance should be avoided.
- **Running sequence**
  A certain logical sequence control is recommended so that each compressor runs for the same amount of time.

3 Active oil control

Individual oil control for each compressor can be attained when each compressor has an Alco TraxOil regulator fitted using an adaptor at the sight glass location. The regulator is fed from an oil reservoir which is itself fed from an oil separator. Filters can be installed in the oil feeding line. The reservoir allows variations in oil quantity in the system to be accommodated. Oil carried over from the compressor to the system is replaced when insufficient oil is being returned. There is a sight glass on each oil level regulator where the oil level can be visually checked approximately 10 seconds after switching off the compressor. This method is recommended by Emerson Climate Technologies provided that certain design points are observed. Since the scroll compressor has no positive displacement oil pump and therefore no oil pressure switch, it is recommended that the oil control system incorporates protection. It will be necessary to add oil to the system and the Emerson Climate Technologies approved lubricants are Emkarate RL 32-3MAF and Mobil EAL Arctic 22 CC. The oil level regulating system for applications should be installed on site. Well tested oil level regulating systems are available from refrigeration wholesalers.

3.1 Low pressure oil reservoir

The oil reservoir is maintained at a pressure slightly above the compressor sump pressure and this limits the amount of refrigerant dissolved in the oil in the reservoir. The pressure drop is low when the oil enters the compressor and the amount of flash gas formed in the sump is small.

Float switches or other devices can be used as regulators. It is recommended that the regulator has an electrical output which can be wired into the control circuit and stop the compressor if the oil level falls below the minimum level and remains below the minimum level for a period of time (maximum 2 minutes). This protects against failure of the oil supply to the individual compressor. A level switch in the reservoir will only protect against insufficient oil in the receiver, but not against loss of oil supply to an individual compressor or against a fault on an individual regulator.

Regulators currently on the market which meet these requirements include ALCO OM3 TraxOil and the AC&R S9040. The TraxOil requires the oil reservoir to be pressurized to 3.5 bar above suction pressure for reliable operation.

When using a regulator care must be taken to set the oil level in the upper half of the sight glass. If an adapter is used to connect the regulator this may have a smaller internal diameter than the glass and this could give rise to a false oil level reading.

When commissioning these systems it is important to allow sufficient time for equilibrium running conditions to be attained. Because the oil carry over rate from the scroll compressors is low it may take some time for stable oil quantities to build up in the coolers. Until this has happened the total oil requirement of the system cannot be determined.

Figure 1: Alco OM3 TraxOil

Model	Oil level control
Functions: - Oil fill - Alarm - Compressor lockout	 Yes Yes Yes
Supply voltage Current	24V AC, 50/60 Hz, 0.7A
Level control	40% – 60% of sight glass height
Switch/Relay release time	120 sec
Reset mode Time delay filling Time delay alarm	Auto 10 sec 20 sec
Oil connection	Screw adapter ¾" – 14 NPTF
Maximum working pressure	450 psi / 31 bar
Solenoid valve MOPD	305 psi / 21 bar
Alarm contact	3A, 230 V
Solenoid coil	Alco ASC 24V AC 50/60 Hz: 8VA

Table 1: OM3 TraxOil properties

3.2 High pressure oil reservoir

The need for a separate oil receiver may be avoided if a combined separator/receiver is used, but in this case the oil will be stored at discharge pressure. It will therefore cause much more disturbance and foaming when it enters the compressor sump. For this reason it is advisable to limit the quantity of oil entering the sump when the valve opens. The Alco OM3 TraxOil (see **Figure 1**) is suitable for this type of application and has been proven to operate satisfactorily with a high-pressure oil supply.

4 Passive oil control

4.1 Equalisation lines with passive oil control

Simple systems which link the compressor sumps via tubes with no control are obviously attractive. They are quite common on air conditioning applications, but in refrigeration additional considerations apply. They can of course only be considered for compressors working at a common suction condition.

If there are large variations in oil quantity in the system due to changing conditions or defrost this may result in too much or too little oil in the compressors. Usually the only means of checking oil level is via the sight glass connection. Once the oil level is above the sight glass it is not possible to determine if the maximum oil quantity is reached. Likewise if no oil is visible in the sight glass there is a danger of operation below the minimum quantity.

A tube connecting the oil level adjustment valves on the compressors is not adequate because when a compressor is stopped, the pressure in the shell rises and oil will transfer to the running compressor(s). The adjustment valve is located below sight glass level and therefore the stationary compressor will show no oil level. Even if all compressors run together at all times, there will be small pressure differences which will cause the same effect.

Alternative methods using the sight glass connections for oil equalisation connections have been shown to work on specific systems. Notes are given below on some possible methods, but because of wide variations in system design and operating conditions, these methods cannot be given general approval by Emerson Climate Technologies. The user has to verify operation in each system type.

4.2 Gas and oil equalization tube at sight glass position

Emerson Climate Technologies has conducted tests to prove the satisfactory operation of up to three compressors in parallel using a gas and oil equalising tube. The configuration of suction line and equalization line should be as described below (see sections 4.3 and 4.4).

This method can be used for:

- Two or three ZF, ZS, ZB refrigeration Scroll compressors;
- They must all be the same model, not uneven sizes;

- All voltages;
- Refrigerants R404A, R507, R22;
- Same operating envelope as single compressor with injection where required;
- Adequate liquid floodback protection must be provided;
- Any sequence of compressors is allowed.

Figure 2: Scrolls in parallel

Compressor models approved		
Low temperature	**Medium temperature**	
ZF09K* to ZF48K*	ZB15K* to ZB220K*	ZS21K* to ZS11M*

Table 2: Model applicability

4.3 Suction line configuration

An adequately sized suction header providing equal distribution of returning refrigerant and oil to each individual compressor must be used. The non-symmetrical design as shown below is acceptable and does not create oil level problems between the compressors.

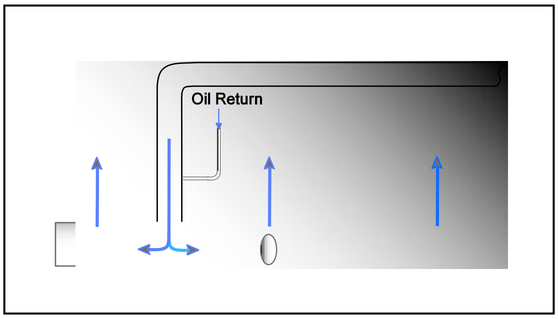


Figure 3: Oil return

Figure 4: Suction line configuration

4.4 Oil equalization line

The oil equalization line between the two or three compressors must be at least 7/8" (22 mm) with a minimum inner diameter of 19 mm. On no account must the internal diameter of any fitting in this line be less than 19 mm. It is strongly recommended that a sight glass be fitted using adaptors. Kits consisting of the adaptor shown below, plus conversion to brazed connections are available (see spare parts list for details). The equalization tube must be level, and the compressors must be mounted level. Tests have shown that smaller tube diameters do not provide proper oil balancing. An oil separator may be used and the oil return line from the separator should be connected to the oil equalization line.

If no oil separator is installed the oil returns into the suction header and is picked up there from the individual compressor suction lines.

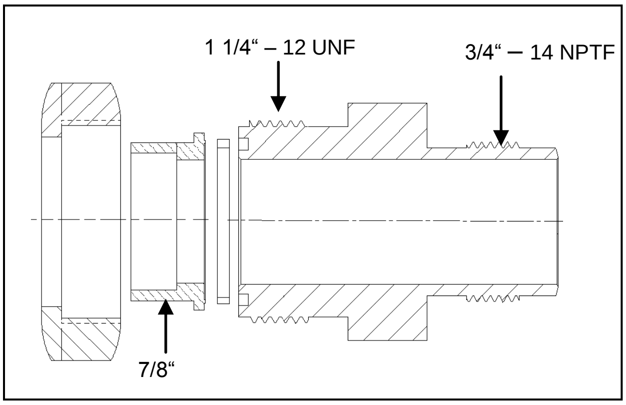


Figure 5: Adaptor for oil sight glass connection

NOTE: **Tightening torque: 41-54 Nm. Use Loctite string or Everseal 483 White Pipe Sealant.**

4.5 Oil and gas equalization plus oil regulator

If the TraxOil or other device is fitted to the equalization line, one device serving 2 or 3 compressors, the proper functioning of the system has to be checked to ensure that no nuisance tripping occurs. The TraxOil sight glass, remote from the sump, does not always accurately follow the sump oil level. The oil separator must be of the combined separator/reservoir high-pressure type, or alternatively a separate oil reservoir may be used if the separator has its own float valve. The separator float valve outlet must not be connected directly to the TraxOil.

5 Oil return to running compressors

If oil returns to the compressor at approximately the same rate as it leaves then the oil level will be maintained. It is always preferable to design the suction manifold in such a way that oil returning with the suction gas can only enter the running compressor(s). This can be done in a number of ways. Perhaps the most common is to use a suction header with vertical pick-ups to each compressor which induces sufficient velocity to lift the oil. Again certain designs have been shown to be satisfactory but each one has to be proven by testing. With some system designs this is sufficient to ensure adequate oil level at all times but there is no fail-safe pressure switch if one compressor loses oil.

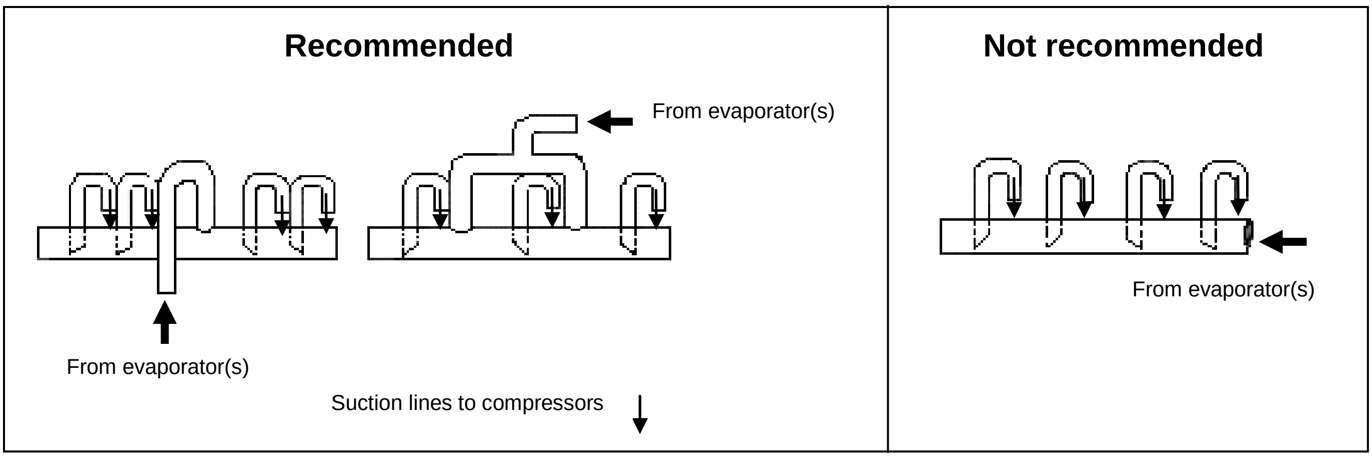


Figure 6: Suction header / lines to compressors – Recommendation

6 Tubing and mounting considerations

6.1 Starting pulse

The standard mount for the scroll compressor is a soft rubber mount. It is designed to transmit the lowest possible disturbance to the mounting frame. Because of the flexibility of this mount, it is essential that tubing to each compressor be designed to accommodate the movement which will occur, particularly upon start-up.

The three phase motors used in the refrigeration scroll compressors exhibit a high starting torque characteristic. The reaction of the stator is directly on the shell because there are no internal spring mounts. This reaction causes easily observable movement of the shell when the standard mounts are used and this is normal. However, if the suction and discharge tubing of the compressor is closely clamped to the frame or linked to another compressor, the tubing will restrain the movement and the motor reaction force will be taken by the tubing. This may cause excessive stress and premature failure of tubing joints.

6.2 Resonance

The discharge pulse can in some configurations give rise to resonance of tubing. It is advisable to avoid a natural frequency of between 45 and 55 Hz for the section of tubing between the compressor and the first clamp. It is often not possible to determine this in advance but in the unlikely event of a resonance problem arising a change in tube configuration will usually resolve it.

6.3 Recommendations for tubing and mounting

Always allow some flexibility in the tubing to the suction and discharge connections. If the standard mounts are used there should be at least two bends and a vertical section before the tube joins a header. Test the finished assembly by rocking the compressor on its mounts. Vibration eliminators may be used but are not essential if the tubing has sufficient flexibility. Vibration eliminators should be fitted in the vertical plane.

An alternative harder mount as detailed in **Table 3** next page is recommended. This will allow more loads to be transmitted via the feet, and the very small additional vibration transmission is not usually a problem in refrigeration applications. It is still advisable to incorporate a vertical section of tube between the compressor and the first rigid mount. This will give flexibility and minimise the risk of resonance.

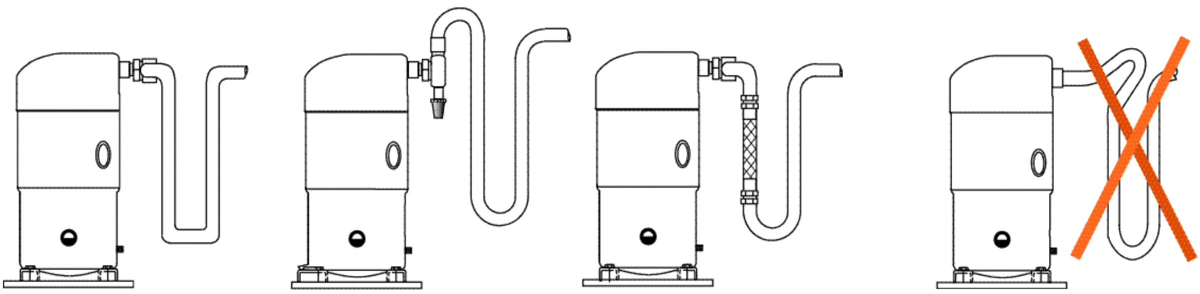


Figure 7: Tubing recommendation

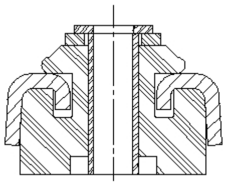
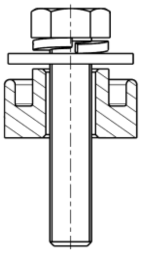
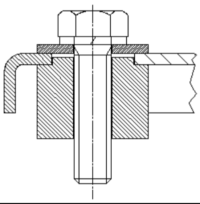
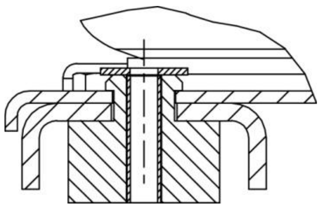
Compressors	Ident number	Characteristics	Drawing
ZB15K* to ZB48K* ZF09K* to ZF18K* ZF13KVE to ZF18KVE ZS21K* to ZS45K*	8030450 527-0157-00	60-70 Durometer	
ZB50K* to ZB114K*	8609592 527-0206-03	Hard steel	
ZB56K* to ZB11M* ZF24K* to ZF48K* ZF24KVE to ZF48KVE ZS56K* to ZS11M*	8522911 527-0168-00 Variation = 8516741	Hard steel	
ZB220K*	8040746 527-0178-00 027-0324-00 (Spacer)	Rubber 60-70 Durometer	

Table 3: Mounting parts for multiple operation

7 Design points

The topics described in the “Scroll Compressors for Refrigeration” Application Guidelines are applicable. The following additional points are for parallel installations.

7.1 Suction line header

The suction lines running from the evaporators to the compressors should be led to a common main suction header in which the suction pressures can equalize. From the main suction header to the compressors, preferably short and similarly constructed pipes have to be provided symmetrically arranged. This serves to achieve a most perfect pressure equalization necessary for the crankcases already at the compressor inlet. Naturally, the lower the speed in the suction line header the more perfect the pressure equalization. Pipes running into the suction line header must not be right opposite outgoing pipes, so that an equalization of the returning oil quantities can take place in the suction line header.

According to the capacity requirement of the system, compressors will be switched on or off. Occasionally however liquid refrigerant can possibly flow into the compressors operating. Therefore, the suction line header should be designed in a manner to simultaneously serve as a liquid separator. Consequently, one has to construct each pipe from the suction line header to the compressor so that the oil return is guaranteed by using additional bores or capillaries. Liquid refrigerant should not return to the compressors when not operating via the oil returning device.

Since installations with parallel compressors mostly have long pipe runs fitted on site, suction filters are commonly used. These filters may just as well be equipped with drier cores as with dust filters only. The filter housings will be rigidly fitted into the system during first installation before the common suction line header. Thus one can employ the appropriate filter core according to the individual requirement, ie, acid absorbing driers too if necessary.

7.2 Discharge line header

The discharge line should slope downwards from the compressor to a lower positioned discharge line header. This is so any liquid returning to the compressor from the condenser on the off cycle does not enter the compressor discharge port.

7.3 Oil separator

One of the features of a parallel compressor installation is the higher refrigeration capacity. With an increasing capacity generally the entire pipe work is extended, more complex and not easy to survey, sometimes resulting in problems with the oil return. It is therefore recommended to install oil separators regardless of the refrigerant and evaporating temperature. Pay careful attention and obey the rules on how to install the pipe work. With the installation using an oil level regulating system the oil separator is already included in this system hence the oil return line has to be fitted to the oil reservoir.

7.4 Oil supply

The more complex a system pipe work is the more influence the installation has on oil return. The extreme possibilities of capacity control resulting in frequent changes of gas velocities inside the suction line will render the oil return difficult as well. Particular attention should be paid to the lubrication problems involved. The oil level in the compressor crankcase should be controlled by using an OMA Traxoil oil level regulator having oil level detection. This device interrupts the compressor control circuit when insufficient oil is in the compressor crankcase.

7.5 Installation

All compressors should be installed as close as possible to each other in order to keep the lines as short as possible. By changing the priority of compressors in operation and keeping running time constant the compressors oil temperature can be kept at a certain level which will reduce the amount of refrigerant absorbed into the compressor oil. Refrigerant flowback into the compressor during standby periods is not possible because the suction line header is below the compressor inlet port. If there is a requirement for isolating the installation against vibrations the frame should be mounted on vibration absorbers. Of course the connecting pipes on suction and discharge sides have to be flexible as well.

7.6 Compressors with multiple vapour injection system

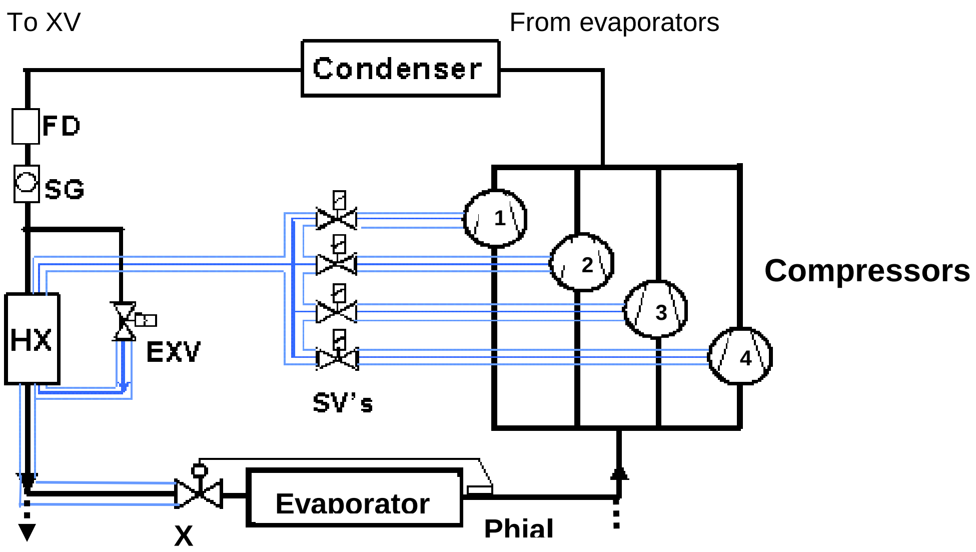


Figure 8: Arrangement for multiple compressors using one heat exchanger (HX)

Multiple vapour injection compressors can share one subcooler (HX) and electronic expansion valve (EXV). Solenoid valves must be fitted to the individual vapour injection lines to close when the compressor is switched off. This is to avoid excessive quantities of liquid entering the compressor during standstill. For further information see the Technical Information C7.19.01 “Copeland Scroll™ Compressors using Vapour Injection for Refrigeration”.