

## Technical Topic

### Low Ambient Refrigeration Applications

#### Head Pressure Control

#### Heated Receiver

Unlike most Air Conditioning Applications, Refrigeration Systems must be designed to operate effectively and efficiently even under the most adverse low ambient conditions.

Factors, which influence the Field System Design and Use of Available Options, are:

- Winter Design Temperature
- Local historical tendencies regarding wind direction and velocity relative to the equipment location
- Low load conditions resulting in long winter off cycles
- Condenser design and liquid sub cooling circuits
- Minimum operating limits of the Nozzles and Expansion Valves reference liquid pressure and temperature
- Location of the liquid line solenoid valve
- Line run connecting the high side to the low side
- Standard receiver capacity verses optional receiver capacities
- Evaporating temperature
- Local customs and regulations

In mild climates simple condenser pressure fan cycling will meet most requirements for head pressure and liquid temperature control. If the condenser is equipped with multiple condenser fans, these fans can be staged using pressure cycling controls or simply turned off using an ambient temperature thermostat leaving one or more fans to cycle as required.

Under no circumstances should all condenser fan motors be allowed to cycle off on one control or all condenser fans to cycle off on condensers having more than one fan while the compressor is running.

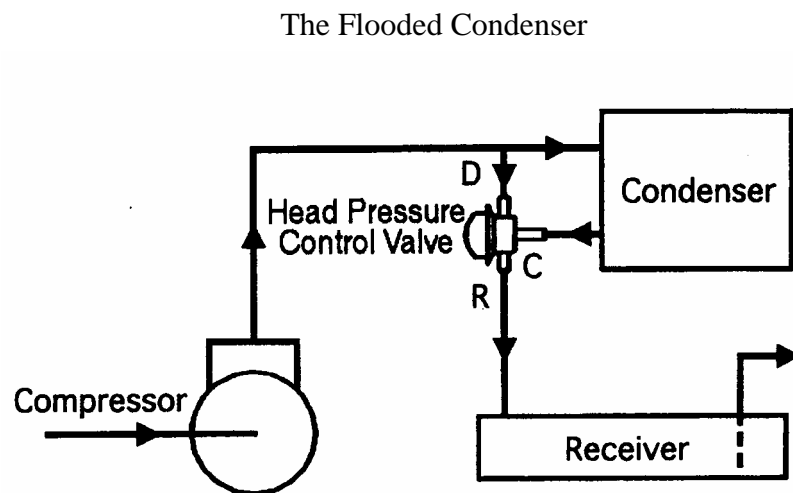
Condensers equipped with multiple fans require the fan nearest the inlet header to run continuous. This is to prevent wide condenser temperature fluctuations causing excessive expansion and contraction above design limits leading to leaks due to metal fatigue from improper operational procedures.

Typically the condenser fan will be set up using a minimum 50-PSI throttling range with the Cut in Set at 200 PSI and Cut Out at 150 PSI. Although this is the most economical method of head pressure control it is the most inefficient from an energy consumption point of view.

Liquid pressure is one of the opening forces of a Thermal Expansion Valve. As the condenser fan cycles within the 50-PSI throttling range so does the liquid pressure in the liquid line. This fluctuation in liquid pressure and presence of flash gas in the liquid line has an equal effect on Mass Flow. If the fluctuation in mass flow is wide enough the expansion valve may begin to hunt.

If the condenser fan throttling range is widened either by physically adjusting the fan cycling pressure switch or by the effects of the prevailing wind and / or ambient sub cooling at the condenser the severity of expansion valve hunting will also increase to a point that adversely affects system capacity and electrical efficiency expressed in Kilowatts Per Ton of Refrigeration.

In a mild climate the effects of fan cycling are acceptable because these ambient conditions are infrequent. Colder climates require a more manageable method of head pressure control in order to prevent these fluctuations



**Figure 1. Single Valve Flooded System**

Under low ambient conditions the condenser surface is reduced by flooding the condenser with excess refrigerant. The excess refrigerant is stored in the receiver when not required in the condenser.

Figure 1 shows a Single Valve Flooded System. The standard valve used by Heatcraft is nonadjustable and fixed at 180 PSI except Scroll Compressor applications, which are fixed at 100 PSI. When 100-PSI Valves are used be sure to select the appropriate valve and nozzle for this lower expected head pressure.

At condensing pressures above the valve setting, flow enters Port C and exits Port R. When the condensing pressure falls below the valve setting, the valve modulates to permit discharge gas flow through Port D. As the Three Way Valve opens Port D, Port C

closes proportionately. The receiver pressure is maintained at the valve pressure setting by injecting hot gas pressure upon the liquid level in the receiver. The reduced opening at Port C restricts liquid refrigerant flow so that the liquid level in the condenser rises. The valve modulates maintaining a constant pressure in the receiver at the valve setting and sufficient liquid in the condenser to maintain that pressure.

If the equipment is equipped with only one condenser fan that fan runs continuously. If the condenser fan is equipped with multiple fans the fan closest to the condenser inlet header should run continuously and the remaining fans can be turned off using an ambient thermostat or a pressure control.

The nozzle and expansion valve should be sized to provide even refrigerant distribution at the minimum expected condensing temperature converted to pressure, which is equal to the valve's nonadjustable factory pressure setting and the maximum condensing temperature typically 105F. The maximum condensing temperature is based on the unit's condenser design upper operating limit. Condensers are typically designed to have the capacity to reject the total heat of rejection up to 105F condensing without loss of rated catalog capacity.

The advantages over this method of head pressure control compared to Pressure Fan Cycling are as follows:

1. A constant and stable minimum head pressure (180 PSI except Scroll Compressor which run at 100 PSI) placed upon the surface of the liquid level of the receiver prevents the loss of efficiency experienced with pressure fan cycling due to expansion valve hunting.
2. Since the condenser is flooded during operation below the valve pressure setting liquid sub cooling is increased however hot gas is injected directly into the vapor side of the receiver warming the liquid in the receiver. If the condenser is not equipped with a separate liquid sub cooling circuit and the liquid line is properly insulated from the receiver outlet to the inlet of the expansion valve the liquid temperature can easily be maintained within the minimum design operating range (minimum design liquid pressure and temperature) of the expansion valve and nozzle.

The disadvantages are as follows:

1. The winter refrigerant charge must be either calculated or the winter charge must be topped off during low ambient conditions. Typically, the system can be charged to a clear sight glass under normal ambient conditions. Weight the charge and add an additional 15% of refrigerant by weight. This winter charge should be sufficient to allow operation down to approximately 0F. If a 30% additional refrigerant charge by weight is added the winter charge should be sufficient to allow operation down to -20F however be sure the receiver capacity is large enough to store the winter charge during summer operation and allow for a pump

down without exceeding the receiver's 90% capacity. An optional oversized receiver may be required. A second charging method is to weight in no more than 90% of the receiver capacity. **These charging methods should not be used when the liquid line solenoid valve is installed at the condensing unit. Use caution. A system should never be charged to levels that exceed 90% receiver capacity.**

2. The valve's pressure setting is not field adjustable.
3. The Single Valve System is limited to low horsepower equipment due to the low flow capacity of the valve. Larger units may require an additional valve piped in parallel to achieve the required flow capacity. Cost and space limitation may now become a factor.

### The Dual Valve System ORI / ORD

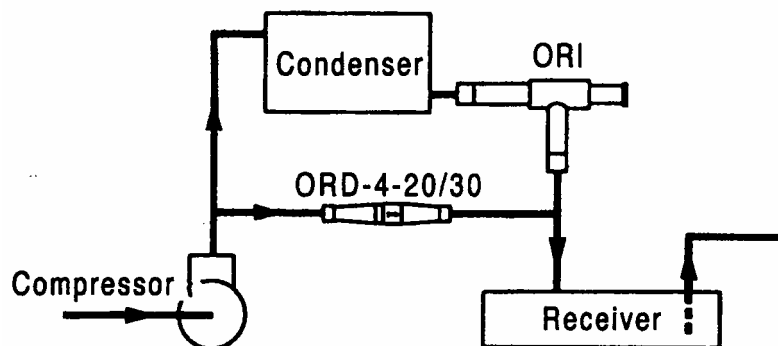


Figure 2. The Dual Valve System ORI / ORD

The Dual Valve System uses an **Open on **Rise of **Inlet Pressure Valve (ORI)** and an **Open on **Rise of **Differential Pressure Valve (ORD)**. The ORI is a field adjustable pressure regulator. The inlet of the ORI Valve is installed at the liquid outlet of the condenser and the outlet of the valve is piped to the inlet of the receiver as detailed in Figure 2.********

If the condenser pressure is above the ORI Valve's set point the valve will open allowing refrigerant flow to the receiver. If the condenser pressure falls below the valve's field adjustable pressure setting the valve will close raising the liquid level of the condenser thereby reducing the available condensing capacity causing a rise in condenser pressure. As the condenser pressure reaches the valve's set point the valve will modulate allowing refrigerant to pass through the valve maintaining a constant minimum condenser pressure during low ambient conditions.

The ORD is a fixed Spring Check Differential Valve meaning it allows refrigerant flow in only one direction and only when the refrigerant pressure is higher at the valve inlet than the outlet of the valve. The direction of flow is defined either by an arrow indicating

direction of flow or a dot or band impressed at the valve outlet. Typically, the differential is fixed between 20 to 30 PSI depending on system design and the refrigerant used. Most Heatcraft applications use a 20-PSI differential.

The ORD valve is located between the compressor discharge line and the outlet of the ORI upstream of the receiver inlet as shown in Figure 2 above. The ORD works in tandem with the ORI. As the ORI modulates to maintain a constant and stable condenser pressure at the valve's field adjustable set point the differential pressure between the compressor discharge line and the outlet of the ORI increases in proportion to condenser pressure. If the differential pressure exceeds the fixed set point of the ORD hot gas is allowed to flow through the ORD into the inlet of the receiver. If the ODI is set to maintain 200 PSI condenser pressure (lowest expected design liquid pressure 180 PSI plus the fixed differential pressure of the ORD 20 PSI or  $180 + 20 = 200$ ) the ORD will allow superheated hot gas flow to maintain 180 PSI pressure upon the liquid level of the receiver.

If the condenser is not equipped with a separate liquid sub cooling circuit the effects of liquid sub cooling outside the minimum design operating range (minimum design liquid pressure and temperature) of the nozzle and expansion valve due to the flooded condenser conditions are negated by the injection of superheated hot gas into the receiver.

If the liquid line is properly insulated from the receiver outlet to the inlet of the expansion valve the liquid temperature can easily be maintained within the minimum design operating range (minimum design liquid pressure and temperature) of the expansion valve and nozzle during low ambient conditions.

If the condenser is equipped with a liquid sub cooling circuit the nozzle and expansion valve's minimum design operating range must be looked at very closely to ensure they not only fall within the minimum design operating range using the lowest expected liquid temperature which is typically equal to the winter design temperature for the locality but also the maximum summer time expected liquid temperature which is typically equal to the summer design temperature for the locality.

If the winter and summer design temperature differential is so wide that a nozzle and expansion valve cannot be selected to operate effectively and efficiently without starving the system in the summer or operating below the design operating range in the winter the minimum expected liquid temperature can be raised by either electing to delete the liquid sub cooler altogether or bypassing it during low ambient conditions in order to prevent the liquid temperature to fall be low the minimum design temperature yet still receive the capacity and energy saving benefits of liquid sub cooling during milder ambient conditions. **(See Technical Topic titled Refrigerant Distribution to learn more about the effects of liquid sub cooling)** Sub cooling circuits will be covered in more detail in the next section.

Liquid pressure is equally as important as liquid temperature. If the ORI is adjusted well above or below the lowest design minimum condensing temperature converted to

pressure using the pressure, temperature relationship for the specific refrigerant used to select the nozzle and expansion valve both will be operating outside their respective operating curves.

Although both may operate effectively at a higher pressure setting which converts to a higher condensing temperature you must ask if the system is operating efficiently from a KW Per Ton Of Refrigeration point of view. The answer is no.

Conversely, if the ORI is adjusted below the minimum design condensing temperature used to select the expansion valve and nozzle both may be oversized for the resulting liquid pressure and temperature drastically affecting evaporator refrigerant distribution and evaporator performance.

Operating a system above the minimum condensing temperature for which the nozzle and expansion valve were selected not only can reduce overall system capacity it will also cause the system to consume more energy per ton of refrigeration effect. This means the correct ORI setting is the minimum condensing temperature converted to pressure used to select the nozzle and expansion valve plus the differential pressure of the ORD. **This pressure setting is not factory set.**

Unlike the Single Valve System the Dual Valve System is not refrigerant specific. An advantage over the Single Valve System is the Dual Valve System can easily handle the high flow rate requirements of large capacity equipment.

The disadvantages with the exception of flow capacity are the same. Charging methods remain the same with the exception that the minimum expected condensing temperature converted to pressure must be field adjusted preferably during low ambient conditions.

### Specific Requirements for Extreme Low Ambient Conditions

#### The Low Ambient Kit and Heated, Insulated Receivers

Operating a refrigeration system under extreme low ambient conditions requires a more aggressive approach in order to maintain the minimum design condensing temperature and receiver pressure for an effective compressor start.

A condenser and receiver exposed to these low ambient conditions will suffer the effects of ambient sub cooling resulting in condenser and receiver pressures corresponding to the equivalent pressure corresponding to the ambient temperature.

In other words, a system using R- 404A for example, if the ambient temperature is –20F the resulting receiver pressure after a short off cycle will drop to its corresponding pressure, temperature relationship in this case 17.1 PSI. On a subsequent call for cooling the receiver pressure will be too low to feed the expansion valve resulting in short cycling on low pressure which may eventually lead to an oil failure trip requiring a manual reset.

In order to overcome this an optional Low Ambient Kit is installed on the unit. This consists of a Single Valve or ORI / ORD Head Pressure Control and a Time Delay Relay wired to delay on break across the low-pressure switch in order to prevent short cycling. Typically this timer is set to delay break across the low-pressure switch for one to two minutes. Once the timer times out the low pressure switch is released to act independently. The coil of the timer is wired across the room thermostat and the liquid line solenoid.

Heaters are installed on the receiver and the receiver is insulated in order to maintain a minimum receiver pressure. An outdoor ambient thermostat initiates the receiver heaters.

The entire liquid line must be well-insulated from the outlet of the receiver to the inlet of the expansion valve in order to conserve valuable liquid temperature so that the liquid pressure and temperature remains within the minimum design limits of the expansion valve and nozzle. **A suction accumulator is highly recommended** to protect the compressor from liquid slugging especially at start up when the liquid in the liquid line is at or near ambient temperature.

In order to prevent refrigerant migration from the receiver to the condenser a check valve is installed between the outlet of the condenser and the inlet of the receiver permitting flow to the receiver only.

Particular attention must be paid to the condenser circuiting. Typically condensers are designed to have the ability to reject 100% of the total heat of rejection in accordance to the compressor-operating curve at 95F ambient and 105F condensing. If a liquid sub cooling circuit is provided an additional 10% of the total surface area is partitioned for liquid sub cooling. Under extreme low ambient conditions the liquid in the liquid line upstream of the solenoid and sub cooling circuit will be at no near ambient far below nozzle and expansion valve's the minimum design liquid temperature. If liquid is allowed to enter the sub cooling circuit under these conditions the resulting liquid temperature will remain below the minimum design liquid temperature leaving us with two options.

1. Order the equipment without a liquid sub cooling circuit and accept the capacity and efficiency loss provided by this circuit during milder ambient.
2. Bypass the sub cooling circuit during low ambient conditions as shown in Figure 5 and enjoy the benefits of the circuit during allowable ambient conditions and a stable liquid temperature that falls within the minimum design limits of the expansion valve and nozzle..

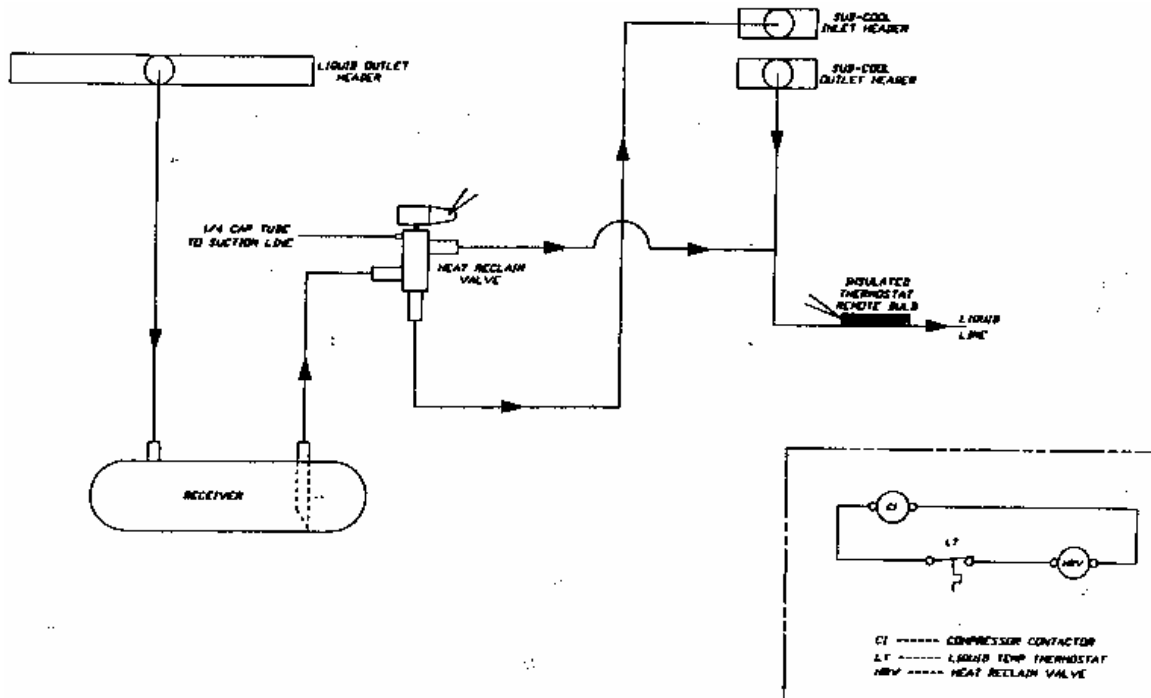


Figure 3. Liquid Sub Cooling Bypass