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Selecting EPR Port Diameters

This paper presents an example for prdicting the full-open (100% wide open) port diameter required for a pressure regulator. Thes method identifies mass flow and specific vapor volume, then calculates a theoretical Cv for the regulator which is used when selecting regulator ports from a manufacturer's catalog. It is usually desirable that the port diameter of a regulator < the connected pipe size.

1.1 Summary of Equations

(1) $\dot{m} = \dfrac{TR \cdot \left(200 \dfrac{btu}{\min} \cdot TR\right)}{h_{leave} - h_{enter}}$ mass flow to evaporator, pounds per minute (lb/min)

(2) $Cv = \dfrac{0.947\,\dot{m}}{\sqrt{\Delta p\,\rho}}$ finding Cv when mass flow, Δp across port, specific volume are known

Nomenclature

h_{enter}	enthalpy of refrigerant entering evaporator, btu/lb
h_{leave}	enthalpy of refrigerant leaving evaporator, btu/lb
$\dot{m}$	mass flow, pounds per minute
P	pressure, pounds per square inch, gauge (psig)
p	pressure, pounds per square inch, absolute (psia)
t	temperature, ºF
TR	net refrigerating effect, tons (1 TR=200 btu/min)
$\overline{V}$	specific volume, cubic feet per pound (also $1/\rho$), (ft^3/lb)
Δp	differential pressure, pounds per square inch (psi)
ρ	weight density of fluid, pounds per cubic foot (lb/ft^3)

1.2 Selecting Minimum Regulator Port Diameter (Cv)

Problem: Select the EPR port diameter for the evaporator shown in Figure 1 below. Given: a 15 TR evaporator to be installed on a dock maintained at 45 ºF. Liquid will be supplied to this evaporator with HPL at a mean condensing pressure of 155 psig (subcooled to 30 ºF) into a thermal expansion valve. The regulator will be set to maintain an evaporating temperature of 25 ºF; the TXV will superheat the leaving vapor by 10 ºF. Figure 1 graphically depicts the process and plots the respective state points for predicting the following:

- *Step 1* - find evaporator mass flow and vapor specific volume
- *Step 2* - find the minimum port Cv required when the EPR is wide open
- *Step 3* - select a regulator port diameter from above

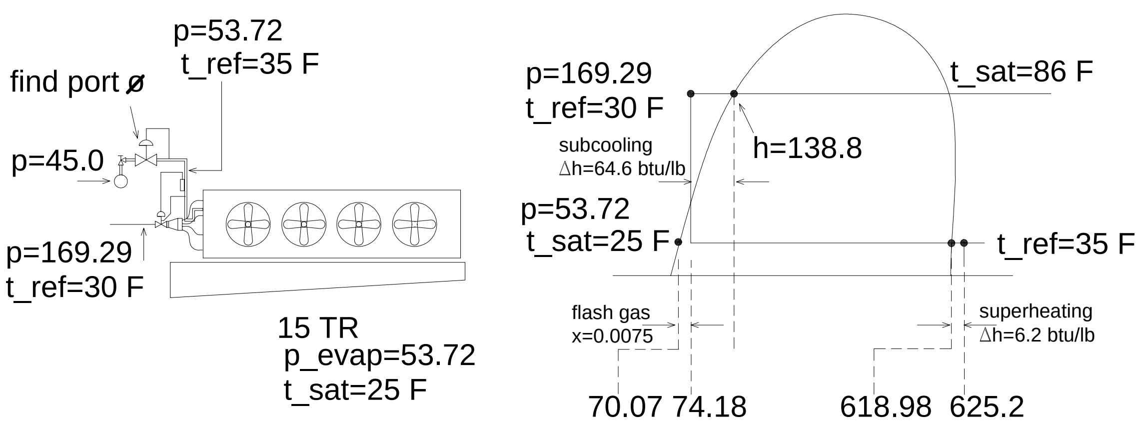

Figure 1

While five values of enthalpy are given in Figure 1, only two of these are needed to solve for mass flow to this evaporator. The other values are shown to emphasize the impact of liquid subcooling and vapor superheat upon mass flow in the following equation:

$$\dot{m} = \frac{TR \cdot \left(200 \dfrac{btu}{\min} \cdot TR\right)}{h_{leave} - h_{enter}} \qquad (1)$$

Step 1 – Find $\dot{m}, \overline{V}$

We first solve Eq 1 for the refrigerant state points used to select both the evaporator and it's companion EPR port diameter. Vapor leaving the evaporator has these state points (and properties): h=625.2, p=73.72, t_{sat}=25 ºF, t_{ref}=35 ºF. Air passes over the evaporator at an entering temperature of 45 ºF. High pressure liquid enters the TXV at a mean condensing pressure = 170 psia, t_{sat}=86 ºF, is then subcooled in a remote heat exchanger to 30 ºF (Δt=56 ºF), then is supplied to the TXV at an enthalpy, h=74.18 btu/lb. The numerator of Eq 1 solves to 3,000 btu/min; the denominator solves to Δh=625.2 – 74.18 = 551.02 btu/lb[1]. The resulting mass flow under these conditions is 5.44 lb/min. Specific volume of the suction vapor will be found on page 54 of the *Little Red Book*, for data in the subcooling and superheat regions, 25 ºF, 53.72 psia saturated refrigerant. Look down the left-most column to 35 ºF then read across to the specific volume, 5.4735 ft^3/lb.

Note that for each pound of liquid supplied to this evaporator, very little heat is exchanged in the gaseous superheat region, Δh=6.22 btu/lb for a 10 ºF rise in sensible temperature. This is a price one pays for superheating ammonia vapor in an evaporator. However, TR is more strongly affected (reduced mass flow) by subcooling HPL by 56 ºF as seen in Eq 1 and Figure 1. If the liquid subcooling process were absent from this analysis, the mass percentage of liquid supplied to this evaporator would have to increase by 13% to 6.17 lb/min for the same 15 TR. No doubt, the HPL line diameter would also have to increase due to the presence of flash gas. It is for this very reason (flash gas inside a HPL line) that subcooling this particular fluid stream has found favor in the industry.

Answer: $\dot{m}$ **= 5.44 lb/min**

Answer: $\overline{V}$ **= 5.4735 ft^3/lb**

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[1] The leaving enthalpy used in this calculation takes credit for vapor superheat because this superheat occurs inside the evaporator, therefore it becomes *useful* to the cycle. However, the loss in net refrigerating capacity of a compressor due to suction vapor superheat outweighs the small increase in evaporator capacity due to this same vapor superheat.

Step 2 – Find Theoretical Port Diameter

This step predicts a theoretical port Cv from Eq 2. In step 3, we use this value to select an available port diameter (Cv) from a manufacturer's catalog. Because of the large increase in vapor specific volume when ammonia vapor is superheated, this increase should be taken into account when solving Eq 2 if accuracy is of importance. After vapor passes through the regulator, the downstream pressure is *p*=45 psia – the intermediate pressure for this facility. Therefore Δp across the regulator is found from $\Delta p = p_{in} - p_{out} = 8.72$ psi.

$$Cv = \frac{0.947\dot{m}}{\sqrt{\Delta p \cdot \frac{1}{\overline{V}}}} \qquad (2)$$

Answer: ***Cv* = 4.08**

Step 3 – Select Regulator Port Diameter from Manufacturer's Catalog

Reference 3 reflects a 6.4 Cv for a 3/4" port installed in an HA4A regulator. Note that the TR reflected in the table for suction vapor capacities is based upon saturated 86 ºF liquid, a saturation temperature for the high side regarded as a typical mean (evaporative cooled systems). These capacities do not take 56 ºF liquid subcooling into account, therefore the manufacturer applies a correction factor to their data = 3% increase for each 10 ºF liquid subcooling below the saturation temperature. After applying the subcooling correction factor and interpolating between data shown in reference 3, *Suction Vapor Capacities* (*Tons*), the adjusted capacity of a ¾" port becomes 24 TR, Δp=9 psi, and 25 ºF evaporating temperature. While this port diameter is somewhat larger than required, it will still give adequate performance. If the solution of Eq 2 yields a Cv between two manufacturers Cv data, select the next larger port.

The selected suction pipe diameter for 15 TR would either be 1½" sch 80 or 2" sch 40, depending upon allowable pressure drop and length of run. Typically, most contractors would rather purchase a larger regulator body rather than purchase and install two concentric reducers. For further data regarding equations used for predicting pressure drop through valves having a port diameter < connected pipe diameter, see reference 2.

Answer: **HA4AD, 2" with 3/4" port**.

end of text

References:

1. ASHRAE, 2005, *Handbook of Fundamentals*, Chapter 2, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
2. Crane, 1976, Technical Paper 410, *Flow of Fluids Through Valves, Fittings and Pipe*, Crane Company
3. Hansen, 2002, *Collection of Instructions,* HA4A suction vapor capacities