Application Engineering Bulletin

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TRANSPORT REFRIGERATION

Truck and trailer refrigeration is an increasingly important segment of the refrigeration industry. Despite the fact that transport applications face many operating problems peculiar to their usage, there exists very little application data pertaining to this field.

Many compressor failures in transport refrigeration usage are the result of system malfunction rather than the result of mechanical wear. It is clear that substantial savings in operating cost, and tremendous improvements in unit performance and life would be possible if the causes of compressor failure could be removed. Primarily the problem boils down to one of making sure that the compressor has adequate lubrication at all times.

Part of the problem of identifying the cause of failure stems from the fact that far too few users realize that ultimate failure of a compressor resulting from lack of lubrication frequently takes place at a time when there is an adequate supply of oil in the crankcase. This is due to continued deterioration of the moving parts resulting from the original or repeated damage in the past. It is not uncommon for a damaged compressor to operate satisfactorily all winter and then fail in the spring when subjected to heavier loads.

Another source of field problems is the fact that many units are installed by personnel who may not have adequate training, equipment, or experience. Often units, particularly those in common carrier service, may be serviced in emergencies by servicemen not familiar with the unit, or indeed, with transport refrigeration generally.

Because of the installation and service hazards, it is extremely important that the unit be properly designed and applied to minimize, and if possible, prevent service problems.

COMPRESSOR COOLING

Air-cooled motor-compressors must have a sufficient quantity of air passing over the compressor body for motor cooling. Refrigerant-cooled motor-compressors are cooled adequately by the refrigerant vapor at evaporating temperatures above 0°F. saturation, but at evaporating temperatures below 0°F. additional motor cooling by means of air flow is necessary.

Normally the condenser fan if located so that it discharges on the compressor will provide satisfactory cooling. For proper cooling, the fan must discharge air directly against the compressor. The compressor cannot be adequately cooled by air pulled through a compartment in which the compressor is located. If the compressor is not located in the condenser discharge air stream, adequate air circulation must be provided by an auxiliary fan.

COMPRESSOR SPEED

Open type compressors operating from a truck engine by means of a power take-off or by a belt drive are subjected to extreme speed ranges. A typical truck engine may idle at 500 RPM to 700 RPM, run at 1,800 RPM at 30 MPH, and run at 3,600 RPM to 4,000 RPM over the highway at high speeds. Whatever the power take-off or belt ratio, this means the compressor must operate through a speed ratio range of 6 to 1 or greater unless it is disconnected from the power source by some means.

The compressor speed must be kept within safe limits to avoid loss of lubrication and physical damage. Operation within the physical limitations of the compressor may be possible, for example from 400 RPM to 2,400 RPM. It may be possible to use a cut-out switch to disconnect the compressor from the power source at a given speed. The compressor manufacturer should be contacted for minimum and maximum speeds of specific compressors.

If the compressor is of the accessible-hermetic type, there is no problem concerning speed so long as the electrical source is operating at the voltage and frequency for which the motor was designed. If the speed of the generator is varied in order to obtain variable speed operation, the voltage and frequency on the normal alternating current generator will vary proportionally. Since the compressor speed and motor load will vary directly with the frequency, it is often possible to operate over a wide speed range with satisfactory results.

However, it should be born in mind that increasing the frequency and voltage of the generator above the level for which the compressor motor was designed will increase the load on the compressor, may overload the motor, can result in bearing or other compressor damage. Operation at speeds too low to provide adequate compressor lubrication must also be avoided, although normally lubrication can be maintained on Copelametic compressors down to 600 RPM and possibly lower speeds.

Each new application involving operation of the compressor at a voltage and frequency differing from its nameplate rating should be submitted to the Copeland Application Engineering Department for approval.

One other problem that may arise with operation from a variable speed generator is the operation of electrical contactors, relays, etc. on voltages below or above their nameplate rating. Field tests have shown that the winding design and physical construction of electrical components can cause wide variation in voltage tolerance. The drop-out voltage of various types of commercially available 220 volt contactors may vary from 145 volts to 180 volts depending on construction. If it is planned to operate at variable voltage and frequencies, the electrical components which are to be used should be extensively tested at the electrical extremes in cooperation with the manufacturer to insure proper operation.

COMPRESSOR OPERATING POSITION

Occasionally compressor failures will occur due to loss of lubrication caused by parking the truck on too steep a slope. The resulting tilt of the compressor may cause the oil level to fall below the pick-up point of the oil slinger or oil pump.

Operation of the unit while the truck is parked on steep inclines should be avoided. If this is unavoidable, then consideration should be given to mounting the compressor so that oil will tend to flow to the oil pick-up point. Since this will vary on different model compressors, and the individual parking arrangement will affect the direction of the compressor pitch, each application must be considered individually.

In severe cases, consult with the compressor manufacturer.

COMPRESSOR DRIVE

Direct drive from an engine, either gasoline or diesel, to a compressor requires very careful attention to the coupling design. Alignment between the engine drive shaft and the compressor crankshaft is critical both in parallel and angular planes. Even slight angular misalignment can cause repetitive compressor crankshaft breakage. Because of the sharp impulses from the engine firing, a flexible coupling should be capable of compensating for slight parallel or angular misalignment and should also allow some slight endplay movement of the crankshafts. Nylon splines, neoprene bushings, and flexible disc type couplings have all been used successfully.

For a compressor driven from a power take-off by means of a shaft and two universal joints, the crosses in the U-joints must be kept parallel to each other. Where possible, the compressor rotation should be in the same direction whether on electric standby or driven from the engine.

In driving a compressor with V-belts, care must be taken to avoid excessive belt tension and belt slap. A means for easily adjusting belt tension should be provided. It may be necessary to provide an idler pulley to dampen belt movement on long belt drives. Care should be taken to mount the compressor so that the compressor shaft is parallel with the engine crankshaft.

REFRIGERANT CHARGE

Refrigerant R-12 is used in most transport systems at the present time, but R-502 is well suited for low temperature applications, and its use is increasing. Since R-502 creates a greater power requirement for a given compressor displacement than R-12, the motor-compressor must be properly selected for the refrigerant to be used. Different expansion valves are required for each refrigerant, so the refrigerants are not interchangeable in a given system and should never be mixed. Receivers for R-502 require higher maximum working pressures than those used with R-12, so normally it is not feasible to attempt to convert an existing R-12 unit for the use of R-502.

The refrigerant charge should be held to the minimum required for satisfactory operation. An abnormally high refrigerant charge will create potential problems of liquid refrigerant migration, oil slugging, and loss of compressor lubrication due to bearing washout or excessive refrigerant foaming in the crankcase.

Systems should be charged with the **minimum** amount of refrigerant necessary to insure a liquid seal ahead of the expansion valve at normal operating temperatures. For an accurate indication of refrigerant charge, a sight glass is recommended at the expansion valve inlet, and a combination sight glass and moisture indicator is essential for easy field maintenance checking. It should be born in mind that bubbles in the refrigerant sight glass can be caused by pressure drop or restrictions in the liquid line, as well as inadequate liquid subcooling. Manufacturer's published nominal working charge data should be used only as a general guide, since each installation will vary in its charge requirements.

REFRIGERANT MIGRATION

Refrigerant migration is a constant problem on transport units because of the varying temperatures to which the different parts of the system are exposed. On eutectic plate applications, liquid refrigerant will be driven from the condensing unit to the plates during the day's operation, with the threat of floodback on start-up. On both plate and blower units not in operation, the body and evaporator immediately after operation will be colder than the condensing unit, causing migration to the evaporator. During daytime hours the body and evaporator will warm up, and because of body insulation will remain much warmer than the compressor during the night hours when the ambient temperature falls, resulting in a pressure differential sufficient to drive the refrigerant to the compressor crankcase.

Excessive refrigerant in the compressor crankcase on start-up can cause slugging, bearing washout, and loss of oil from the crankcase due to foaming. Dilution of oil with excessive refrigerant results in a drastic reduction of the lubricating ability of the oil. Adequate protective measures must be taken to keep migration difficulties at a minimum. Consideration should be given to keeping the refrigerant charge as low as possible, using a pump down cycle, use of a suction accumulator, and the use of a liquid line solenoid valve.

OIL CHARGE

Compressors leaving the Copeland factory are charged with Suniso-3G, 150 viscosity refrigeration oil and on other oil should be used without specific authorization from the Copeland Application Engineering Department. The napthenic base of the Suniso-3G oil has definite advantages over paraffinic oils because of less tendency to separate from the refrigerant at reduced temperatures.

Compressors are shipped with a generous supply of oil. However, the system may require additional oil depending on the refrigerant charge and system design. After the unit stabilizes at its normal operating conditions on the initial run-in, additional oil should be added if necessary to maintain the oil level at the 3/4 full level of the sight glass in the compressor crankcase. The high oil level will provide a reserve for periods of erratic oil return.

OIL PRESSURE SAFETY CONTROL

A major percentage of all compressor failures are caused by lack of proper lubrication. Only rarely is the lack of lubrication actually due to a shortage of oil in the system or failure of the oiling system. More often the source of the lubrication failure may be refrigerant floodback, oil trapping in the coils, or excessive slugging on start up.

To prevent failures from all these causes, the Copeland warranty requires that an approved manual reset type oil pressure safety control with a time delay of 120 seconds be used on all Copelametic compressors having an oil pump. The control operates on the differential between oil pump pressure and crankcase pressure, and the time delay serves to avoid shut down during short fluctuations in oil pressure during start up. A non-adjustable type control is strongly recommended, but if an adjustable type control is used, it must be set to cut out at a net differential pressure of 9 psig. Oil pressure safety controls are available with alarm circuits which are energized should the oil pressure safety control open the compressor control circuit.

OIL SEPARATORS

Proper refrigerant velocities and good system design are the only cure for oil trapping problems. Oil separators are vulnerable to damage from float valve vibration, and for that reason are not commonly used on transport units. Oil separators are not normally recommended for over-the-road use on trailers, but they have been used successfully in some city operations on ice cream truck applications.

The oil separator traps a major part of the oil leaving the compressor, and since the oil is returned directly to the crankcase by means of a float valve, oil circulation in the system is minimized. On low temperature systems, oil separators may be of valve in holding the amount of oil in circulation to level which can be adequately returned to the compressor by the refrigerant in the system. However, on systems where piping design encourages oil logging in the evaporator circuit, an oil separator may only serve to delay lubrication difficulties.

The oil separator should be insulated to prevent refrigerant condensation and return of liquid to the compressor crankcase. A convenient means of returning oil to the compressor, and still providing maximum protection against liquid return is to connect the oil return line to the suction line just before the suction accumulator.

CRANKCASE PRESSURE REGULATING VALVE

In order to limit the load on the compressor, a crankcase pressure regulating valve may be necessary. During periods when the valve is throttling, it acts as a restrictor, and on start-up or during a hot gas defrost cycle, it acts as an expansion valve in the line. The preferred location for the CPR valve is ahead of the suction line accumulator. The accumulator will trap liquid refrigerant feeding back and allow it to boil off or feed the compressor at a metered rate to avoid compressor damage. However, location of the accumulator ahead of the CPR valve is acceptable if the accumulator has adequate capacity to prevent liquid floodback to the compressor.

The CPR valve should be sized for a minimum pressure drop to avoid loss of capacity, and should never be set above the published operating range of the compressor.

CONDENSERS

Condenser construction must be rigid and rugged, and the fin surface should be treated for corrosion resistance unless the metal is corrosion resistant. The area in which the condenser is mounted affects its design. Condensers mounted on the skirt of a truck or beneath a trailer receive a great deal of road splash, while those mounted high on the nose of a truck or trailer are in a somewhat cleaner atmosphere. If the condenser in mounted beneath a trailer facing in the direction of travel, a mud guard should be provided. The type of tube and fin construction affects the allowable fin spacing, but in general, fin spacing of no more than 8 fins to the inch is recommended, although some manufacturers are now using fin spacing as high as 10 and 12 per inch.

Since the unit will operate for extended periods when the vehicle is parked, ram air from the movement of the vehicle cannot be considered in designing for adequate air flow, but the condenser fan should be located so that the ram air effect aids rather than opposes condenser air flow. It also should be born in mind that often many trucks or trailers will be operating side by side at a loading dock, and the air flow pattern should be such that one unit will not discharge hot air directly into the intake of the unit on the next vehicle.

Since the space available for condenser face area is limited in transport refrigeration applications, the condenser tube circuiting should be designed for maximum efficiency.

Low head pressure during cold weather can result in lubrication failure of compressors. With trucks operating or parked outside or in unheated garages in the winter months, this condition can frequently occur. A decreased pressure differential across the expansion valve will reduce the refrigerant flow, resulting in decreased refrigerant velocity and lower evaporator pressures, permitting oil to trap in the evaporator. Frequently the feed will be decreased to the point that short-cycling of the compressor results. The use of a reverse acting pressure control for cycling the condenser fan, or some other type of pressure stabilizing device to maintain reasonable head pressure is highly recommended.

RECEIVER

Because of field installation and repair, all units should be equipped either with a receiver or an adequately sized condenser so that the refrigerant charge is not critical. Valves should be provided so that the system can be pumped down. A positive liquid level indicator on the receiver will aid in preventing over-charging, and high and low test cocks have been used satisfactorily for this purpose. The size of the receiver should be held to the minimum required for safe pump down.

It is recommended that a charging valve be provided in the liquid line. While not essential, it is a fact that most servicemen will charge liquid rather than vapor into a system, and a charging valve makes this possible without damage to the compressor.

On units in operation over-the-road, powered either from the truck engine or a separate engine power source, the receiver may be subjected to temperatures higher than the condensing temperature because of heat given off by the engine. This can result in abnormally high condensing pressures because of liquid refrigerant being forced back into the condenser, excessive refrigerant charge requirements, and flashing of liquid refrigerant in the liquid line. If excessive hating of the receiver can occur, provisions should be made for ventilation of the receiver compartment with ambient air, or the receiver should be insulated.

PURGING OF AIR FROM SYSTEM

Occasionally due to improper installation or maintenance procedures, a unit will not completely evacuated, or air will be allowed to enter the system after evacuation. The non-condensable gases will exert their own pressures in addition to refrigerant pressure, and will result in head pressures considerably above the normal condensing pressure.

Aside from the loss of capacity resulting from the higher head pressure, the presence of air in the system will greatly increase the rate of corrosion and can lead to possible carbon formation, copper plating, and/or motor failure.

As a temporary measure, it may be possible to purge refrigerant from the top of the condenser while the unit is not operating, and blow out any air trapped in the condenser. However, it is almost impossible to purge all of the air out of the compressor crankcase, and air may also trap in the receiver. If it is discovered that air has been allowed to contaminate the system, the refrigerant should be removed, and the entire unit completely evacuated with an efficient vacuum pump.

LIQUID LINE FILTER-DRIER

On all transport refrigeration systems, because of the uncertainties of installation and service, a liquid line filter-drier is essential. It is recommended that the filter-drier be oversized by at least 50% for the refrigerant charge because of the many opportunities during field maintenance for moisture to enter the system. It should have flare connections for easy replacement.

HEAT EXCHANGER

A heat exchanger should be considered mandatory on all units. It improves the performance, insures liquid refrigerant at the expansion valve, and helps assure the return of dry gas. Normally it should be located inside the refrigerated space to avoid loss of capacity, but it can be located externally if insulated.

LIQUID LINE SOLENOID VALVE

When, because of the design of the system, the refrigerant charge cannot be held to a level which can be safely handled by the compressor should refrigerant migration occur, a normally closed liquid line solenoid may be required. On 3 HP systems with refrigerant charges exceeding 15 pounds, and on 5 HP systems with refrigerant charges exceeding 20 pounds, a liquid line solenoid is recommended, and some manufacturers make liquid line solenoids mandatory on all units 1 1/2 HP and larger.

The valve should be wired in parallel with the compressor so that it will be closed when the system is not in operation. It should be installed between the receiver and the expansion valve, and should have a filter-drier or strainer mounted just upstream from it in the liquid line. A soft-seated valve, of teflon or similar material, is preferred for better control during over-the-road operation.

SUCTION LINE ACCUMULATOR

A suction line accumulator is considered mandatory on all systems 2 HP and larger in size, and is recommended for all units. The purpose of the accumulator is to intercept any liquid refrigerant which might flood through the system before it reaches the compressor, particularly on start-up or on hot gas defrost cycles. Because crankcase heaters or a pumpdown cycle are not always operative on transport units, the accumulator is the best protection that can be provided for the compressor.

Provisions for positive oil return to the crankcase must be provided, but a direct gravity flow is not acceptable since this would allow liquid refrigerant to drain to the crankcase during shutdown periods. Capacity of the accumulator usually should be a minimum of 50% of the system charge, but the required size will vary with the system design. Tests are recommended during the design phase of any new unit to determine the minimum capacity for proper compressor protection.

An external source of heat is desirable to accelerate the boiling of the liquid refrigerant in the accumulator so that it may return to the compressor as gas. Mounting in the condenser air stream or near the compressor will normally be satisfactory.

CRANKCASE HEATERS

Because of the interruptable power source inherent in transport refrigeration, it is difficult to insure continuous operation of the heaters. A continuous drain on the truck battery would not be acceptable.

Crankcase heaters will help when connected to a continuous power source, but cannot be relied on for complete protection against damage from liquid migration.

PUMPDOWN CYCLE

A pumpdown cycle is the best means of protecting the compressor from refrigerant damage, particularly if an excessively large charge cannot be avoided. As in the case of crankcase heaters, the fact that power may not always be available makes a pumpdown system unreliable. It is quite possible that the power to the unit might be shut off at any moment with the unit in operation and refrigerant in the coils. If pumpdown control is used, special operating precautions should be taken to insure complete pumpdown before the electric power is disconnected.

FORCED AIR EVAPORATOR COILS

Air velocities across the coil should not exceed 500-600 FPM in order to avoid blowing water from the coil onto the load. Care should be taken to insure even air distribution across the coil, since uneven air flow can cause uneven loading of the refrigerant circuits. Fin spacing exceeding 6 per inch is not recommended because of the rapid build-up of frost on the fins. However, some users and manufacturers recommend spacing as low as 3 or 4 fins per inch, while others report satisfactory experience with spacings as high as 8 per inch provided proper defrost controls are used.

Delivered air velocity should be adequate to insure good air circulation in the vehicle. Noise level is not a design limitation in a van, so velocities up to 1,500 FPM or higher can be used.

Internal volume of the refrigerant tubes should be kept to a minimum to keep the refrigerant volume as low as possible. Since pressure drop at low temperatures is critical so far as capacity is concerned, multiple refrigerant circuits with fairly short runs are preferred. Pressure drop in the evaporator should be no more than 1 to 2 psig. At the same time, it is essential that velocities of refrigerant in the evaporator be high enough to avoid oil trapping. 5/8" evaporator tubes are acceptable, but 1/2" are preferred, and 3/8" tubing has been used successfully. Vertical headers should have a bottom outlet to allow gravity oil draining.

An evaporator face guard should be provided to protect the fins and tubing from cargo damage. Ample air inlet area should be provided, with access from both sides and the bottom if possible, to prevent blocking of air to the evaporator by cargo stacked in the vehicle.

THERMOSTATIC EXPANSION VALVE

Because of the wide range of load conditions and the premium on pulldown time in the transport field, it has been common practice for some manufacturers to oversize expansion valves used on transport units, particularly on units equipped with blower evaporator coils. If the expansion valve is oversized too greatly, surging of the refrigerant feed will result with possible floodback and erratic operation. If this occurs, a smaller valve must be used.

A liquid charged type valve is essential to retain control, since the head may frequently be colder than the sensing bulb. Vapor charged expansion valves should not be used on transport refrigeration systems.

Valve superheat should be present by the valve manufacturer and field adjustment should be discouraged. However, valves in need of adjustment should be set to provide 5° F. to 10° F. superheat at the evaporator. Too high a superheat setting will result in starving the evaporator and poor oil return. Too low a superheat setting will permit liquid floodback to the compressor.

Pressure limiting type valves are sometimes used to limit the compressor load according to the allowable suction pressure. Since oil return to the compressor is extremely slow during the pulldown period due to the throttling action of this type of valve, MOP valves are generally not recommended for transport applications, and a crankcase pressure regulating valve is recommended if the compressor load must be limited.

It should be born in mind that the pressure across the valve affects its maximum capacity and its rate of feed. Therefore, the valve operation and the amount of superheat may be materially affected by charges of head pressure caused by changes in the ambient temperature. Some means of stabilizing head pressure is desirable to provide a uniform expansion valve feed.

DEFROST SYSTEMS

A defrost system, either electrical, reverse cycle, or hot gas, is essential for satisfactory operation of any low temperature transport unit equipped with forced air evaporators. If trucks are to used as weekend storage containers at temperatures close to 32° F., return air as a defrosting medium may result in load temperature fluctuations.

An electrical defrost system is feasible when the unit is operating from an engine generator set or from a stationary electrical supply. The reverse cycle defrost using a four-way valve is exceedingly fast and effective, but may be sensitive to any foreign material in the system. Hot gas defrost using the heat of compression is effective only if some means of maintaining head pressure on the compressor is available, or if refrigerant condensing in the evaporator can be re-evaporated. Partial flooding of the condenser has been used, but this results in carrying a very large charge of refrigerant in the system. Some proprietary systems using heat from the engine cooling water or heat from the engine exhaust have been used with success.

Drain pan heaters are required on low temperature installations to prevent the build up of ice in the drain pan. To prevent the defrost heat from entering the cargo space, the evaporator fan should be stopped during defrost, or a damper installed in the air outlet.

Automatic start of the defrost cycle is recommended to avoid excessive accumulation of frost on the evaporator, and automatic termination should be provided to avoid returning overheated gas to the compressor. Since vibration will cause maintenance problems on time clocks, a control responsive to fan air pressure is frequently used for defrost initiation, and a temperature responsive control for defrost termination. Another method of automatic defrost control that has been used satisfactorily is a two element control sensing return air and coil temperatures, and operating on the differential between the two temperatures.

A suction accumulator is considered mandatory with any system using a hot gas or reverse cycle defrost system. The use of stream or hot water for cleaning or defrost purposes should be avoided unless a suction accumulator of adequate size is used to intercept the liquid driven out of the plates or evaporator by the heat.

THERMOSTAT

If the unit is controlled by a thermostat, a snap action type is essential to prevent chattering of the contacts. It is recommended that enclosed type switches be sealed against moisture. A calibrated adjustment with a set temperature indicator is highly desirable. The construction of the control should be such that it will withstand road shock and vibration. A liquid charged sensing bulb is desirable for fast response and accuracy of control.

HIGH-LOW PRESSURE CONTROL

A combination high and low pressure control is recommended for all systems. If a thermostat is used for unit control, and a pumpdown system is not used, a low pressure control of the manual reset type should be wired in series with the thermostat to serve as a safety cut-off in the event of loss of refrigerant charge or other abnormal conditions resulting in low suction pressures.

When used for low temperature unit operational control, the low pressure control should be provided with a low differential for accurate control. For accuracy, refrigeration gauges must be used in setting cut-in and cut-out points, since the indicator on the control is not sufficiently accurate for control purposes.

Motor-compressors with single phase motors having inherent protection, 2 HP and smaller, can be operated directly on a pressure control, but larger HP compressors usually require a contactor since oil pressure safety controls require a pilot circuit, as they cannot carry the running current.

EUTECTIC PLATE APPLICATIONS

Eutectic plate applications are subject to both oil logging in the evaporator and liquid floodback to the compressor on start-up unless care is taken in system layout and installation. Since either of these conditions can result in compressor failure, adequate steps must be taken to protect the compressor.

In order to avoid trapping oil, high refrigerant velocity must be maintained through the evaporator tubing. Since the velocity is dependent on the volume of refrigerant in circulation, plates should be connected in series as required to provide an adequate refrigeration load for each expansion valve circuit.

The following table may be used as a guide in determining the minimum eutectic plate surface that must be connected to one expansion valve to insure velocities sufficient to return oil to the compressor. The recommendations are based on refrigerant evaporating temperatures 15° F. below the plate eutectic temperature, plate manufacturers' catalog data and recommendations, and a leaving gas velocity of 1,500 FPM. For easy field calculation, the eutectic plate surface shown is for one side of the plate only, e.g. a 24" x 60" plate would have 10 square feet of surface.

RECOMMENDED PLATE SURFACE FOR EACH EXPANSION VALVE CIRCUIT

Tubing Diameter	Low Temperature Plates Below 0° F. Eutectic		Medium Temperature Plates Above 0° F. Eutectic	
	Minimum	Maximum	Minimum	Maximum
⅝" O.D.	12 sq. ft.	32 sq. ft.	15 sq. ft.	32 sq. ft.
¾" O.D.	17 sq. ft.	40 sq. ft.	22 sq. ft.	40 sq. ft.
⅞" O.D.	35 sq. ft.	50 sq. ft.	40 sq. ft.	50 sq. ft.

Basically the circuiting and valving of a truck plate system should be designed so that velocities in each refrigeration circuit will be above a given minimum (for adequate oil return) and below a given maximum (for a pressure drop that does not cause excessive capacity penalty). It is recommended that circuits approaching the maximum should be used whenever possible.

For example, if in a given truck for low temperature use, plates with below 0° F. eutectic solution were used, circuits might be selected as follows:

Given:

2 - 24" x 120" plates @ 20 sq. ft. each
2 - 24" x 60" plates @ 10 sq. ft. each
1 - 30" x 60" plate @ 12.5 sq. ft.

<u>5/8" O.D. Tubing</u>

Circuit

A	1 - 24" x 120" plate	20 sq. ft.
B	1 - 24" x 120" plate	20 sq. ft.
C-Series	(1 - 30" x 60" plate	12.5 sq. ft.
	(2 - 24" x 60" plates	20 sq. ft.

<u>3/4" O.D. Tubing</u>

Circuit

A-Series	(1 - 30" x 60" plate	12.5 sq. ft.
	(2 - 24" x 60" plates	20 sq. ft.
B-Series	2 - 24" x 120" plates	40 sq. ft.

<u>7/8" O.D. Tubing</u>

Circuit

A-Series	(1 - 30" x 60" plate	12.5 sq. ft.
	(2 - 24" x 60" plates	20 sq. ft.
B-Series	2 - 24" x 120" plates	40 sq. ft.

Normally the eutectic plates are selected by the system designer for the particular truck and application requirement. In order to keep the refrigerant charge within acceptable limits, it is important that both the total number of plates and the plate internal refrigerant volume be kept to an absolute minimum required to accomplish the desired refrigeration.

Because of the large refrigerant charge required for plates, and the variable nature of the load impose on the compressor, plate circuits are subject to extreme variations in refrigerant velocity. It has been our experience that proper velocities are of much greater importance than low pressure drop in determining the heat transfer rate between the refrigerant and the eutectic solution. Many users, following normal commercial refrigeration practice where it is assumed that refrigerant charges are low and velocities are consistently high, have placed an undue importance on low pressure drop in selecting and circuiting plates, and as a result have unknowingly created lubrication problems in their systems while gaining little or nothing in capacity performance. In many instances capacity has actually been reduced due to loss of proper refrigerant control.

A common misconception is that the use of separate expansion valves on each plate will give increased capacity and more rapid pulldown. This is not necessarily so. The use of more expansion valves will result in a lower pressure drop through the refrigerant circuit which might aid capacity slightly, but in most cases the resulting improper control actually decreases capacity.

On two plates, for example, the use of two expansion valves would result in two sections of tubing being used as drier area in order to obtain the necessary superheat for proper operation of the expansion valves. If only one expansion valve were used, only one length of tubing for this superheating function would be required, and the effective refrigeration area would be increased. The use of one expansion valve on multiple plates results in a much higher velocity, and as a result the scrubbing action of the refrigerant on the walls of the tube causes a much higher rate of heat transfer. Our experience would indicate, particularly at low evaporating temperatures, that very possibly multiple plates operating on one expansion valve will have more capacity and a better pulldown than the same plates operating with individual expansion valves.

A similar misconception is that the use of larger O.D. tubing in plates will result in a lower pressure drop and therefore increase capacity. As in the case of expansion valves, the use of smaller tubing, although possibly resulting in a slightly higher pressure drop, will greatly increase refrigerant velocity, increase the heat transfer rate as a result, and again our experience indicates on low temperature plates that capacity may actually be increased because of the smaller tubing. The smaller tubing requires a smaller refrigerant charge, and therefore also decreases the problem of refrigerant migration.

Expansion valves on plate circuits should be no larger than 1 ton size, and 1/2 ton valves will give better control on smaller circuits in the medium temperature range. The piping and thermal sensing bulbs should be located so that each valve operates independently and is not influenced by the return line controlled by another valve.

Field experience indicates that due to the throttling action of an MOP valve after shutdown or defrost periods, oil may not be returned to the crankcase at a fast enough rate to maintain compressor lubrication in the event oil is lost from the compressor on start-up due to liquid refrigerant foaming in the crankcase. Therefore, pressure limiting type expansion valves are not recommended for plate circuits.

Because of the amount of oil trapped in the plates during operation, additional oil normally must be added to the compressor during the initial pulldown cycle, or after the unit reaches its normal operating conditions. Sufficient oil should be added to maintain the oil level at approximately the 3/4 full level of the compressor oil sight glass.

As the eutectic solution becomes frozen, the boiling action of the refrigerant slows, and a higher percentage of liquid refrigerant lies in the bottom of the evaporator tubing. When the unit cycles off, or the power is disconnected, the plates may be partially filled with liquid refrigerant and oil. At some later time when the compressor is again started, the liquid will flood back to the compressor.

To protect against liquid floodback, a suction accumulator is mandatory on units of 2 HP and larger, and is recommended on all transport units. If a crankcase pressure regulating valve is used, the accumulator should be located if possible between the CPR valve and the compressor in order to provide the maximum protection.

A liquid line solenoid valve can be helpful in minimizing migration from the condenser and receiver to the evaporator and compressor during periods when the unit is not in operation. If the system refrigerant charge is not excessive, a liquid line solenoid may not be required, but some manufacturers feel they should be mandatory on all plate systems 1 1/2 HP in size and larger.

All plate applications should be equipped with the following:

a. Properly sized expansion valves.

b. A liquid to suction heat exchanger for maximum efficiency.

c. A liquid line filter-drier.

d. A combination sight glass and moisture indicator for easy maintenance.

e. An oil pressure safety control on all compressors having oil pumps.

f. A reverse acting pressure control to stop the condenser fan in order to maintain satisfactory compressor head pressure during cold weather operation.

g. Suction line accumulator (2 HP and larger).

One of the major problems in low temperature eutectic plate applications is the practice of the operator or serviceman of reducing the low pressure cut-out below the operating limits of the refrigeration system, possibly to such a low setting that the resulting refrigerant velocities are too low to return oil to the compressor. This practice has been stimulated by the demand for lower and lower ice cream temperatures, and the serviceman often fails to realize the hazard he is creating. The increased compression ratio is not a problem in a properly designed compressor so long as adequate lubrication is maintained. But once the eutectic solution is frozen, the decrease in evaporator load causes the compressor suction pressure to drop rapidly, and at extremely low suction pressure, compressor capacity falls off rapidly. From -25° F. to -40° F. the capacity may decrease by 50% in the best R-12 low temperature compressor, and from -25° F. to -50° F. the reduction in capacity may be as high as 75%. As a result, there may no longer be adequate refrigerant velocity in the evaporator circuit to return oil to the crankcase. At such low capacities, the expansion valve may no longer be able to properly control the liquid refrigerant feed.

A very promising recent development in the application of eutectic plates is the use of hot gas bypass as a means of maintaining adequate suction pressures. A hot gas control valve modulates open at a predetermined pressure, bypassing hot gas into the entrance of the evaporator circuits just after the expansion valve. Velocities through the evaporator circuit are maintained at a high level, preventing oil trapping, while heat transfer through the evaporator is greatly improved. This type of control system can prevent many of the basic problems which have been a frequent cause of failure on low temperature eutectic plate applications.

The user must realize that a compressor's application is limited by the rest of the system. Because of the inherent problems of oil return presented by the shape and mounting characteristics necessitated in truck applications, and the large amounts of tubing which must be used in plate construction, the minimum satisfactory evaporating temperature for both R-12 and R-502 is approximately -40° F. **Low pressure controls on all plate systems must be set to cut out at or above the equivalent pressure setting; for R-12, 11" of vacuum, and for R-502, 5 psig.**

In order to maintain the evaporating temperature within acceptable limits, it is essential that the combination of condensing unit and plates be properly balanced. The selection of too small a condensing unit may result in a freezing rate that is too slow. But of equal and possibly greater importance, the selection of too large a condensing unit may result in an excessively large temperature difference between the plate eutectic temperature and the refrigerant evaporating temperature. This condition most frequently occurs when a large condensing unit is selected in order to achieve a quick pulldown, or to shorten the time necessary to freeze the eutectic solution. Since the minimum satisfactory evaporating temperature is approximately -40° F., the condensing unit should be selected so that the normal operating evaporating temperature on low temperature plates is not below -30° F. to -35° F.

REFRIGERANT PIPING

Normal good piping practice should be followed in installing refrigerant lines for split systems. A silver solder alloy should be used for making connections to the compressor and for long runs of tubing where vibration may be a problem, and a high temperature silver solder alloy only must be used on compressor discharge lines. For other connections, 95/5 solder is acceptable, and makes possible easier field repair. 50/50 solder should not be used since it does not have sufficient strength for transport usage. Acid core type solder should not be used.

The suction line should be sized to keep refrigerant velocities above 700 FPM for horizontal runs, and 1,500 FPM for vertical risers at the lowest expected capacity.

VIBRATION

The greatest single hazard of transport refrigeration usage is damage from vibration and shock. Although shock tests on the nose of trailers have recorded very high shock levels, the great majority of all failures from this source are due to the cumulative effect of small vibrations. Any line, capillary tube, or structural member that is subjected to continuous sharp vibration, or that against a neighboring member in operation is almost certain to fail within a fairly short period of time. It cannot be stressed too strongly that normal commercial construction of condensing units and evaporators for the usual commercial application is not adequate for over the road usage.

Copeland manufactures a line of condensing units especially designed for transport usage. The frames are ruggedly constructed, and all components are mounted to minimize vibration.

When compressors are installed in a system manufacturer's condensing unit, care must be taken to see that the compressor is bolted down firmly. Neoprene or other resilient shock mounts may be used, but spring mounting is not acceptable. Internally spring mounted compressors are not suitable for transport applications due to the danger of internal damage from severe shocks, and continuous spring movement.

Vibration eliminators should be mounted in the compressor discharge and suction lines. A very common fault is the installation of a vibration absorber between two sections of rigid piping, in which case the vibration absorber may be as rigid as the piping. Metal vibration eliminators should never be mounted in such a fashion that they are subjected to stress in either compression or extension. An improperly installed vibration eliminator can actually cause line failure. Flexible refrigerant lines such as Aeroquip, Stratoflex, or Anchor which are specifically designed for use with the appropriate refrigerant may be used in place of metallic vibration absorbers. Metallic vibration absorbers should have joints adequately sealed to prevent condensation from freezing and damaging the joints.

Welding is preferable to bolting in fastening structural members. Sheet metal screws, and other metal fasteners not securely held by lock washers or lock nut are not dependable. All wiring and piping should be protected with grommets where passing through sheet metal holes.

Evaporator and condenser tube sheets, when used for mounting, should be of solid, one piece construction, and may require heavier gauge construction than used in normal commercial practice for strength purposes. Coil tube sheets should be manufactured with collars, as raw edge holes can cut the tubing due to vibration.

ELECTRICAL PRECAUTIONS

Electrical failures are a common field maintenance problem due to the wet environment, shock, and vibration, and the possibility of improper power from an engine generator set.

For the safety of operating and maintenance personnel, the electrical system should be grounded to the frame, and the frame in turn grounded by means of a chain or metal link to the ground if a generator set is mounted on the vehicle. All components should be grounded from one to the other, such as the generator set to condensing section to evaporator section. Cables to remote sources of power should carry an extra wire for grounding purposes at the supply plug.

At the time of manufacture, each system should be given a high potential test to insure against electrical flaws in the wiring. All relays and terminals should be protected against the weather, and all wiring should be covered with protective loom to guard against abrasion. All switches should be one of the sealed type, recommended by the manufacturer for use in wet environments. Plug type line connectors should be of the waterproof type. Electrical cables connecting split units should have a watertight cable cover, or should be run in conduit. All wiring should be fastened securely to prevent chafing, and should be clearly identified by wire marking and/or following the color code specified by the National Electrical Code.

Adequately sized extension cords, plugs, and receptacles must be used to avoid excessive voltage drop. Voltage at the compressor terminals must be within 10% of the nameplate rating, even under starting conditions. Many single phase starting problems on small delivery trucks can be traced to the fact that power is supplied to the compressor from household type wiring circuits through long extension cords, neither of which are sized properly for the electrical load. Single phase open type motors which are used for belt driving a compressor during over-the-road operation, must be equipped with a relay to break the capacitor circuit, rather than a centrifugal switch. The variable speed operation experienced during truck operation may cause a centrifugal switch to fail because of excessive wear at low operating speeds. All start capacitors must be equipped with bleed resistors to permit the capacitor charge to bleed off rapidly, preventing arcing and overheating of the relay contacts.

When units are operated from several power sources, be sure all plugs and receptacles are wired in the same sequence, so that the compressor rotation will not be reversed.

INSTALLATION

A large number of field failures that now occur could be prevented by proper installation practice. To insure trouble free operation, every effort should be made to carry out the following minimum procedures.

1. Read the manufacturer's instructions.
2. Be sure that structural or reinforced members are provided to mount the units.
3. Thoroughly clean all cooper lines before assembling. Do not use steel wool for cleaning since the metal slivers may cause electrical problems in the compressor. If the tubing is not precleaned and capped, pull a rag saturated with refrigerant oil through the tube and blow out with nitrogen prior to connecting lines to the evaporator and condenser.
4. Use only a suitable silver solder alloy or 95/5 solder in making soldered joints.
5. When brazing lines, circulate inert gas such as dry nitrogen through the line to prevent oxidation.
6. Install piping in the wall or floor of the vehicle, or provide an adequate guard.
7. After the lines are installed, pressurize to 150 psig, and leak test. The use of an

electronic leak detector is recommended for greater sensitivity. As a final check, the system should be sealed for 12 hours after pulling a deep vacuum. If the vacuum will not hold, the system should be rechecked for leaks, repaired, and retested to insure that it is ready for evacuation and charging.

8. Use a good high vacuum pump to evacuate the system and leave the pump on the system for a minimum of 4 hours. Evacuate to less than 1,500 microns, and break the vacuum with refrigerant to 5 psig. Repeat the evacuation process, and break with refrigerant as before. Evacuate a final time to 500 microns or less and the system is ready for charging.

   WARNING: To prevent motor damage do not use the motor compressor to evacuate the system. A motor-compressor should never be started or operated while the system is under deep vacuum, or serious damage may result because of the reduced dielectric strength of the atmosphere within the motor chamber.

9. Charge the unit with refrigerant, either vapor through the suction valve, or preferably liquid through a liquid line charging valve if provided. **The compressor must never be charged with liquid refrigerant through the suction side.**

10. If using an engine-generator as a power source, start the engine and check the generator output voltage to be sure it is correct.

11. Check the voltage at the compressor terminals, start the unit, check the amperage draw of the compressor, and the rotation of the fans to be sure the unit is phased properly.

12. Observe the discharge and suction pressures. If an abnormal pressure develops, stop the unit immediately and check to see what is causing the difficulty. Take corrective action if required.

13. Observe the refrigerant oil level and check the oil pressure, if the compressor is equipped with a positive displacement oil pump. If the oil level becomes dangerously low during the pulldown period, add oil to the compressor. After the unit reaches normal operating conditions, add oil if necessary to bring the level to a point 3/4 full in the crankcase sight glass.

14. Check all manual and automatic controls.

15. After a minimum of two hours of operation, make another leak test.

16. After the unit has reached the proper operating conditions, and all controls have been checked, run the unit overnight on automatic control to be sure operation is satisfactory. Check oil level in the compressor, and add oil if necessary.

17. When unit is delivered to the customer, be sure that operating personnel have proper written instructions on operating and maintenance procedures. The responsible sales personnel should verbally explain the operation of the unit to the user, and wiring diagrams and operating instructions should be permanently carried on the vehicle, either by means of a decal or in an envelope properly protected from loss or damage.

FIELD TROUBLESHOOTING ON TRANSPORT UNITS

The great majority of all low temperature compressor failures in transport refrigeration can be traced to lubrication problems. No compressor can operate satisfactorily unless oil logging and liquid floodback can either be prevented or safely controlled by safeguard devices in the refrigeration system.

The following check-off list covers possible corrective action on units experiencing field difficulties. For a more detailed discussion of each item, refer to the appropriate section in this manual. The need for any particular modification would of course depend on the individual application.

1. **Eutectic plate circuiting for high refrigerant velocity**

   It is essential for proper oil return to the compressor that high refrigerant velocities be maintained through the evaporator circuits. For a rough rule of thumb on plates with 7/8" or 3/4" O.D. tubing, there should be no less than 3 small or 2 large plates in series on one expansion valve. On plates with 5/8" O.D. tubing, there should be no less than 2 small or one large plate on one expansion valve.

2. **Expansion valves on eutectic plates**

   Expansion valves should be no longer than 1 ton capacity in size, liquid or cross charge, and internally equalized.

3. **Refrigerant Charge**

   The refrigerant charge must be held to a minimum to avoid refrigerant migration problems. Use a sight glass to check for a liquid seal at the expansion valve at low temperature operating conditions.

4. **Liquid Line Solenoid Valve**

   If excessive refrigerant migration to eutectic plates is occurring during over-the-road operation, a liquid line solenoid valve may be required to properly control large refrigerant charges.

5. **Suction Line Accumulator**

   A suction line accumulator is the best protection that can be provided to guard against liquid floodback. **It should be mandatory on all truck applications 2 HP and larger.** For maximum efficiency, it should be installed close to the compressor, and if a CPR valve is used, between the compressor and the CPR valve. The accumulator must have provisions for positive oil return.

6. **Head Pressure Control**

   In winter operation, head pressures may drop so low that inadequate feeding of the expansion valve may result, and the evaporator may be starved. A reverse acting high pressure control should be used to cycle the condenser fan if head pressures drop below 80 psig on R-12 operation, or 125 psig on R-502 operation, unless other acceptable means of controlling head pressures are provided.

7. **Oil Level in Crankcase**

   When compressors without oil pumps are used on truck applications, the oil level should be maintained high in the compressor sight glass to assure a reserve of lubricating oil for periods of erratic oil return. The user should be warned that the compressor may not be getting adequate lubrication if the oil level drops below the bottom of the sight glass. Only Suniso 3G oil should be used which has a viscosity of 150, a pour point of -35° F. and a floc point of -70° F. This oil has proven satisfactory for all low temperature applications.

8. **Oil Pressure Safety Control**

   On all compressors having positive displacement type oil pumps, an oil pressure safety control is required.

9. **High Pressure Cut-Out**

   Several manufacturers have produced units with no high pressure control. Failure of the condenser fan motor may result in excessive head pressures, and subsequent compressor failure. A high pressure control is essential.

10. **Liquid Line Filter-Drier and Heat Exchanger**

    These should be standard on all units.

11. **Low Pressure Control Setting**

    A major educational effort is required to point out to the user the dangers of bypassing the low pressure cut-out, or setting it at dangerously low levels.

    When eutectic plates are completely frozen, the compressor suction pressure falls very rapidly, with a consequent sharp drop in compressor capacity, and resulting lubrication difficulties, since velocity in the plates may no longer be sufficient to return oil to the compressor. Users, particularly ice cream distributors, frequently try to reduce the van body temperature to the lowest temperature possible as an added safety factor for the day's operation.

Since the system is normally not designed for the extremely low evaporating temperatures at which the compressor can operate under such conditions, the compressor pays the penalty. The user must realize that a compressor's application is limited by the rest of the system. Because of the inherent problems of oil return presented by the shape and mounting characteristics necessitated in truck applications, and the large amounts of tubing which must be used in plate construction, the minimum satisfactory evaporating temperature for both R-12 and R-502 is approximately -40° F. **Low pressure controls on transport systems must be set to cut out at or above 11" of vacuum on R-12 , and 5 psig on R-502.**

12. **Location of Truck while System is Operating**

Trucks must be parked on a reasonably level surface while the refrigeration unit is in operation. Short periods of operation on an incline such as experienced in over-the-road operation are not a problem, but long periods of operation while the truck is parked on a steep incline or on the side of a hill may rob the compressor of lubrication if the oil level flows away from the pick up point of the oil flinger or oil pump.

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