Relief Valve Sizing

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Learning Outcomes

- Perform preliminary sizing of a relief valve for liquid, gas, and two-phase flow scenarios.

Reading

- Foundations of Spiritual and Physical Safety: with Chemical Processes; Section VII.3.1.

The above equations can be rearranged to solve for the area of the orifice, A, for a given flow rate and other conditions. Note that the discharge coefficient, C_d, is a function of the geometry of the orifice and the flow conditions. The discharge coefficient is typically determined experimentally with viscosity, downstream piping, backpressure, and other factors influencing the value. Estimates for some of those parameters can be found in Chapter 10 of Crowl and Louvar. For a preliminary estimate, a value of 0.65 is often used for liquid flow and 0.9 for gas flow.

Relief valve sizing in some instances does required verification with actual flow per the AMSE Boiler and Pressure Vessel Code.

Note
See in-class examples

Download a pdf of the example using freeform here: physical/supportfiles/GasFlowExample311.pdf

1 In Class Example: Venting CO2 from 2L Bottle

A two liter bottle is half filed with water. There is a relief valve on the top designed to relieve at 60 psig with a flow of 61 scfm. What is the flow rate of CO2 through the relieve per the above equations?

```
import numpy as np

#fist find the Mach number
gamma = 1.3 #specific heat capacity ratio for CO2, estimate
```

```
P1 = 60 + 12.5 #initial pressure, estimate, psia
Patm = 12.5 # atmospheric pressure, psia
Ma = min(1, np.sqrt(2/(gamma -1)*((P1/Patm)**((gamma -1)/gamma) -1))) #Mach number

Ma

#now calculate the molar flow rate
R = 8.314 # gas constant, J/(mol*K)
Temp = 295 # temperature, K
Area = np.pi/4*(1/4*0.0254)**2 # area of the pipe, m^2
Cd = 0.9 # discharge coefficient
Mw = 0.04401 # molar mass of CO2, kg/mol
# molar flow rate, mol/s
ndot = P1*6894.76*Area*Cd*np.sqrt(gamma/(R*Temp*Mw))*Ma*(1+(gamma -1)/2*Ma**2)**((gamma+1)/(2 -2*gamma)
print(f'The molar flow rate is {ndot:0.2f} mol/s')

#now convert that molar flow rate into scfm, PV = nRT
Tstandard = 298.15 # standard temperature, K
Pstandard = 101325 # standard pressure, Pa
scmps = ndot*R*Tstandard/Pstandard #units of m^3/s
scfm = scmps*60*(3.281**3)
print(f'The flow rate in scfm is {scfm:0.1f}')
```

Why is this number different than the reported flow rate of CO2 through the relief valve? Could the diameter of the relief be slightly larger?

How would you get the generation rate of CO2 from the submlimation of dry ice?

$$Q = hA(T_{water} - T_{ice})mdot = Q/\Delta H_{vap} \tag{1}$$

Does area (A) change? How would you get the heat transfer coefficient (h)?

Action Items

1. Determine the size of the vent needed for a 50 cubic meter tank filling with water at 5 kg/sec, assuming a MAWP of 1.5 barg and a discharge coefficient of 0.95.
2. Personal Reflection: Explain the importance of "back pressure" in sizing a balanced bellows relief valve versus a standard spring-operated valve.
3. Using the 2L soda bottle heating example, estimate the vent area needed to prevent the overpressure from exceeding the fire scenario max accumulation of 81 psig.
4. Explain why the gas flow from desorbing CO_2 dominates the venting requirement compared to the vapor pressure effect.