

SUBCOOLING

Getting supermarket refrigeration head pressure under control can be done with subcooling. Here, from Sporlan Valve, is how.

By Steve Esslinger

Supermarket Subcooling

Head pressure control on supermarket refrigeration systems is used to maintain a minimum high to low side pressure relationship. In supermarket systems, low side pressures are the result of established refrigerated case or walk-in cooler temperatures that remain relatively constant year round. Therefore, minimum pressure ratio becomes the result of the minimum high side pressure expected.

With the minimum pressure ratio established, the design engineer can select the appropriate head pressure control system that will result in efficient year-round operation.

The greatest influence on thermostatic expansion valve (TEV) capacity is the pressure difference that exists between

its inlet and outlet (TEV pressure drop). Considering pressure drop only, a typical TEV will have approximately 60% of its capacity at 65°F condensing compared to a typical design condensing temperature of 105°F. This assumes a constant evaporator temperature of 20°F. A further loss in TEV capacity results if vapor is present in the liquid at its inlet. This is often the case when there are low condensing pressures with low saturated liquid temperatures leaving the receiver.

If the high to low side pressure ratio is allowed to fall because of inadequate head pressure control, the resulting reduction in TEV capacity can create a number of problems, including:

- High evaporator superheats with loss of evaporator capacity

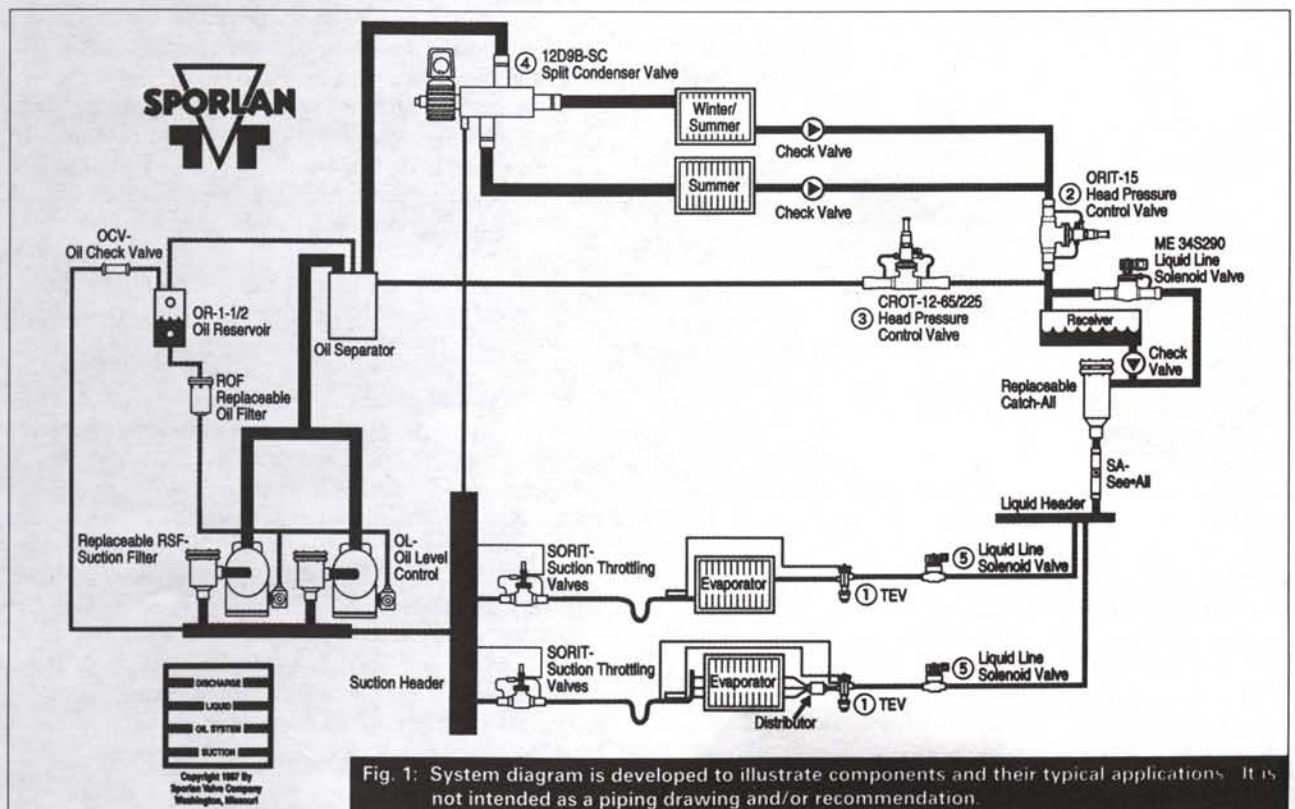


Fig. 1: System diagram is developed to illustrate components and their typical applications. It is not intended as a piping drawing and/or recommendation.

- Oil logging in the evaporator and suction piping
- Higher than normal compressor temperatures and short-cycling
- Poor refrigerant distribution with irregular evaporator frost patterns interfering with air flow and evaporator capacity
- Unusually low evaporator pressure unless controlled

by evaporator pressure regulators or compressor unloading.

An additional consideration regarding the minimum design pressure ratio of a refrigeration system is the type of compressors being utilized. Manufacturers of reciprocating-type compressors have found that very low pressure ratios can cause valve damage. As pressure ratios decrease, the volume of gas pumped increases, causing the compressor valves to bend or flex beyond their design limits, leading to metal fatigue and breakage.

Having established the need for head pressure control in order to maintain the high to low side pressure ratio, consideration should be given to the methods by which it can be accomplished. The two methods used are characterized as air side and refrigerant side con-

trol. Often a combination of the two are involved.

Air side control

Air side control consists of increasing or decreasing the air movement across the condenser coil. Supermarkets generally use remotely located air-cooled condensers for heat transfer. This type of heat exchanger usually employs six or eight individual fans to move the air. Head pressure lowers with decreased evaporator load and/or lower ambient temperatures. A typical method of holding the head pressure within design parameters is to cycle each fan motor with pressure switches. This approach works very well in geographical areas where ambient temperatures seldom fall below 50°F.

Stable head pressures may be more difficult to achieve if ambient temperatures consistently fall below 50°F. The entire system becomes increasingly unstable as lower than design air temperature is pulled across the condenser.

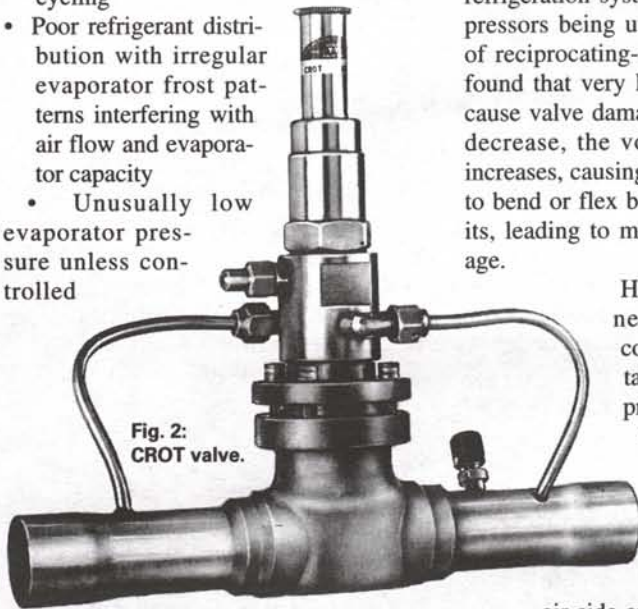


Fig. 2: CROT valve.

The instability is caused when the fan(s) suddenly start dropping the high side pressure rapidly, overshooting the corresponding liquid temperature.

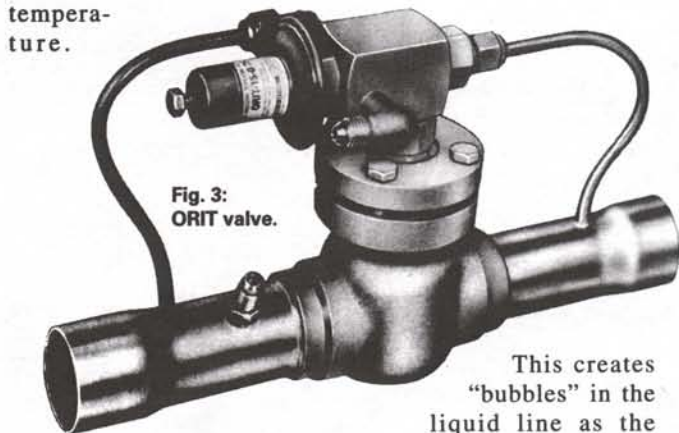


Fig. 3: ORIT valve.

This creates "bubbles" in the liquid line as the

refrigerant pressure lowers below its saturation temperature and boils, thereby cooling to the new saturation pressure.

During the "overshoot", each TEV is fed with less than a solid head of liquid refrigerant, which drastically reduces their capacity and ability to properly feed the evaporators.

Refrigerant side control

Refrigerant side control becomes advisable and advantageous when outdoor ambient temperatures are consistently lower than 50°F. This control system may or may not be used in conjunction with air side controls.

Refrigerant side control systems accomplish head pressure control by reducing the size of the condensing surface. In one case, this is done by flooding a portion of the condenser with liquid refrigerant, thus reducing its condensing surface. This is called the "flooded condenser method".

Another refrigerant side control is the splitting of the condenser into two or more sections. With the use of valve(s), discharge gas is diverted only to the section that is large enough to maintain discharge pressures under given ambient conditions. This is called the "split condenser method." This method is usually used in combination with the flooded condenser method, along with fan-cycling or fan speed control. A more detailed discussion of the split condenser method is covered later.

Refrigerant side valves to flood the condenser

An ORI valve (Open on Rise of Inlet pressure) is installed in the condenser outlet line and is adjusted to a pressure setting corresponding to the desired minimum head pressure. As inlet pressure falls below the setting, the valve moves toward the closed position or throttles to reduce the refrigerant flow and "back up" liquid into the condenser, thereby reducing the effective condensing surface.

During higher outdoor ambient temperatures, the valve responds by Opening on a Rise of its Inlet pressures. It must be sized so that it is near its maximum open position at this time with a minimum of pressure drop. Therefore, during periods of high ambient temperatures, the system operates as though the valve were not there.

When the ORI valve throttles and holds back liquid, it produces a pressure drop, and the liquid that does flow has more than normal subcooling. The additional subcooling is picked up in the backed-up portion of the condenser. Without raising the temperature and pressure of this liquid, pressures would remain too low in the receiver, even though they are elevated in the condenser.

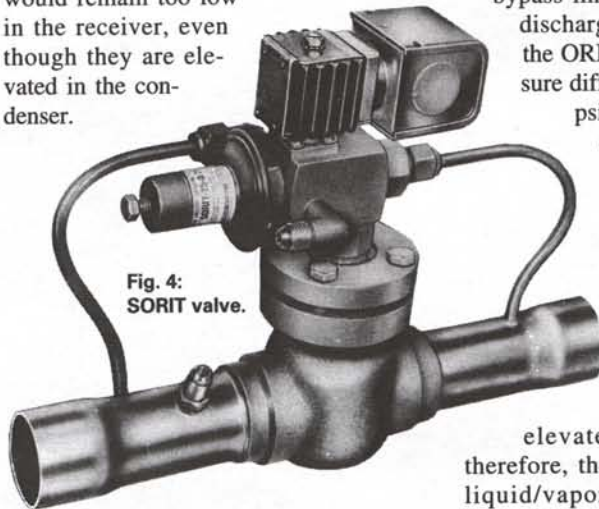


Fig. 4:
SORIT valve.

It is important to remember that the pressure in the liquid line as it leaves the receiver is a function of the temperature of the liquid-vapor interface at the liquid level.

Therefore, to complete the head pressure control system, an ORD (Open on Rise of Differential) is installed in a bypass line between the compressor discharge and the downstream of the ORI valve. The standard pressure differential for this valve is 20

psi, which means that as the downstream pressure (or receiver pressure) is reduced to 20 psi below discharge, the valve opens to allow high pressure, hot gas to mix with the liquid leaving the ORI.

The introduction of hot discharge gas by the ORD valve essentially elevates the temperature, and therefore, the pressure at the receiver liquid/vapor interface, producing a

receiver and liquid line pressure equivalent to the saturation temperature.

In cases where the ORD capacity is insufficient, and it is not practical to install two or more in parallel, a CRO type of valve (CRO-12-65/225 from Sporlan, for example) is used. This valve Closes on a Rise of Outlet pressure, and controls liquid receiver pressure in the same manner as the ORD with a setting 10 to 20 psi below the ORI setting.

Refrigerant charge

The subject of refrigerant side head pressure control is not complete without a discussion of system refrigerant charge. To maintain head pressure during winter operation, extra refrigerant must be available to partially fill the condenser. Furthermore, with additional refrigerant being required for winter operation, consideration must be given to the size of the receiver so it will have enough capacity to hold the extra refrigerant charge during summer conditions.

With the high cost of refrigerants, it is important to take additional steps in system design to minimize the need for the extra refrigerant charge.

A common method used for minimizing the amount of refrigerant needed is to combine refrigerant-side control with air-side control. This is usually accomplished by either cycling the condenser fan(s) or controlling their speed. Both of these methods use pressure as the controlling signal to reduce air flow during periods of low outdoor ambient temperatures. The reduced or eliminated air flow across the condenser means that less heat is rejected to the air, and therefore, less refrigerant flooding is required.

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method is to split the condenser into two or more circuits, usually within the same "tube bundle." Systems of this type will use one of the condensers during both summer and winter conditions. The second is not in the circuit during the winter, and during this time, is drained of refrigerant. It is activated only in summer when the maximum condenser capacity is

Split condenser control

To save refrigerant charge on supermarket systems, another

required to keep condensing pressures as low as possible.

An additional step toward saving on the amount of system charge is to combine the two-condenser set-up with fan control as described earlier.

As an example, Fig. 1, pg. 28, illustrates a typical schematic piping diagram using a Sporlan type 12D9B-SC split condenser valve (#4 at top of sketch). This valve incorporates a solenoid usually controlled by an outdoor thermostat or high-side pressure control. During summer operation, the solenoid is de-energized, which allows discharge gas from the compressor to flow equally into both condensers.

As the outdoor temperatures fall, a thermostat or pressure control energizes the solenoid at a predetermined setting, and the valve shifts to close the flow of discharge gas to the "summer condenser." Taking the summer condenser completely out of the circuit assists in maintaining head pressure. From this point on, head pressure is maintained by the ORI/ORD or ORI/CRO valves by flooding refrigerant in the "summer/winter condenser" in the manner previously described.

As outdoor ambients increase with only the "summer/winter condenser" in the circuit, head pressures will increase until the pressure or temperature control de-energizes the 3-way split condenser valve. This allows refrigerant flow to both condensers with head pressure still being maintained by "refrigerant side" control provided by ORI/ORD or ORI/CRO valves.

A bleed built into the valve allows refrigerant to bleed from the inactive condenser (summer condenser) back to the suction side of the system. A check valve installed in the outlet prevents the flow of refrigerant by this path.

During winter operation, head pressure is best maintained by using “refrigerant side” control. However, combining this with “air side” and “split condenser” controls, the amount of refrigerant charge can be minimized. Considering today’s cost of refrigerants, the end result is a substantial net savings.

Reducing operating costs with liquid subcooling

Part of the liquid refrigerant that is recirculated in a refrigeration system is used to remove its own heat content (enthalpy). The liquid’s heat is absorbed at the point of pressure reduction (the TEV drops the pressure from high to low side). During cool weather operation, when it is possible to capitalize on “free subcooling,” system efficiency can be increased by about 5% for every 10°F of liquid subcooling, resulting in reduced operating costs.

Using a 100 hp multiplexed low temperature system as an example, 30°F of liquid subcooling will reduce the required refrigerant flow in the system by 15% or enough to idle one 15 hp compressor. The cost for operating a 15 hp compressor is approximately 78¢ an hour based on 7¢ per kWh. Assuming that the compressor was designed to operate 22 hours a day, an approxi-

mate savings of \$515 a month could be realized.

Suction/liquid line heat exchangers are frequently used to transfer heat from the liquid line into the suction line.

How is liquid subcooling accomplished?

Suction/liquid line heat exchangers are frequently used to transfer heat from the liquid line into the suction line. While this arrangement is helpful in providing subcooled liquid, it is not without cost to the system capacity, since heat added to the suction gas reduces the volumetric efficiency of the compressor.

Mechanical subcoolers are occasionally employed in the form of auxiliary refrigeration systems or by using a portion of the main system capacity. While there are situations where these methods are advantageous, like the suction/liquid line heat exchange, subcooling accomplished with the use of these procedures does not come without some penalty, requiring additional cost.

Subcooling in the condenser comes with no cost to the system, but unfortunately is only available when outdoor ambient conditions are favorable and the system is designed to use them to its advantage.

Very little subcooling is possible in the condenser during summer operation because of the temperature difference (TD) between the air across the condenser and the leaving refrigerant temperature. During winter operation, with refrigerant side head pressure control, the TD between the elevated condensing temperature (pressure) and the low outdoor ambient can be significant.

Preserving subcooled liquid

When a conventional “flow through” liquid receiver is used, any subcooling produced in the condenser is essentially lost when it reaches the receiver. In the earlier discussion of refrigerant side head pressure control, it was noted that hot gas bypassed from the compressor discharge to the receiver served the purpose of warming the subcooled liquid from the condenser to a higher saturated condition.

By changing the liquid receiver flow pattern from “flow through” to “surge,” subcooling can be preserved. The system illustrated in Fig. 1 uses a piping arrangement that allows the receiver to be converted from “flow through” to “surge” during winter operation when substantial subcooling is available.

By opening the solenoid valve placed in the bypass around the receiver, subcooled liquid flows from the condenser around the receiver directly to the evaporators. The liquid bypassed around the receiver prevents subcooled refrigerant from returning to a saturated condition in the receiver vessel. The addition of condenser fan pressure switches, a thermostat on the drop leg, and insulation on the liquid line may be necessary if not currently applied on the system.

Selecting and setting up controls for maintaining head pressure and subcooling

The settings and adjustment sequence are critical. The adjustments are designed to maximize system efficiencies when ambient conditions enable liquid refrigerant subcooling. Individual system application variables may necessitate that the range of some recommended examples be shortened or lengthened.

In the example as illustrated, the equipment is a 100 hp multiplexed low temperature rack system. The remote air-cooled condenser has eight fans, with two banks of four fans on a common fin tube sheet that is circuited for a 50/50 split. The compressors are single-stage, and the refrigerant selected is R-404A. A Sporlan ME34S290 is selected for the receiver bypass line and is rated at 30 tons flowing 50°F liquid at a 1.1 psi pressure drop.

1) Select the TEV.

The capacities of Sporlan type EBF expansion valves are selected to match the refrigerated case capacities at the minimum pressure drops that the valves will be required to operate. For example, a glass door frozen food case is rated at 10,000 Btu/Hr at a -20°F saturated suction temperature.

A balanced port expansion valve rated at 10,000 Btu/Hr at -20°F suction and 100 psi pressure drop matches the fixture capacity, also rated at 10,000 Btu/Hr.

2) Determine the minimum condensing pressure in order to provide 100 psi pressure drop across the TEV.

A) Calculate pressure at TEV outlet:

Evaporator pressure @ -20°F	16 psig
Pressure drop across Refrigerant Distributor	+35 psi
Pressure at TEV outlet	51 psig

B) Calculate TEV liquid inlet pressure for a 100 psi drop:

Outlet pressure (from above)	51 psig
100 psi required minimum pressure drop	+100 psi
Pressure at TEV inlet	151 psig

C) Determine minimum condensing pressure for a minimum 100 psi drop across TEV:

TEV inlet pressure (from B)	151 psig
Estimated high side pressure drop	+10 psi
Minimum condensing pressure required	161 psig

3) Check for compression ratio.

To calculate the compression ratio, the suction and discharge pressures must be converted to absolute values (psia = psig + 14.7). The compression ratio is then expressed as a ratio of the absolute discharge pressure to absolute suction pressure.

Discharge pressure 161 psig = **175.7 psia**

Suction pressure 16 psig = **30.7 psia**

Compression ratio = $175.7 \div 30.7 = 5.7$

Minimum compression ratio recommended is **2**

4) Set the head pressure control valves.

The head pressure control valves selected are Sporlan ORIT-15-65/225 and CROT-65/225, both with sufficient capacity for 30 tons.

Since R-404A has a saturation pressure of 160 psig at 74°F, the outdoor ambient temperature on the day the settings are made should be lower.

Setting the ORI valve:

With the ORIT valve adjustment fully open, all condenser fans locked on, and 50% of the refrigeration circuits temporarily valved off, allow the discharge pressure to fall until it reaches approximately 150 psig. This will occur because under these conditions on a 70°F day, the condenser will be oversized.

The ORIT valve should now be slowly adjusted for a 170 psig setting, allowing sufficient time to flood the condenser.

Setting the CROT valve:

With the ORIT valve set and the condenser fans still locked on, the receiver pressure will drop. The CROT is then set at 160 psig, which is the minimum liquid pressure required as calculated in "C" above.

5) Set the split condenser valve.

A 12D9B-SC valve is selected for this service. Using a pressure control, it should be set to energize and split the condenser at 175 psig and de-energize at 200 psig.

6) Set the receiver bypass valve.

The ME34S290 solenoid valve used as a receiver bypass valve should be controlled by a thermostat set to energize and open the valve at a temperature of 65°F.

7) Set the four condenser fans on the "Summer/Winter Condenser" (in psig).

	<u>ON</u>	<u>OFF</u>
#1	175	165
#2	180	170
#3	185	175
#4	190	180

8) Set the four fans on the "Summer Condenser" (in psig).

	<u>ON</u>	<u>OFF</u>
#5	185	175
#6	200	190
#7	205	195
#8	210	200

It is important to note that the last fan to cycle off is set at 5 psi lower than the setting of the ORIT valve. Therefore, on a 35°F day, the condenser will be split, the ORIT valve will have the condenser pressure held at 170 psig by holding liquid in the condenser, and the condenser fan set to cut out at 165 psig will be moving 35°F air over the liquid refrigerant held in the condenser.

This amount will require 15 less horsepower to accomplish the same refrigeration effect.

The drop leg temperature will be approximately 40°F. This liquid having 34°F of subcooling will be bypassing the receiver on the way to the expansion valves.

As estimated earlier, this amount of subcooling will require 15 less horsepower to accomplish the same refrigeration effect. In addition, with less compressor running time, the life of the equipment will be extended, resulting in additional savings.

Operating cost may be higher or lower in different supermarkets depending on the preventive maintenance program and regional climatic conditions. However, as demonstrated here, with proper control selection and set up, taking advantage of lower ambients will have a significant impact on the supermarket's bottom line. □

EDITOR'S NOTE: The author is senior application engineer of Supermarket Refrigeration for Sporlan Valve Co., and has based this article on material in the following Sporlan bulletins: #10-9, 10-10, 10-11 (Thermostatic Expansion Valves); 30-10 (Solenoid Valves); 30-10-2 (Split Condenser Valves); and 90-30 and 90-30-2 (Head Pressure Control Valves). More information can be obtained by contacting Sporlan, 206 Lange Dr., Washington, MO 63090.

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