One of the major causes of compressor failure is damage caused by liquid refrigerant entering the compressor in excessive quantities. Improper control of liquid refrigerant in a system can cause a loss of lubrication, as well as excessive stress, on several components in the compressor. Such compressor failures are often classified as lubrication system or component failures, but in reality the problem actually originates with the refrigerant.

A well-designed, durable, and efficient compressor for refrigeration, air conditioning, or heat pump duty is primarily a vapor pump designed to handle a small quantity of liquid refrigerant and oil. To design and build a compressor to handle more liquid would require a serious compromise in size, weight, capacity, efficiency, noise, or cost.

For any design there are limits to the amount of liquid a compressor can handle, and these limits depend on factors such as internal volume of the crankcase, oil type or charge, type of system and controls, and normal operating conditions.

Improper control of liquid refrigerant in a system is an application problem and is largely beyond the control of the compressor manufacturer.

The potential hazards to the compressor increase with the size of the refrigerant charge. The cause of damage usually can be traced to one or more of the following:

1. Excessive refrigerant charge for the application.
2. Frosted evaporator.
3. Dirty or plugged evaporator filters.
4. Failed evaporator fan or fan motor.
5. Incorrect capillary tubes or orifice.
6. Incorrect selection or adjustment of expansion valves.
7. Refrigerant migration during the off cycle.

Refrigerant - Oil Relationship

In order to correctly analyze system malfunctions, and to determine if a system is properly protected, an understanding of the basic relationship between refrigerant and oil is essential.

In refrigeration compressors, oil and refrigerant mix continuously. Refrigeration oils are soluble in liquid refrigerant, and at room temperature they may even mix completely.

A small amount of oil is always circulating with the refrigerant. Oil and refrigerant vapor do not mix readily. Oil can be properly circulated through the system and returned to the compressor only if gas velocities are high enough to sweep the oil along through the tubing found throughout the system. If velocities are not sufficiently high, oil will tend to accumulate in the bottom of the evaporator tubing, decreasing heat transfer and eventually cause a shortage of oil in the compressor.

As evaporating temperatures are lowered, this problem becomes more critical since the viscosity of oil increases with a decrease in temperature. For these reasons, proper design of piping is essential for satisfactory oil return to the compressor.

One of the basic characteristics of a refrigerant and oil mixture in a sealed system is the fact that refrigerant is chemically attracted by oil and will vaporize and migrate through the system to the compressor crankcase even though no pressure difference exists to cause the movement. On reaching the crankcase the refrigerant may condense into a liquid, and this migration will continue until the oil is saturated with liquid refrigerant. The amount of refrigerant that the oil will attract is primarily dependent on the temperature difference between the oil in the crankcase and refrigerant in the system. Refrigerant tends to migrate to cold oil.

When the pressure of a saturated mixture of refrigerant and oil is suddenly reduced, as happens in the compressor crankcase on start-up, the amount of liquid refrigerant required to saturate the oil is drastically reduced, and the remainder of the liquid refrigerant “flashes” (evaporates) into vapor, causing violent boiling of the refrigerant and oil mixture. This causes the foaming often observed in the compressor crankcase at start-up, which can drive all of the oil out of the crankcase in a very short period. (Not all foaming is the result of excess refrigerant in the crankcase-normal agitation of the oil will also cause some foaming.)

One condition that is often surprising when first encountered by field personnel occurs during the presence of excessive liquid refrigerant in the
compressor crankcase. This situation can result in a loss of oil pressure and a trip of the oil pressure safety control even though the level of the refrigerant and oil mixture may be observed to be high in the compressor crankcase sight glass. The high percentage of liquid refrigerant entering the crankcase not only reduces the lubricating quality (viscosity) of the oil, but on entering the oil pump intake may “flash” into vapor which blocks the entrance of adequate oil necessary to maintain oil pump pressure. This condition can continue until the percentage of refrigerant in the oil in the crankcase is reduced to a level which can be tolerated by the oil pump and pressure control.

Typical Effects of Improper Refrigerant Control
Liquid refrigerant problems can take several different forms, each having its own distinct characteristics.

1. Refrigerant Migration

Refrigerant migration is the term used to describe the accumulation of liquid refrigerant in the compressor crankcase during (long) periods when the compressor is not operating. It can occur whenever the compressor becomes colder than the evaporator, since a (small) pressure differential then exists to force refrigerant to the colder area. Although this type of migration is most pronounced in colder weather, it can also exist even at relatively high ambient temperatures with remote type condensing units for air conditioning and heat pump applications.

System designers should recognize that any time the system is shut down and not operative for several hours, migration to the crankcase can occur due to the normal chemical attraction of the oil for refrigerant.

If excessive liquid refrigerant has migrated to the compressor crankcase, severe liquid slugging may occur on start-up, and frequently compressor damage such as broken valves, damaged rods or pistons, bearing failures due to loss of oil from the crankcase, and bearing washouts (refrigerant washing oil from the bearings) occurs.

2. Liquid Refrigerant Flooding

If an expansion valve malfunctions, an evaporator fan fails or air filters become clogged, liquid refrigerant may flood through the evaporator and return through the suction line to the compressor as liquid rather than vapor. During the run cycle, continuous liquid flooding can cause excessive wear of the moving parts because of dilution of the oil, loss of oil pressure resulting in trips of the oil pressure safety control, and loss of oil from the crankcase. During the “off” cycle after running in this condition, since the compressor is often very cold, migration of refrigerant to the crankcase can occur rapidly, resulting in liquid slugging when restarting.

3. Liquid Refrigerant Slugging

Liquid slugging is a term used to describe the passage of liquid refrigerant through the compressor suction and/or discharge valves. It is evidenced by a loud metallic clatter inside the compressor, often accompanied by extreme vibration of the compressor. Depending upon the amount of liquid upstream of the compressor suction valve, slugging can last for as much as several seconds.

Slugging often results in broken valves, blown gaskets, broken connecting rods, or other major compressor damage.

If excessive liquid refrigerant has migrated to the compressor crankcase during (long) periods when the compressor is not operating, it may return to the evaporator during the defrost period, and on start-up, this refrigerant floods back to the compressor crankcase, causing a loss of oil pressure and recurring trips of the oil pressure safety control.

One trip or a few trips of the oil pressure safety control may not result in serious damage to the compressor, but repeated short periods of operation without proper lubrication are almost certain to result in compressor bearing failure. Trips of the oil pressure safety control under such circumstances are frequently viewed by the serviceman as nuisance trips, but it cannot be stressed too strongly that they are warning trips, indicating the compressor has been running without oil pressure for two minutes and that prompt remedial action is required to ensure durability. (See AE8-1095 and AE-1275 for additional discussion of oil pressure safety controls.)
Recommended Corrective Action

The potential hazard from liquid refrigerant to a refrigeration or air conditioning system is in almost direct proportion to the size of the refrigerant charge. It is difficult to determine the maximum safe refrigerant charge of any system without actually testing the system with its compressor and other major components. Compressor manufacturers can determine the maximum amount of liquid the compressor will tolerate in the crankcase without endangering the working parts, but have no way of knowing how much of the total system charge actually will return to or reside in the compressor under all conditions. The maximum amount of liquid a compressor can tolerate depends on its design, internal volume, and oil charge. Where liquid migration, flooding, or slugging can occur, corrective action should be taken, the type normally being dictated by the system design and the type of liquid problem.

Table 1 lists refrigerant charge limits for Copeland® compressors used in systems without some means of off cycle liquid refrigerant control. It is possible that on systems where large quantities of liquid can flood to the compressor on start-up, some protective action may be required even though the system contains a refrigerant charge smaller than the limits listed in Table 1.

Minimize Refrigerant Charge

The best compressor protection against all forms of liquid refrigerant problems is to keep the charge within the compressor limits listed in Table 1. Even if this is not possible, the charge should be kept as low as reasonable possible. Use the smallest practical size tubing in condensers, evaporators, and connecting lines. Receivers should be as small as possible.

Charge the system with the minimum amount of refrigerant required for proper operation. Beware of bubbles showing in the sight glass caused by small liquid lines and low head pressures. This can lead to serious overcharging.

Pumpdown Cycle

The most positive and dependable means of properly controlling liquid refrigerant off-cycle migration is by means of a pumpdown cycle. By closing a liquid line solenoid valve, the refrigerant is pumped into the condenser and receiver, thereby isolating the refrigerant during periods when the compressor is not in operation, and preventing migration to the compressor crankcase.

Two basic types of pumpdown systems are commonly used today:

Continuous Pumpdown

Recommended for use in all refrigeration systems and in air conditioning systems where long (several weeks or months) off periods are not expected. Compressor operation is controlled by a low pressure control set to pumpdown the system whenever the suction pressure is above the set point. Should refrigerant leak past the solenoid valve during the off cycle, suction pressure increases thereby restarting the compressor; hence the term “continuous pumpdown”.

One Time Pumpdown

Recommended for use only on Discus equipped commercial air conditioning systems where long off periods are expected. With this type system, pumpdown will occur only once after the liquid line solenoid is closed. This prevents the possibility of continually short cycling in order to clear the low side of refrigerant that has leaked past the solenoid or compressor valves. Short cycling over extended periods may result in crankcase oil pump-out since this oil is prevented from returning to the compressor by the closed solenoid valve. When after several weeks or months the solenoid valve finally opens,

| Compressor Model | Crankcase Heater or Pumpdown Cycle Required if Refrigerant Charge Exceeds |
|------------------|------------------------------------------------|---|
| **Copeland™**    |                                               |   |
| H                | 2.0 lbs                                        |   |
| K                | 4.0                                            |   |
| E                | 6.0                                            |   |
| 3                | 8.0                                            |   |
| L                | 8.0                                            |   |
| N                | 10.0                                           |   |
| M                | 15.0                                           |   |
| 2D               | 15.0                                           |   |
| 9                | 17.5                                           |   |
| 3D               | 17.5                                           |   |
| 4                | 23.0                                           |   |
| 6                | 28.0                                           |   |
| 8                | 11.0                                           |   |

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<th><strong>Copelaweld™</strong></th>
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<td>RR’2</td>
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<td>CR’4 &amp; CR6</td>
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<td>BR</td>
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<tr>
<td>ZR (Compliant Scroll)</td>
<td>See AE4-1280</td>
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</table>
much of the oil is brought back to the compressor quickly which could result in compressor damage.

When One Time Pumpdown is used, a crankcase heater is also recommended.

Emerson Climate Technologies engineering tests have demonstrated the superior flooded start capability of the Discus™ compressor compared to conventional reed compressors. An occasional flooded start is therefore deemed preferable to continual cycling with limited oil in the crankcase and the potential for large oil returns during start-up.

During pumpdown the crankcase pressure is rapidly reduced. If the crankcase pressure is reduced low enough, the oil will foam due to the outgassing of the refrigerant trapped in the oil. This will cause oil to be rapidly pumped out of the crankcase and increases stress on the valves and running gear as well as causing an oil shortage during the next run cycle. In order to minimize this effect, Emerson recommends setting the low pressure control cut-out point as close as possible to the lowest saturated suction pressure expected while the unit is running.

Although the pumpdown cycle is the best possible protection against migration, it will not protect against liquid flooding during operation. A suction accumulator is recommended if flooding is expected. See Section 4.

When a pumpdown cycle is used, an approved start capacitor and relay must be used on all compressors having single phase PSC motors since the compressor will be starting against unbalanced pressures.

Superheat Requirements

In order to assure that liquid refrigerant does not return to the compressor during the running cycle, attention must be given to maintaining proper superheat at the compressor suction inlet. Emerson recommends a minimum of 20°F (11°C) superheat, measured on the suction line 6 inches (152mm) from the suction valve, to prevent liquid refrigerant floodback.

Another method to determine if liquid refrigerant is returning to the compressor is to accurately measure the temperature difference between the compressor oil crankcase and the suction line. During continuous operation we recommend that this difference be a minimum of 50°F (27°C). This “crankcase differential temperature” requirement supersedes the minimum suction superheat requirement in the last paragraph. To measure oil temperature through the compressor shell, place a thermocouple on the bottom center (not the side) of the compressor shell and insulate from the ambient. During rapid system changes, such as defrost or ice harvest cycles, this temperature difference may drop rapidly for a short period of time. When the crankcase temperature difference falls below the recommended 50°F (27°C), our recommendation is the duration should not exceed a maximum (continuous) time period of two minutes and should not go lower than a 25°F (14°C) difference.

Contact your Emerson Climate Technologies representative regarding any exceptions to the above requirements.

Crankcase Heaters

On some systems, operating requirements, cost, or customer preference may make the use of a pumpdown cycle undesirable, and crankcase heaters are frequently used to retard migration.

The function of a crankcase heater is to maintain the oil in the compressor at a temperature higher than the coldest part of the system. Any refrigerant entering the crankcase will be vaporized and driven back into the system through the suction line. However, in order to avoid overheating and carbonizing of the oil, the wattage input of the crankcase heater must be limited, and in ambient temperatures approaching 0°F., or when exposed suction lines and cold winds impose an added load, the crankcase heater may be overloaded and migration can still occur.

In no event should a compressor be started in a system with a crankcase heater unless it has been energized for a period of a least four hours immediately prior to compressor startup.

Crankcase heaters are effective in combating migration if conditions are not too severe, but they will not remedy slugging or liquid floodback.

Crankcase heater elements will burn out if overheated and historically, crankcase heaters have not had a good reliability record in the field. Past studies indicate that overvoltage may be a major cause of crankcase heater failure. Traditionally, heaters have been specified at nominal 220 volt and 440 volt conditions, but modern electrical transmission systems may operate at 10 to 15 percent above those voltages. Motors are designed to withstand wide swings in supply voltage without damage, but high voltage on the heater increases current, power input, and temperature, resulting in heater burnout.

In order to improve heater reliability, Emerson specifications for crankcase heaters have been established at nominal voltage ratings of 120, 240, 480, and 600. These coincide with the standardized nominal service voltage specified by ARI and NEMA. The heaters listed in Tables 2 and 3 reflect these voltage ratings.
Suction Accumulators

On systems where liquid flooding may occur, a suction accumulator should be installed in the suction line. Basically, the accumulator is a vessel which serves as a temporary storage container for liquid refrigerant which has flooded through the system, with a provision for metered return of the liquid refrigerant (and oil) to the compressor at a rate which the compressor can safely tolerate. (See AE11-1147 and AE11-1247.)

Flooding typically can occur on heat pumps at the time the cycle is switched from cooling to heating, or from heating to cooling, and a suction accumulator is mandatory on all heat pumps unless otherwise approved by the Emerson Climate Technologies Application Engineering Department. (For Copeland Scroll™ compressors, see AE4-1280 and CR4 & CR6 compressors see AE4-1276.)

Flooding can occur on an air conditioning system during short off cycles in high ambient conditions. This is especially true on capillary tube or fixed orifice systems with large condenser volumes and high refrigerant charges. During the off cycle, the hot condenser will drive a majority of the system charge (liquid) back to the compressor crankcase. Should the amount of refrigerant exceed the charge limit for the compressor, dangerous start up slugs can result.

To guard against this situation, Emerson recommends testing any air conditioning system with a charge greater than those listed on Table 1 for floodback which would require an accumulator. (See following section, “Air Conditioning Accumulator Test.”)

Systems utilizing hot gas defrost are also subject to liquid flooding either at the start or termination of the hot gas cycle. Compressors on low superheat applications such as liquid chillers and low temperature display cases are susceptible to occasional flooding from improper refrigerant control. Truck applications often experience extreme flooding conditions at startup after long non-operating periods.

On two stage compressors the suction vapor is returned directly to the low stage cylinder without passing through the motor chamber, and a low stage suction accumulator should be used to protect the compressor valves from liquid slugging.

Since each system will vary with respect to the total refrigerant charge and the method of refrigerant control, the actual need for an accumulator and the size required is to a large extent dictated by the individual system requirement. If flooding can occur, an accumulator must be provided with sufficient capacity to hold the maximum amount of refrigerant flooding which can occur at any one time, and this can be well over 50 percent of the total system charge. If accurate test data as to the amount of liquid floodback is not available, then 50 percent of the system charge normally can be used as a conservative design guide.

Air Conditioning Accumulator Test

To test for need of an accumulator, obtain a sample compressor with a vertical sight tube.

Elevate the evaporator five feet above the condensing unit, and use 25 foot line lengths with no traps in the suction line. If the system is field charged, Emerson recommends testing with a 10 to 20 percent system overcharge.

Operate the system for one hour in a 95°F outdoor and 75°F indoor ambient. Shut the compressor and condenser fan off. Keep the evaporator fan running. Observe the compressor sight tube after a five-minute off cycle.

If the liquid level rises above a predetermined point, (obtained from Application Engineering) an accumulator is required. This test should be repeated several times.

Accumulators for systems with long lines should be considered separately.

Oil Separators

Oil separators cannot cure oil return problems caused by system design, nor can they remedy liquid refrigerant control problems. However, in the event that system control problems cannot be remedied by other means, oil separators may be helpful in reducing the amount of oil circulated through the system, and can often make possible safe operation through critical periods until such time as system control returns to normal. For example, on ultra-low temperature applications or on flooded evaporators, oil return may be dependent on defrost periods, and an oil separator can help to maintain the oil level in the compressor during the period between defrosts.

WARNING - Extreme care must be taken in starting compressors for the first time after system charging. At this time all of the oil and most of the refrigerant might be in the compressor, creating a condition which could cause compressor damage due to slugging. Activation of the crankcase heater for several hours prior to start-up is recommended. If no crankcase heater is present, then directing a 500 watt heat lamp or other safe heat source on the lower shell of the compressor for approximately thirty minutes will be beneficial in eliminating this condition which might never reoccur.
## Table 2
### Crankcase Heaters
Copeland® Weld Compressors

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<thead>
<tr>
<th>J MODELS</th>
<th>Watts</th>
<th>Volts</th>
<th>Copeland Part No.</th>
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* Kit includes Reference Drawing

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<td>70</td>
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* Kit includes Reference Drawing and insulator

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| Round | 40 | 240/480/600 | 018-0031-02 | SW. SO-111 |

* Kit includes Reference Drawing

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Table 3 - Crankcase Heaters Copelametic Compressors

### H, K MODELS

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<th>Watts</th>
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<th>Indeeco Part No.</th>
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### 2D, E, 3R, L, M, N, 9, 3D, 4, 6 MODELS

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* Kit Includes Bolts and Reference Drawing

### 2D, M MODELS, Internal Immersion Type For Deep Oil Sump

### 9, 3D MODELS, Internal Immersion Type For Flat Bottom Plate or Deep Oil Sump

### 4, 6 MODELS, Internal Immersion Type For Flat Bottom Plate

### 4, 6, 8 MODELS, Internal Immersion Type For Deep Oil Sump

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