Twenty-five Years of Evolving Flow Assurance
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A Brief Reminder of Staffa
Timeline for the Staffa Development

➢ Discovered in 85
➢ Subsea development of 2 production wells tied back to Ninian South platform
  • 3/8b-10
  • 3/8b-14z
➢ First oil in Mar 92, peak at 11,000bopd and gas at 18mmcf/d
➢ Pipeline suffered from wax build-up and blocked in June 93
➢ 2km section replaced in Oct 93, restarted in Nov 93
➢ Second blockage occurred in Nov 94
➢ Cessation of production approval Mar 95
➢ Wells abandoned Dec 95/Jan 96
➢ Pipeline and remaining subsea facilities decommissioned Dec 97
➢ Seabed clearance certificate issued - Aug 98

➢ Deposition of wax in Staffa was not considered a problem during design
The Staffa System Design

- 8-inch x 9.5km X65 Steel Flowline
- FBE external corrosion coat
- NO INSULATION
- Chemical injection umbilical
The blockage was a 2.0km long mix of:
- Friable brown wax deposits firmly adhering to the flowline wall
- Highly viscous wax sludge
- Scales and hydrate crystals (including LSA)
Staffa is NOT untypical of North Sea Crude

<table>
<thead>
<tr>
<th></th>
<th>Staffa</th>
<th>Typical North Sea</th>
</tr>
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<tbody>
<tr>
<td>Onset WAT</td>
<td>38°C</td>
<td>25°C – 45°C</td>
</tr>
<tr>
<td>Bulk WAT</td>
<td>16°C</td>
<td>15°C – 35°C</td>
</tr>
<tr>
<td>Re-melt</td>
<td>52°C</td>
<td>45°C – 60°C</td>
</tr>
<tr>
<td>Wax Volume</td>
<td>5.5wt%</td>
<td>4% - 8%</td>
</tr>
<tr>
<td>Pour Point</td>
<td>Below -20°C</td>
<td>-10°C to +20°C</td>
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What has changed in the last 30 years?
Digital Technology in the Early 1990s

Desktop Computing

Apple Macintosh Classic

IBM PS/2 model 30

Useful for word processing and the occasional spreadsheet

Workstation Computing

RISC System/6000 or RS/6000

Multiple users, technically complex command line interfaces, not great for post-processing
Moore’s Law

Moore’s Law states that (empirically) the number of transistors on an integrated circuit doubles every two years.

The data visualization is available at OurWorldInData.org. There you find more visualizations and research on this topic.

Licensed under CC-BY-SA by the author Max Roser.
The radical acceleration of computing technology

<table>
<thead>
<tr>
<th></th>
<th>1994 Workstation</th>
<th>2019 Laptop</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transistor Count</td>
<td>1,000,000</td>
<td>1,000,000,000</td>
<td>1,000</td>
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<tr>
<td>Clock speed</td>
<td>20MHz</td>
<td>2.8GHz</td>
<td>140</td>
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<tr>
<td>RAM</td>
<td>128MB</td>
<td>16.0GB</td>
<td>125</td>
</tr>
<tr>
<td>Disc</td>
<td>800MB</td>
<td>512GB</td>
<td>640</td>
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<tr>
<td>CPU Word Size</td>
<td>32-bit</td>
<td>64-bit</td>
<td>2</td>
</tr>
<tr>
<td>Operating System</td>
<td>Command Line Unix</td>
<td>Windows 10</td>
<td></td>
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<tr>
<td>Cost</td>
<td>£5,600 (£4,000 in 1994)</td>
<td>£1,500</td>
<td>0.25</td>
</tr>
<tr>
<td>The World Wide Web</td>
<td>16 million users</td>
<td>4,313 million users</td>
<td>250</td>
</tr>
<tr>
<td>E-mail</td>
<td>Mainly academic use</td>
<td>5.6 billion accounts</td>
<td></td>
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</tbody>
</table>
Operational Experience

➢ **North Sea Mature Basin**
  ➢ Southern sector gas discoveries (West Sole, Leman Bank, Viking, Indefatigable) in mid 1960s
  ➢ Central sector oil discoveries (Ekofisk, Montrose, Forties, Ninian) in early 1970s
  ➢ 50 years of operational experience?

➢ **Very Wide Variation in Subsurface Conditions**
  ➢ Large southern sector gas fields in shallow water (Indefatigable)
  ➢ Deep HPHT condensate fields (Rhum, Elgin-Franklin)
  ➢ Viscous heavy oil fields (Kraken)
  ➢ Remote deepwater (Foinaven, Schiehallion)

➢ **BUT - High Level of Operator and Staff Turn-over**
  ➢ Highly commercialised
  ➢ Extensive turnover of Operatorships
    • “Start-up” O&G companies, venture capital
  ➢ Significant loss of core engineering skills and knowledge during downturns
Modelling

➢ **Early 1990s:**
   - Command line driven bespoke software
   - Early versions of key software
     - Multiflash/OLGA/PIPESIM
   - Lack of readily available computational “horsepower”
     - Lots of empirically based methods for estimating fluid properties

➢ **Significant investment in computational modelling of reservoir and fluids**
   - Investment in OLGA via JIPs and by Norwegian Government
   - Extensive research and development by SINTEF in Trondheim
   - Very high cost software development programmes
   - Universities invest in Oil and Gas specific degrees (RGU, Aberdeen, Strathclyde, Newcastle and Heriot Watt)

➢ **Late 2010s:**
   - More tools available (Ledaflow)
   - More capacity for analysis
   - More focus on offshore oil and gas specific training and education
LedaFlow Dynamic Simulation

Continuous gas phase
Continuous oil phase
Continuous water phase
Dispersed gas phase
Dispersed oil phase
Dispersed water phase

9 mass equations
3 momentum equations
3 energy equations
1 volume equation
3N composition equations

16 equations per cell ⇒ more accurate
Both mass and volume conserved at all times
Can We Still Make the Same Mistakes?
Do We Still Make the Same Mistakes?

Hart Energy News:

“Then, in February 2013, a pig became stuck in a wax plug in the Gannet oil export pipeline, resulting in the entire system being shut in for 18 months.”


Offshore Energy Today:

“On January 22, 2018, during routine pipeline cleaning operations of the Lomond platform to Everest condensate export pipeline, a blockage occurred in the pipeline”


The answer is yes

Is the question really:

“Why Do We Still Make the Same Mistakes?”
Pertinent Questions

1. **Lab Data**
   1. Is the lab report accurate?
   2. How many tests have been run?
   3. How many samples have been assessed and what are the sample histories?
   4. Is the data from one lab or multiple different sources?
   5. Is the data being used appropriately?
   6. IT’S NOT JUST WAT, BUT PRODUCTION CONDITIONS AND PRODUCTION HISTORY THAT ARE IMPORTANT

2. **Subsurface data**
   1. How well understood are the profiles?
   2. Are through field life changes in composition (WAT, water-cut, GOR) understood?
   3. Is there mixing of fluids from different compartments and are the implications understood?

3. **Design Data**
   1. Does the BoD accurately reflect all lab and well-test data?
   2. Does the BoD outline any concerns or uncertainty about lab or well-test data?
   3. Does the SoR accurately reflect how the system will operate?
   4. Does the SoR target robustness, reliability, minimum OPEX or minimum CAPEX?
   5. What are the design risks and are they properly understood (not HAZOP, which is operationally focussed)?

4. **Design Process**
   1. Has the Detailed Design properly addressed the engineering (risks of “legacy engineering” early concept)?
   2. Have the appropriate tools been applied at the appropriate level and HAVE THE DESIGN RISKS BEEN ASSESSED?
Conclusions

➢ Technology has moved forwards significantly
  ➢ Advances in desktop processing speed and massive reductions in cost
  ➢ Significant research and development into all aspects of flow assurance
  ➢ New software which is powerful and easy to use (although perhaps not to understand!)

➢ Understanding is vastly improved
  ➢ Operational experience and feedback
  ➢ Online simulation and history matching
  ➢ Better lab data

➢ The experience is there and we have learned lessons

But:
➢ The problem is very complex and inherently difficult to predict
➢ People with knowledge and experience are leaving the industry and not being replaced
➢ The cost of designing problems out is very high
➢ Risks will HAVE TO BE taken, because the commercial opportunities can’t be realised otherwise