# Operational flow assurance

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## Intention

- To communicate proven principles and practices arising from a number of examples of flow assurance operational lessons learnt
- To illustrate the principles and practices by looking briefly at a series of examples

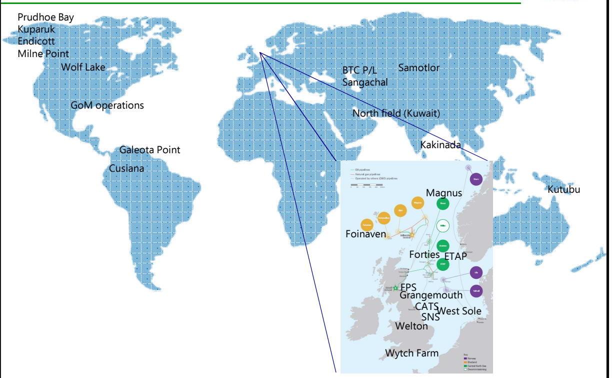
## History

- Over the course of 35+ years in the industry, almost all of which have involved some flow related work, there have regularly (although not that frequently) been lessons learnt from operational flow related issues
- The level of difficulty and consequence varied between issues
- But for a variety of reasons their underlying cause was not immediately obvious and needed investigation of fluid flow behaviour from first principles

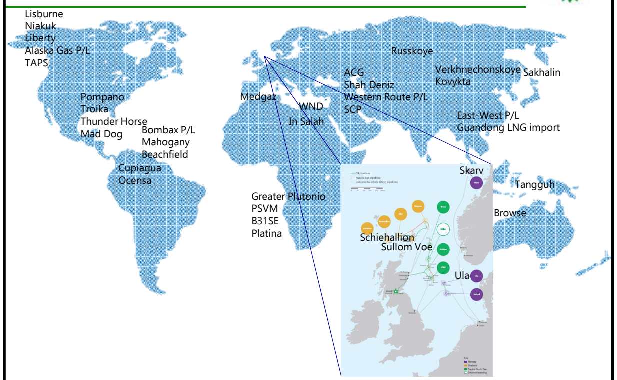
## Lessons learnt

- Central flow assurance support was requested to assist in the investigations
- It is the principles and practices emerging from these investigations that I want to pass on
- Hopefully for at least some of you this session will just reinforce what you already know, but with some different examples
- Whilst we always strive for and work towards safe, consistent, efficient, trouble-free operation, we should be always be prepared
- Some of these lessons were hard won, taking considerable analysis
- Be persistent…

## Assets visited and worked in




## Other assets worked on



## Outline of principles and practices

## Content

- 3 principles
- 9 practices
- Several examples…

## Principles

- The laws of physics always apply
- Flow assurance 'common sense' usually provides the key to understanding
- Unusual events can occur so be prepared

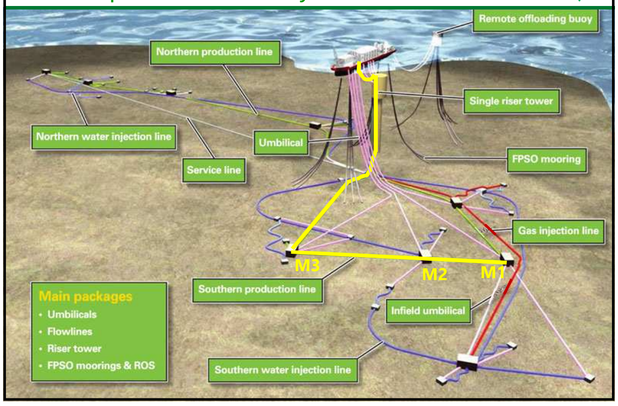
## Practices

- Ask the operators for a view
- Develop an understanding of the system
- Obtain process data and logs for the incident and develop a timeline
- Obtain process data for normal conditions
- Check the confidence in instrumentation
- Check ambient conditions and other factors
- Develop a theory
- Revise the theory
- Test the theory

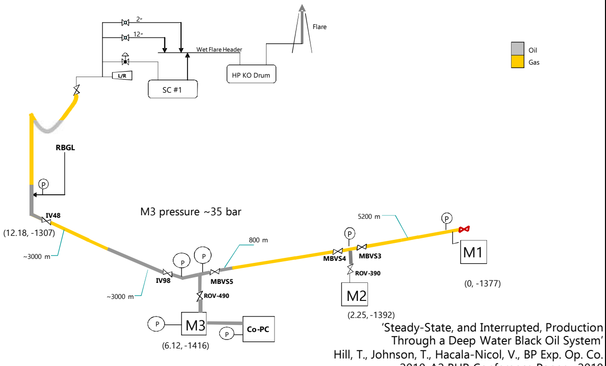
## Examples…

- Deep water flowline ‘hydrate’
- Cold region flowline rupture
- Offshore platform hydrate
- Offshore pipeline stuck pig
- Metering on offshore platform
- Onshore flowline slugging

## 1. Deep water flowline ‘hydrate’

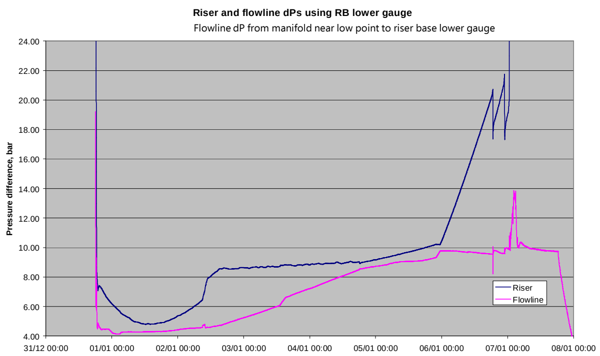


## State of system after shutdown
### Flowline-riser fluid positions

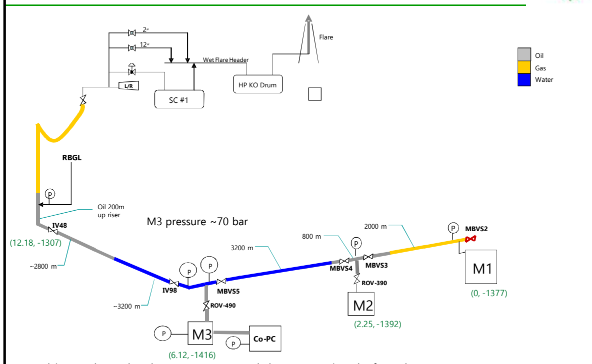



'Steady-State, and Interrupted, Production Through a Deep Water Black Oil System'
Hill, T., Johnson, T., Hacala-Nicol, V., BP Exp. Op. Co.
2010-A2 BHR Conference Paper - 2010

## December 31, 2008 shutdown through to January 7, 2009

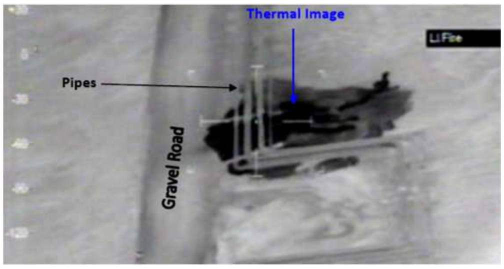



## State of system prior to Jan 7 start-up
### Flowline-riser fluid positions

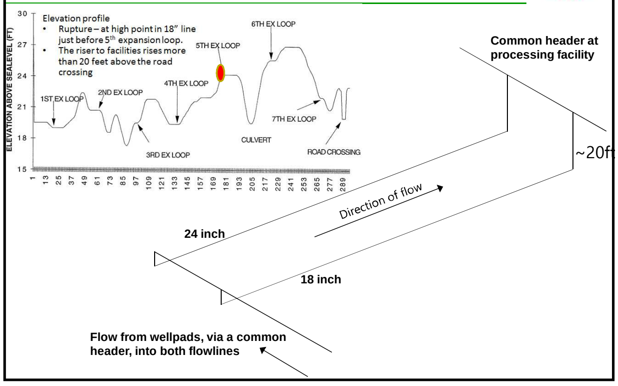



This was how the theory represented the system just before the restart.

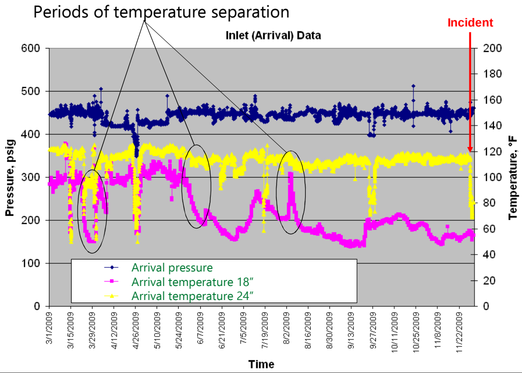
## 2. Cold region flowline failure



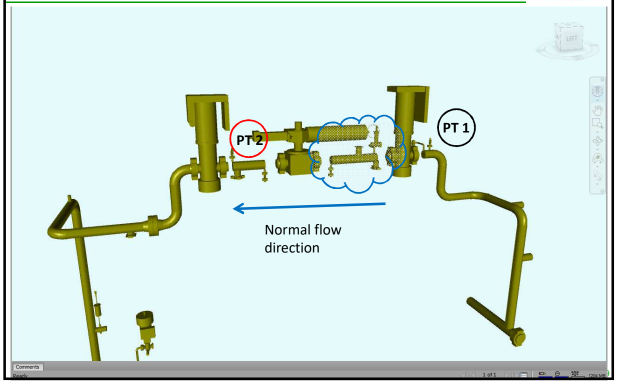

## Cold region flowline failure

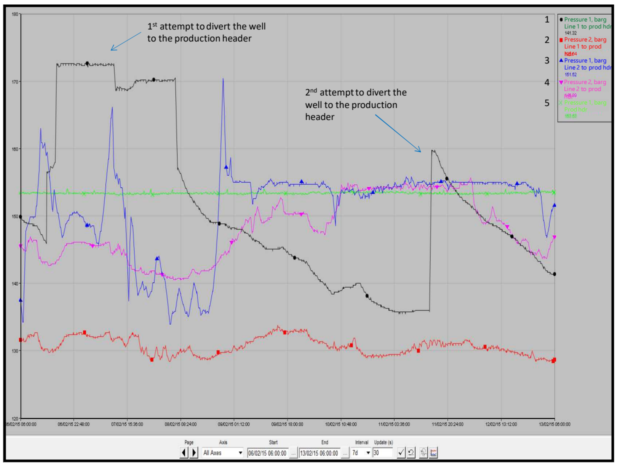



## Cold region flowline failure

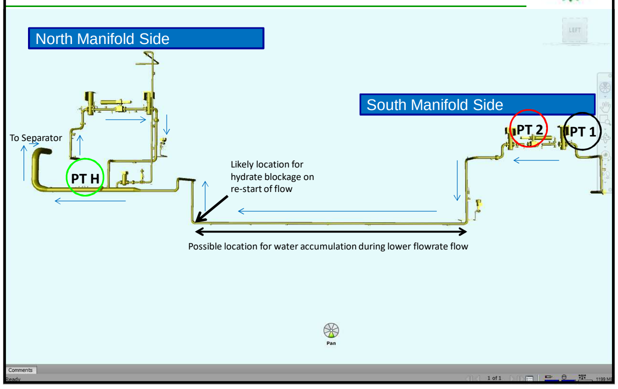


## 3. Offshore platform hydrate



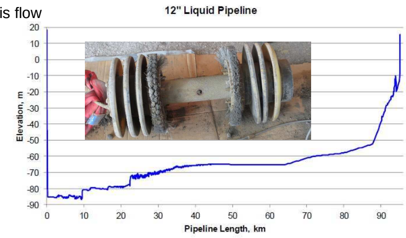




## Likely hydrate formation location

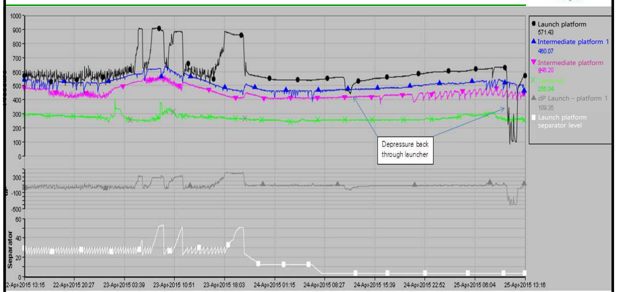


## 4. Offshore pipeline stuck pig

- Offshore platform separates gas and condensate at 900 psi, and gas goes to dedicated pipeline
- Onshore liquids terminal was at 250-300 psi
- Condensate flashed across control valve downstream of separator and into 12" 'liquid' pipeline, but normally two phase flow in pipeline
- Pig launched into this flow




## Pressure traces from offshore pipeline




- Indication of stuck pig was that separator level increased and pressure downstream of control valve rose up to 900 psi
- Rate of pressure rise after the various occurrences of sticking, together with PVT understanding, gave an indication of location

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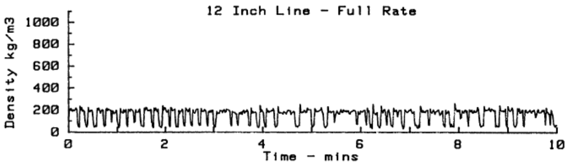
## 5. Metering on offshore platform

## Metering on offshore platform




- Very low slug density, but at high velocity
  Density measurements confirmed by lower velocity, higher density measurements
- Simple math of slug frequency x length x density through a 12 inch pipe to get approximate liquid flowrate highlighted an inconsistency in separator liquid outflow meter factor, which was then investigated and corrected

## 6. Onshore flowline slugging

## Onshore flowline slugging

- 30” manifold header to slugcatcher/separator receiving flow from well site collection lines of different sizes
- The one 24” flowline had been reduced down in the design to 16” near the facility to enable the use of a smaller valve
- However, slugs arriving at the reduced diameter caused a back pressure increase, packing gas upstream
- When the tail of the slug went through the reduced diameter and into the header, expansion of the packed gas in 24” line then caused acceleration of the fluids in the header
- Over time these periods of faster flow resulted in damage to the internals of the slugcatcher/separator

## Concluding comments

## Learning lessons

- After completion of any analysis, feed back as to how the risks could have been better managed
  - What to look for in monitoring
  - Any extra instrumentation that would have assisted
  - Any procedural modifications
  - Any engineering modifications
  - Any changes to strategy for future projects

## Concluding comments

- Variety in oil and gas fields, and how they have been developed
- Interesting and challenging technical issues, that can be addressed by a good understanding of first principles
- Great interactions with so many different people, in many different companies, universities and supporting organisations
- Over to you…

Thank you

Thanks for joining this session

Back up and further information

Principles

## Principles

- The laws of physics always apply:
  - Gravity and relative densities (what ‘floats’ on what?)
  - Gas law (corrected for non-ideality)
  - Motion (momentum, friction)
  - Conservation of mass (we can’t create or destroy mass, but there is mass transfer between gas and liquid phases)
  - Conservation of chemical species (we can’t create, destroy, or mutate the elements – but what comes out is an indication of what went in)
  - Conservation of energy, and ‘heat flows from hot to cold’

## Principles

- Flow assurance ‘common sense’ usually provides the key to understanding:
  - From your understanding and experience of flow assurance and the laws of physics, look for what makes common sense
  - Initial interpretations made in the incident aftermath by others may need to be revisited as more information emerges, particularly if there is not local awareness of flow assurance issues
  - Coming in with a fresh viewpoint, and time to think and analyse, may lead you to new insights

## Principles

- Unusual events can occur so be prepared:
  - Sometimes unanticipated events do happen in operations
  - Accept the possibility, and rigorously investigate before then sharing

## Practices

## Ask the operators for a view

- Ask operations staff what they think happened - they know a lot about the facility and operation and can quickly give you insights about the operation, both under normal conditions and during the incident
- They may well have good theories about what might have occurred
- However they don't need to know about flow assurance in any depth, so treat their input and theories as information to be considered, but not as a complete or validated picture
- Seek to sit on the same side of the table as them, at least metaphorically if not actually – the aim is to find out what happened, to plan how to remediate safely and efficiently, and to communicate how to best prevent future occurrences – not to apportion blame
- Sharing about similar sorts of issues in other locations can be helpful in facilitating communication

## Develop an understanding of the system

- Understand the system in which the incident occurred
  - Fluid inputs and outputs, fluid characteristics, layout / topography / isometrics around and substantially beyond the incident location, components, design intent
  - What should have happened instead of the issue or incident?
- Are there any related systems that could have had an influence?
  - What is connected? Look widely… You may need to rule them out one by one
- Ask for, or build, flow models (steady state, transient, CFD, physical, as seems helpful through the investigation) of the system that can at least reproduce normal operating conditions

## Obtain process data for the incident and develop a timeline

- Get to know the P&IDs, isometrics, and instrument locations, and if possible visit (or get photographs of) the actual site and equipment
- Pick out the instrumentation that you think could give insights, even if you have already been given an amount of data
- Ask for the relevant process data from the time period covering the incident
- Find out what the highest resolution is to which the data can be delivered
  - Sometimes the additional resolution, if available, can greatly clarify what has happened
  - Operations staff may be used to seeing a certain data resolution, but may not understand what is actually stored and therefore possible to retrieve
- Develop a timeline of actions and issues arising, preferably using some key process data starting from a normal condition before the incident as the framework
- Begin to reconcile the data, any logs, and the opinions on timing

## Obtain process data for normal conditions

- When the incident has occurred during a repetition of a recurring operation, ask for process data that is representative of previous 'normal conditions' e.g. a re-start, or a pigging run
- There may be good clues in this data that perhaps no one has appreciated before, especially from a flow assurance perspective
  - There may be patterns or markers in the historic data that could be helpful in understanding why this particular set of circumstances resulted in an incident
- Understanding what 'normal' looks like can greatly assist in understanding where conditions during the incident have deviated from that normal behaviour
- This in turn can provide insights into what has actually happened

## Check confidence in instrumentation data

- In an ideal world we should be able to assume that recorded data is correct / accurate, and believe the values
- However, there are many possible reasons for which the output from instrumentation may not actually be 100% representative of the conditions in which we are interested, and this can confuse the analysis
- Be aware of where instrumentation is located, and how the information from instrumentation might be compromised by external factors
  - Insufficient insulation from ambient
  - Incorrect meter factor or unit conversion factor
  - Calibration drift / offset
  - Blocked ports, especially by wax or hydrates or sand
  - Communication dropout, or repetition of last received reading
  - Conditions going outside range of instrument
- Information from normal operation can help in the checking of what is immediately useful data and what may need to be verified
- Some compromised data can still be useful, if carefully interpreted

## Check ambient conditions and other factors

- Get an understanding of how ambient conditions may be relevant
  - Data may show patterns that match or extrapolate to ambient conditions of pressure and temperature
    - External pressure when subsea
    - External (to the instrument) temperature in any location (subsea, topsides / onshore – outdoors or indoors), and especially any variation in external temperature with time
- Ask operations about any other unusual circumstances that may be a contributing factor
  - Go through the operations logbook if possible, looking for events or circumstances that others may not have thought to be relevant

## Develop a theory

- Develop a theory that is consistent with the laws of physics, with common sense, and with the data
- This may need several iterations if there is not an obvious underlying cause, especially if there are various possibilities that are each consistent with some of the data and information

## Revise the theory

- Be prepared to revise the theory
- Don't be afraid of asking 'odd' questions about what might have happened
  - Some possible but very unlikely events do happen
  - Don't rule out too quickly any odd questions that others ask or suggestions that others make, as they may have a valid point

## Test the theory

- Assess whether there is any way to test the theory in addition to comparison with data from the actual incident
  - Flow modelling (steady state, transient, CFD)
  - Smaller scale test rig
  - Data from similar events, perhaps less severe, at other times
  - Data from other locations
- Once tested and generally supported, be prepared to share more widely