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SPE DISTINGUISHED LECTURER SERIES

Low-cost, Non-invasive, Remote
Pipeline and Well Inspection Technologies

Alberto Di Lullo       Eni E&P Division
SPE – Italian Section
WHAT IS MEANT HERE FOR “INSPECTION”

Information about the space available to flow (i.e. the pipe from the point of view of the fluid)

- Changes in the effective Diameter profile e.g. deposits, valves, wall thickness
- Presence of interfaces (G/ L, L/ L) created by stratification of the fluids
FLOW ASSURANCE
WAX PLUGS
Flow Assurance

guarantees the achievement
of the life-time production targets
of a lifting and transportation system

by predicting, preventing and solving problems
directly originated by the behavior of
the transported substances
(gases, liquids, solids)

either as single phases or
in multiphase conditions
WHY FLOW ASSURANCE NEEDS MONITORING

WE NEED FLOW ASSURANCE MONITORING BECAUSE:

- Solutions may reduce the rate of problems or may create new problems
- Cost reduction leads to progressive optimizations, which must be validated
- Some problems may affect Pipeline Integrity or impede intelligent pigging
- Some problems require really expensive interventions, which must be optimized
Overview

• Contexts needing pipeline and tubing inspection

• **Limitations of Steady-State Monitoring Techniques**

• Alternatives to Steady-State Techniques

• Transient based inspection technologies

• Field applications and examples

• Conclusions
STEADY–STATE MONITORING
Different states, same measurements

DISTRICTED vs CONCENTRATED RESTRICTIONS

- 5km deposit 0.5” thick
- Thin 90% obstruction

Induce the SAME additional $\Delta P$

Deposit volume = 73 m³

Deposit volume = 0.5 m³

QUANTITY AND POSITION OF DEPOSITS CANNOT BE ESTIMATED
STEADY–STATE MONITORING
Different states, same measurements

SENSITIVITY in DETECTING DEPOSITS

Induce a SMALL additional $\Delta P$ (<0.5 bar)

Equivalent causes: $\Delta Q < +5\%$  $\Delta \mu < 20\%$  $\Delta \rho\ldots$  $\Delta T\ldots$

5km deposit 0.5” thick

15” ID

Thin 90% obstruction

UNCERTAINTY HIDES THE EFFECT OF SLOWLY GROWING RESTRICTIONS
STEADY–STATE MONITORING
Different states, same measurements

SENSITIVITY in DETECTING DEPOSITS

ΔP [bar]

Q+5%

Q−5%

Minimum volume of deposits practically detectable

Volume of deposits [m³] uniform over 5km
STEADY–STATE MONITORING
Different states, same measurements

DEPOSITS WITHOUT PHASE-DIAGRAM PREDICTABILITY

Sand
Ineffective chemicals
Unexpected bottoms

THE PRESENCE AND QUANTITY OF UNPREDICTABLE DEPOSITS MUST BE GENUINELY DETECTED
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ALTERNATIVES TO STEADY-STATE TECHNIQUES?

TWO POSSIBILITIES

• ANALYSIS OF PASSIVE NOISE
  Noise with no change of production conditions
  Potentially applicable for continuous monitoring

• ANALYSIS OF FLOWRATE TRANSIENTS
  Transients create waves which “explore” the line
  Need for temporary changes in production conditions
ALTERNATIVES TO STEADY-STATE TECHNIQUES?

PRO’S and CON’S OF THE TWO POSSIBILITIES

• PASSIVE NOISE
  PRO: Works under normal production
  CON: Applicable to very short pipelines (<200m?)

• FLOWRATE TRANSIENTS
  PRO: Applicable to long wells and pipelines
  CON: Temporary change of flow conditions

Passive noise not discussed here, but might deserve more exploration
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TRANSIENT-BASED INSPECTION CONCEPT

1) GENERATING A FAST FLOW RATE TRANSIENT
2) MEASURING THE RESULTING PRESSURE EVOLUTION
3) ANALYZING THE DATA

MEASURING PRESSURE IN ONE POINT AND NOT MEASURING FLOWRATE
TRANSIENT: EXAMPLE OF A REAL MEASUREMENT

Well Head

1675m

3 1/2 (74.2mm ID)

3820m

2 7/8 (59.0mm ID)

444m

THP [bar]

FTHP

STOP discharge

Time

3.6s 3.6s 4.0s
EXPLOITATION OF FLOW RATE TRANSIENTS

**Theory**
- Correct modeling
- Simulation software

**Pressure sensors**
- Accurate at high P
- Fast response

**Inverse problem**
- From P data to profile of variables along pipe

**Data acquisition**
- In the field with operators
- Portable and reliable tools

**Exploiting Transients**

PATENTED
TRANSIENT–BASED MEASUREMENTS EXECUTION

TRANSIENTS EXPLOITATION REQUIRES STRONG INTERACTION WITH PLANT OPERATORS:

• Transients must be produced by somebody’s **hands**: he/she has to learn how

  **Can you learn Tango by exchanging e-mails?**

• There is no “standard plant” Application **flexibility** is mandatory Operator’s **understanding** is mandatory
TRANSIENT-BASED, REMOTE INSPECTION TECHNOLOGY

TBI

Transient Based Inspection

(In Eni, we call it PRIMEFLO)
Overview

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DEMONSTRATED APPLICABILITY

Pipes  
Tubing, Pipeline, Sealine

Geometry  
Any (H, V, sloped, winded...)

Type  
Oil, Gas, Emulsions (*no G/L flowing regimes!*)

Diameter  
1/6" – 32" ↑

Viscosity  
from gas to 600 cP ↑

Length  
Oil 200 m – 530 km ↑
Gas 3 m – 530 km ↑

(*) Field demonstrated, not technology limit
Signal dispersion (width): negligible broadening after a 1060km trip
Equally true for OIL and GAS pipelines
USEFUL TRANSIENTS
TYPES AND METHODS

ANY TRANSIENT WILL PROVIDE USEFUL INFORMATION (BUT NOT IDENTICAL INFORMATION !) AS LONG AS IT IS FAST AND SHARP
DEMONSTRATED SENSITIVITY

Light crude with $\mu = 2 \, \text{cP}$

350'000 m far from sensor, ¼” / 24” diameter change

Heavy crude with $\mu = 600 \, \text{cP}$

300 m far from sensor, ⅛” / 16” diameter change
TBI can detect, localize and estimate:

- Changes in the effective Diameter profile e.g. deposits, obstructions, restrictions, ...
- Presence of interfaces (G/ L, L/ L) created by stratification of the fluids
- Changes in composition or properties of the transported fluids
TBI LIMITATIONS

CASES WITH LIMITED APPLICABILITY

• **Gas lines:**
  - Need to shut-in long lines on both sides
  - Can only localize sharp restrictions, obstructions and interfaces

• **Multiphase lines and wells:**
  - Never applicable in presence of flow
  - After shut-in:
    - in wells: wait for fluids stratification
    - in lines: pressurize with liquid
  - Limited to localize (almost) complete obstructions
CASES WITH LIMITED APPLICABILITY

- Leaks:
  - No definitive conclusions
  - Probably applicable only with:
    - very low ΔP between inside and outside, to avoid critical flow across the leak (hydrostatics may prevent this)
    - rather big holes, e.g. like a coin

⇒ THEFT of hydrocarbons
LOW–COST, LOW–RISK, REMOTE AND FAST

TBI ATTRIBUTES:

- **Remote**: only access to the ends of the pipe is necessary → no “walking” along the line

- **Fast**: measurements does not require long flow stabilization and production is affected for about 5s/km (oil lines) and 15s/km (gas)

- **Low risk**: nothing is introduced in the line, no excavations, no installation, etc.

- **Low cost**: see above + low cost instrumentation
Oil well losing productivity

Deposits of unknown nature, localization (tubing/reservoir) and distribution

Plan best remedial technique and verify its effectiveness
TBI APPLICATION
OIL WELL INSPECTION

Well Head

Before acid job

TBI measure

Internal diameter profile
TBI APPLICATION
OIL WELL INSPECTION

Deposits actually removed by the acid job

Diagnosis:
Inorganic scales
(no asphaltenes
no fines)
Well Head

Before acid job

After acid job

TBI APPLICATION
OIL WELL INSPECTION

TBI measure

Internal diameter profile

Diameter profile

Diameter profile
TBI APPLICATION TO GAS WELLS

Fluid stratification: interface localization
Completion and wireline operations control
Compositional changes tracking

The speed of wave propagation enables the detection of interfaces and of changes in several parameters.

The velocity of the flow rate waves is as a function of P, T and composition.

TBI APPLICATION TO AN OIL SEALINE

LOCATE STUCK PIG (OBSTRUCTING)

Production platform

Onshore terminal

LOCATED PIG

CUT 1

CUT 2

sea level

FINAL SOLUTION

cut and substitute a pipeline section

LOCATE STUCK PIG (OBSTRUCTING)
TBI APPLICATION TO PIG TRACKING

Estimate pig arrival time and monitor its trip when other tracking techniques not applicable

Curves artificially separated for the sake of clarity

(grey) Difference due to the deposits removed by the pig

Pig traveling direction

Progressive pig positions

TBI APPLICATION TO PIG TRACKING

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Since its first Eni field application (Dec 2000), TBI impact has been evaluated.

- Several million US$ savings on OPEX
  (reduction of repair and intervention costs, optimization of well cleaning jobs, reduction of time-to-action)
- Several thousands bbl of oil production NOT delayed or lost
WHAT’S NEXT FOR TBI - LIKE TECHNOLOGIES:

• APPLY TO PRODUCTION OPTIMIZATION (e.g. gas condensate wells)

• TUBING + PIPELINE MONITORING

• NEAR-WELL FORMATION DAMAGE MONITORING

• MULTI PHASE FLOWING SYSTEMS
OVERALL TECHNICAL MESSAGE FROM TBI:
Often very easy to gain precious information from annoying shutdowns or flowrate changes

GENERATE “CULTURAL” ACCEPTANCE OF TRANSIENTS AS MONITORING TOOLS:

Never apply transients without asking which information they could provide

Stop just “tuning simulations” and start to “measure through simulations”

Thank you for your attention