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# Recommended Compressor Installation Practices

## 1. COMPRESSOR SELECTION AND USE

The selection of a compressor should be made according to the following system cooling characteristics and where it will be installed:

1. Minimum Evaporator Temperature
2. Cooling Capacity or Thermal Load
3. Refrigerant Type
4. Ambient Temperature
5. Electrical Power Available
6. Compressor and Drive Cooling

### 1.1 Minimum Evaporator Temperature

The minimum evaporating temperature and the condensing temperature allows for the identification of the compressor application (LBP, MBP, or HBP). Low Back Pressure systems such as freezers have evaporator temperatures below -20ºC (-4ºF). Medium Back Pressure systems such as food coolers or beverage dispensers have evaporator temperatures higher than -20ºC (-4ºF). High Back Pressure systems such as chillers and air conditioners have evaporator temperatures higher than -5ºC (+23ºF).

### 1.2 Refrigeration Capacity

This is usually defined as the specified cooling capacity at normal working conditions of the system in watts or kcal/h, according to evaporating and condensing temperatures. The capacity is determined by the mass flow rate of refrigerant, which depends on the compressor’s displacement, RPM, and volumetric efficiency.

### 1.3 Refrigerant Type

Refrigerant selection can be made on the basis of availability, performance, and ecological considerations such as ozone depletion potential (ODP) and global warming potential (GWP). Aspen rotary compressors have been verified for use with R134a and R404a. Other low-pressure refrigerants or refrigerant blends may perform satisfactorily, but have not been verified.

### 1.4 Ambient Temperature

The compressor must be selected in order to ensure it’s suitable to operate at the highest expected ambient temperature. Compressors are usually intended for indoor use, and a minimum of +5ºC is required in order for proper lubrication.

### 1.5 Electrical Power Available

Generally, DC compressors are used in mobile or portable refrigeration systems. DC power is produced by batteries, fuel cells, vehicle alternators, solar panels, or from an AC inverter power supply. The compressor must be selected for use according to the DC voltage available. Aspen compressors are available in 12V, 24V, and 48V versions.

### 1.6 Compressor and Drive Cooling

Compressors with small motors can often be cooled in a static environment, with refrigerant removing most of the heat generated. Nonetheless, Aspen compressors due to their small size and high power density should not be placed within a sealed enclosure. Aspen recommends a small volume of air for cooling by forced convection for both the compressor and drive. If the compressor case temperature reaches 275ºF (135ºC), permanent damage could result in the motor magnets.

## 2. COMPRESSOR STORAGE AND HANDLING

Aspen's compressors are built to order. Prior to installation, compressors should be stored in an upright position to prevent oil from entering the suction or discharge tubes. If compressors are to be stored in inventory for long periods of time, they should be stored in climate chambers or storage areas that can control both temperature and humidity. Aspen compressors are built with high precision parts that are susceptible to chemical attack and corrosion from contaminants in ambient air. Compressors are always shipped with a low-pressure nitrogen blanket sealed with rubber plugs to maintain this pressure and prevent internal parts from exposure to moisture and other contaminants. If long shelf life is anticipated, it is important to maintain the inert atmosphere to prevent internal corrosion or chemical attack.

## 3. COMPRESSOR UNPACKING

All compressors shipped from Aspen are charged with 21cc of polyolester oil, are evacuated, sealed with low-pressure nitrogen, and capped. In addition to the compressor, other system components should be internally dried, sealed, and stored in an inert atmosphere until installation, preferably <u>no more than 15 minutes</u> from assembling of components.

Remove the compressor from its packaging while keeping it in an upright position. Failure to keep the compressor upright can result in the flow of oil into the suction accumulator and process connections, which can cause brazing problems. The compressor must also remain upright while assembling the grommets in the mounting bracket to the base plate.

## 4. PREPARATION OF REFRIGERATION SYSTEM COMPONENTS

The cleaning and removal of solid substances and non-condensibles and the removal of moisture and other gas contaminants in all components of the refrigeration system are key to successful compressor operation and long life. In addition, the use of R134a and R404a with new polyolester oils has been accompanied by new stricter standards in comparison with CFC or HCFC refrigerants. Any non-compatible products that can contaminate these refrigerants and polyolester oils including chlorine compounds and non ester-based oils need to be eliminated. Other system components such as tubing, evaporators, condensers, receivers, valves, capillaries, and separators need to have these contaminants removed before the system is assembled.

**Aspen recommends that all components remain sealed as long as possible before assembly, performing the brazing no more than 15 minutes after exposure to ambient.**

It is important to avoid residual oil during brazing by blowing out components with nitrogen or dry air, with a dew point lower than -40ºF. Internal oil on surfaces of the suction or discharge tubes can cause difficulty in brazing, and even more hazardous, it can introduce contaminants into the system from 'cracking of oil'.

The moisture and non-condensible residual contents should be reduced by 50% in comparison to what is prescribed by DIN Standard 8964. A filter drier should be selected with the molecular sieve suitable to the refrigerant type used.

| | |
|---|---|
| R134a | XH-7 (8x12) |
| R404a | XH-9 (8x12) |

The filter drier needs to be protected from absorption of ambient humidity during assembly of the system components using the following practices:

(1) Remove protective caps just prior to brazing
(2) For filters supplied without protective caps in hermetic boxes, these must also be protected to avoid moisture absorption before brazing.

If the drier does not have complete water absorption in the molecular sieve, then moisture can circulate freely in the system with the following effects:

| | |
|---|---|
| 1. Ice Buildup: | Reduces cross-sectional area of capillary tube or TX valve |
| 2. Acid Buildup: | Causes serious attack in compressor and to the molecular sieve in filter drier |
| 3. Oil Contamination | Acidification reduces lubrication, changes oil color, buildup of sludge, and poor lubrication of compressor |

Aspen is not responsible for damage to its compressors from the introduction of such contaminants.

## 5. REFRIGERANT USE GUIDE

This section provides guidelines for use with refrigerants R134a and R404a. Due to extreme differences that can exist in systems, their working conditions, and duty cycles, the performance and reliability should be verified through working prototypes and field tests prior to commercial implementation. All operations related to the use of refrigerants should be conducted according to applicable laws, regulations, and engineering standards related to this subject.

Aspen compressors have been designed and tested for operation with R134a and R404a refrigerants. Some users may want to employ other refrigerants or refrigerant blends, and other refrigerants may perform quite well. However, due to case design pressure considerations, refrigerants that have a maximum working pressure greater than 350 psi (24.13 bar) are not recommended. If other refrigerants are to be used, the compressor should be thoroughly tested and evaluated with those refrigerants to verify reliability with expected conditions in the intended application. Because of the wide differences in refrigeration systems with different working fluids, the reliability of all equipment should be evaluated for appropriate life through field tests.

Rotary compressors perform best when the pressure ratio between the high and low sides of the compressor is less than 8:1. When the pressure ratio exceeds this value, the compressor's coefficient of performance (COP) is adversely affected. Good refrigeration practice requires that careful evaluation of the refrigeration system and evaporator conditions be specified, and that an appropriate refrigerant is selected to avoid excessive pressure differential.

### 5.1 R134a Refrigerant

R134a (tetrafluorethylene) is a replacement for R12 in applications with medium and high evaporator temperatures in Aspen's compressors. Its physical properties are:
Molecular Weight – 102
Critical Temperature – 101.1ºC
Critical Pressure – 40.6 bar
Boiling Point -26.5ºC

This refrigerant also requires the exclusive use of polyolester oil (POE) as a lubricant. R134a refrigerant is associated with strict requirements for internal cleanliness of the cooling system. In addition to chlorine and water, solid residues must be carefully removed including dust, metal particles, etc., which can damage the compressor. The recommended lubricating oil is POE RL 68H. This lubricant is highly hygroscopic (water absorbing) which can cause the formation of acid residues. When present, these acid residues can create a blockage in the capillary tube and reduced lubricity in the compressor.

The level of moisture in the refrigeration system should be below 40 ppm. It is recommended that a filter dryer compatible with R134a and POE be installed with a

capability to remove moisture from the system to below 20 ppm. The compressor and other components should remain sealed until they're ready to use. The compressor and other system components should not be open to the ambient for more than 15 minutes. Good refrigeration practice also calls for system evacuation of both low and high sides, achieving a minimum vacuum level of 0.14 bar (100 µHg).
When evaporator temperatures below 23ºF (-5ºC) are expected, the volumetric efficiency and COP with R134a will decrease. At these conditions, it is desirable to switch to R404a.

### 5.2 R404a Refrigerant

R404a is a replacement for R22 in medium evaporator temperatures and R502 in low evaporator temperatures. Its physical properties are:
Near Azeotropic Mixture 3 HFC Components
Critical Temperature – 101.1ºC
Critical Pressure – 40.6 bar
Boiling Point -26.5ºC

R404a is a mixture of R125, R143a, and R134a with a
boiling point of – 46.3ºC. Its recommended lubricating oil is also POE RL 68H. The same procedures for contaminant control should be used here as described for R134a.

### 5.3 Cooling Compressor & Drive

Both the compressor and drive produce heat when operating, which must be dissipated to the surroundings. Most of the heat is removed with the refrigerant. Still, some forced air circulation should be passed across the compressor and the motor drive to ensure they do not operate at elevated temperature. In most cases, a dedicated air fan is not necessary. But, a modest amount of airflow from the condenser fan is enough to maintain adequate cooling and safe temperatures.

### 5.4 Vacuum Operations

The vacuum level for R134a is the same as for a system with R12. A proper evacuation process will assure that the air and moisture contents are well below allowable limits. The primary refrigerants for Aspen's compressors are R134a and R404a. Both of these new refrigerants require the use of polyolester oils, which are highly hygroscopic and have high water-absorbing capacity. These oils require the greatest level of care in system evacuation. Thus, the evacuation method should aim to reach a vacuum level on both the high and low side of the compressor of at least 0.14 mbar (100 µHg). The maximum level of non-condensable should not exceed 0.3%. The quantity of R134a refrigerant is generally less (~10%) than the charge for R 12.

### 5.5 Refrigerant Charge

Following the system evacuation, it must be charged with refrigerant. For a low capacity system, as little as 40 grams might be used, while as much as 120 grams might be used in a high capacity system. After refrigerant is pumped into the system, it is wise to wait 5-10 minutes before starting the compressor to allow refrigerant evaporation and avoid the ingestion of liquid into the compressor. For high charge levels, the system should be equipped with a liquid receiver. An accumulator should always be used with rotary compressors to minimize liquid intake in the compressor.

For each system, the optimum refrigerant charge should be determined by controlled testing in order to obtain the best working conditions, and to avoid the return of liquid refrigerant to the compressor. In order to evaluate system performance, instrumentation should be added at certain locations to record key data. Recommended data points to be recorded include the following:

| | |
|---|---|
| Date | |
| Refrigerant | |
| Charge Amount | |
| Ambient Temp. | |
| Evaporator Inlet / Outlet Temp. | |
| Compressor Suction Pressure | |
| Compressor Discharge Pressure | |
| Compressor RPM | |
| Compressor Amps | |
| Cooling Load (Watts) | |
| Condenser Inlet / Outlet Temp. | |
| Quantity of Oil in System | |

## 6.0 OIL MANAGEMENT

Even the most experienced refrigeration technicians need to read these instructions carefully, since the quantity of oil used in Aspen compressors is much less than found in other types. Some lubricating oil will travel with the refrigerant in any refrigeration system. Thus, it is imperative that they be miscible and fully soluble in one another at all temperatures. This provides good oil return and lubricity for the compressor, while avoiding heat transfer losses in the evaporator. During the prototyping of the refrigeration system, it is vital that the proper amount of oil in the system be determined. Aspen compressors are all shipped with 21cc of POE RL 68H. This has been found to be adequate for many compact cooling systems. However, in systems that use large evaporators and condensers, some of this oil may not return back to the compressor causing a reduction in oil inventory and potentially harmful conditions.

There is no sight glass to visualize oil flow within the compressor. Therefore, the following procedures are highly recommended to ensure that adequate oil is present at all times. Keep in mind that oil entrainment occurs in all compressors, and typically is a function of compressor speed (RPMs). **The cooling system should be designed to be fully drainable with no traps in heat exchangers or other components where pools of oil can collect.**

### 6.1 Orientation and Positioning

The orientation and position of a compressor can affect the flow of lubricant. Aspen's compressor operates properly when it's oriented within ± 35º of vertical. Some mobile or portable refrigerators are not always oriented vertically. If the compressor's position is more than 35º from vertical, oil flow will be affected and the first sign of this is a decrease in cooling capacity. The compressor can operate in these conditions for short periods of time without damage. But, compressors should not be permanently operated in extreme orientations, or their life will be shortened.

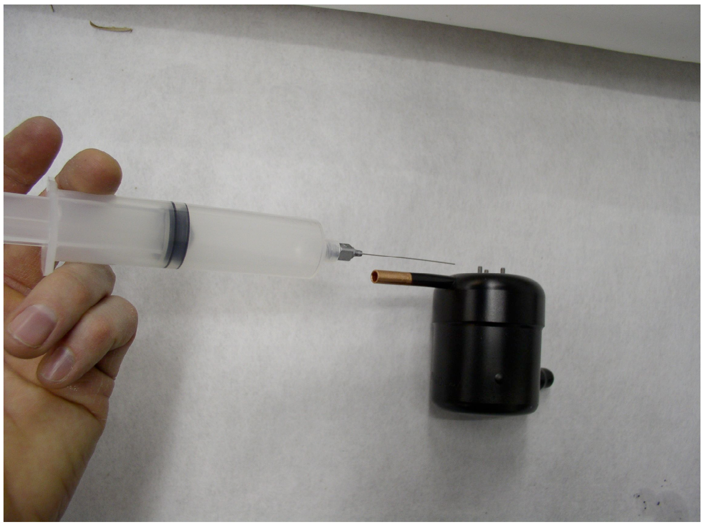
### 6.2 How to Determine Adequacy of Oil in the Cooling System Prototype

The following steps are suggested when setting up the initial prototype cooling system for testing:

- Install the compressor initially with temporary quick disconnect compression fittings. The compressor contains 21cc of POE when shipped by Aspen. The following test will reveal whether 21cc is adequate, or if more oil is needed.
- Evacuate and charge the system with refrigerant. (Note: During evacuation, it is possible for some oil to leave the compressor. A sign of this would be an increase in the oil level in the vacuum pump.)
- Energize compressor and bring it slowly to maximum speed (6,500 RPM).
- After the system has stabilized, take a complete set of performance data. Compare the capacity measured against the compressor capacity charts provided by Aspen. If the cooling capacity measured is approximately the same, the compressor is being lubricated adequately. If the measured capacity is significantly lower, there may not be adequate lubricant oil within the compressor.
- Shut down the compressor when the test data has been recorded.
- Disassemble compressor and remove it from prototype cooling unit.
- Turn the compressor over and drain the entire contents of oil into a container; then measure the quantity in cc's.
- If the quantity removed is less than 10 cc, then more oil should be added. Add at least 12cc of fresh oil to the compressor. Keep in mind that residual oil (21 cc minus amount removed) still resides in other parts of the prototype unit. Check for signs of trapped oil as necessary.
- Reinstall compressor, evacuate, and recharge with the same amount of refrigerant. Then, continue testing over the full operating range. Again remove the compressor and measure the oil content inside. If it contains at least 10 cc, the compressor is being lubricated adequately.
- After satisfactory oil inventory has been demonstrated, the compressor can now be permanently connected to the prototype system. Carefully braze the compressor into place. Ensure there is no oil on the inner surface of the suction and discharge tubes prior to brazing. During the brazing process a damp cloth should be wrapped around the compressor case to help prevent excess heat from damaging the compressor's components.

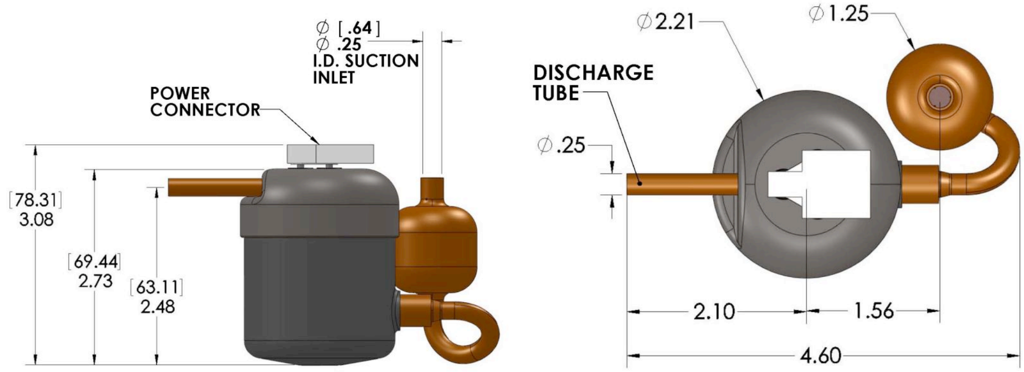
### 6.3 Oil Charging

Using a syringe (see photo below) load the compressor with adequate (RL 68H, Viscosity: 300SUS, recommended or equivalent) refrigerant oil through the discharge port. Make sure the syringe is inserted just far enough to reach inner chamber to allow air to purge but not to contact internal electrics, which might cause damage.



"Note" Syringe must have large enough ID to allow oil flow and a small enough OD to allow air to purge from canister.

## 7. COMPRESSOR SPECIFICATIONS




| | |
|---|---|
| Refrigerant | HFC-134a/HFC404a |
| Oil Type | POE RL 68H |
| Oil Quantity | Factory Charged With 21cc's of Emkarate RL68H POE Oil |
| Motor | Brushless DC |
| Voltage | 24 Vdc (nominal) |
| Voltage Range | 20 – 30 Vdc |
| Max Current | 9.5 Amps Continuous |
| Compressor Displacement | 1.4 cc (.085 $in^3$) |
| Compressor Speed | Variable |
| Speed Range | 2000 – 6500 RPM |
| Compressor Weight | 1.3 lb (590 g) |
| Evaporator Temperature Range | 0–75°F (-18–24°C) |
| Condenser Temperature Range | 80-160°F (27-71°C) |
| Max Discharge Temp. | 265°F (130°C) |
| Max Compression Ratio | 8:1 |
| Max Compartment Temp. | 130°F (54°C) |
| Suction Port Size | 0.32" ID Cup |
| Discharge Port Size | 0.25" OD Tube |
| Suction/Discharge Tube Orientation | 180° Standard, Custom Available |
| Compressor Mounting | Option Mounting Bracket Available |
| Motor Drive Type | Sensorless |
| Analog Voltage<br>Speed Command (Linear) | 0 - .499 VDC = OFF<br>.50 VDC = ~1800 RPM<br>4.5 VDC = ~6500 RPM |
| Drive Board Footprint | 1.5" x 2.5" |
| Drive Board Weight | 1.0 oz (28 g) |
| Drive Board Heat Sink | Anodized Aluminum |
| Heat Sink Footprint | 1.83" x 3.25" |
| Heat Sink Weight | 1.4 oz (39 g) |

### 7.1 Drive Board Speed Control

| RPM | Control Signal VDC |
|---|---|
| 1800 | 1.13 |
| 2000 | 1.35 |
| 2500 | 1.77 |
| 3000 | 2.13 |
| 3500 | 2.48 |
| 4000 | 2.8 |
| 4500 | 3.15 |
| 5000 | 3.54 |
| 5500 | 3.78 |
| 6000 | 4.1 |
| 6500 | 4.5 |
| 7000 | 4.94 |