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Kuwait Oil Company
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Challenges in Gas Metering
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Introduction

The associated gas produced at various crude production facilities at WK fields was so far processed at local gas compression units or centralized Booster Station.

In reality, achieving an acceptable mass balance is a challenge.

Practically, wide discrepancies (30%) between the predicted and the actual flow.

A TFT was formed to study and resolve this discrepancy by investigating into installation, DCS setup and other Process associated issues.
A significant discrepancy was found in gas mass balance in a typical facility as shown below:
Gas flow measurement in a typical facility in WK is handled by four different types of flow meters, Orifice, Nozzle - Long Radius, Ultrasonic, and Annubar. They are distributed typically as follows:
## Flow Meter Application

<table>
<thead>
<tr>
<th>Meter Type</th>
<th>Service / Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice &amp; Senior Orifice</td>
<td>Most common Specificity, HP Sep gas outlet</td>
</tr>
<tr>
<td>Long Radius Nozzle</td>
<td>LP Sep gas outlet</td>
</tr>
</tbody>
</table>
| Ultrasonic          | Tank gas outlet (0.5” -5”)
                     | TV flare & HP flare (5” – 45#)
                     | HP & LP gas export 45# to 900#                                                  |
| Annubar             | TV compressors suction and HP flare header.                                      |
Investigation

Investigation used the Gas Meter Datasheets and P&IDs as the basis.

Investigation acquired the PVT gas analysis report for every gas stream for summer and winter cases.

Field FM Installations were inspected and the following were observations:
- FMs have not been inspected ever since commissioning.
- Impulse lines were found long with many bends.
- US flow meters were not reading correctly.
- Some flow transmitters are field configured for square root extraction.

DCS Configurations were inspected and the following were the observations:
- DCS configured in a conventional manner for the datasheet case (only for pressure and temperature variation).
- Some flow meter ranges were found less than the actual flow.
- DCS for Long Radius Nozzle was configured as for orifice.
- DCS Configuration cannot deal with the gas compositional changes for summer and winter.
The TFT implemented the following modifications in DCS configuration:

- AGA-8 and AGA-3 modules were used for configuring all orifice flow meters.
- Orifice module wrongly selected for the Long Radius Nozzle was corrected and reconfigured based on ISO 5167.
- Annubar & US flow meters were reconfigured based on Vendor’s sizing calculation.
Field Recalibrations

All Impulse lines were flushed clean and Transmitters recalibrated without field square root extraction.

US flow meters were zero checked by vendor.
Improvement Activities

- the following activities were implemented as part of a MOC to improve the gas flowmeters calculations in this GC:
  
  - AGA-3 calculations implemented in all orifice meters.
  - Flow calculations for all Nozzle - Long Radius meters corrected as per the original FDS of RS-3 DCS.
  - Ultrasonic flow calculations verified and corrected based on vendor calibration reports
  - Annubar flow calculations verified and corrected based on manufacturer vendor data.
  - Base conditions considered for all meters corrected.
  - Process parameters considered for all meters corrected based on instrument data sheets.
  - DCS range scale matched with the Instrument range.
  - Offline Flow calculation models were created in MS Excel and tested for the flow meters. Based on this, the parameters are being corrected in DCS.
After implementing the modifications, GC gas production figures were consistently found satisfactory and achieve the desired mass balance between produced (Gas in) and export (Gas out):

![Gas-In vs. Gas-Out (MMSCFD)]
Therefore, for a representative comparison, gas production was compared with gas obtained from wells GOR plus recycled condensate equivalent gas.

The graph shows nearly perfect match.
CONCLUSION

It has been found that the performance of separator gas flow meters is least satisfactory, compared to other areas flowmeters, mainly due to the large quantity and different type of meters installed at this area.

Many of the flowmeters problems are inherited from the original design of the facility, such as Orifice/Flow Nozzles installation issues (straight length requirement, pressure tabs locations, impulse tubes layout) at separators area in the GC.

Other issues were found maintenance related, such as no recent inspection and calibration were performed to detect abnormality and measure the performance of the reading instrument.
RECOMMENDATIONS

Project Phase
1. Engineering shall use Appropriate Datasheet for the selected meters (such as Long Radius Nozzle)
2. P&IDs shall have distinct symbology for various flow meters selected for a Project.
3. Ensure meter installations are in accordance with Company Hook-up standards.
4. DCS Configurations shall be set up for upstream production facilities as below:
   1. Configure flow meter for winter and summer cases
   2. Implement AGA-8 and AGA-3 for orifice flow meters
   3. Model other types of flow meters such as Annubar, Long Radius Nozzle, ultrasonic in order to provide dynamically correction

Operation Phase
1. Inspect all flow meters at every Major survey.
2. Periodically analyze the gas compositions and accordingly enter into AGA-8 module
THANK YOU
### Long Radius Flow Meter Modelling

#### Dynamic Links
- **FIT (Cp)**: DP Transmitter (without field square extraction) (in H2O)
- **PIT (pf)**: Line Pressure (PSI/G)
- **TIT (Tf)**: Line Temperature (Deg C)

#### Pressure Correlation

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowing Density</td>
<td>((P_f + P_b) + 6895 \times (9.86923 \times 10^{-6} \times 6 + MW)/(0.08203 + 2f + (7f + 273.15)))</td>
</tr>
<tr>
<td>Base Density</td>
<td>((P_b) + 6895 + 9.86923 \times 10^{-6} \times 6 + MW)/(0.08203 + Zb + (7b + 273.15)))</td>
</tr>
</tbody>
</table>

#### Density Calculation
- **d**: Nozzle Diameter (inch)
- **D**: Line ID (inch)

#### Flow Calculation
- **Qm**: Flow Calculator for \(\text{Cd}=1\)

\[
\text{Flow (Qm)} = \frac{(Y + \pi + (d + 0.254) \times 2 \times \sqrt{Df + Dp + 248.7})}{(4 \times \sqrt{1 - \beta^{**4}})}
\]

#### Reynolds No Calculation

\[
\text{Reynolds No (Re)} = \frac{\pi + \mu + 0.001 + D + 0.0254}{Qm}
\]

#### Discharge Coefficient Calculator \(\text{Cd}\)

\[
\text{Cd} = 0.9955 \times 0.00653 \times \sqrt{\beta + 10^{**6}} / \text{Re}
\]

#### Flow Corrected for \(\text{Cd} \) \(Q_{corr}\)

\[
Q_{corr} = Qm \times \text{Cd} \times F_{pv}
\]
# Orifice Modelling

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>28-FIT-2408</td>
<td>28-FIT-2518</td>
<td>28-FIT-2550</td>
</tr>
<tr>
<td></td>
<td>28-PIT-2408</td>
<td>28-PIT-2518</td>
<td>28-PIT-2550</td>
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<tr>
<td></td>
<td>28-TIT-2408</td>
<td>28-TIT-2518</td>
<td>28-TIT-2550</td>
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<tr>
<td></td>
<td>V-5201</td>
<td>V-6201</td>
<td>V-1201</td>
</tr>
<tr>
<td></td>
<td>V-1202</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pd (psig)</td>
<td>14.69</td>
<td>14.69</td>
<td>14.69</td>
</tr>
<tr>
<td>Tb (deg C)</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Summer</th>
<th>Winter</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>0.237</td>
<td>0.263</td>
<td>0.237</td>
<td>0.203</td>
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<tr>
<td>H2S</td>
<td>2.83</td>
<td>2.807</td>
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<td>2.807</td>
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<tr>
<td>C1</td>
<td>60.185</td>
<td>62.576</td>
<td>60.185</td>
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<tr>
<td>C2</td>
<td>15.381</td>
<td>14.76</td>
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<tr>
<td>C3</td>
<td>7.676</td>
<td>6.613</td>
<td>7.676</td>
<td>6.613</td>
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<tr>
<td>iC4</td>
<td>0.858</td>
<td>0.491</td>
<td>0.853</td>
<td>0.491</td>
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<tr>
<td>nC4</td>
<td>1.795</td>
<td>1.313</td>
<td>1.795</td>
<td>1.313</td>
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<tr>
<td>iC5</td>
<td>0.335</td>
<td>0.234</td>
<td>0.335</td>
<td>0.234</td>
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<tr>
<td>nC5</td>
<td>0.481</td>
<td>0.305</td>
<td>0.481</td>
<td>0.305</td>
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<tr>
<td>pC6</td>
<td>0.3</td>
<td>0.177</td>
<td>0.3</td>
<td>0.177</td>
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<tr>
<td>pC7</td>
<td>0.119</td>
<td>0.065</td>
<td>0.119</td>
<td>0.065</td>
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<tr>
<td>pC8</td>
<td>0.043</td>
<td>0.018</td>
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<tr>
<td>pC9</td>
<td>0.007</td>
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<tr>
<td>pC10</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW</td>
<td>25.54</td>
<td>25.54</td>
<td>25.54</td>
<td>25.54</td>
</tr>
<tr>
<td>Gas Gravity (Air)</td>
<td>0.882</td>
<td>0.847</td>
<td>0.882</td>
<td>0.847</td>
</tr>
<tr>
<td>Gas Density (kg/m³)</td>
<td>1.079</td>
<td>1.038</td>
<td>1.079</td>
<td>1.038</td>
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<tr>
<td>Gross Heat Value</td>
<td>1228</td>
<td>1165</td>
<td>1228</td>
<td>1165</td>
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<tr>
<td>Net Heat Value (kJ/kg)</td>
<td>1117</td>
<td>1059</td>
<td>1117</td>
<td>1059</td>
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<tr>
<td>Zb</td>
<td>0.89373</td>
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<td>Zr</td>
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<td>0.923499</td>
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</tbody>
</table>

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# Ultrasonic Modelling

## Dynamic Links
- FIT (Qa): Ultrasonic (ACFH)
- PIT (Pf): Line Pressure (PSIG)
- TIT (Tf): Line Temperature (Deg C)

## Density Calculation
- Flowing Density (Df) = \((Pf+Pb)\times6895 + \frac{9.86923\times10^{-6}\times6 + MW}{(0.08203 + 2f)(TF+273.15)}\)
- Base Density (Db) = \((Pb)\times6895 + \frac{9.86923\times10^{-6}\times6 + MW}{(0.08203 + 2b)(Tb+273.15)}\)

## User (Manual) Entries
- Pb: base Pressure (14.659 psig)
- Tb: base Temperature (15.6 deg C)
- MW: Molecular Weight
- Zf: Compressibility factor
- Qs: Flow Calculator "Qs"

## GC-28 Flow Meter
- Ultrasonic Flow Meter

<table>
<thead>
<tr>
<th>Volumetric</th>
<th>597,312.15 ACFH</th>
<th>2,755,830.50 SCFH</th>
<th>66,139,931.96 SCFH</th>
<th>66,237,570.11 SCFH</th>
<th>2,754,758.53 SCFH</th>
<th>66,114,204.67 SCFH</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>26.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P base</td>
<td>14.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T base</td>
<td>de°F</td>
<td>15.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>deg C</td>
<td>19.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### ORIFICE PLATES and FLANGES

<table>
<thead>
<tr>
<th>Rev.</th>
<th>BY</th>
<th>CHK'D</th>
<th>APPR.</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>QMY</td>
<td>TCQ</td>
<td>WYM</td>
<td>20.11.97</td>
</tr>
<tr>
<td>1</td>
<td>HZY</td>
<td>TCQ</td>
<td>WYM</td>
<td>25.06.99</td>
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</tbody>
</table>

**Specification No.: WK00-RP-IN-0131**

**Contract No.: 95G071**

**Requisition No.: WK01-ER-IN-0131**

**Purchase Order: PA/B-2007-051**

**Document No.:** P & ID DWG. No.: GC28-DW-PR-2203 1/1

**Service:** LIG. CRU. OIL SEP. GAS OUTLET

### ORIFICE PLATES

- **Other Nozzle-long Radius**
- **Other ASME MFC-3M**
- Nearest 1/8" |
- 316 SS |
- Other |

### ORIFICE FLANGES

- **7. Taps: Flange** |
- **8. Tap Size: 1/2in.** |
- **9. Type: Weld Neck** |
- **10. Material: Steel** |
- **11. Flanges Included** |

**PECO/Asme long radius flow nozzle**

**Tag Number:** 28-FE-2539