Chapter 6 Understanding Process Conditions

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Heuristics

- Temperature

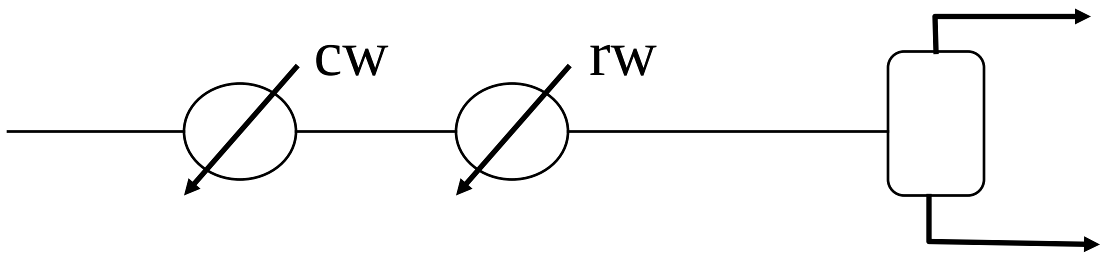
< 40ºC	> 250ºC	> 400ºC
Require Refrigeration	Require Fired Heater	Special M.O.C

- Pressure

< 1 atm	> 10 atm
need Vacuum	Thick Walls - $

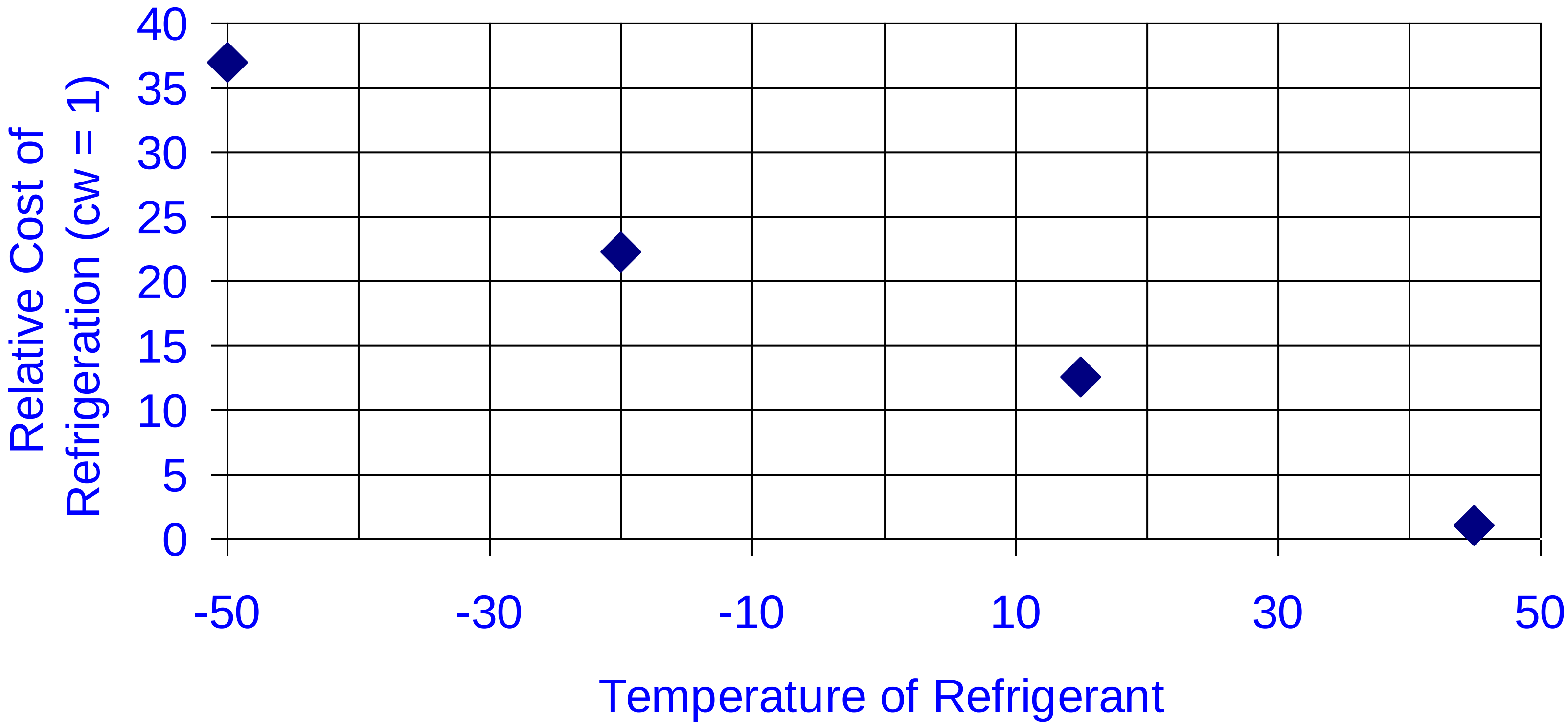
Temperature

- *T* < 40º C – Refrigeration
  - Use as much cooling water as Possible



  - Operating Costs (Table 8.3)
    - Cooling Water (30-40°C) $0.354/ GJ
    - Refrigerated Water (5-15°C) $4.43/ GJ

Temperature



Temperature

- T > 250°C – hp steam @ 260°C (600 psig)
  - Need a molten salt / Dowtherm loop
    - Fired Heaters are very expensive
  - Compare - vaporizer

$$Q = 10{,}000\ \mathrm{kW}$$

$$U = 1000\ \mathrm{W/m^2K}$$

$$\Delta T = 30^\circ C$$

$$A = \frac{\left(10 \times 10^6\right)}{\left(10^3 \times 30\right)} = 333\ \mathrm{m}^2$$

Temperature

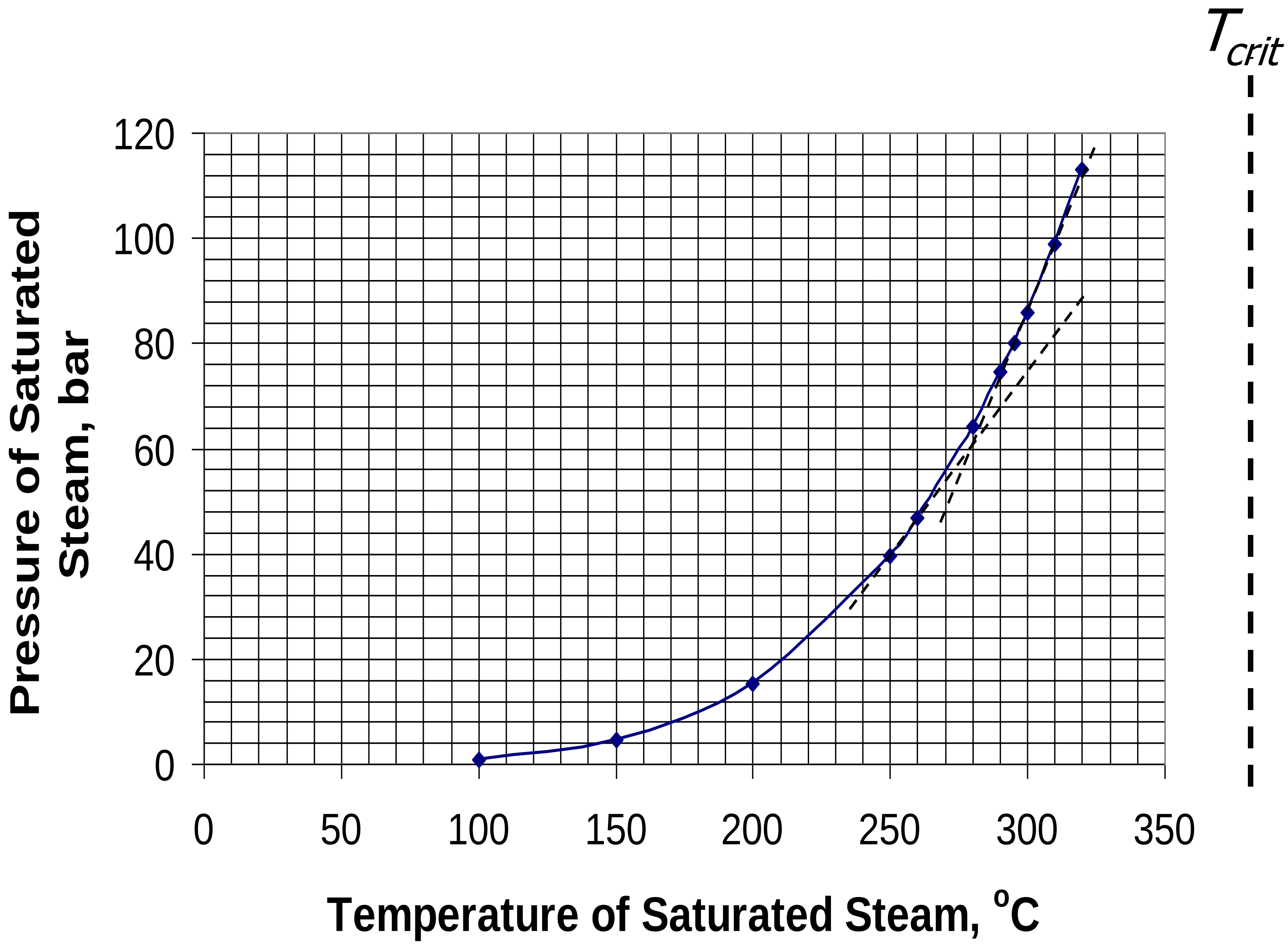
- C_{BM}
  - Heat Exchanger = $ 1.70×10^5
  - Fired Heater = $ 1.81×10^6
- $T > 400°C$
  - M.O.C. is very Important

Why not use High-Pressure Steam?

P_{sat} (bar)		T_{sat} (^oC)
15.2		200
39.7		250
46.9		260
64.2		280
86.0		300
74.5		290
80.1		295
98.8		310
113.0		320

Graph of Saturated Steam vs. Pressure

Why not use High-Pressure Steam?



Pressure

- Vacuum
  - Slightly Higher Cost due to Stiffening Rings
  - Large Equipment
  - Air Leaks
- High Pressure
  - Thick Walls - $
  - H_2 Embrittlement
  - Safety

Minimum Wall Thickness

$$t = \frac{PR}{SE - 0.6P} + CA$$

Wall thickness, *t* = m , design pressure, *P* = bar , vessel radius, *R* = m

S = Design Stress (Max Allowable Working Pressure, bar) this is a function of material and temperature

E = Weld Efficiency(~ 0.9)

CA = Corrosion Allowance (0.00315 to 0.00625 m)

Minimum Wall Thickness

- Look at 36 inch Diameter Vessel with a CA of ¼ in made of CS with S = 13,700 psi

P	t (m)	t/CA
14.7 = 1 barg	0.0069	1.09
58.8 = 4 barg	0.0085	1.34
147 = 10 barg	0.0118	1.86

- As P > 10 then $t > CA$

What About S vs. T ?

- Look at Several Steels in Graph
- For CS $S \downarrow$ as $T > 400$ºC
- Must use Stainless Steel and \$$\uparrow$
- For a given Pressure
  - $t \uparrow$ as $T \uparrow$

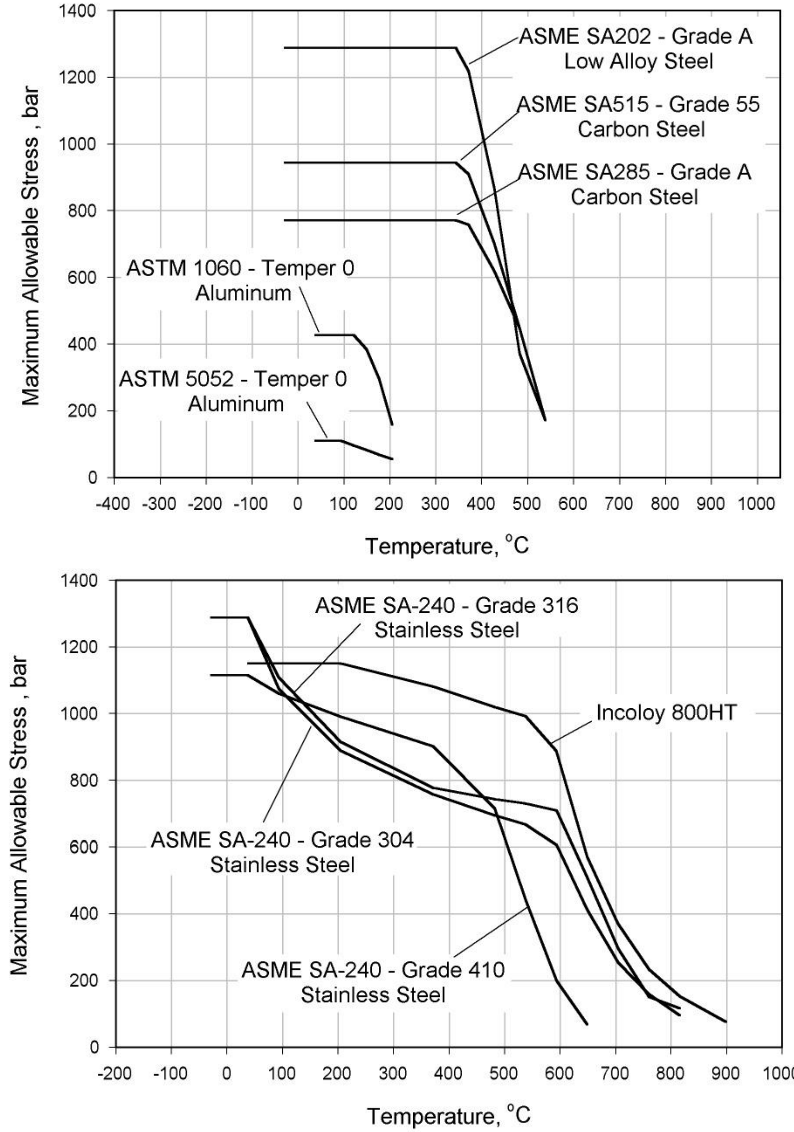
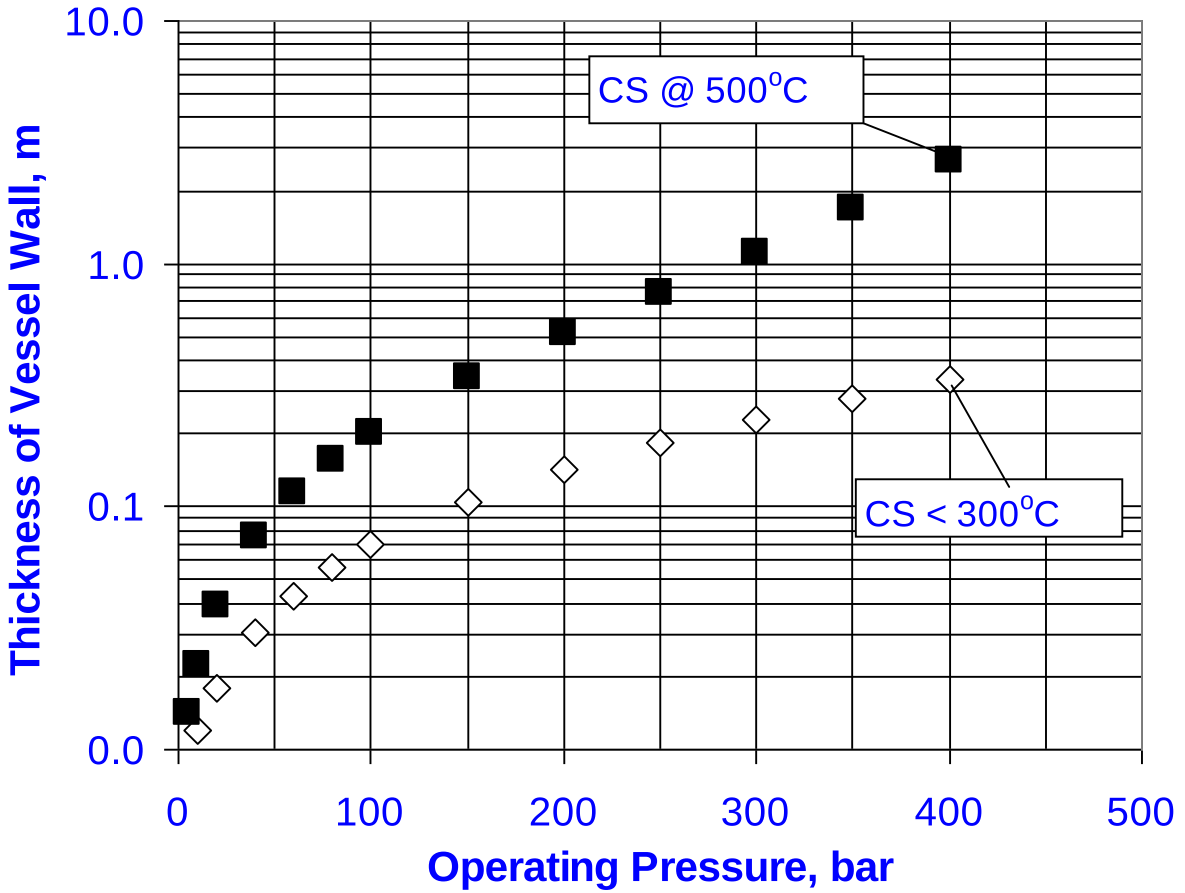


Figure 5.5: Maximum Allowable Stresses for Materials of Construction as a Function of Operating Temperature (Data from Perry et al. [3], Chapter 10 and Ref [15])

Material of Construction

1 m Diameter Vessel made of SA285 - Grade A Carbon Steel



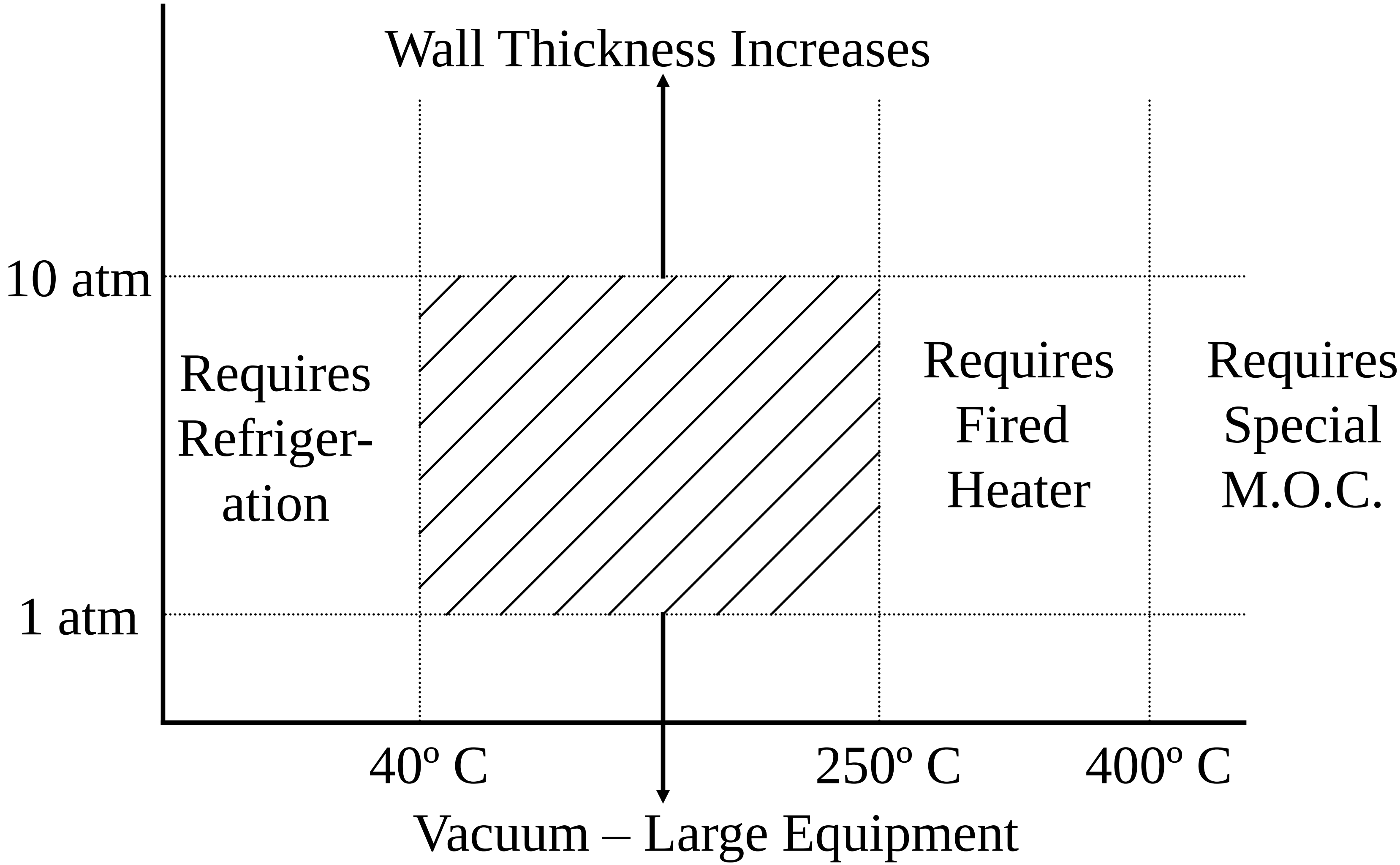
Material of Construction

- Carbon Steel
  - Cheap
- Stainless Steel
  - Expensive
  - Better Chemical/Thermal Resistance
- What About T = 700-900°C?
  - Insulate inside of Pipe
  - Metal – Refraction Lining

Conclusions

- $T < 40°C$ – Refrigeration
- $T > 250°C$ – Fired Heater or Furnace
- $T > 400°C$ – M.O.C. Issues
- $P < 1$ atm – Vacuum and Large Equipment
- $P > 10$ atm – Cost

Operating Conditions



Do we ever operate outside these limits?

- Tables 6.1 – 6.3
  - Reactors and Separators
- Table 6.4
  - Other Equipment

Examples

- Example 1 – Acrylic Acid
  - Appendix B.9
  - Why does T-305 Operate with the top pressure at 0.07 bar?
  - Feed – 86.6 kmol/h Acrylic Acid – nbp =140°C

    6.1 kmol/h Acetic Acid – nbp = 118°C

  Table 6.2 – Reasons for using *P* < 1 atm

  1. Obtain a gas phase for VLE
  2. Temperature sensitive materials

Examples

- Example 2 – Separation of Propane
  - Typical depropanizer operates at 220 psig (16 bar) – why?

  Table 6.2 – reasons for using *P* > 10 bar

  1. Obtain a liquid phase for VLE