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
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

Include Tag Numbers for All Lines Crossing Envelope

Charge Pump → Desalter → Precipitate → Furnace → Crude Tower

BS&W (un-measured) → Gas → LSR → Nap → Dist

AGO
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

This section of pipe may contain 2-phase flow
Flow Data is Reconciled Against Tank Volume

Crude Tower → Distillate Stripper → Distillate Prod Pump → Distillate Tank

‘Strapping Tables’ provide net liquid volume at any level

Tank Does Not Have to be Inactive for Entire Test Period
Downstream Data Reconciles Product Rate

Crude Tower -> Distillate Stripper

Distillate Prod Pump

Feed meter at DHT confirms product rate

Distillate HydroTreater
This method works best when a third meter is not involved.
This method works best when a third meter is not involved.
Identify Problems **BEFORE** Test Begins

Real Example: Product Flowmeter Inside Recycle Loop – Caused 75% Error in Flow

Problem was identified **before test** because of poor material balance closure.
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

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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  ○  Sample Caught
Gas Oil  ○

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

Simulation cannot find equilibrium P and T that match

Non-condensibles reduce refrigerant partial pressure

Operators reduce suction pressure to get extra cooling

Refrigerated exchangers unable to provide enough cooling for max rates

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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

<table>
<thead>
<tr>
<th>Time</th>
<th>Raw Flow</th>
<th>Press</th>
<th>Temp</th>
<th>Dens</th>
<th>Factor</th>
<th>Comp Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0100</td>
<td>112.0</td>
<td>1820</td>
<td>58.2</td>
<td>24.1</td>
<td>1.002</td>
<td>112.2</td>
</tr>
<tr>
<td>0115</td>
<td>112.2</td>
<td>1819</td>
<td>58.1</td>
<td>24.1</td>
<td>1.002</td>
<td>112.4</td>
</tr>
<tr>
<td>0130</td>
<td>112.3</td>
<td>1819</td>
<td>58.1</td>
<td>24.1</td>
<td>1.002</td>
<td>112.5</td>
</tr>
</tbody>
</table>

Simulator calculates density for compressible fluids

Ensure continuity with reference density
### Add New Process Liquid Tag

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>fi-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>overhead</td>
</tr>
<tr>
<td>Flow Units</td>
<td>lb</td>
</tr>
<tr>
<td>Time Units</td>
<td>hr</td>
</tr>
<tr>
<td>Gravity Units</td>
<td>lb / cu ft</td>
</tr>
<tr>
<td>Flow Compensation Type</td>
<td>Liq Mass</td>
</tr>
<tr>
<td>Base Gravity Measurement</td>
<td>not measured</td>
</tr>
<tr>
<td>Flow Gravity Measurement</td>
<td>none</td>
</tr>
<tr>
<td>Temperature Tag</td>
<td>ti-1</td>
</tr>
<tr>
<td>Gravity Tag</td>
<td>gi-1</td>
</tr>
<tr>
<td>Full Scale Flow</td>
<td>100.00 Mlb / hr</td>
</tr>
<tr>
<td>Base Gravity or Density</td>
<td>50.00 lb / cu ft</td>
</tr>
<tr>
<td>Design Temperature</td>
<td>90.00 °F</td>
</tr>
<tr>
<td>Grav / Dens at Design Temp</td>
<td>49.00 lb / cu ft</td>
</tr>
</tbody>
</table>
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 ($\Delta P$)
- Mass flow proportional to $(\Delta P \times \rho)^{\frac{1}{2}}$
- 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
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:
Comp Factor = \( \left( \frac{P}{P_0} \times \frac{T_0}{T} \times \frac{MW}{MW_0} \right)^{1/2} \)

Standard Vapor Flow Compensation:
Comp Factor = \( \left( \frac{P}{P_0} \times \frac{T_0}{T} \times \frac{MW_0}{MW} \right)^{1/2} \)
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:

Comp Factor = \( \left( \frac{\rho}{\rho_0} \right)^{1/2} \)

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

Standard Liquid Flow Compensation:

Comp Factor = \( \left( \frac{GF}{GF_0} \right)^{1/2} / \left( \frac{GB_0}{GB} \right) \)

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

<table>
<thead>
<tr>
<th></th>
<th>Date: xx</th>
<th>Time Start: yy</th>
<th>Time End: zz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Last 4 Hours</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Feeds

<table>
<thead>
<tr>
<th></th>
<th>MB/D</th>
<th>LB/HR</th>
<th>MB/D</th>
<th>LB/HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude A</td>
<td>aa</td>
<td>bb</td>
<td>cc</td>
<td>dd</td>
</tr>
<tr>
<td>Crude B</td>
<td>etc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Products

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>......</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Include Tag Numbers for All Streams

% Error
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!