



# SUBCOOLING

your way to

# SAVINGS

Part II

In the January/February edition of Mechanical Business, refrigeration columnist Phil Boudreau opened a discussion about subcooling. What follows is an extension of his article.



In order to correctly select components for use in a subcooling circuit, it is necessary that the capacity of the subcooler be calculated accurately. In this example, we will determine the power input of a low-temperature system with no subcooling (Cycle A) and compare this to the same system but with a 60F liquid temperature entering the TEV (Cycle B). To provide subcooling for Cycle B, we will add another system (Cycle C).

Cycle A operates at the following conditions:

- -20F SST
- 100F SDT
- 65F RGT
- 0F Subcooling
- 60 MBH Total Capacity
- 30.08 CFM Compressor Displacement

Note: SST = Saturated Suction Temperature; SDT = Saturated Discharge Temperature; RGT = Return Gas Temperature; MBH = Btu/hr ÷ 1000

By referring to a pressure-enthalpy (PE or PH) diagram for R507, it is determined that the enthalpy entering and leaving the evaporator is 46.76 Btu/lb and 103.08 Btu/lb respectively. Therefore, the net refrigeration effect or NRE equals 56.32 Btu/lb. The mass flow rate is 17.77 lbs/minute and the coefficient of performance or COP (also known as energy efficiency ratio or EER) for this cycle is 2.52. This gives us something to start with.

To find the heat of compression, we would use the PH diagram to find the heat of compression. The heat content entering and leaving the compressor is 103.08 and 125.4 Btu/lb respectively. Therefore, the heat of compression is 125.4 minus 103.08 or



22.32 Btu/lb. The work of compression for Cycle A is 17.77 lbs per minute multiplied by 22.32 Btu/lb which equals 396.63 Btu/minute. We can then convert the work of 396.63 Btu/min to approximately 6,970 watts. Therefore, the total power input is approximately 6.97kW.

By subcooling the liquid in Cycle A to 60F, the parameters will change. Cycle B, is the same as Cycle A but with 60 F liquid entering the main TEV. As mentioned previously, we will use a separate system (Cycle C) to provide the work required to subcool the liquid in System B.

The operating conditions for Cycle B are:

- -20F SST
- 100F SDT
- 65F RGT
- 40 F Subcooling or 60F Liquid Entering the TEV
- 30.08 CFM Compressor Displacement (The compressor does not change)

Again referring to the pressure-enthalpy diagram for R507, we can determine that the enthalpy entering and leaving the evaporator is 32.02 Btu/lb and 103.08 Btu/lb respectively. Therefore, the NRE = 71.06 Btu/lb. Since the compressor's entering conditions remain unchanged, we can now achieve 75,764 Btu/hr with the same mass flow rate [17.77 Btu/lb \* 60 minutes \* (103.08 - 32.02)]. Note that the capacity increased by 26%. Also, the power input

requirement for Cycle B remains the same. Of course, there are other costs associated with the operation of Cycle C that must be taken into consideration.

Now we will determine the power input requirements for Cycle C. Here are the operating parameters for Cycle C. Note that the power input requirements of this cycle must be added to the power input of Cycle B in order to determine the total power required to achieve the performance of Cycle B.

- 50 FSST, which is 10F colder than the 60F liquid in Cycle A.
- 100 FSDT
- 60F RGT
- 100F Liquid entering the subcooler TEV
- 15,764 Btu/hr Total Capacity (75,764 Btu/hr minus 60,000 Btu/hr)\*

\* Note that the additional capacity obtained in Cycle B was provided by Cycle C.

Referring to the pressure-enthalpy diagram for R507, we can determine that the enthalpy entering and leaving the subcooler-evaporator is 46.76 Btu/lb and 96.85 Btu/lb respectively. Therefore, the NRE of the subcooler is 50.09 Btu/lb. The mass flow rate for this cycle is 15,764 Btu/hr ÷ 60 minutes ÷ (50.09 Btu/lb), which equals approximately 5.25 lbs/min.

Note that the work of compression for Cycle C is approximately 5.25 lbs per minute \* Heat of Compression (103.13 - 96.85Btu/lb) which equals 32.97 Btu/minute. We can then convert this work of 32.97 Btu/min to approximately 579.37 watts. Therefore, the total power input to the mechanical subcooler (Cycle C) is about 579.37 watts or 0.58kW.

Looking back at Cycle A, our total power requirements were 6.97kW.

The total power requirement for Cycle B = (6.97 kW + 0.58 kW) or 7.55 kW. Now we can recalculate the coefficient of performance for Cycle B so that it can be compared to Cycle A:

COP of Cycle B: The overall capacity of 75,764 Btu/hr can be directly converted to 22,199 watts since 1 watt = 3.413 Btu. The total power input for Cycle B = 7,550 watts, the COP is 22,199 ÷ 7,550 = 2.94 which is about 16.67% higher than Cycle A. This represents the theoretical savings available. By factoring in our energy costs, we can easily come up with an estimate as to the operating costs of each cycle. Of course, the actual operating conditions such as evaporator superheat along with other inefficiencies must be taken into consideration in order to provide the most accurate results.

## SUBCOOLING

Subcooling is the process of removing heat from liquid refrigerant which remains at a constant pressure. If additional heat is removed from the refrigerant before it is expanded, it follows that additional heat may be picked up in the evaporator.

## FLASH-GAS

Flash-gas forms when there is insufficient liquid subcooling present to offset a pressure drop. Refrigerant flashing is a phenomenon that occurs as a refrigerant cools itself to a lower saturation temperature.

## SYSTEM EFFICIENCY

System Efficiency may be increased through subcooling of the liquid refrigerant.

## MECHANICAL SUBCOOLING

Mechanical Subcooling is achieved through the addition of a subcooler-heat exchanger and TEV to an existing system or by integrating a separate system to refrigerate the liquid line of the main system.

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