MULTIPHASE MEASUREMENT FOR CONTROL OF PRODUCTION FROM OIL AND GAS WELLS

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Lo que no se mide no se puede controlar, Lo que no se controla no se puede mejorar
Objectives of presentation

- Review role of Multiphase Measurement
  - Pipeline management
  - Well management
- Review history of multiphase metering
  - Emphasis on the different approaches
    - Western oil industry and Russia
- Illustrations of continuous well monitoring
  - Large potential benefits
- Slug detection and suppression
  - Example of use of multiphase measurements
Introduction

- Oil and gas industry has thrived for 150 years
  - Limits to world reserves
    - Much wider range of hydrocarbons produced
    - Must be done in cost-effective manner
- A “Multiphase Infrastructure” has grown
  - Multiphase well management
  - Multiphase pipeline operation
- Multiphase measurement and monitoring
  - Plays critical role in this infrastructure
Multiphase Technologies

- **Multiphase pipeline operation**
  - Multiphase pumping
  - Multiphase pipeline integrity systems
  - Severe slug suppression
- **Multiphase well management**
  - Intermittent well testing
  - Continuous well monitoring
  - Severe slug suppression
- **Multiphase flowrate and composition**
  - Important in all of these technologies
- **Severe slugging appears in both**
**Multiphase pipeline operation**

- **Multiphase pumping**
  - Unseparated well fluids transported
    - production facilities at much longer distances
  - Work over a specific range of gas volume fractions
  - Need flowrate and composition
    - For pump control and protection

- **Multiphase pipeline integrity systems**
  - Don’t exist yet, to my knowledge
  - Long multiphase pipelines installed
    - Subsea tiebacks of 50 km
  - BP Gulf of Mexico oil spill
    - can be regarded as failure of pipeline integrity
Impact of multiphase technologies

- Changing to multiphase technologies
  - Forces changes to whole field development plan
  - Requires a change in ways of thinking

- Example
  - Gas condensate field development
    - Utilises multiphase pipeline
  - Wanted to use wet gas metering
    - Would save high cost of separators
  - Critical to know when formation water appeared
    - Pipeline must be protected against hydrates
    - No multiphase formation water detector available
  - Conventional separator metering installed
FUNCTIONAL ASPECTS OF MODERN METERING, MEASUREMENT AND MONITORING SYSTEMS

CONTRACTUAL LEGISLATIVE BUSINESS NEEDS

Production Reporting Requirements
Allocation and Sales Agreements
Safety, Environmental and Operational Requirements

INFORMATION

Sensors → Local Processing → Secure Data link → Office Processing → Secure Data link → Further Processing, Reporting

Data Integrity checks
Process simulation models
Calibration information

MECHANICAL

Sensor packaging and installation
Packaging: e.g. land, offshore, subsea
Comms link e.g. wire, radio, microwave
Packaging
Comms link e.g. wire, radio, microwave
Packaging
Why have a multiphase infrastructure?

- What is the business case?
  - Are there significant cost savings?
    - In development, operations and maintenance
  - Are there significant improvements in ability to manage operations?
    - Own production, third parties, governments, environment
  - If answers are “yes”, then we should go further

- What is the applicable regulatory framework?
  - Can the existing framework be used or extended?
    - This should be answered in a structured manner
  - Is there sufficient knowledge to allow this?
    - In some area “yes” and in others “no”
Development of Multiphase Meters

- We have answered “Why measure?”
- Next: - “What do we want to measure?”
  ➔ There are types of multiphase fluid
    - Many ways to classify them
  ➔ Wells and fields change with time
  ➔ Need to estimate field or well production profile
    - How else can we specify the measurement equipment?
- I like to use “Multiphase triangle”
  ➔ Pictorial way to represent applications
    - Easily display well profiles
  ➔ There will NOT be a universal “multiphase meter”
Multiphase triangle
Multiphase triangle

HEAVY OIL

OIL

WATER

Well Testing by Coriolis Meter

Annular Mist

Slug Flow

Bubble Flow

Transition Region

GAS

1 2 3

90% 80% 70%

4 5 6 7 8

10% 20% 30% 40% 50% 60% 70% 80% 90%
Wet gas categories:
- Humid gas from separators
- Humid gas with entrained liquid carryover and/or occasional slugs of liquid
- High GVF multiphase fluids, GVF > (say) 90%
Mass Fraction Triangle - Gas 10 kg/m³
Wet gas at different densities

- Figures for gas densities
  - 10, 50, 200Kg/m³

- At low densities, wet gas dominates

- At high densities, wet gas significant
Measuring “unseparated flow”

- **Multiphase measurement techniques**
  - Compact separation systems
    - Rough separation into liquid and gas
    - Detailed measurements on separated phases
  - Phase fraction and velocity measurement
    - Identify fractions of oil, water and gas
    - Determine the usually different phase velocities
  - Tracers
    - Injected dyes for water and oil
    - Useful for wet gas
  - Pattern recognition
    - Low cost sensors and sophisticated computation
Development approaches – West

- Multiphase test loops seen as way forward
  - Oil (refined), water, gas(air) mixed
    - Passed through horizontal or vertical test sections
    - Fluids separated for recombination and recirculation

- Concept meters designed to operate
  - On these artificially generated multiphase flows
  - Recognised that test loop multiphase flow
    - might not be the same as real well flows

- Difficulties arose when applied in field
  - In practice difficult to verify meters in the field

- Slowly operational experience has built up
  - Multiphase meters are slowly being accepted
Development approaches – Russia

- Relatively low production rates
  - Low cost meter was essential
- Clamp on fast gamma densitometer available
  - Could survey large number of wells
  - Establish flow characteristics
- Investigate fluctuating density signal
  - For suitability for multiphase flow measurement
- Now meter-per-well installed on field
  - Heavy oil in Arctic Russia
- Russian standards for fluids extracted
  - Development of field verification system
Outlook for development

- Neither approach is ideal
  - Test loops don’t simulate well fluids accurately
  - Manufacturers can’t easily get access to real wells
- Can test loops simulate wells better?
  - Need to redesign test loops
  - Generate more realistic multiphase flows
- Field verification techniques required
- Oil companies are not investing in multiphase research
- The potential benefits are still large
Well management

- **Current practice**
  - Not to monitor wells continuously
  - Well testing for several hours per month
    - Fixed or mobile test separators
    - Mobile multiphase meter assemblies
    - Problem wells may receive more attention

- **Key assumptions**
  - Wells produce in a stable manner
  - Switching to test does not affect production
  - BUT THESE ASSUMPTIONS ARE SELDOM VALID
    - Later slides will demonstrate this

- **Continuous monitoring**
  - Long recognised as key to optimising production
  - Requires inexpensive measurements per well
Beam Pumped Well

Liquid flowrate (T/day)  Watercut (%)  Gas flowrate (m³/day)


Скважина 8331 (НН2Б 44-30)
Downhole centrifugal pump

- Liquid flowrate (T/day)
- Watercut (%)
- Gas flowrate (m³/day)

Data for Skvazhina 3026 (ЭЦН 80-1400) from 3 June to 6 June:

- Liquid flowrate: Varies between 50 and 140 T/day
- Watercut: Stays relatively constant at around 80%
- Gas flowrate: Increases from 100 to 300 m³/day
Down-hole screw pump

- Liquid flowrate (T/day)
- Watercut (%)
- Gas flowrate (m³/day)

4 June 5 June 6 June 7 June 8 June 9 June 10 June 11 June

Скважина 3308 (ЭВН 25-1500)
Comments on pumped wells

- These are representative of TYPICAL wells

- Beam pump well
  - Liquid flowrate steady; gas breakout in well bore

- Centrifugal pump well
  - Liquid flowrate similar to that from formation
  - Liquid production varies by ~50% in one day
  - When do you test such a well?

- Screw pump well
  - Similar to the centrifugal pump well
  - Again, when does one test such a well?
Well data 1: Density vs. Time (5 hours)
Well data 3: Density vs. Time (10 hours)
Well data 5: Density vs. Time (3 hours)
Well data 6: Density and Flow vs. time (21 hrs)

May 15 - May 16

Graph showing density and flow over time from May 15 to May 16, with data points indicating fluctuations in density and flow throughout the period.
Comments

- Problem well
  - Operators unable to test it

- Five slides illustrate different patterns
  - Multiphase data taken from 15 day record

- One slide illustrates density and flow
  - Over a 21 hour period

- Wide variations in flow pattern
  - Low and high liquid “wet gas”
  - Various slug flows
  - Surging flow

- Not suitable for intermittent testing
Nasty oilyslug must be controlled

Dregs of ice cream, ice & lemonade, 3 phase flow

Dregs of oil, gas & water, 3 phase flow
Problems with

- Slugging is due to reduced well pressure
  - In brown ‘older’ fields like the North Sea

- Slugging gives operational problems
  - Most in deep-sea fields
  - In oil fields where there is proportionally a higher amount of water in the oil.

- Big problem - losses in production.
  - World wide loss - estimate $200bn p/a
    - ~5MMBbl/d or ~6% of world oil production
  - North Sea, one major oil company $18m p/a
Slug control and TSB

- In 2007 UK government (TSB) funded a 2 year programme
  - Extend the life of North Sea reserves with cost effective solutions.

- Generate benefits to the UK
  - In places there is still 50% oil reserves left in the North Sea - but the dregs are difficult to extract.
  - The innovators of the slug control system (named below) can now export the technology for world wide applications.
TSB 2-year programme activities

- **Method**
  - Using Cranfield test rig
  - Neftemer meter (data up to 250 Hz)
  - SPT OLGA software

- **Data from Chevron**
  - Extensive well data
  - Visits to Alba platform

- **Object**
  - Forecast slug imminent arrival.
  - Taming the slugs by regulating the control valve

Cranfield Developed System

- DeltaV
- Ethernet
- Neftemer
- Three-phase Facility
- Coriolis
- OPC Link
- RS232
- Inferential Slug Controller

Diagram with Cranfield Developed System components and connections.
Our answer to the problem is regulating the flow through the control valve.

Control valve has been alerted by the slug control system.

Before slug control < > After slug control
Energy Innovation and future benefits.

- Extends life of North Sea revenue.
- Existing platforms can be upgraded
  ➔ With standard off-the-shelf equipment
- Our system is simple
  ➔ Installed on the platform above the sea.
  ➔ NO complicated subsea, seabed or down well instrumentation required.
- Equipment is easily attached onto existing piping
  ➔ Slug control system interfaces with existing control equipment.
- Can increase production by about 11% per day
  ➔ Most end users happy with 4%
Conclusions

- **Multiphase technologies important**
  - for the oil and gas industry
    - Huge savings can be made

- **Necessary to consider production system afresh**
  - Multiphase technologies impact on each other

- **Continuous monitoring of flow and density**
  - allows better assessment of well production

- **Suppression of severe slugs good example**
  - continuous monitoring of multiphase parameters
    - production facilities stabilised
    - production to be enhanced
Thanks for your attention!

Questions?