



Refrigeration Scroll for Parallel Applications

Application Guidelines

APPLICATION GUIDELINES: COPELAND SCROLL SCROLL COMPRESSORS IN PARALLEL FOR REFRIGERATION APPLICATIONS

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1 Introduction

The concept of parallel operation for refrigeration scroll compressors brings several benefits:

- **Efficient Capacity Control:**
If the load or ambient conditions change, compressors can be switched on and off to match capacity requirements. This is more efficient than running larger semi-hermetic compressors at part load and also will generally give a better power factor. Use of unequal compressors allows many capacity possibilities.
- **Redundancy:**
If one compressor cannot run for any reason, the load can often be met by the remaining compressors.
- **Ease of Service:**
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 3 - 6 hp models.
- **Matching Several Evaporating Conditions:**
If there are two or more temperatures to be controlled, individual compressor(s) can be matched to each evaporator while working on a single condenser circuit, and this will give power savings compared with an alternative system working at one (the lowest) suction pressure.

Parallel operation of compressors is not new, but 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, but 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 Definitions

- **Oil Equalisation Line:**
Tubing connecting compressor sumps at or below oil level.
- **Regulator**
A device to meter oil into a compressor sump, and control the oil level within limits.
- **Oil Charge Supplied:**
Oil quantity supplied by Copeland when compressor is shipped.
- **Maximum Oil Quantity:**
Maximum amount of oil recommended. Above this amount the oil level will be above the sight glass and could be too high affecting power consumption.
- **Minimum Oil Quantity:**
Minimum amount of oil recommended. Below this amount lubrication may be insufficient and so the life of the compressor may be shortened.
- **Oil Recharge Quantity:**
Amount of oil to refill compressor after drain the oil.

3 Model Range

Model Name			HP	Oil charge supplied [l]	Oil charge quantity [l]
		ZB15	2	1,0	1,0
		ZB19	2,5	1,0	1,0
ZF09	ZS21	ZB21	3	1,24	1,12
ZF11	ZS26	ZB26	3,5	1,24	1,12
ZF13	ZS30	ZB30	4	1,95	1,83
ZF15	ZS38	ZB38	5	1,95	1,83
ZF18	ZS45	ZB45	6	1,77	1,66
ZF24	ZS56	ZB56	7,5	4,14	4,05
ZF33	ZS75	ZB75	10	4,14	4,05
ZF40	ZS92	ZB92	13	4,14	4,05
ZF48	ZS11M	ZB11M	15	4,14	4,05

Tab 1: Model Range

Note: Air-conditioning type applications may use ZR models in parallel. Due to operating envelope limitations ZR models are not normally suitable in Refrigeration applications.



4 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 control:**
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 at the mounting positions and eventually give rise to a leak. Also 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.

5 Oil Control using Regulators

Individual oil control for each compressor is the safest method. Each compressor can be fitted with a regulator which supplies oil only when required. Oil carried over to the system is replaced via the regulator when insufficient oil is being returned from the system. A reservoir of oil is provided, and hence variations in oil quantity in the system can be accommodated. There are many refrigeration scroll compressors operating today with regulators and this method is recommended by Copeland provided that certain design points are observed. Because the scroll compressor has no positive displacement oil pump and no oil pressure switch, it is recommended that the oil control system incorporates protection as detailed below. It will be necessary to add oil to the system and the Copeland approved lubricants are:

HFC-refrigerants: Mobil EAL Arctic 22 CC

HCFC-refrigerants: Suniso 3GS

5.1 Low Pressure Oil Reservoir

This is the traditional method used also in many piston compressor systems. 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 AC&R S9040 and the ALCO OMA Traxoil. 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.



Fig 1: Alco OMA Traxoil

Model	S1 Oil Level Control
Functions:	
- Oil Fill	Yes
- Alarm	Yes
- Compressor Lockout	Yes
Set point	½ Sight glass
Switch/Relay release time	120 sec
Reset mode/Time delay	Auto/ 13 sec
Oil connection	¼" flare
MOPD psi/bar	300/ 20,7
Max. working pressure psi/bar	400/ 27,6
Contact ratings	0,4 A, 125 V 0,2 A, 250 V
Solenoid Coil type/Watts	MCK-1/10W

Tab 2: Properties OMA Traxoil

5.2 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 desirable to limit the quantity of oil entering the sump when the valve opens. The Alco OMA Traxoil (see Fig 1) is suitable for this type of application and has been proven to operate satisfactorily with a high pressure oil supply.

6 Oil Equalisation Lines without Active 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 Copeland. The user has to verify operation in each system type.

6.1 Oil Equalisation Tube at Sight Glass Position

Generously sized suction lines will minimise the flow along the oil connecting tube but will not eliminate it. Use of a large diameter oil header tend to reduce oil transfer. Certain gas pressure equalisation designs have been shown to be satisfactory but each one has to be tested and proven.

6.2 Gas and Oil Equalization Tube at Sight Glass Position



Fig 2: Scrolls in Parallel

Copeland 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 (6.3 and 6.4).

This method can be used for:

- Two or three ZF, ZS, ZB Refrigeration Scroll Compressors
- No uneven configurations (all same model)
- All voltages
- Refrigerants R404A, R507, R22
- Same operating envelope as single compressor with injection where required
- Adequate liquid flood back protection must be provided
- Any sequence/combination of compressors is allowed

Model Applicability

			ZB15 KCE
			ZB19 KCE
	ZF09 K4E	ZS21 K4E	ZB21 KCE
	ZF11 K4E	ZS26 K4E	ZB26 KCE
ZF13 KVE	ZF13 K4E	ZS30 K4E	ZB30 KCE
	ZF15 K4E	ZS38 K4E	ZB38 KCE
ZF18 KVE	ZF18 K4E	ZS45 K4E	ZB45 KCE
ZF24 KVE	ZF24 K4E	ZS56 K4E	ZB56 KCE
ZF33 KVE	ZF33 K4E	ZS75 K4E	ZB75 KCE
ZF40 KVE	ZF40 K4E	ZS92 K4E	ZB92 KCE
ZF48 KVE	ZF48 K4E	ZS11 M4E	ZB11 MCE

Tab 3: Model Applicability

6.3 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.

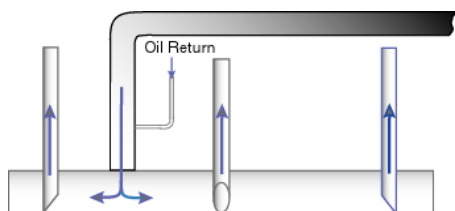


Fig 3: Oil Return



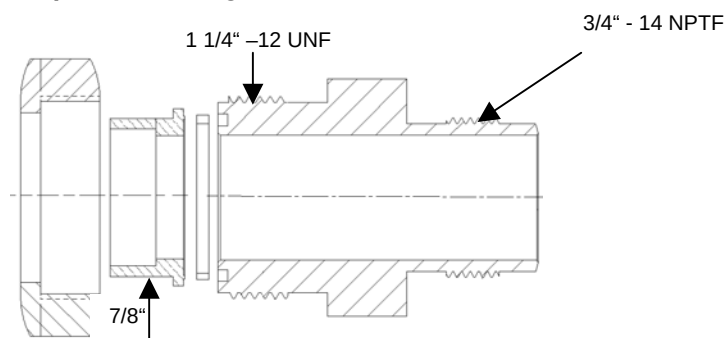
Fig 4: Suction Line Configuration

6.4 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. Adaptors to fit to the sight glass connection on. It is strongly recommended that these are used. Kits consisting of the adaptor shown below, plus conversion to brazed connections are available (see spare parts lists 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.

Adaptor for Oil Sight Glass Connection



Notes:

- Tightening Torque:
41-54 Nm
- Use Loctite String:
Everseal 483 White Pipe Sealant

Fig 4: Adaptor for oil sight glass connection

6.5 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.

7 Oil Return to Running Compressors

Systems without active oil control are covered in section 6. For systems using oil regulation it is still recommended to arrange for oil to be returned to the 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 induce sufficient velocity to lift the oil. Again, certain designs have been shown to be satisfactory but each one has to be tested proven. 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.

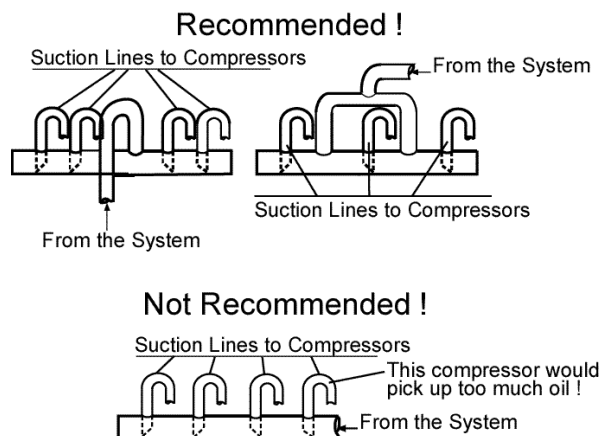


Fig 5: Suction Lines to Compressors – Recommendation

8 Tubing and Mounting Considerations

8.1 Starting Pulse

The standard mount for the scroll compressor is a soft rubber mount. This 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 is designed to accommodate the movement which will occur, particularly on 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 – the motor reaction force will be taken by the tubing and may cause excessive stress and premature failure of tubing joints.

Care should be taken to avoid this situation in parallel arrangements of compressors where it is desired to minimise the space between them (see also 8.3.).

8.2 Resonance

The discharge pulse can in some configurations give rise to resonance of tubing. It is desirable to avoid a natural frequency of between 45 and 55 Hz for the section of tubing between the compressor and the first clamp. Often it is 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.

8.3 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 Fig. 7 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 desirable 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.

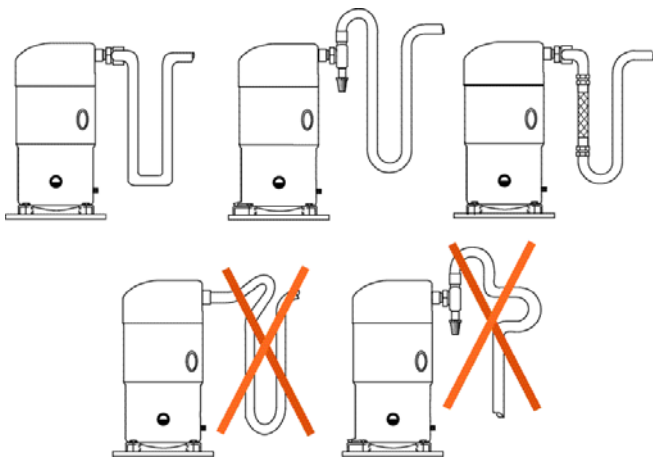


Fig 6: Tubing Recommendation

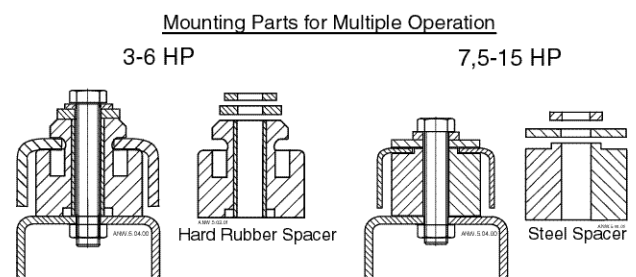


Fig 7: Mounting Parts for Multiple Operation

9 Additional Design Points

The topics described in the Application Guidelines are applicable. The following additional points are for parallel installations.

9.1 Check valves and Pump Down

Pump down is not normally used or necessary for parallel Scroll installations. All Scroll compressors are fitted with an internal check valve, and ZF/ZS models have a dynamic discharge valve also. Therefore external check valves are not needed.

9.2 Heat Exchangers for Economised Scrolls (Vapour Injection)

A single heat exchanger may be used in multiple compressor installations. A plate heat exchanger with a single circuit on the liquid side, and multiple circuits on the vapour side is a good solution (see Fig. 8 & 9 below). It is essential that solenoid valves are fitted to ensure that refrigerant is not fed to the injection port of a stationary compressor.

If a single circuit heat exchanger is used, the solenoid valves must be fitted in the vapour lines as shown in the figures below. A TEV can be used to regulate the injection. Depending on the configuration, the operational envelope may be restricted due to higher vapour temperatures than with the capillary tube. Discharge temperature thermostats should always be fitted.

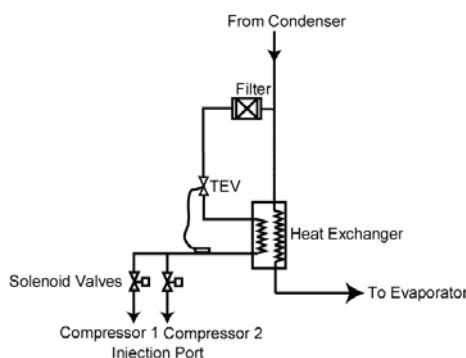


Fig 8: Heat exchanger configuration example 1

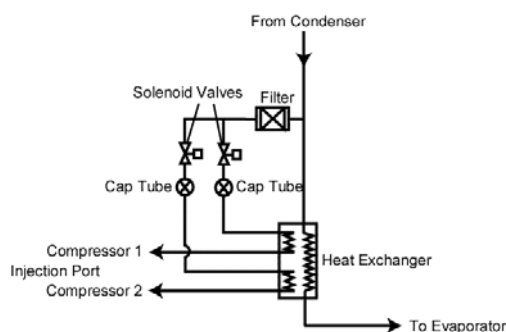


Fig 9: Heat Exchanger configuration example 2

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