

Parallel Compressor Oil Management in Supermarkets

By Steve Esslinger, Senior Application Engineer-Supermarket Refrigeration, Sporlan Valve Company

The primary purpose of oil in a refrigeration system is to lubricate the moving parts of the compressor. The operation of the oil management system on a supermarket compressor "rack" is one of the least understood parts of the refrigeration system. Many service engineers believe that the oil separator, reservoir and compressor oil level controls are the only system components that will determine the compressor oil level. This is a misconception.

It is important to note that the addition of an oil separator, reservoir and oil level controls **will not** reduce the oil charge of a *properly designed, installed and operating refrigeration system*. The oil separator simply serves to minimize the amount of oil that enters the system. Once equilibrium is reached between the amount of oil entering the system and the amount returning to the compressors, the oil reservoir and oil level controls serve only as storage containers for the surplus oil.

Any change in operating conditions that disrupts the equilibrium (oil leaving vs. oil returning) will either be corrected by the oil control system or under many conditions, as will be pointed out, be unable to manage. It is the later conditions that lead to the unmerited condemnation of oil level controls.

Oil separator efficiency has little effect on a refrigeration system that is of *incorrect design*, or has *incorrectly sized piping* or is *poorly maintained*. When this occurs, there will be excessive oil in the system piping due to insufficient refrigerant velocities that are needed to return the lubricant to the compressor crankcase. It is on these type "problem" applications that an oil management system will yield a surplus of oil. The oil surplus is realized as the oil system acts as a time delay and limits the amount of oil circulated into the refrigerant piping between defrost cycles (refrigerant velocities are much greater after defrost termination and will sweep oil that was trapped in piping back to the compressors.)

Oil levels in compressors that drastically rise after a refrigeration circuit defrost termination are an indicator of a system abnormality. The problem should be identified and corrected. Excess oil decreases heat transfer in the evaporator. Oil slugs damage compressors.

Compressors on common discharge and suction piping do not recirculate exactly the same amount of oil, nor do the compressors have identical wear patterns or run times. The oil system's purpose is to compensate for *moderate* differences between the individual compressors oil recirculation rates due to size, run time, or wear. The oil system reservoir and oil level controls will make oil *available* to the compressors. There are *moderate differences in the* amount of oil returning to each of the compressors through the suction line relative to the amount of oil leaving the same compressors through the individual discharge lines.

Properly functioning reciprocating compressors typically recirculate somewhere between one and three percent oil

per pound of refrigerant. Many rack manufacturers "multiplex" compressors (differing size on common piping) to selectively operate the appropriate compressor based on system load. As an example, if the load is high, the controller would select a 15 HP compressor to operate rather than a 5 HP compressor on the same rack.

A typical 15 HP compressor operating at 110°F condensing temperature and a 15°F evaporator recirculates approximately 1,790 lb. of refrigerant an hour, or at 1% oil recirculation rate, 17.9 lb. of oil per hour. A typical 5 HP compressor operating at the same conditions recirculates approximately 445 lb. of refrigerant per hour, or at a 1% oil recirculation rate, 4.5 lb. of oil per hour. Assuming the two compressors are in parallel and are operating 100% of the time, the oil in the recirculation is 22.4 lb. per hour. With a *perfect* suction header, and both compressors *maintaining peak efficiency*, there would be as much oil returning to each compressor through the individual suction lines as was leaving each compressors discharge line. With this ideal but unlikely scenario, the oil levels would remain constant with no need for an oil level control system.

Using as an example the above compressor rack, cycle the 15 HP compressor off for fifteen minutes during a one hour period due to a light load. The average amount of oil in recirculation has been decreased by 4.5 lb. of oil per hour. However, with the 15 HP cycling, the average rate of oil in recirculation returning temporarily through the suction line is 17.9 lb. per hour. When the 15 HP compressor is not running, the 5 HP compressor could be receiving 2 times more oil per hour through the suction line than it is circulating out of it's discharge line. The 5 HP compressor will have to run for two hours to discharge enough oil to lower the oil level to the center of the sight glass.

Installing an oil separator, reservoir and level control on the example system would not reduce the system oil charge. Actually, oil would need to be added to the system to fill the separator, reservoir and level controls. Externally equalized oil level controls would permit excess oil in the 5 HP compressor crankcase to flow to the 15 HP compressor when both are running. The separator, reservoir and oil level control would prevent the 15 HP compressor from a "too low" oil level.

One compressor manufacturer's study on "too high" oil levels indicated a 4% energy penalty on specific model compressors. This is because the higher than recommended lubricant was found to run 30 to 40°F warmer than normal, increasing the compressor body temperature. The cool suction gas expands at a quicker rate upon entry to the 40°F warmer cylinder temperature reducing the volumetric efficiency of the pump. Assuming an 18 hour run time at .07 cents per KW, the "too high" oil level cost is approximately \$68 annually. (5 HP x .746 KW x .07 KWH x 18 HRS/Day x 4% x 365 days = \$68)

Refrigerant recirculation rates for a typical medium temperature rack may be 8,000 to 10,000 pounds of refrigerant per hour at design conditions. Eighty to 100 lb. of oil will be moving through the (combined) compressor's crankcases per hour at a 1 percent rate. (240 to 300 lb. at 3%) A worn compressor could reach higher oil pumping rates.

All compressors eventually wear out. It is common to see several older compressors in parallel with a new compressor. I.E. A worn 5 HP compressor pumping at a 5% rate will circulate 22 lb. of oil an hour, while a less worn 15 HP compressor in parallel is circulating 17 lb. an hour. Reciprocating compressors that are typically used in supermarket refrigeration racks incorporate a flow control between the returned vapor motor compartment and the crankcase. The purpose of the control is to prevent oil in the crankcase from being forced into the motor compartment during the instant the compressor starts. The referenced 5 HP compressor will eventually wear to a point that the piston rings permit blow by to the crankcase. When the wear leading to blow by reaches the point where the crankcase pressure is **greater** than the return vapor motor compartment, oil return to the compressor crankcase from the system refrigerant piping ceases. The 5 HP compressor now relies on the oil management system reservoir to replenish the 22 lb. (3.5 gal.) of oil it is discharging every hour. There is a point in time when the wear pattern on this compressor will be severe enough that it will deplete the reservoir oil supply (potentially affecting other compressors oil feed) and lose oil pressure, locking out on the safety switch. (If the oil level controls are equalized, the blow down may transfer to other crankcases, closing off their supply of oil from the suction return). As more oil is added to the system to compensate for the compressor(s) that are worn, less worn compressors overflow with the additional oil in recirculation. It is not uncommon to see several 20 HP compressors on the same rack with oil levels over the top of the sight glass.

Oil Return Piping Practices

Properly installed refrigerant piping is one of the key elements of oil return. Several basic rules of thumb apply when installing the roughly four miles of piping in an average supermarket. The first is to utilize oil traps at the base of each suction riser, down size the riser pipe diameter to increase gas velocities to 1200 feet per minute or more at design temperatures. Decreasing the piping diameter not only increases the gas velocities, but also increases the line's pressure drop. The higher velocities are needed to facilitate oil movement up the pipe. The second rule is to upsize the horizontal run section of pipe, this will offset the pressure drop taken in the suction riser. This compensation is necessary so that the overall pressure drop of that specific circuit does not exceed the equivalent pressure drop of a 2°F change in temperature.

The horizontal piping must be supported and be sloped at least one inch per twenty feet of length toward the compressor to return oil. Because of this necessary offset, velocities as low as 400 feet per minute in long horizontal

lines are not uncommon. The third rule of thumb is to be sure the thermostatic expansion valves are adjusted properly. Higher than normal superheats decrease gas velocities at the evaporator coil outlets, trapping oil and decreasing heat transfer efficiencies. Operating at saturated suction temperatures below the system design temperature will also decrease suction gas velocities and trap oil.

The Oil Charge

The total oil charge of a given system is equal to the sum of:

- * The oil charge in the compressor crankcases.
- * The oil charge in the separator and reservoir.
- * The oil necessary to charge the piping and heat exchangers to the point where design gas movement velocities are adequate to sweep the oil back to the compressor crankcase.

When a supermarket rack is started and has stabilized, the oil system is a direct indicator of:

- 1) Correctly sized and correctly installed field piping.
- 2) Correctly sized rack piping and component selection by the system designer.

The correctly designed, installed, and balanced system will have compressors with the correct oil level in the compressor and oil reservoir 24 hours a day.

The Oil Separator

Oil separators can be purchased in varying stated efficiencies. The more efficient the separator, the less oil will enter the system. However, in a given system it is only a matter of time before the oil accumulates in the same quantities, and at the same places as the less efficient separator.

The Oil Reservoir

The purpose of the reservoir is to store the amount of oil needed for a system in the "steady state" condition of oil recirculation. Assuming a properly installed and operating refrigeration system, 3/4 of a gallon of oil in a reservoir is more than enough oil when applied on any size system. It is impossible to size an oil reservoir to compensate for a system that is incorrectly piped or is improperly maintained. There are a number of supermarket systems in operation today that would fall short of oil *regardless* of the reservoir size.

The Oil Check Valve

The purpose of the oil check valve is to hold the oil reservoir at the correct pressure necessary to feed the oil level control if the oil level in the compressor drops below the set point. Referencing the attached diagram, the separator

will begin to fill the reservoir with high pressure oil and vapor when the oil level in the separator float opens a “dump” valve. The spring loaded oil check valve is in a line between the top of the reservoir and the “rack” suction manifold and will bleed off excess vapor pressure. (Check valves are available with several different settings). In this example, the OCV has a 20 PSI setting and will permit the high pressure vapor coming from the separator to the reservoir to bleed off to 20 PSI above the suction manifold pressure. This reduction in pressure is necessary to prevent the mechanical float from being “blown open” by too high of a pressure. With the reservoir pressure approximately 20 psi above the crankcase pressure, there will be adequate pressure differential for oil flow to occur through the oil level control.

The Oil Level Control

The purpose of an oil level control is the same as any other type of “make up valve”. The only time the level control will feed is to “make up” for oil that is not returning through the suction manifold. On a properly designed and balanced system, a large percentage of oil returns to the compressor through the suction line. The level control feed will make up for moderate differences in:

- 1) Compressor oil pumping rates due to size or wear.
- 2) Different oil return rates due to turbulence in the suction manifold.

Sporlan Valve Company offers an electronic oil level control, which can control an oil level that is too high or too low. The control utilizes the compressors oil pump to remove oil from the crankcase when a “too high” level is determined. It may be applied on both high pressure and conventional oil systems. Figure 1 illustrates the electronic oil level control applied to a low pressure oil control system.

Diagnosing An Oil System That Is Out Of Control

There should never be sudden fluctuations in the oil level. Oil levels that change quickly are a direct indication of oil logging caused by low velocities. Compressors are damaged beyond field repair by oil slugs returning after defrost cycles. Oil logging can be caused by any number of problems that limit heat transfer and slow gas velocities. Some of the more common are:

- 1) High store humidity levels that insulate evaporators with frost above design limits.
- 2) Iced coils from plugged drains.
- 3) TEV's out of adjustment
- 4) Incorrect defrost cycle times

All refrigeration racks have compressors that will eventually wear out. There will be a point in time during each compressor operating life that piston ring “blow by” will reach a critical point. This “critical” point is when the ring blow down causes the crankcase pressure to exceed the suction pressure. The equal or slightly positive pressure closes an oil flow control found in the crankcase of most supermarket compressors. It is at this point that two things happen:

- 1) The compressors oil pumping rate is much higher than normal because of piston ring wear. In some severe cases oil pumping rates will surpass a gallon a minute.
- 2) The compressor can no longer return oil to the crankcase through the suction line because the oil flow control in the compressor crankcase inlet is closed. The oil reservoir will empty in a matter of minutes regardless of the oil separators degree of efficiency. If the compressor crankcases are equalized, the pressurization may be enough to prevent oil return in the surrounding “healthy” compressors. It is at this point the compressor oil failure switches trip and servicemen add oil to the system on a regular basis due to “emergency service calls”. Oil added to the system will now circulate through the entire piping circuit and over fill the healthy compressors, potentially causing further compressor damage.

When the oil reservoir and one or more compressors on a rack system are low on oil, and other compressors on the same rack are over filled with oil, proceed with the following checks to identify the “oil pumper” compressor:

Disconnect all compressor body equalization lines and install a 1/4” soft copper tube from above the oil level of the compressor crankcase to the suction service valve. Open the suction service valve and operate the compressor.

- * If the copper tube remains cool, the compressor does not have “blow down” and is healthy.
- * If the copper tube goes to discharge temperature, repair or replace the compressor.

If a rack is diagnosed as having a compressor that is an “oil pumper” and the problem corrected, be prepared to drain substantial amounts of oil from the rack system over a several day time period.

NOTE: A compressor with damaged discharge valves or otherwise operating at higher than design discharge temperatures will accelerate piston ring wear. This may lead to crankcase pressurization in a matter of hours.

The single most expensive component in the refrigeration system is the compressor. Properly maintained oil levels unquestionably add years to the life of the compressors. Additional information regarding oil management systems and their operation can be found in Sporlan bulletins 110-10, 110-20, and 110-30.

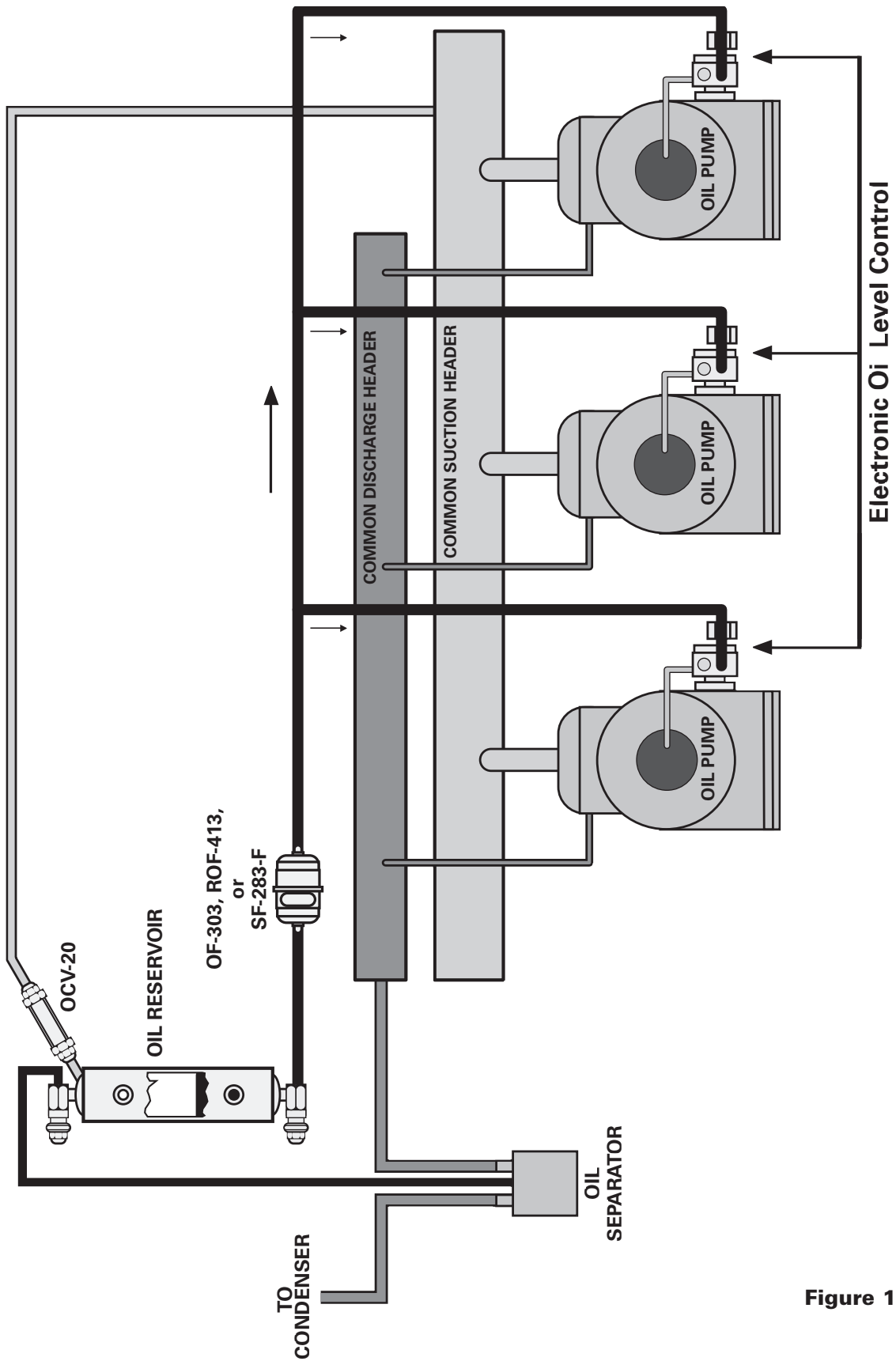


Figure 1