Achieve Test Run Objectives with Advance Preparation and Real Time Reports

Charles D. Herzog, PE

Consulting (Retired) Chemical Engineer

Herzog Process Services, PLLC

AIChE South Texas Section, Jan 2019

HERZOG PROCESS SERVICES, PLLC

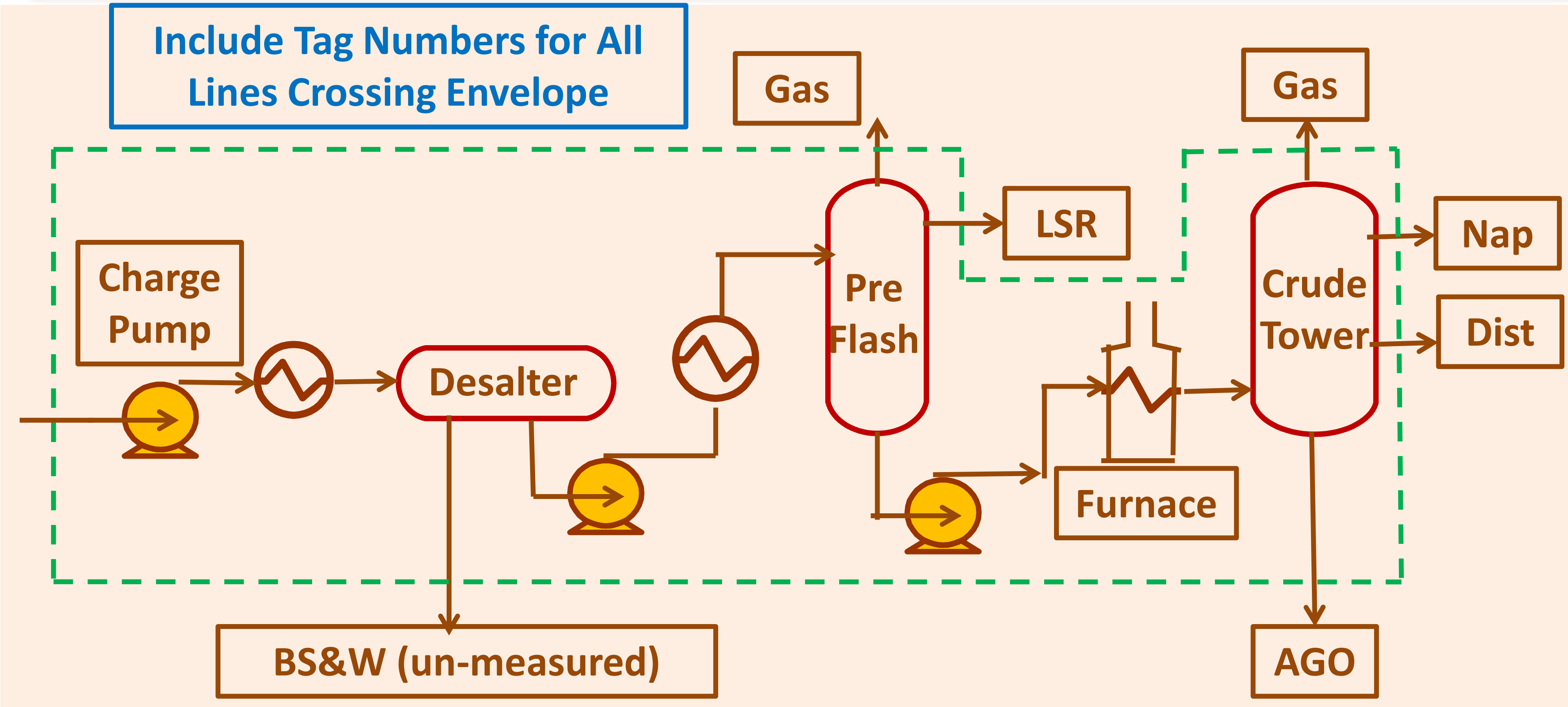
Types of Test Runs

- Performance guarantee
- Root cause analysis
- Scope identification for revamp project
- Others?

Test Run Preparation

- **Confirm material balance envelope**
- Prepare Excel calcs and reports in advance
- Obtain or create a simulation of the system
- Verify DCS data acquisition / migration to Excel
- Synchronize lab data with DCS data
- **Make a plan to reconcile data into a balance**

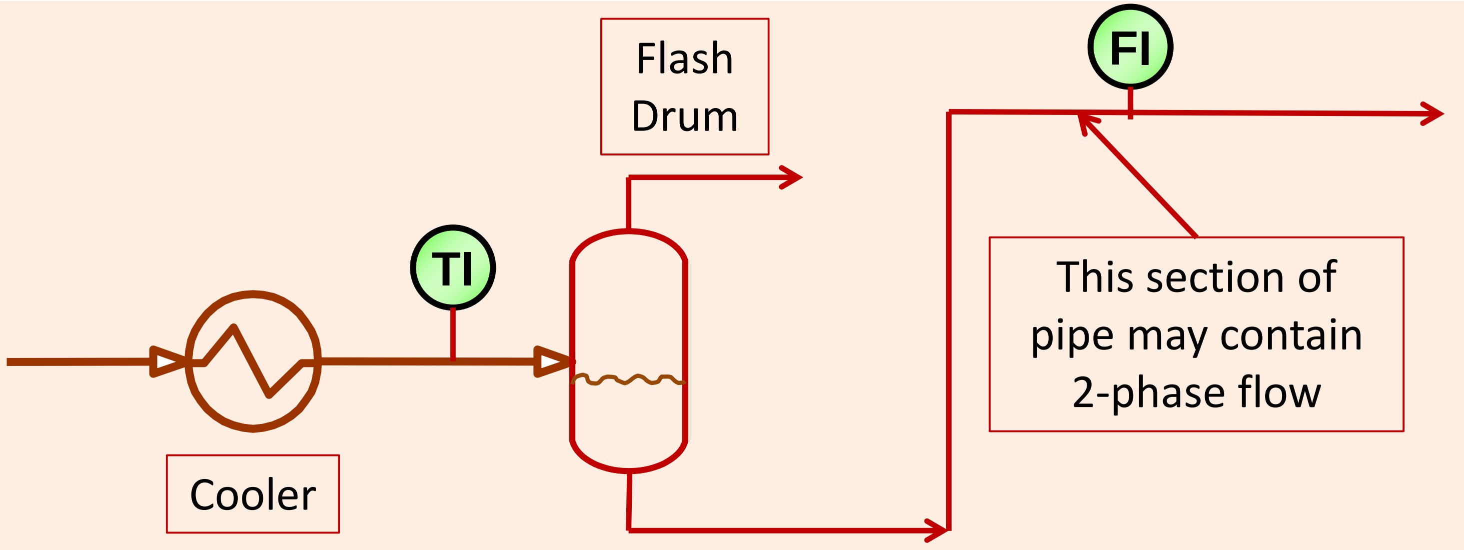
Material Balance Envelope for Crude Oil Unit



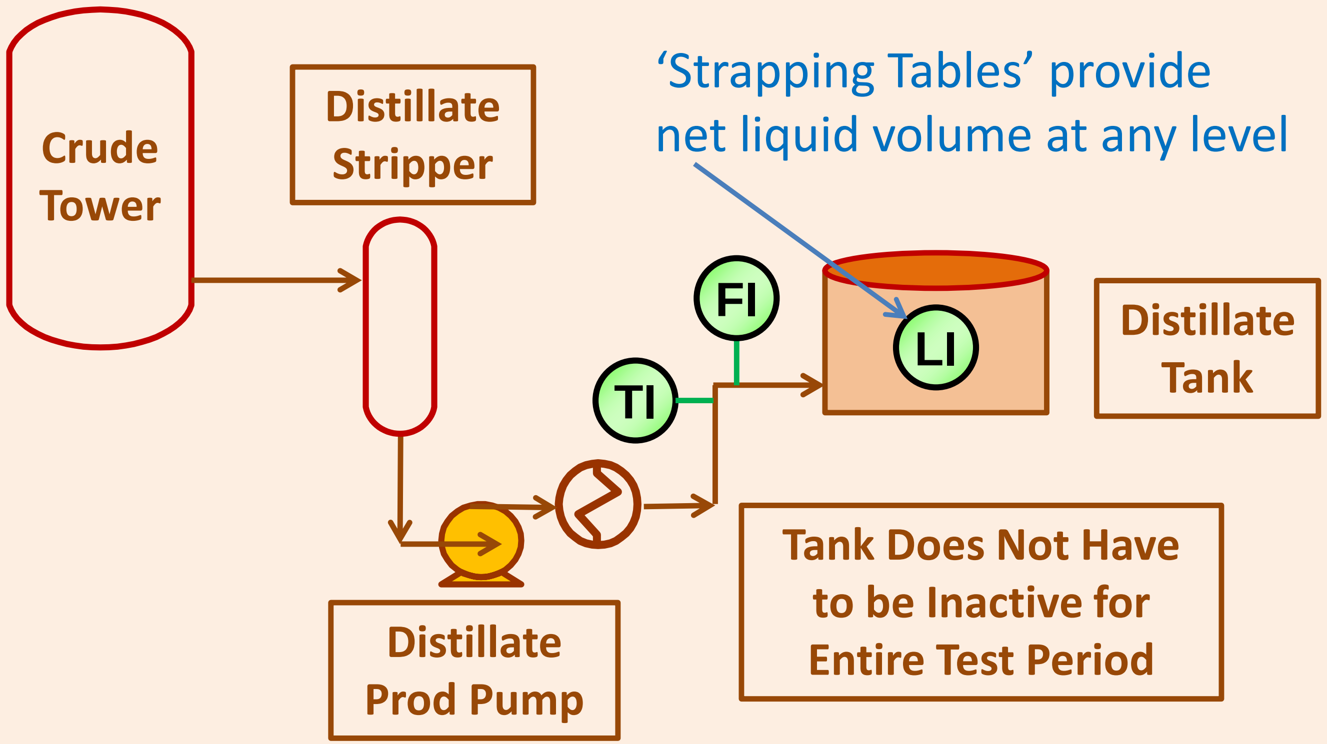
Confirm Material Balance Envelope

- Use daily material balance calcs as a starting point
- Normally closed lines must be included
- Agree how to account for any flaring during the test
- Identify any un-measured lines crossing envelope
- Try to use single-phase lines for flow measurement
- **Confirm material balance closure prior to test**

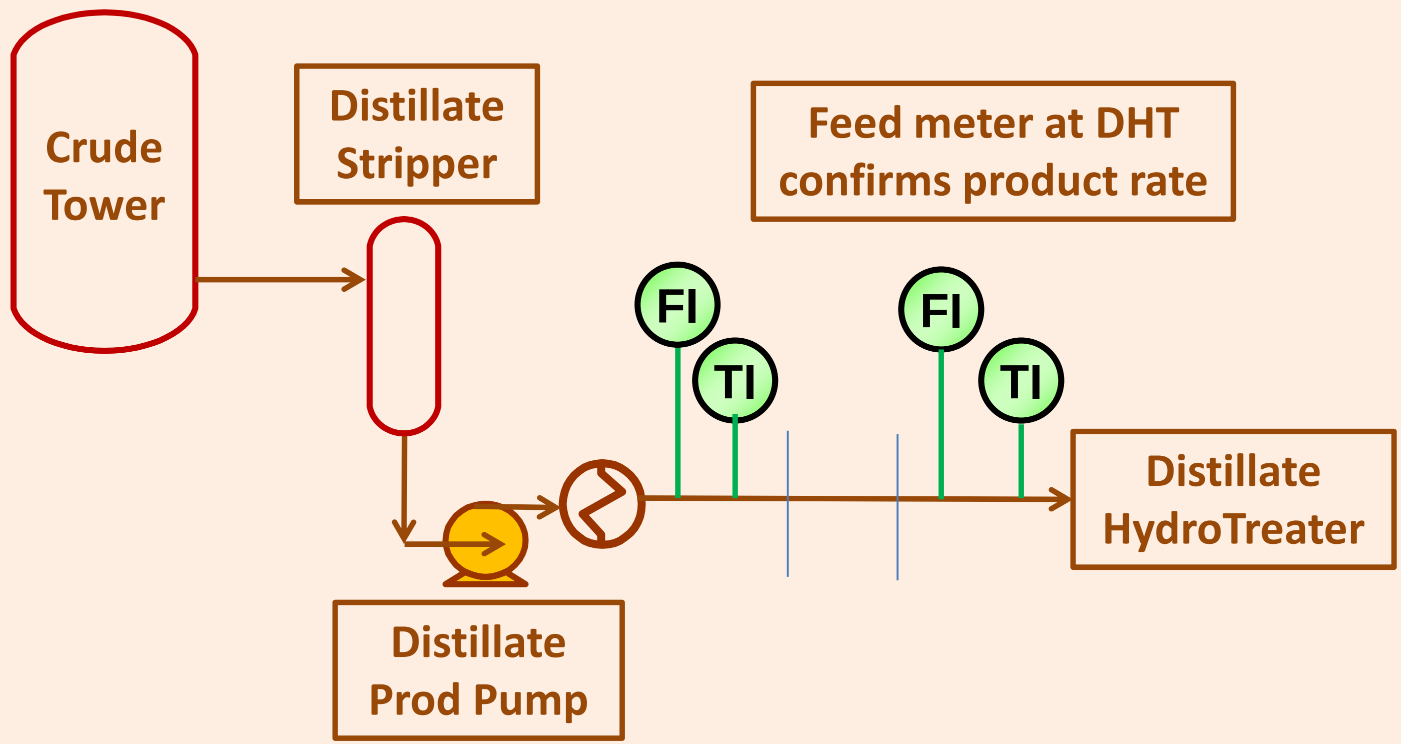
Orifice Meters Work Best with One-Phase Flow



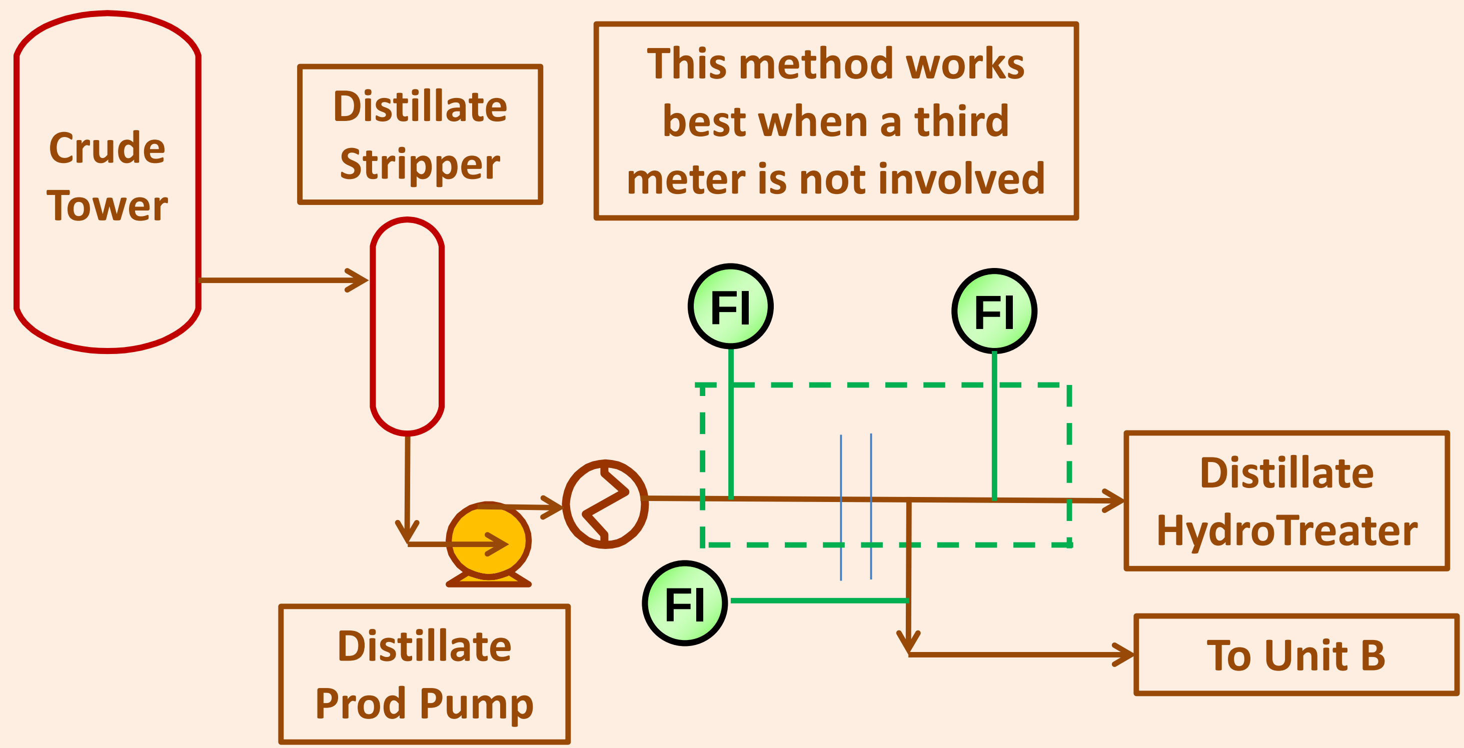
Flow Data is Reconciled Against Tank Volume



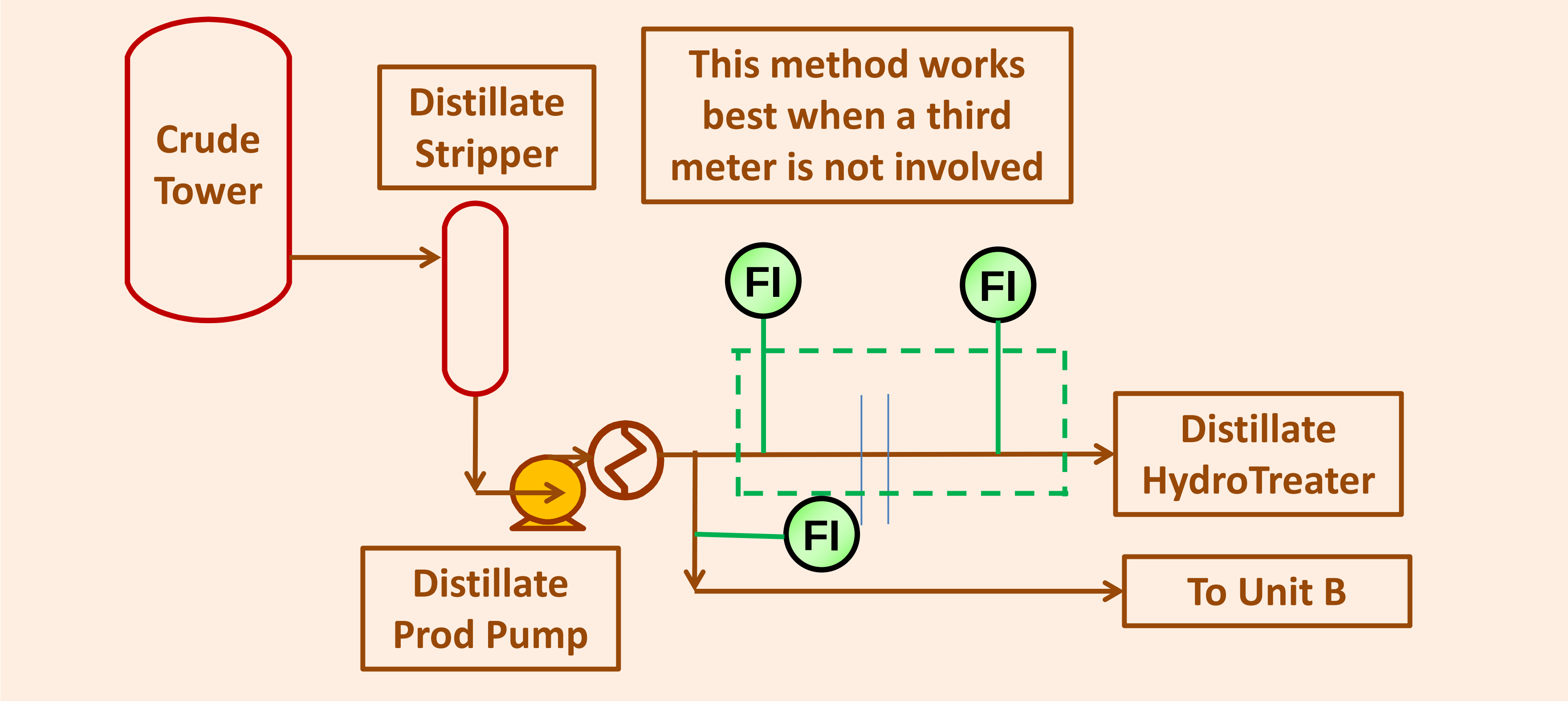
Downstream Data Reconciles Product Rate



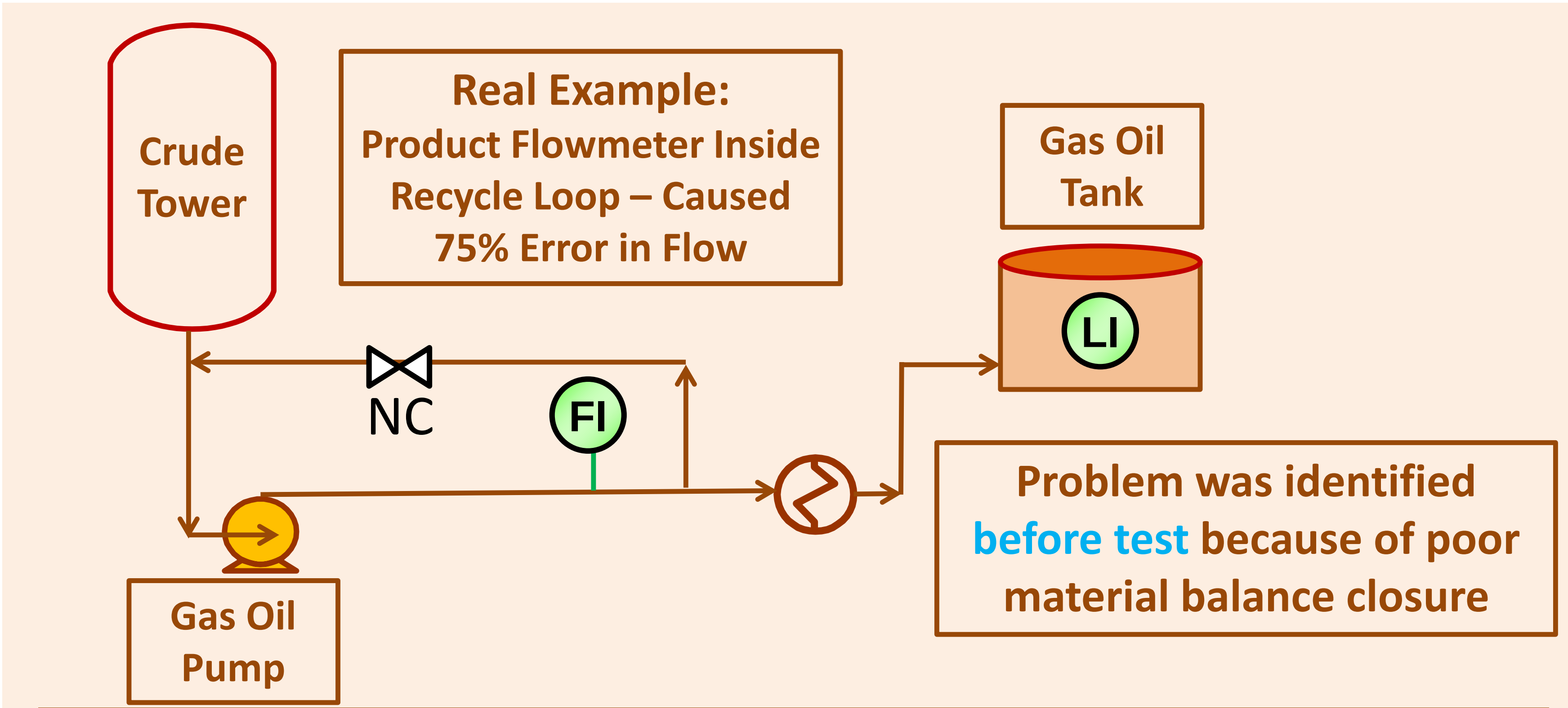
Confirm Envelope with Downstream Unit



Confirm Envelope with Downstream Unit

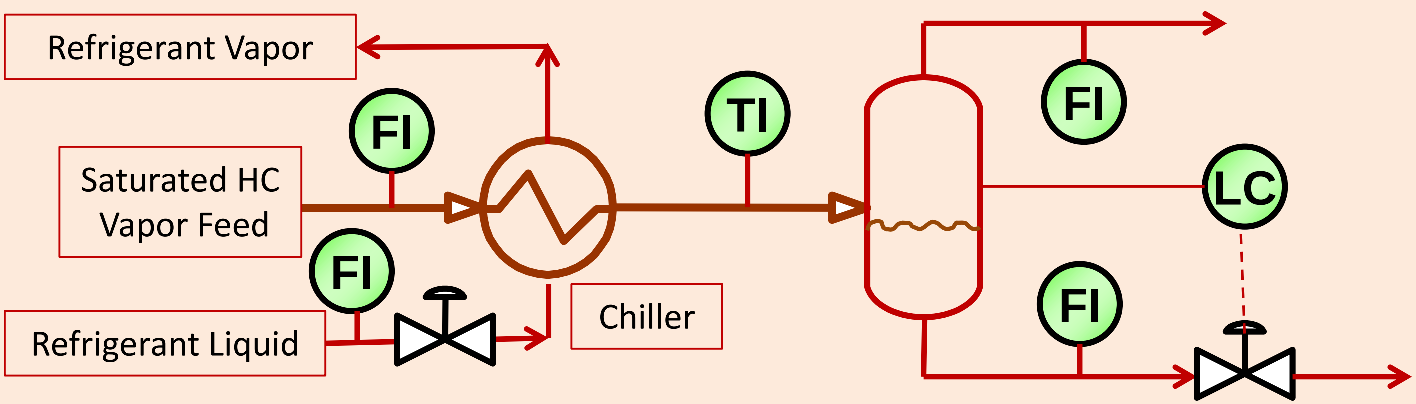


Identify Problems **BEFORE** Test Begins



Refrigeration Example: Simulation Helps!

Level Must be Steady to Reconcile Data



Use Chiller Data Sheet and Condensing Curve

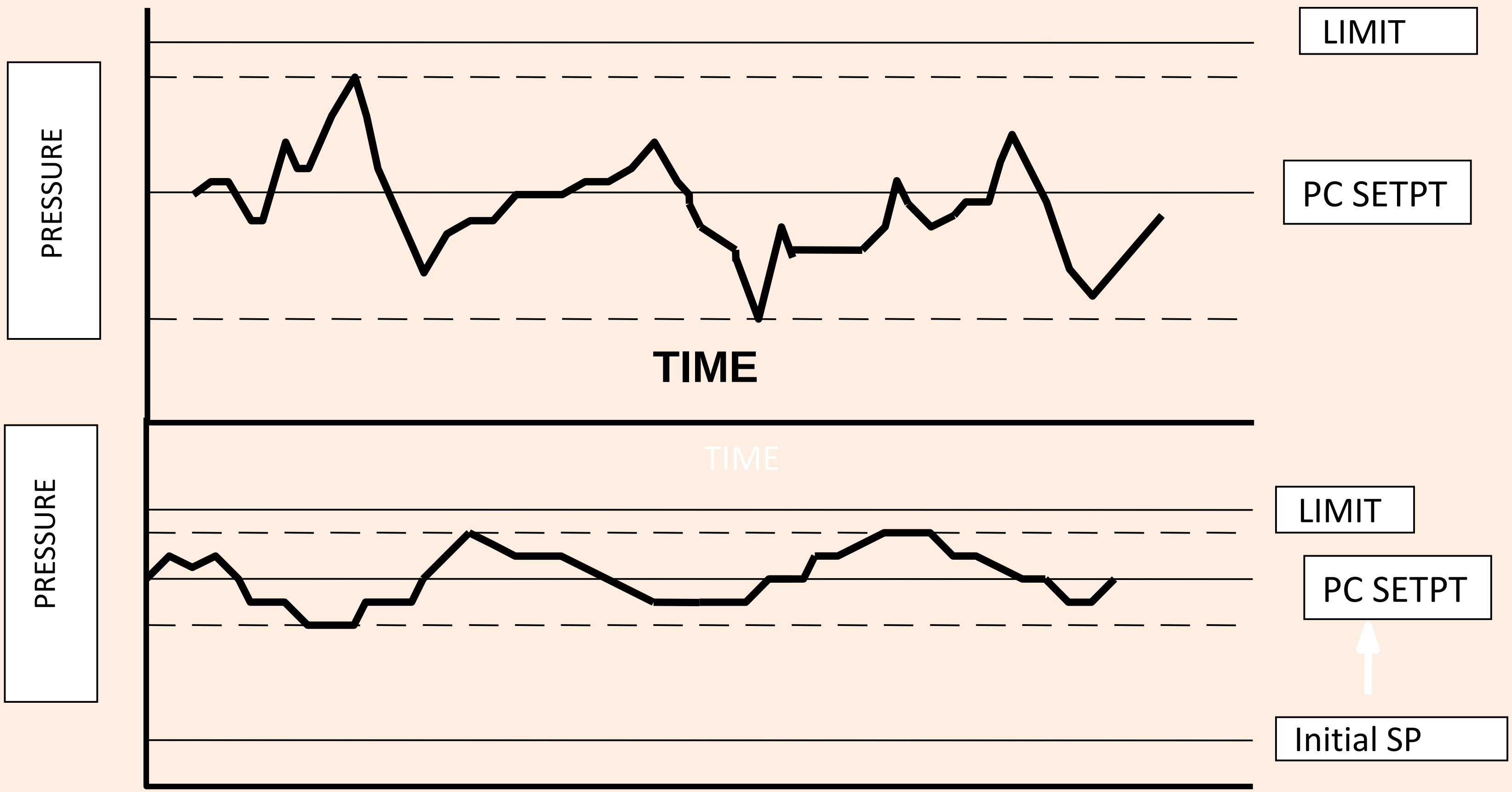
Sources of Flaring During Test

- Venting of non-condensibles from exchangers
- Exceeding capacity of condensing heat exchanger
- Making off-spec product
- **Increasing the feed too rapidly can result in flaring**

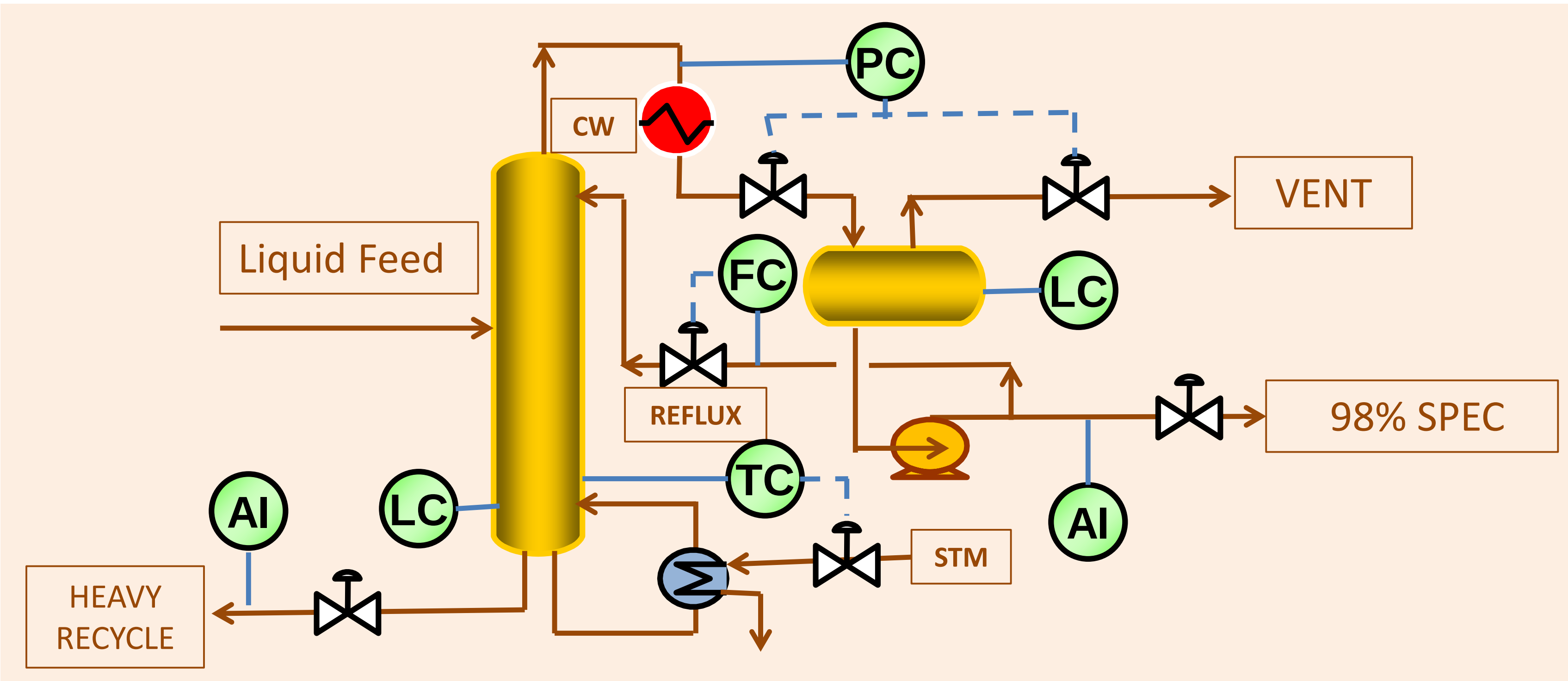
What Happens if Feed Increases too Rapidly?

- Control system may fail to keep unit steady
- Equipment constraints may cause adverse result

Reduce Pressure Variation to Reduce Flaring



Condenser Constraint Causes Test Failure



Synchronize Lab Data with DCS Data

1. Create a ‘Lab Data’ page on the Operator console
2. List all samples to be taken during the test
3. Operator clicks ‘Sample Caught’ as sample is drawn
4. Lab results are correctly saved in test historian

Synchronize Lab Data with DCS Data

Typical 'Lab Data' Entry Page

Date: xx Time: yy

Crude Oil ○

Naphtha ○

Kerosene ●

Gas Oil ○

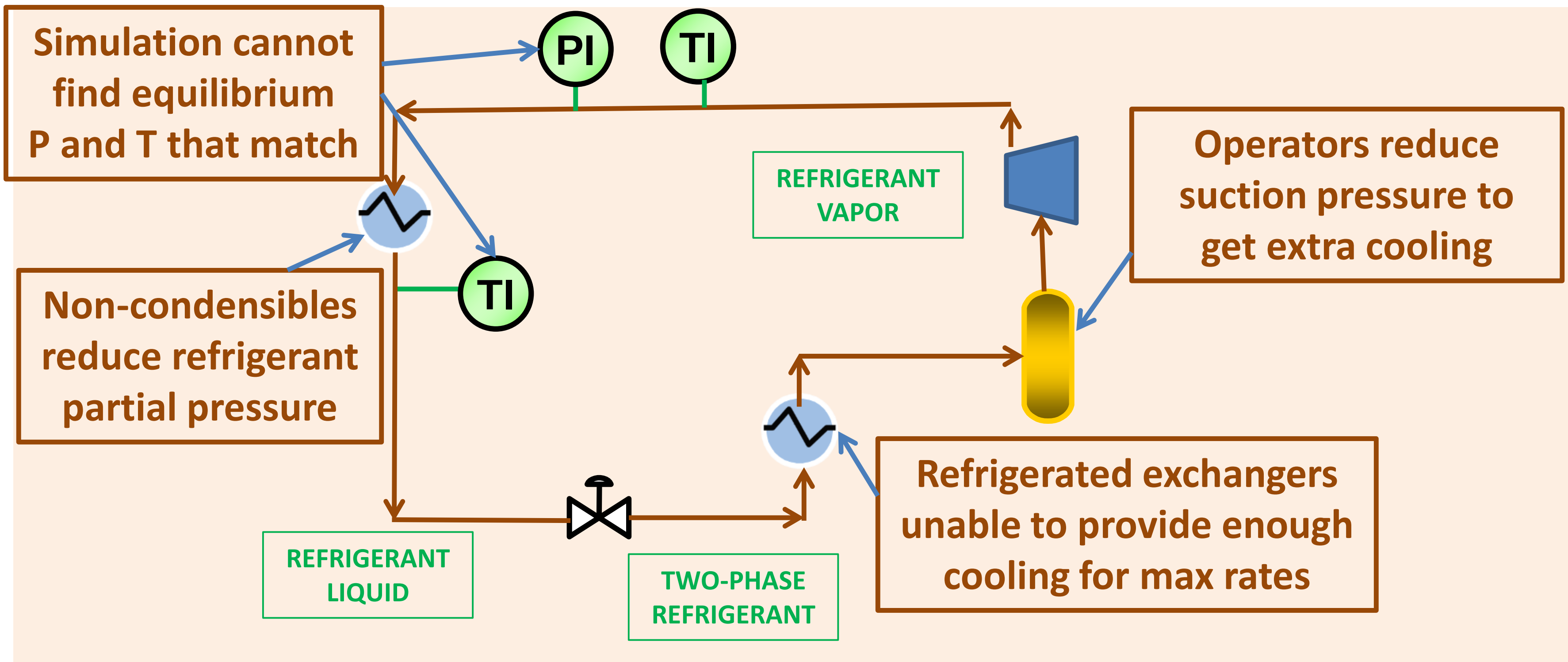
Sample Caught

Operator uses this display to time-stamp Kerosene sample

Obtain or Create a Simulation of the System

- Often there is an existing simulation available
- Use simulators for balances and density calculations
- Simulation can help identify certain problems
- Simulating the system adds credibility
- **Agreed simulation leads to report acceptance**

Use Simulation to Identify Root Cause



On Site Test Activities

- **Verify material balance closure in advance**
- Bring plant to test run conditions **SLOWLY**
- Get products **on spec** before increasing feed
- Ensure levels are steady before increasing feed
- Provide real-time feedback to Operations
- Identify equipment nearing its capacity limit

Test Run Spreadsheet

Use spreadsheet for most functions:

- Data Acquisition / Flow Compensation
- Heat and material balancing
- Management reports
- Saving intermediate results of all complex calcs

Test Run Spreadsheet

- Only the spreadsheet ‘**Owner**’ changes formulas
- Owner provides data entry areas as necessary
- Exercise care in copying and pasting formulas
- Naming cells or ranges eliminates some errors

Data Acquisition

Establish a single data acquisition sheet for raw data

- Create a data block for every flowmeter in the system
- Include columns for temp, press, and compensation calcs
- Verify instrument ranges from latest instrument data sheets
- Include all related tags in the data acquisition list
- Include ‘redundant’ tags at upstream or downstream units

Typical Data Block

Tag: FI-1000	Desc: Ethylene Product			Units: Mlb/hr		
Flow: 120.0	Oper P: 1800 psi		Oper T: 60° F		Dens: 24.0 lb/cf	
Time	Raw Flow	Press	Temp	Dens	Factor	Comp Flow
0100	112.0	1820	58.2	24.1	1.002	112.2
0115	112.2	1819	58.1	24.1	1.002	112.4
0130	112.3	1819	58.1	24.1	1.002	112.5

Simulator calculates density for compressible fluids

Ensure continuity with reference density

Consider Using a Tool to Create Data Blocks

- ○ Steam
- ○ Condensate
- ● Process Liquid
- ○ Process Gas

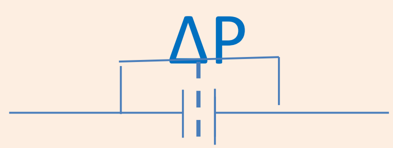
Add New Process Liquid Tag		
Tag Name	fi-1	
Description	overhead	
Flow Units	lb	
Time Units	hr	
Gravity Units	lb / cu ft	
Flow Compensation Type	Liq Mass	
Base Gravity Measurement	not measured	
Flow Gravity Measurement	none	
Temperature Tag	ti-1	
Gravity Tag	gi-1	
Full Scale Flow	100.00	Mlb / hr
Base Gravity or Density	50.00	lb / cu ft
Design Temperature	90.00	° F
Grav / Dens at Design Temp	49.00	lb / cu ft

Establish Flow Compensation

- Engineering units may be mass, volume, or std volume
- Flow compensation equation depends on units of flow
- Create columns for each flow tag:
  - “Raw” flow from DCS
  - Compensating temperature
  - Compensating pressure
  - Molecular weight (based on analysis)
  - Flowing gravity for liquids
  - Compensated flow

Orifice Flow Meter Compensation

- Based on Bernoulli's Principle
- Typical orifice measures differential pressure (ΔP)
- Mass flow proportional to $(\Delta P \times \rho)^{1/2}$
- Flow meter compensation accounts for density
- **L.K. Spink** is a reference for flow compensation



Frequently Used Compensation Equations

Vapor Streams:

- P, T, MW compensation for compressibility > 0.9
- Typical Eng Units are Mass or 'Standard Vapor Volume'

Liquid Streams:

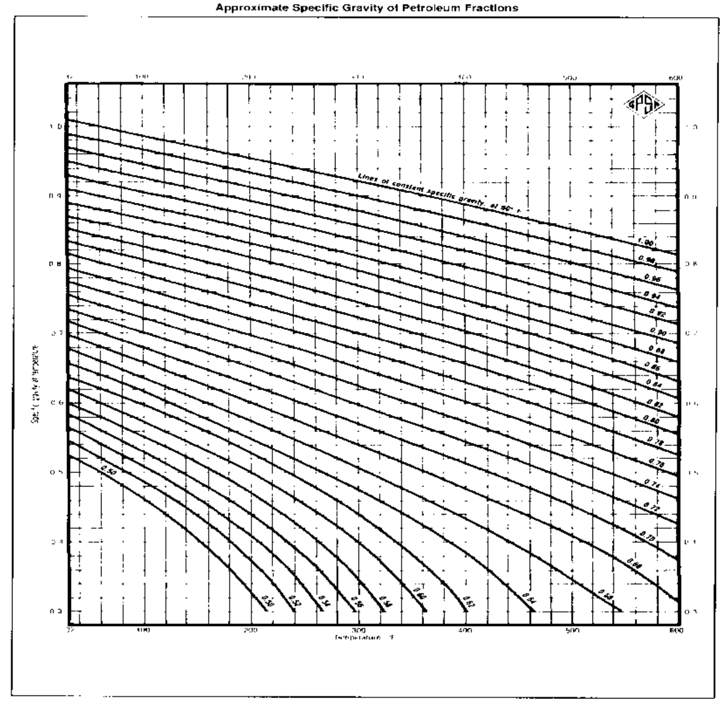
- Liquid density independent of pressure
- Estimate slope of density vs temperature
- Standard volume (e.g., barrels) use different equations

Use GPSA Tables for Oil Products

GPSA Fig 23-10

Gravity vs Temp

FIG. 23-10
Approximate Specific Gravity of Petroleum Fractions



23-19

Standard Vapor Comp vs Mass Flow Comp

Examples of Standard Vapor Flow Units:

- Standard Cubic Feet Per Minute (SCFM)
- Normal Cubic Meters Per Hour

Standard Vapor Flow is Proportional to **MOLES / HR**

Standard Vapor Comp vs Mass Flow Comp

Vapor Mass Flow Compensation:

$$\text{Comp Factor} = (P/P_0 \times T_0/T \times MW/MW_0)^{1/2}$$

Standard Vapor Flow Compensation:

$$\text{Comp Factor} = (P/P_0 \times T_0/T \times MW_0/MW)^{1/2}$$

Standard Liquid Comp vs Mass Flow Comp

Example of Standard Liquid Flow Units:

Standard Barrels Per Day (BPD)

Standard Barrels are Referenced to 'Base Gravity'

Base Gravity = GB = Specific Gravity at 60°F

The base gravity is a function of composition only

Standard Liquid Comp vs Mass Flow Comp

Mass Flow Compensation:

$$\text{Comp Factor} = (\rho / \rho_0)^{1/2}$$

$$\rho = \rho_0 + \text{slope} \times (T - T_0)$$

Standard Liquid Flow Compensation:

$$\text{Comp Factor} = (GF / GF_0)^{1/2} / (GB_0 / GB)$$

GF and GF_0 refer to flowing specific gravity at T and T_0

Common Problems to Avoid

- Allowing insufficient time to prepare
- Using the incorrect flow compensations
- Failure to review report with Operations
- Failure to verify balances before test
- Failure to tune DCS control loops

Create a Tool for Operations Staff

- Establish flexible test run report with user-entered start and end times
- Having a computer-savvy person on the team helps
- Make certain that operations staff understand report format and calculations before actual test begins

Test Run Report for Crude Oil Unit

Date: xx   Time Start: yy   Time End: zz

	Overall Test			Last 4 Hours	
Feeds:	MB/D	LB/HR		MB/D	LB/HR
Crude A	aa	bb		cc	dd
Crude B	etc				
Total					
Products					
……					
Total					
% Error					

Include Tag Numbers for All Streams

Final Test Preparations

- Review unit operation for 24 hours prior to test
- Ensure that the unit material balance is reaching acceptable closure
- Identify any unsteady flows or operating conditions. Fix control problems if possible
- Control problems tend to get worse when equipment operates near capacity limit

Offer Assistance During the Test

- Once the actual test has begun, be available to offer assistance as needed.
- Monitor the initial reports during the first few hours of the test.
- Identify any material balance errors or any performance criteria that are not being satisfied.

Thank You!