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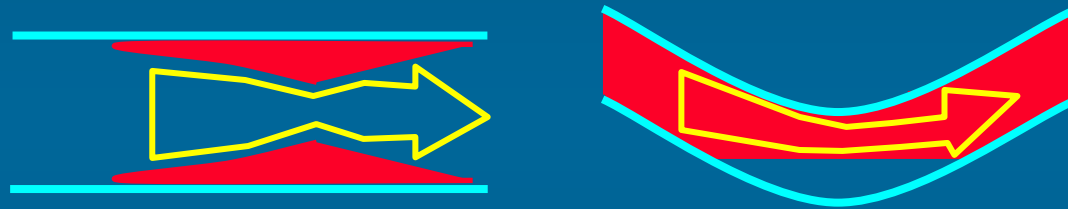
*SPE DISTINGUISHED LECTURER SERIES*

# **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 DEFINITION

## Flow Assurance

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

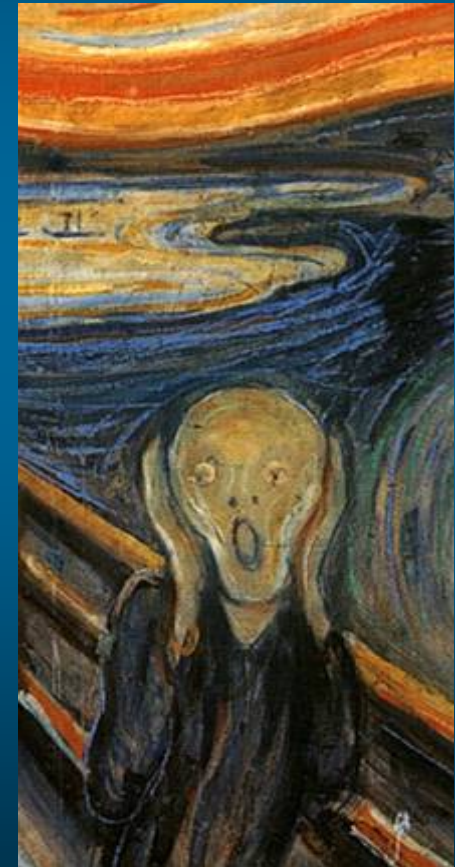
**by predicting, preventing and solving problems  
directly originated by the behavior of  
the transported substances  
(gases, liquids, solids)**

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**



# PRESENTATION AGENDA

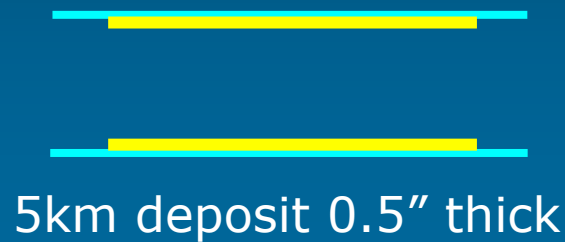
## Overview

- 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

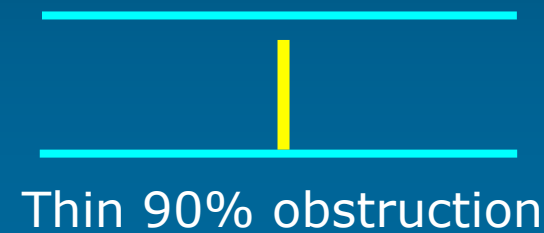
# STEADY-STATE MONITORING

## Different states, same measurements

### DISTRIBUTED vs CONCENTRATED RESTRICTIONS



15" ID



Induce the SAME additional  $\Delta P$

Deposit volume = 73 m<sup>3</sup>

Deposit volume = 0.5 m<sup>3</sup>

**QUANTITY AND POSITION OF DEPOSITS  
CANNOT BE ESTIMATED**

# STEADY-STATE MONITORING

## Different states, same measurements

### SENSITIVITY in DETECTING DEPOSITS



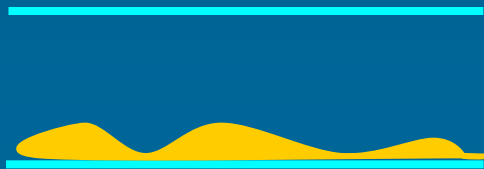
Induce a **SMALL** additional  $\Delta P$  ( $<0.5$  bar)

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

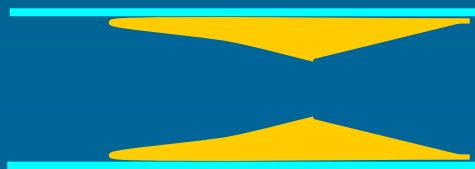
**UNCERTAINTY HIDES THE EFFECT OF SLOWLY GROWING RESTRICTIONS**

**STEADY-STATE MONITORING**  
**Different states, same measurements**

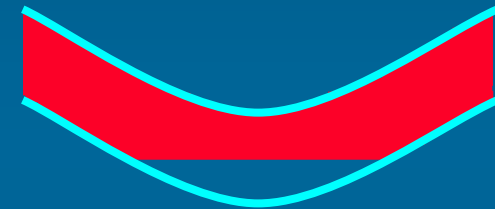
**DEPOSITS WITHOUT  
PHASE-DIAGRAM PREDICTABILITY**



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



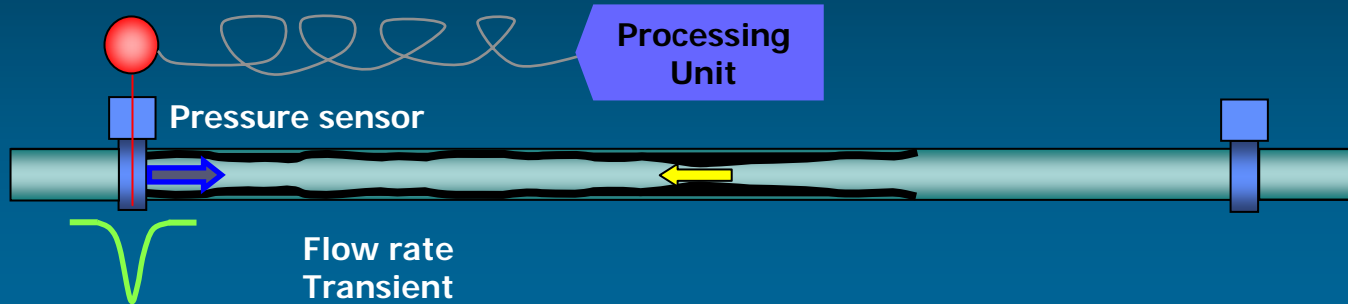
**Passive noise not discussed here,  
but might deserve more exploration**

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# TRANSIENT-BASED INSPECTION CONCEPT

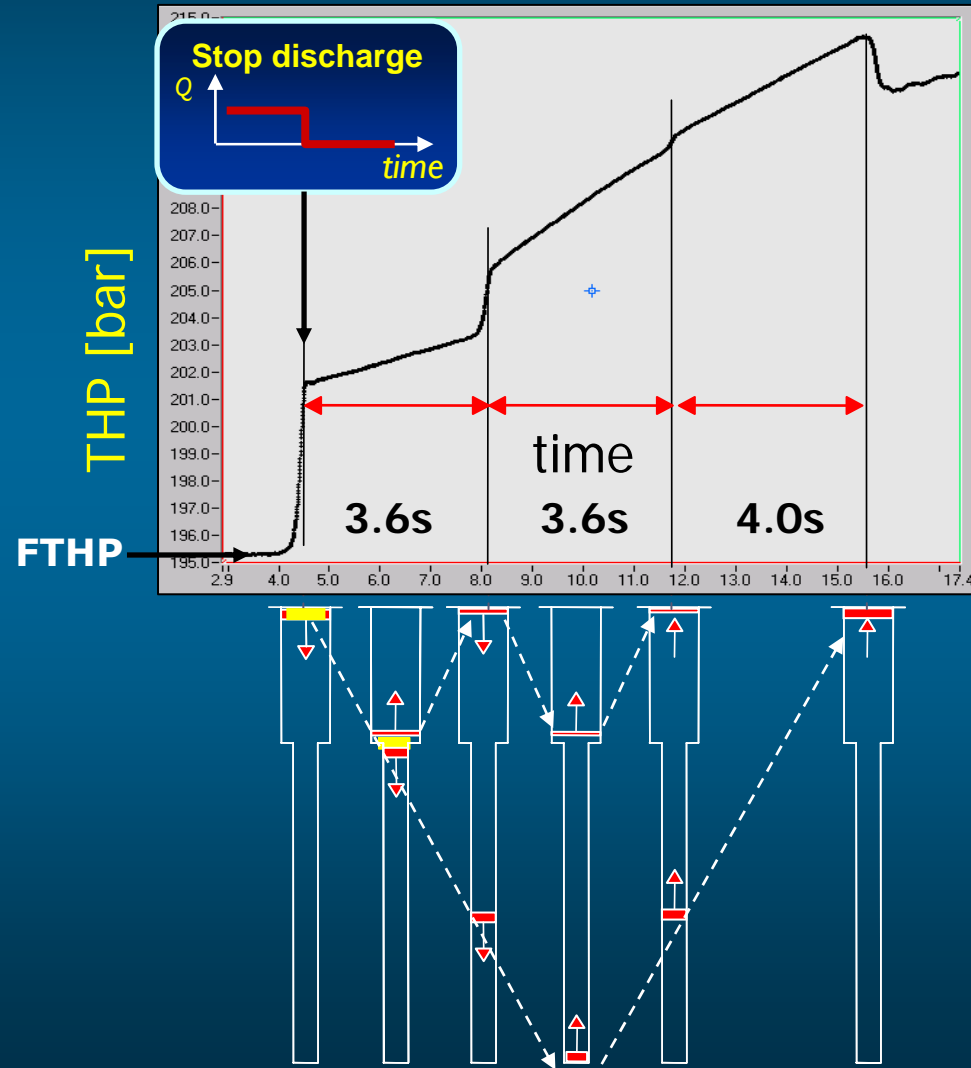
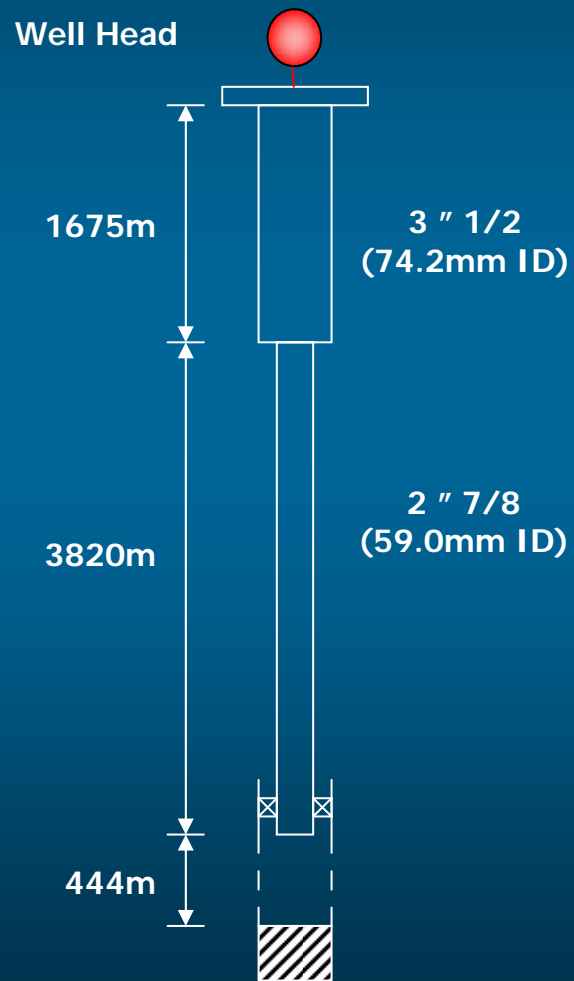


## INSPECTION ACCOMPLISHED BY:

- 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



# EXPLOITATION OF FLOW RATE TRANSIENTS

## Theory

Correct modeling  
Simulation software

## Pressure sensors

Accurate at high P  
Fast response

## EXPLOITING TRANSIENTS

## Inverse problem

From P data to profile  
of variables along pipe

## Data acquisition

In the field with operators  
Portable and reliable tools

**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

**T**ransient

**B**ased

**I**nspection

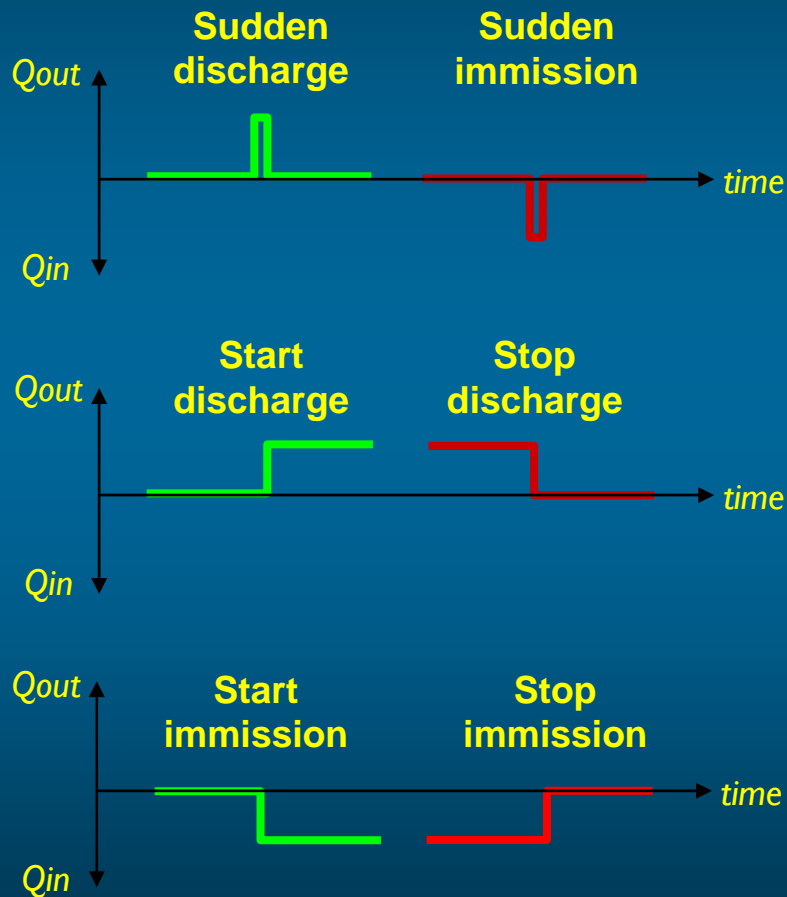
*(In Eni, we call it PRIMEFLO)*

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# USEFUL TRANSIENTS TYPES AND METHODS



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

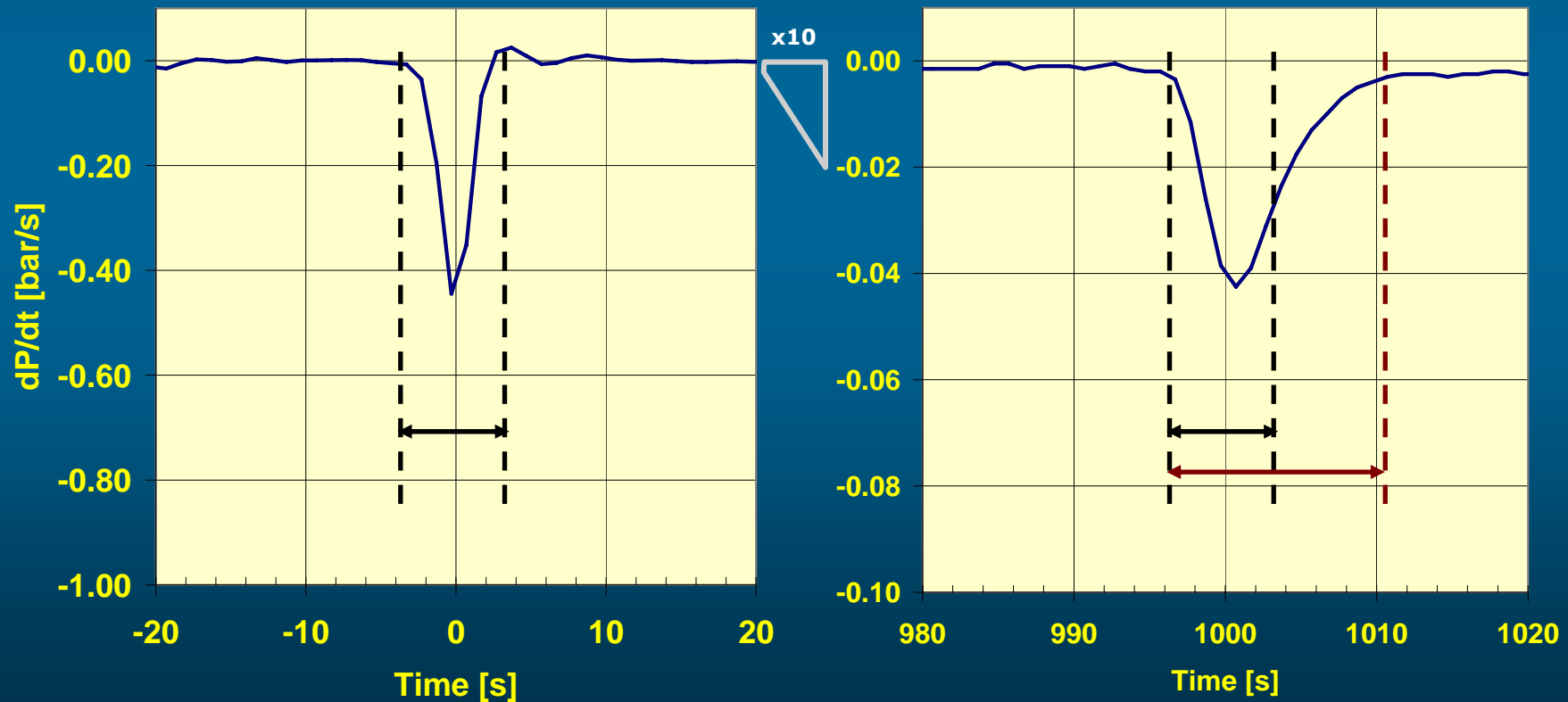
# TBI DEMONSTRATED PERFORMANCE

## FIELD DEMONSTRATED APPLICABILITY

<b>Pipes</b>	Tubing, Pipeline, Sealine
<b>Geometry</b>	Any (H, V, sloped, winded...)
<b>Diameter</b>	1/6" – 32" ↑
<b>Fluid Type</b>	Oil, Gas, Emulsions ( <b>no flowing G+L !</b> )
<b>Viscosity</b>	from gas to 600 cP ↑
<b>Length</b>	<b>Oil</b> 200 m – 530 km ↑
	<b>Gas</b> 3 m – 530km ↑

# TRANSIENTS DISPERSION EXAMPLE OF OIL PIPELINE (530km)

Signal dispersion (width):  
negligible broadening after a 1060km trip  
Equally true for OIL and GAS pipelines



# TBI SENSITIVITY

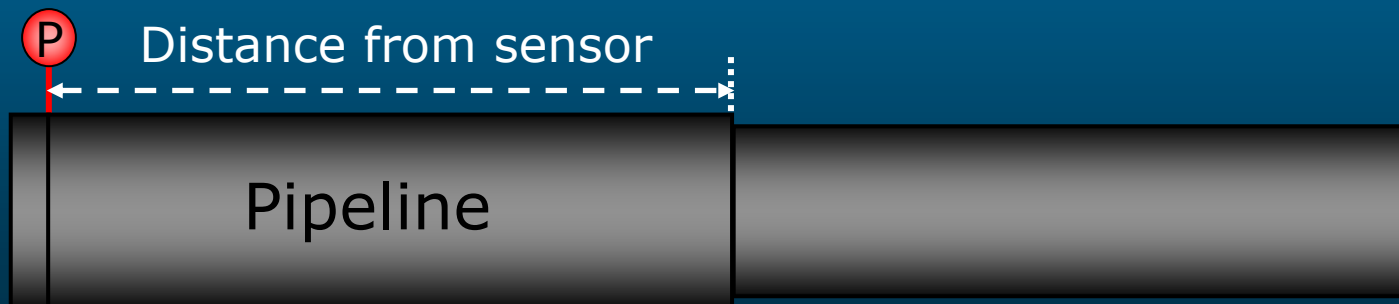
## DEMONSTRATED SENSITIVITY

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

**350'000 m** far from sensor, **1/4"** / 24" diameter change

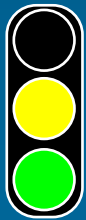
Heavy crude with  $\mu = 600 \text{ cP}$

**300 m** far from sensor, **1/8"** / 16" diameter change



# 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



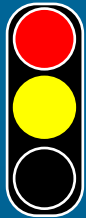
- **Multiphase lines and wells:**

- ✓ 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

# TBI LIMITATIONS

## CASES WITH LIMITED APPLICABILITY

- **Leaks:**



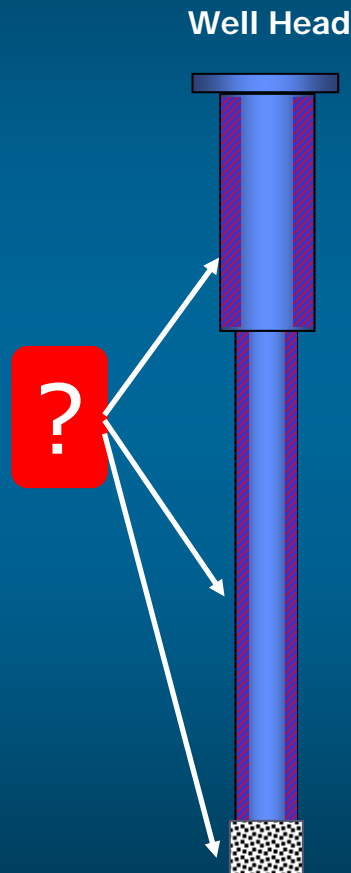
- ✓ No definitive conclusions
- ✓ Probably applicable only with:
  - ✓ very low  $\Delta P$  between inside and outside, to avoid critical flow across the leak (hydrostatics may prevent this)
  - ✓ rather big holes, e.g. like a coin  
→ **THEFT**

## 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

# TBI APPLICATION OIL WELL INSPECTION



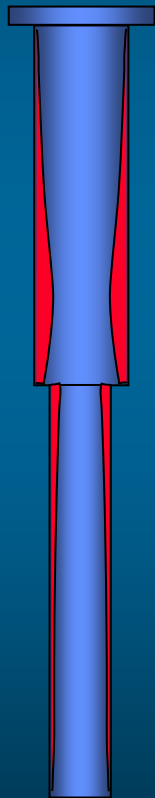
**Oil well losing productivity**

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

**Plan best remedial technique  
and verify its effectiveness**

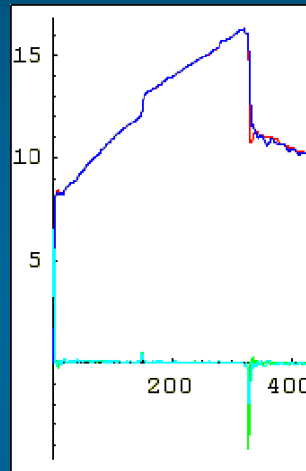
# TBI APPLICATION OIL WELL INSPECTION

Well Head

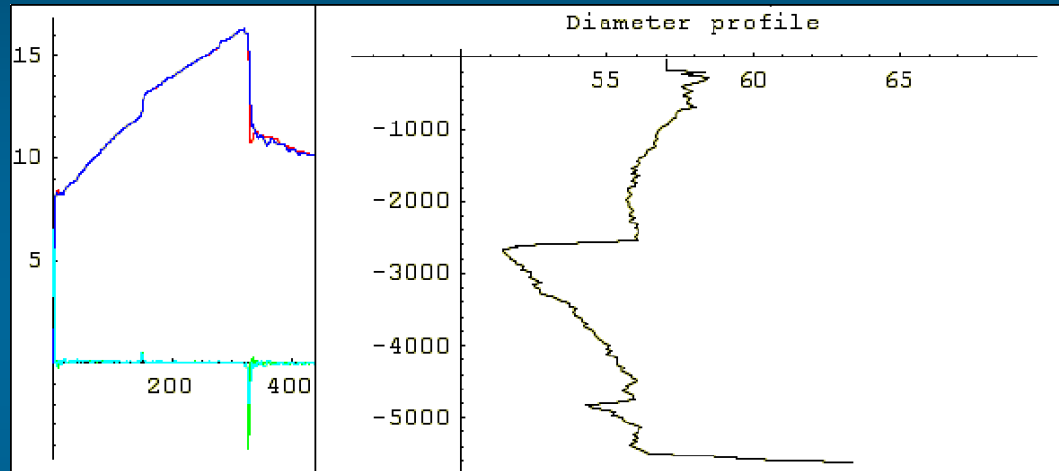


**Before  
acid job**

**TBI  
measure**



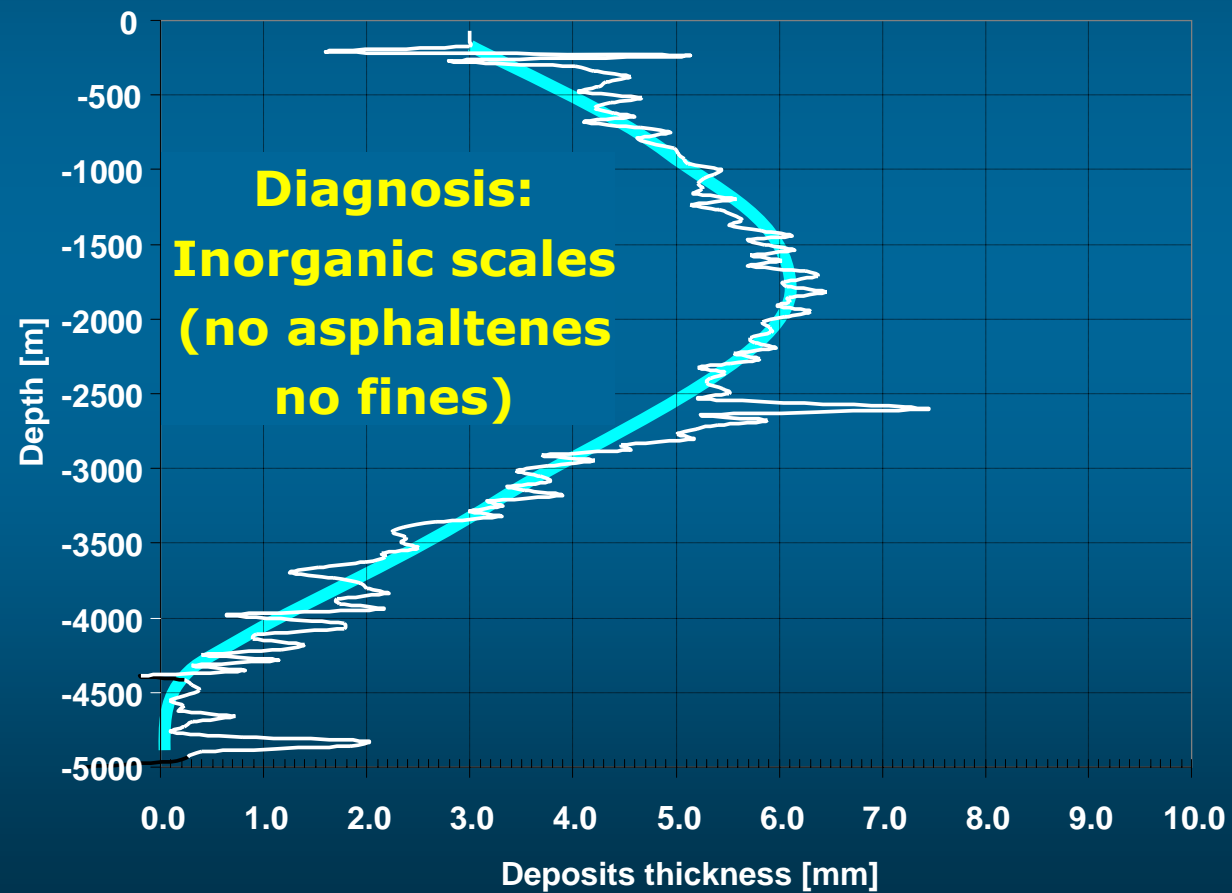
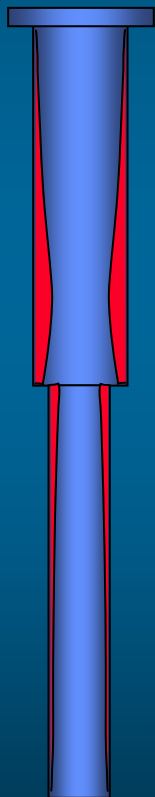
**Internal  
diameter profile**



# TBI APPLICATION OIL WELL INSPECTION

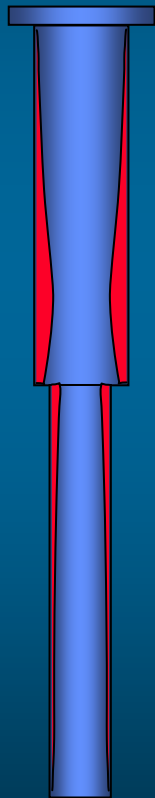
Deposits actually removed by the acid job

Well Head



# TBI APPLICATION OIL WELL INSPECTION

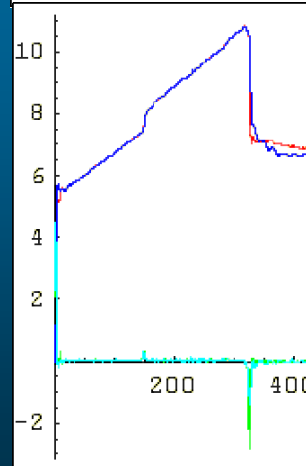
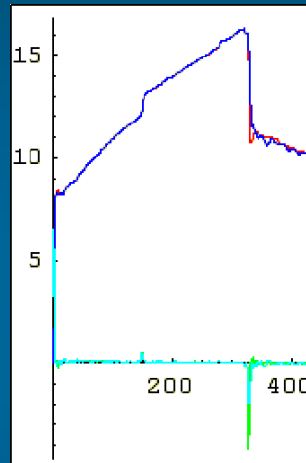
Well Head



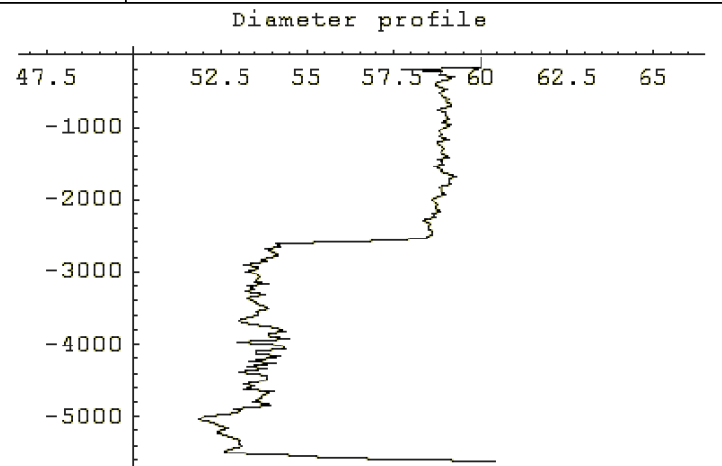
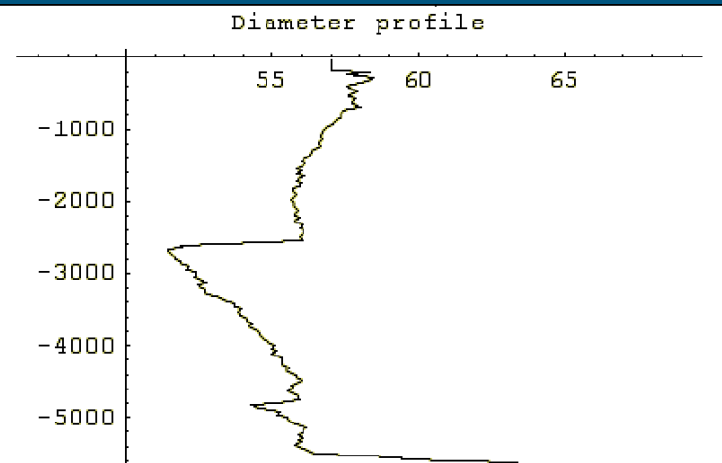
**Before  
acid job**

**After  
acid job**

**TBI  
measure**



**Internal  
diameter profile**

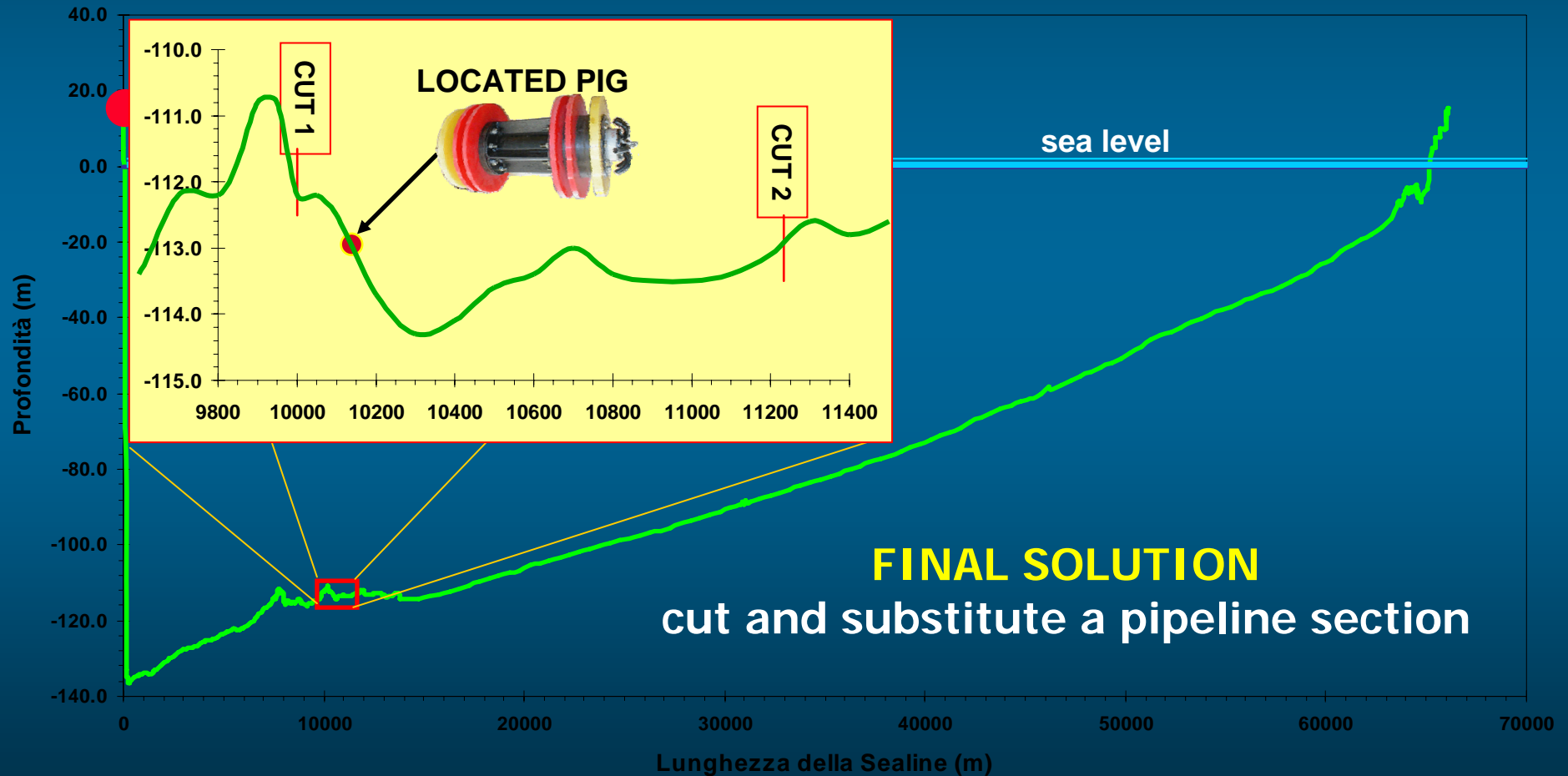


# TBI APPLICATION TO AN OIL SEALINE

Production  
platform

## LOCATE STUCK PIG (OBSTRUCTING)

Onshore  
terminal



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## **ECONOMIC CONCLUSIONS**

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**

## TECHNICAL CONCLUSIONS

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*