ChE 101.04

MASS & ENERGY BALANCES PREPARATION & USE

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MASS & ENERGY FLOW

Mass/Energy, Losses/Gains

- for mass loss/gain, do not forget unexpected things!

Shedgum DGA Plant Simplified Process Flow Diagram

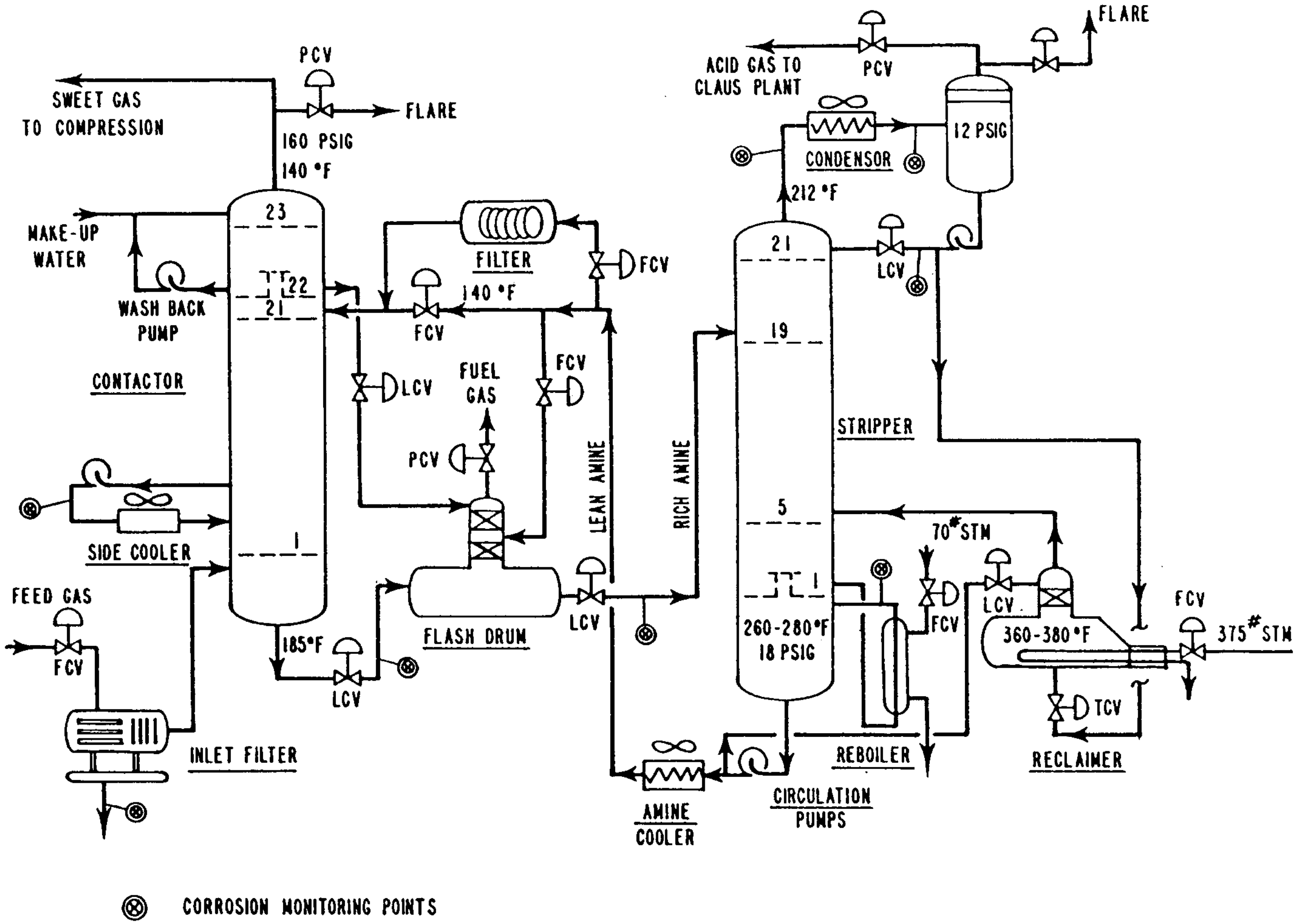
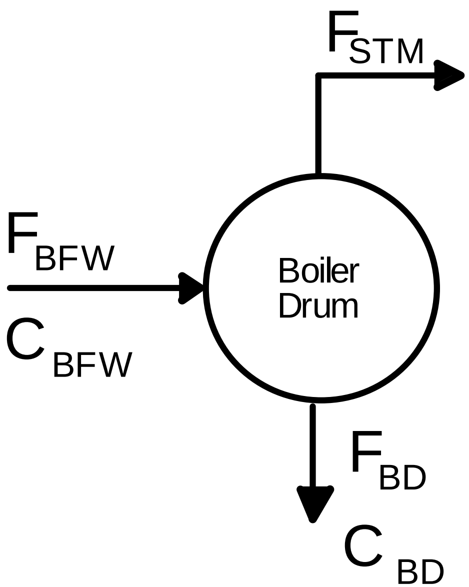


Figure 3

Recycle & Purge Streams

Boiler Blowdown Method



$$X = \frac{F_{BD}}{F_{BFW}}(100)$$

$$F_{BFW} \, C_{BFW} = F_{BD} \, C_{BD}$$

$$\frac{C_{BFW}}{C_{BD}} = \frac{F_{BD}}{F_{BFW}} = \frac{X}{100}$$

where:

- **F_{BFW} = Feedwater flow, lb/hr.**
- **F_{BD} = Blowdown flow, lb/hr.**
- **F_{STM} = Steam flow, lb/hr.**
- **C_{BFW} = Solids concentration in boiler feedwater, ppm.**
- **C_{BD} = Solids concentration of blow down (circulating boiler water), ppm.**
- **X = Percent blowdown, percent of boiler feed water.**

Recycle & Purge Streams

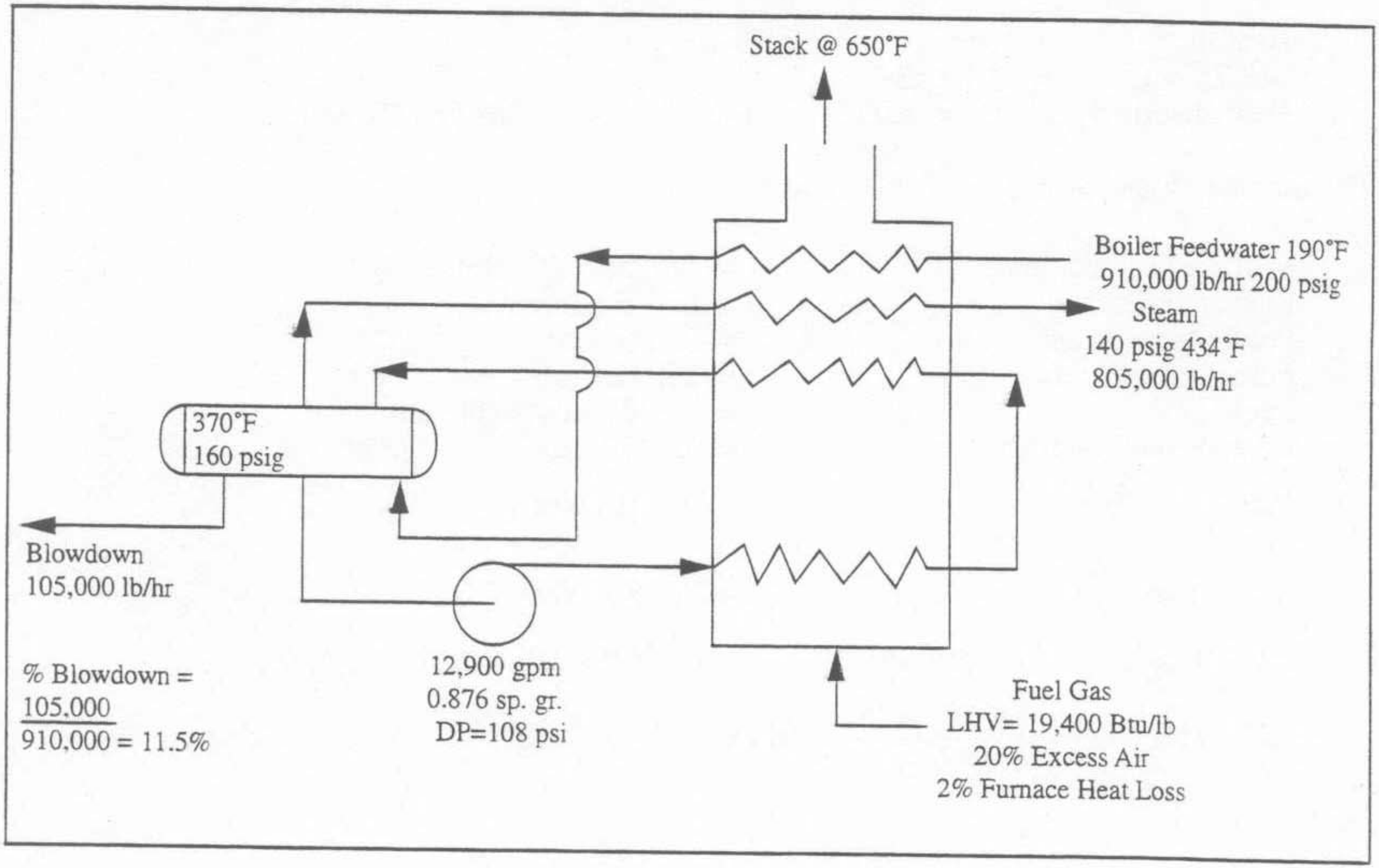


Figure 6. Steam Boiler System

Recycle Streams

Hydrotreating Purge

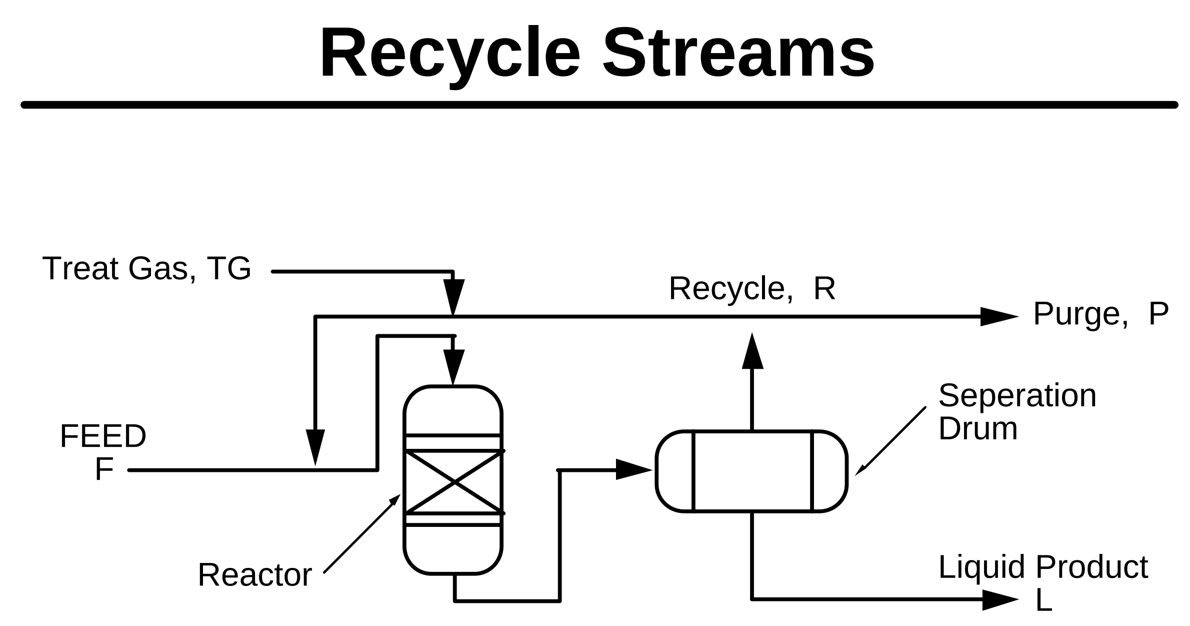


Figure 4

Chemical Reactions

- Overall Mass Balance Not Changed
- Mole Balance and Composition Change
- Reversible Reactions
- Irreversible Reactions
- Predict Reaction Products
- Heat of Reaction

Exercise 3

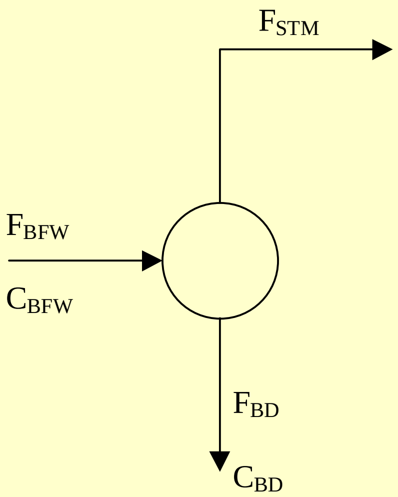
Directions:

Water is fed into a boiler from a demineralizer plant. There are specifications on solids and chlorides in the boiler water. If the chloride specification is met, the solids specification is automatically met, since demineralized water is good quality boiler feedwater and the chloride specification is the harder of the two specifications to achieve.

The chloride content of the boiler water must be kept equal to or lower than 8 wppm (weight parts per million). The feedwater has a chloride content of 0.2 wppm. The boiler raises 200,000 lb/hr of steam. Calculate the boiler feedwater and blowdown rates.

Exercise 3, Cont'd

Answer:



$$X = \frac{F_{BD}}{F_{BFW}}(100)$$

$$F_{BFW} \; C_{BFW} = F_{BD} \; C_{BD}$$

$$\frac{C_{BFW}}{C_{BD}} = \left(\frac{0.2}{8}\right) = 0.025 = \frac{F_{BD}}{F_{BFW}}$$

$$F_{BD} = 0.025\,(F_{BFW})$$

$$F_{BFW} = F_{Stm} + F_{BD}$$

$$F_{BFW} = F_{Stm} + .025\,F_{BFW}$$

$$0.975\,F_{BFW} = F_{Stm} = 200{,}000$$

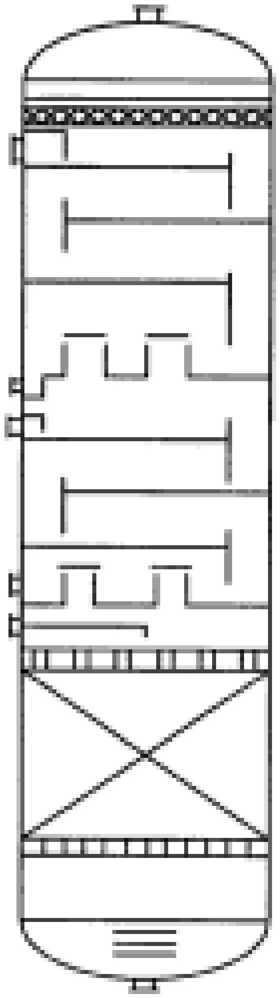
$$F_{BFW} = 205{,}128$$

$$F_{BD} = 5128$$

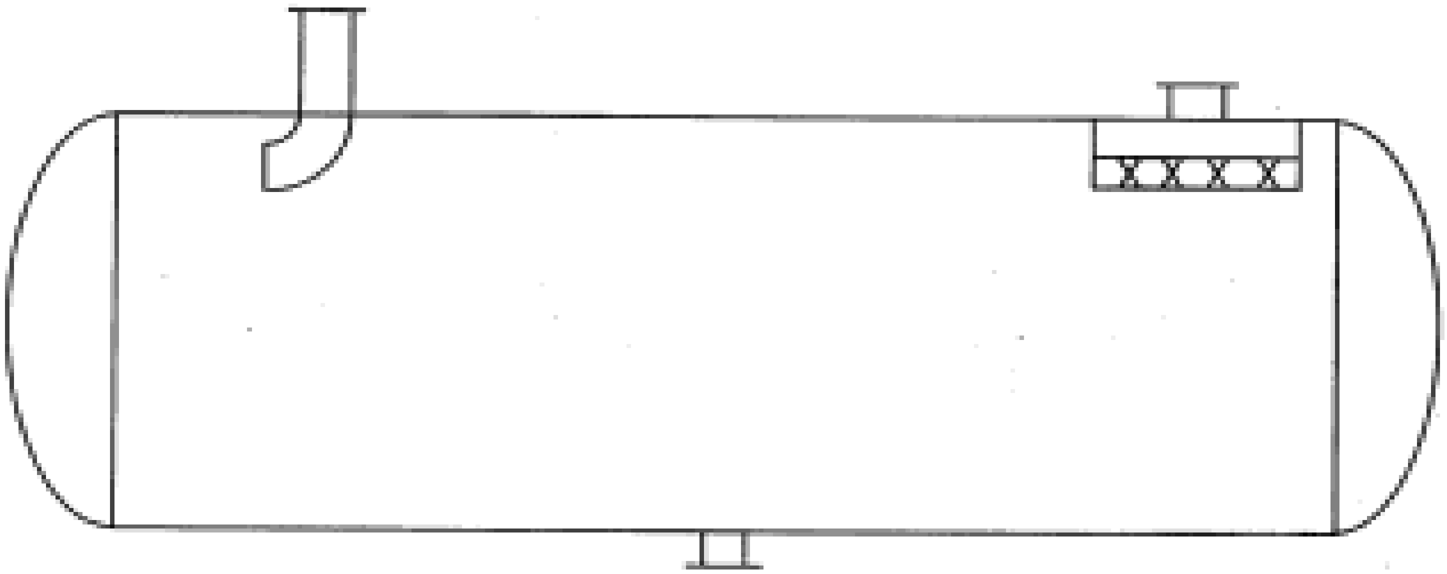
Debottlenecking

- Towers
- Drums
- Exchangers
- Pumps
- Compressor
- Control Valves
- Piping

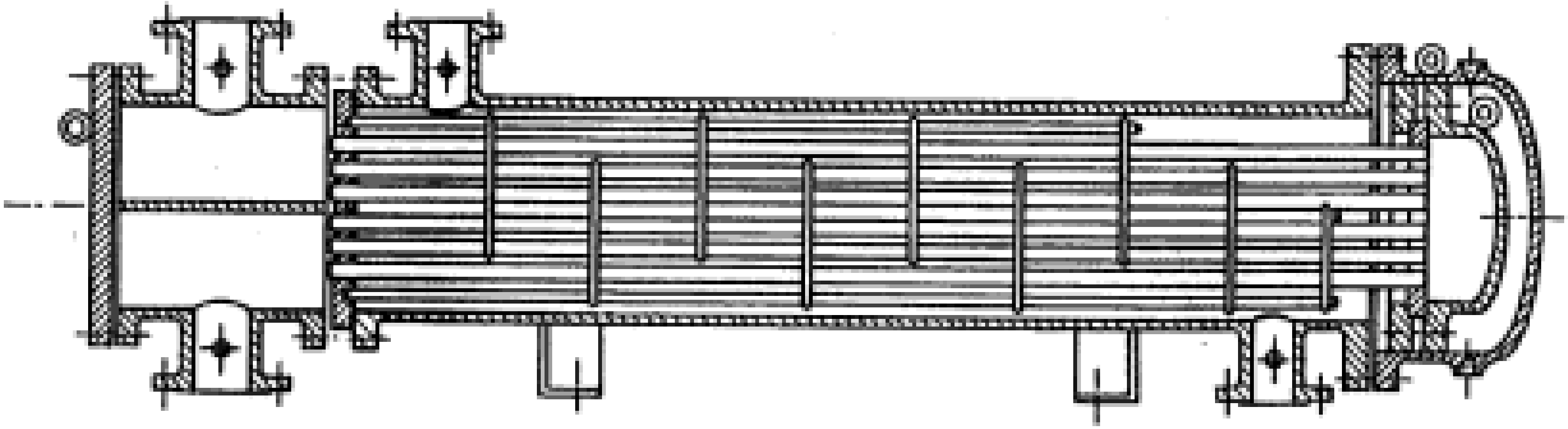
Towers



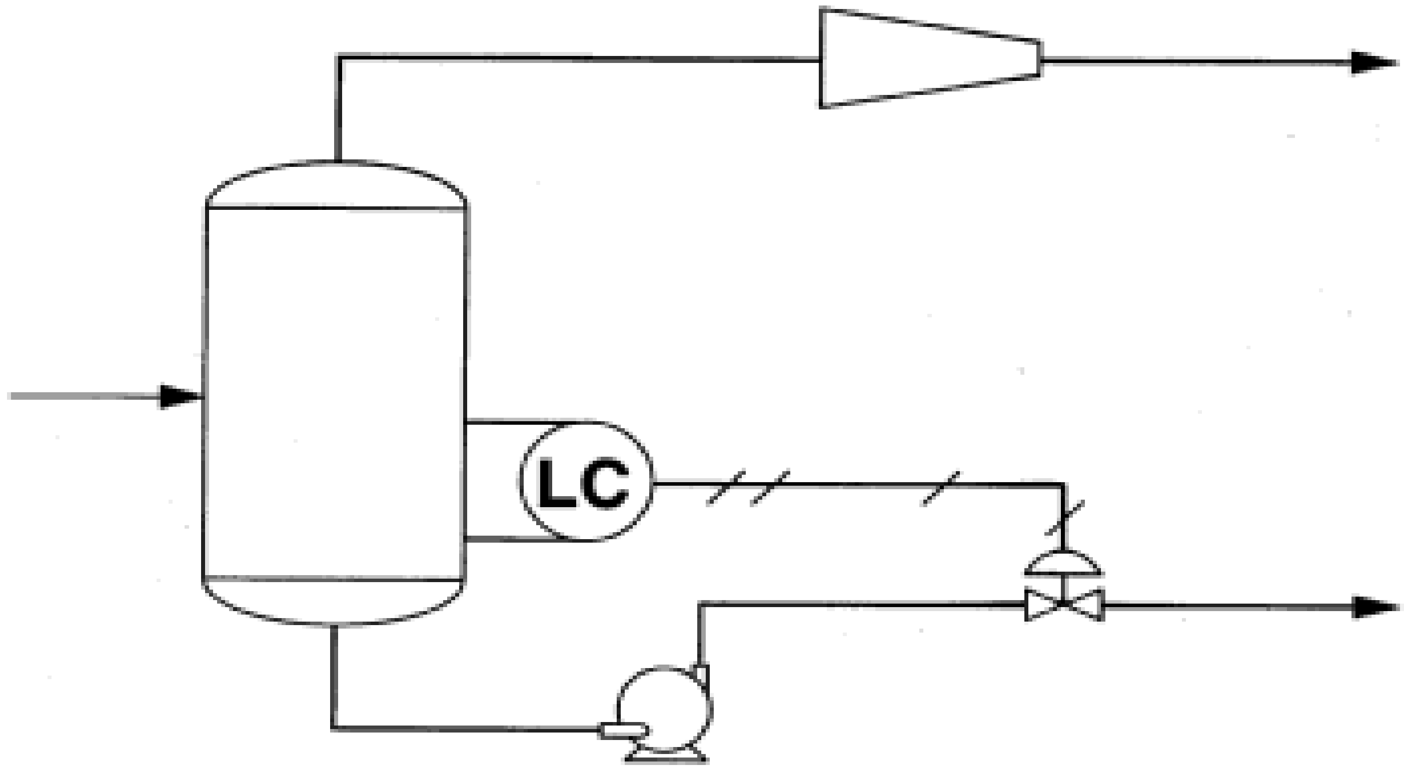
Drums



Shell and Tube Exchanger



Pumps/Compressors/ Control Valves/Piping



Exercise 4

Introduction:

This Exercise will be worked on as a class discussion. In Exercise 3 you prepared a mass and energy balance around a C_3/C_4 splitter system. The owner of this

1. What would you do to find the bottlenecks?

2. How would you fix them?

Exercise 4, Cont'd

Answer:

1. **Unless there are known limitations, a unit test would be the first step. This would determine the major limitations and uncover other areas that are close to limiting. The class should suggest possible areas at which to observe bottlenecks.**

2. **The instructor should propose bottlenecks and ask the class how they would find and solve them. A list of proposed bottlenecks should include:**

First Step Unit Test

- **Tower flooding upper section**
- **Tower flooding lower section**
- **Overhead exchanger**
- **Pumps**
- **Reboiler**
- **Feed/effluent exchanger tube leak**
- **Control valve**

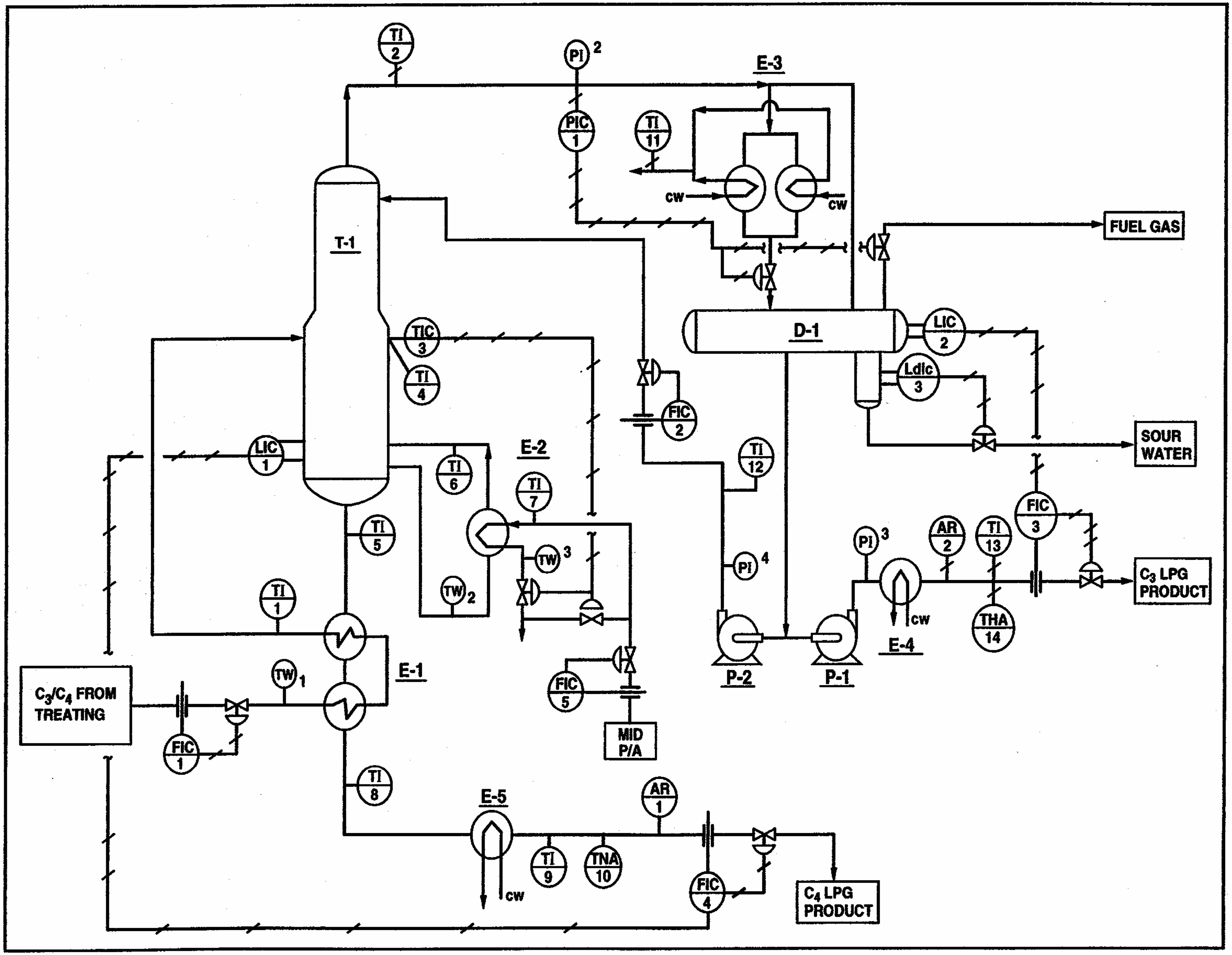


Figure 8 C3/C4 Splitter

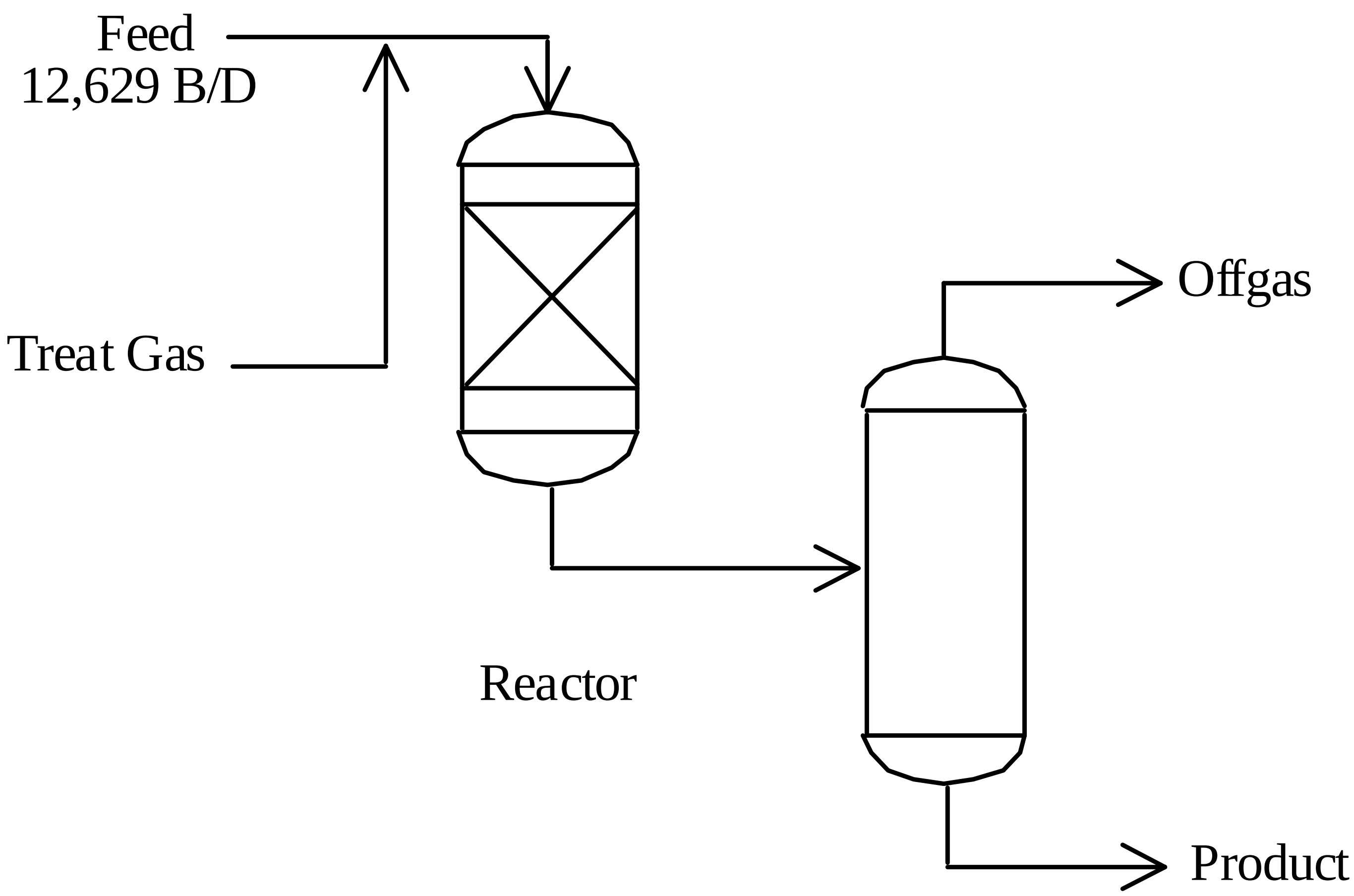
Computer Input/Outputs

Key Formulas

Summary

Evaluation

Evaluation



Evaluation, Cont'd

The refinery has 12,629 B/D of naphtha to hydrotreat. The process licenser has the following process requirements and data:

- **Treat gas rate must provide a minimum of 241 SCF H_2/bbl feed.**
- **The hydrogen partial pressure in the reactor must be a minimum of 56.6 psia.**
- **The hydrogen consumption is 5.83 SCF/bbl. The consumed hydrogen appears as H_2S.**

Evaluation, Cont'd

The refinery Information are as follows:

- **Treat gas is 69.23 mole percent hydrogen. The remainder is methane.**
- **The feed is totally vaporized in the reactor**
- **Feed information:**

	moles per hour (mph)
iC5	0.19
C5	0.19
C_6/310	182.74
310/360	223.52
360/395	202.23
395/430	166.67
430 +	175.23
	950.76
MW	152
sp. Gr.$_{60}$	0.785

Evaluation, Cont'd

Calculate

1. The material balance around this unit.
2. The reactor pressure in psia.

Note that since there is insufficient time to run a computer flash, assume a perfect split of components and that all the feed components leave in the product.

Evaluation, Cont'd

Answer:

Feed rate:

$$1629\,\frac{B}{D}\ \text{x}\ \frac{42\,\text{gal}}{B}\ \text{x}\ \frac{(833)(.785)\,\text{lbs}}{\text{gal}}\ \text{x}\ \frac{D}{24\ \text{hr}} = 144518\,\frac{\text{lbs}}{\text{hr}}\ \text{or}$$

950.76 mph x 152 mw = 144,515 lbs/hr

Hydrogen treat gas rate : 241 SCFH_2/bbl feed.

$$1629\,\frac{B}{D}\ \text{x}\ 241\,\frac{SCFH_2}{B}\ \text{x}\ \frac{D}{24\ \text{hr}} = 126816.2\,\frac{\text{scf}}{\text{hr}}\ \text{x}\ \frac{\text{mole}}{379\ SCF} = 334.6\ \text{mph}\ H_2$$

Evaluation, Cont'd

Total treat gas: Treat gas is 69.23 mole percent H_2

$$0.6923\,X = 334.6 \text{ mph}$$
$$X = 483.3 \text{ mph}$$

Treat Gas	mph
total treat gas rate	483.3
hydrogen	-334.6
methane	148.7 mph

Evaluation, Cont'd

Hydrogen consumed:

Consumption = 5.83 SCF/bbl feed

$$1629\ \frac{B}{D}\ x\ \frac{D}{24\,hr}\ x\ \frac{5.83\,SCF}{bbl} = 3067.79\ \frac{SCF}{hr}\ x\ \frac{mole}{379\ SCF} = 8.1\,mph$$

- H_2S created = H_2 consumed = 8.1 mph.
- Offgas composition (mph):

Treat Gas mph	Consumed mph	Offgas mph
148.7 CH_4	0 CH_4	148.7 CH_4
334.6 H_2	8.1 H_2	326.5 H_2
		8.1 H_2S
483.3	8.1	483.3

Evaluation, Cont'd

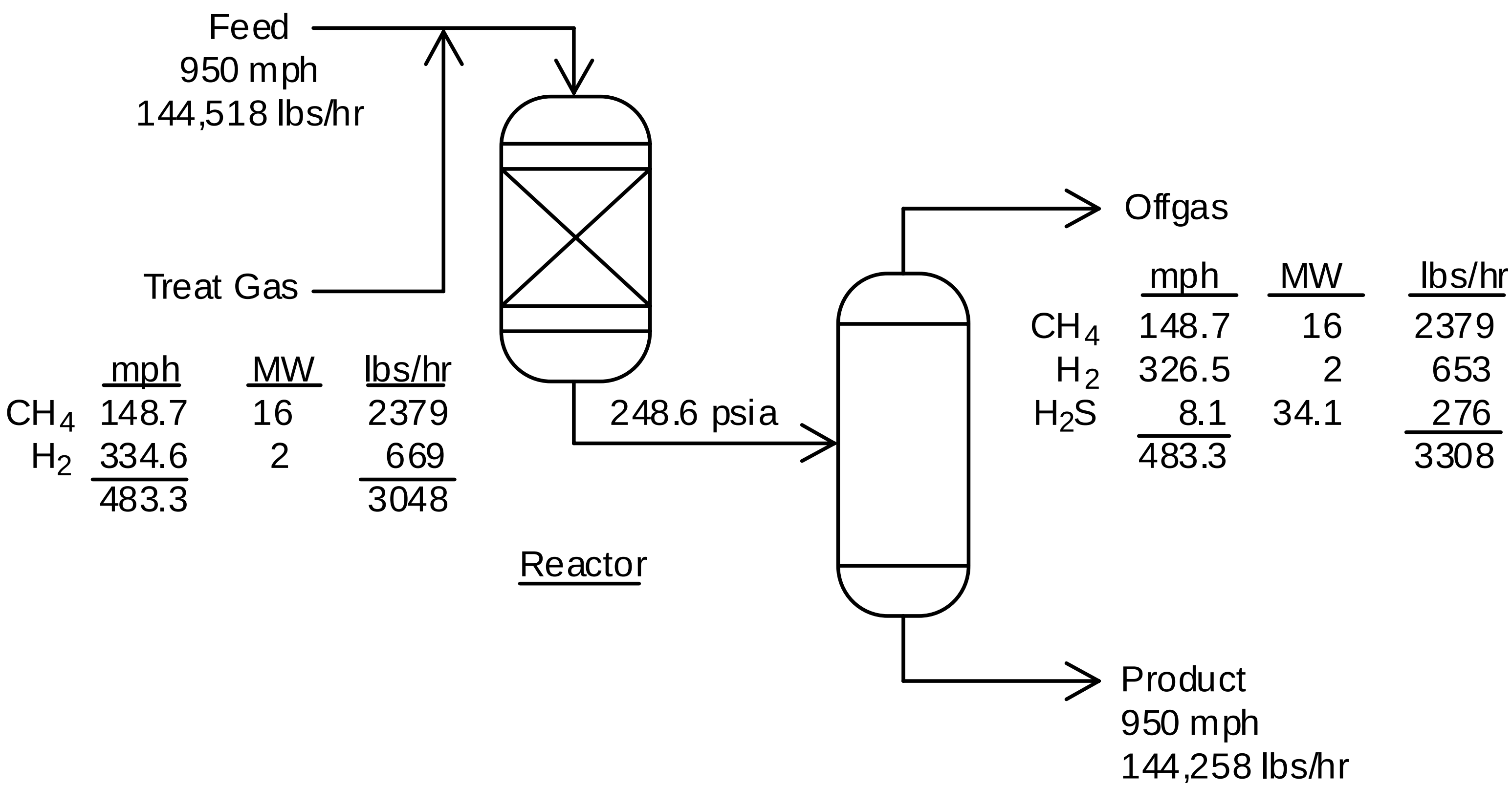
- Minimum H_2 partial pressure = 56.6 psia. This will occur at the outlet where the pressure and H_2 content are at the minimum.

$$\frac{\text{moles } H_2}{\text{total moles}} \times \text{pressure} = 56.5$$

$$\frac{326.5}{483.3 + 950.76} \times \text{pressure} = 56.5 = 0.2277 \times \text{pressure}$$

Reactor outlet pressure = 248.6 psia = 233.9 psig

Evaluation, Cont'd



Evaluation; Cont'd

Mass Balance

n	lbs/hr
Feed	144,518
Treat Gas	3,048
	147,566

Out	lbs/hr
Off gas	3,308
Product	144.25(By difference)
	147,566

Thanks