Using Uncertainty Analysis to Optimise Allocation Measurement System Performance

Alick MacGillivray

NEL

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The Impact of Uncertainty

88 Million barrels of Oil per day

The total cost was approximately $9.9 Billion

Uncertainty was 0.25%

Financial exposure $25 Million per day
The Cost of Errors

Cost per barrel: $50

Revenue: $1.0M per day

Suppose the meter under-reads (error) by

1% → Loss of $10,000 per day

3% → Loss of $30,000 per day
Determination of the quantity of products belonging to each user when processed together in a commingled system.
Why Do We Need Allocation?

- Common for production facilities to process fluids from multiple fields
- Fields have different compositions, ownership and tax regimes
- Not uncommon for a single platform from several distinct formations and have several users.
Why Do We Need Allocation?

Field delivering 500,000 Barrels per day.

Revenue of $25,000,000 per day

A **bias** of 0.1% in the system would generate $7,500,000 per annum misallocation.

**SO IT’S IMPORTANT!**
Proportional Allocation

Adjusted flow is calculated from flow proportions.
Note that allocated flows sum to fiscal flow.
Fraction of the imbalance between the reference quantity and the sum of the proportioned to the production units

**Uncertainty Based Allocation**

Unscr 1  
Uncr 2  
Uncr 3

Fiscal

Fiscal  
Inflow

Balance
The Problem

• Three partners sharing a gas pipeline
• Using Uncertainty Based Allocation (UBA) to allocated gas to each partner
• Partner 2 had large flow uncertainty, caused by high densitometer uncertainty (roughly 5.0%)
• Caused in turn by instability in the instrument
• Considered that this may be losing them revenue
• Changed to gas chromatograph with uncertainty of 0.5%
• Compared allocated hydrocarbons
• Calculate savings
Flow System (Gas Flow)

Unit 1: 1,761
Unit 2: 5,283
Unit 3: 6,606

Inflow: 13,650
Fiscal: 13,350
Balance: -300 (2.5%)
Proportional Allocation

Unit 1
1,761
1,722

Unit 2
5,283
5,167

Unit 3
6,606
6,461

Venturi
Density

Fiscal
13,350

Balance
-300

Inflow
13,650
Differential Pressure Principle

- Fluid flows through a restriction
- Accelerates to a higher velocity
- Static pressure decreases
- $\Delta p$ is proportional to the square of the flowrate

Flow

\[ Q = \rho \cdot A_1 \cdot V_1 \]
Venturi Meter

- $\Delta p$ measured across the upstream to throat section
- Typical discharge coefficient $C$ of 0.95
- Here measuring gas flow
# Venturi Meter Uncertainty

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Value</th>
<th>U</th>
<th>K</th>
<th>u</th>
<th>C</th>
<th>u.c</th>
<th>(u.C)^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Coefficient</td>
<td>0.995</td>
<td>0.0075</td>
<td>2</td>
<td>0.00373</td>
<td>88.5</td>
<td>0.330</td>
<td>1.09E-1</td>
</tr>
<tr>
<td>Pipe Diameter</td>
<td>0.700</td>
<td>0.0035</td>
<td>1.72</td>
<td>0.00202</td>
<td>-5.7</td>
<td>-0.012</td>
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<td>352.1</td>
<td>0.122</td>
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<tr>
<td>Pressure Drop</td>
<td>16,295</td>
<td>16.30</td>
<td>2</td>
<td>8.148</td>
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<tr>
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<td>506.62</td>
<td>2</td>
<td>253.313</td>
<td>0.0000</td>
<td>0.006</td>
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<td>0.0660</td>
<td>4.36E-3</td>
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<td>Density</td>
<td>46.75</td>
<td>2.3375</td>
<td>2</td>
<td>1.169</td>
<td>0.543</td>
<td>0.635</td>
<td>4.03E-1</td>
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<tr>
<td>Calculated Flow</td>
<td>88.05</td>
<td>1.459</td>
<td>2</td>
<td>0.7293</td>
<td>1</td>
<td>0.7293</td>
<td>5.32E-1</td>
</tr>
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1.6%
Uncertainty Based Allocation

Unit 1
1,761
1,755

Unit 2
5,283
5,073

Unit 3
6,606
6,522

Venturi

Density 5%

Fiscal
13,350

Balance
-300

Inflow
13,650

Fiscal
13,350
### Venturi Meter Uncertainty

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</tr>
<tr>
<td>Density</td>
<td>46.75</td>
<td>0.2333</td>
<td>2</td>
<td>0.11662</td>
<td>0.543</td>
<td>0.0640</td>
<td>4.03E-3</td>
</tr>
<tr>
<td>Calculated Flow</td>
<td>88.05</td>
<td>0.728</td>
<td>2</td>
<td>0.3641</td>
<td>1</td>
<td>0.3641</td>
<td>1.33E-1</td>
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0.8%
Venturi Meter Uncertainty

Unit 1
- 1,761
- 1,722

Unit 2
- 5,283
- 5,171

Unit 3
- 6,606
- 6,461

Fiscal
- 13,350

Inflow
- 13,650

Balance
- 300

Density
0.5%
Part 2: Effect of Reduced Uncertainty

On partner 2 allocated flow

Difference

98 kg/min  →  0.77 Therm/s
             →  0.85 $/s

Cost

$1.10 per Therm

£27m Per annum
Difference from Measured Value

On partner 2 allocated flow

Difference

210 kg/min  \rightarrow  1.66 \text{ Therm/s}

\rightarrow  1.82 \text{ $/s}

\text{COST}

\$1.10 \text{ per Therm}

\text{\£57m Per annum}
Conclusions

• Reducing the uncertainty in density increases the allocated flow to partner 2 (using UBA)
• This increases Partner 2 flow from 5,073 kg/min to 5,171 kg/min.
• Increases revenue by $27 million per year.
• Illustrates the effect of uncertainty on a measurement system in an allocation scenario.