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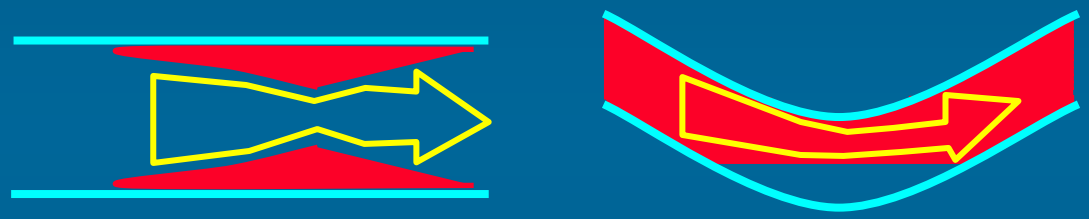
SPE DISTINGUISHED LECTURER SERIES

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)



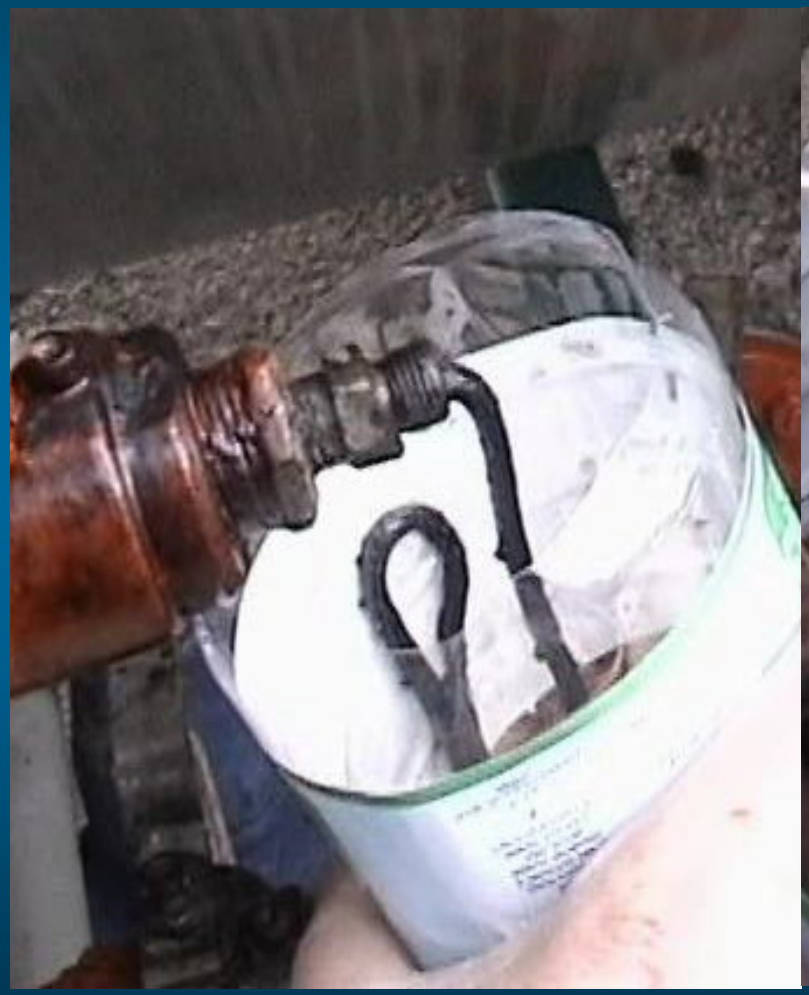
- **Changes in the effective Diameter profile**
  e.g. deposits, valves, wall thickness

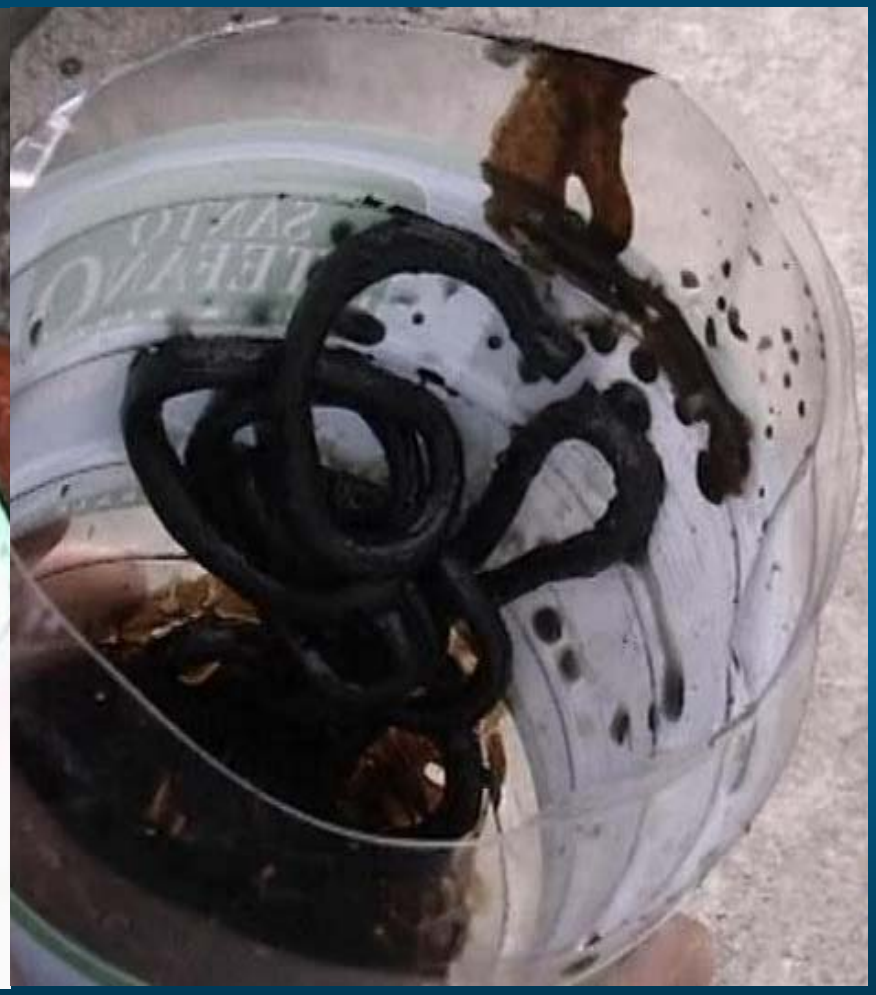
- **Presence of interfaces (G/L, L/L)**
  created by stratification of the fluids

FLOW ASSURANCE
WAX PLUGS

FLOW ASSURANCE
ASPHALTENES

FLOW ASSURANCE EMULSIONS





FLOW ASSURANCE DEFINITION

Flow Assurance

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

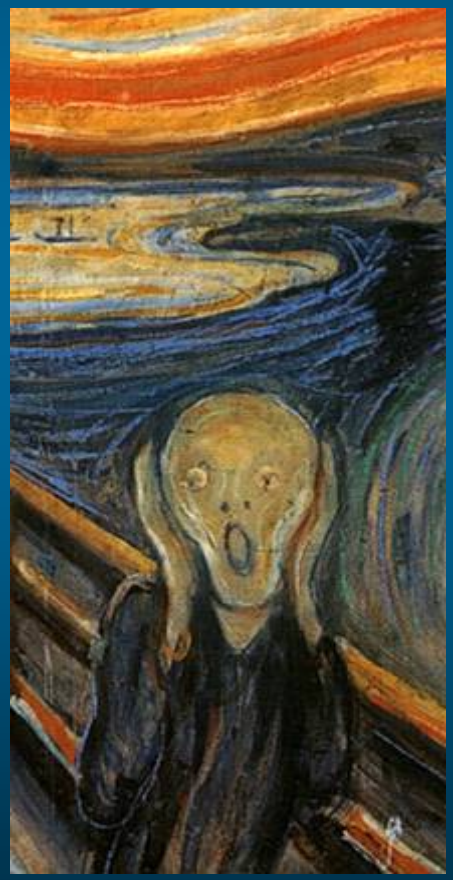
by predicting, preventing and solving problems directly originated by the behavior of the transported substances (gases, liquids, solids)

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

5km deposit 0.5” thick

Thin 90% obstruction

Induce the SAME additional ΔP

Deposit volume = 73 m^3

Deposit volume = 0.5 m^3

QUANTITY AND POSITION OF DEPOSITS CANNOT BE ESTIMATED

STEADY–STATE MONITORING
Different states, same measurements

SENSITIVITY in DETECTING DEPOSITS

15” ID

5km deposit 0.5” thick

Thin 90% obstruction

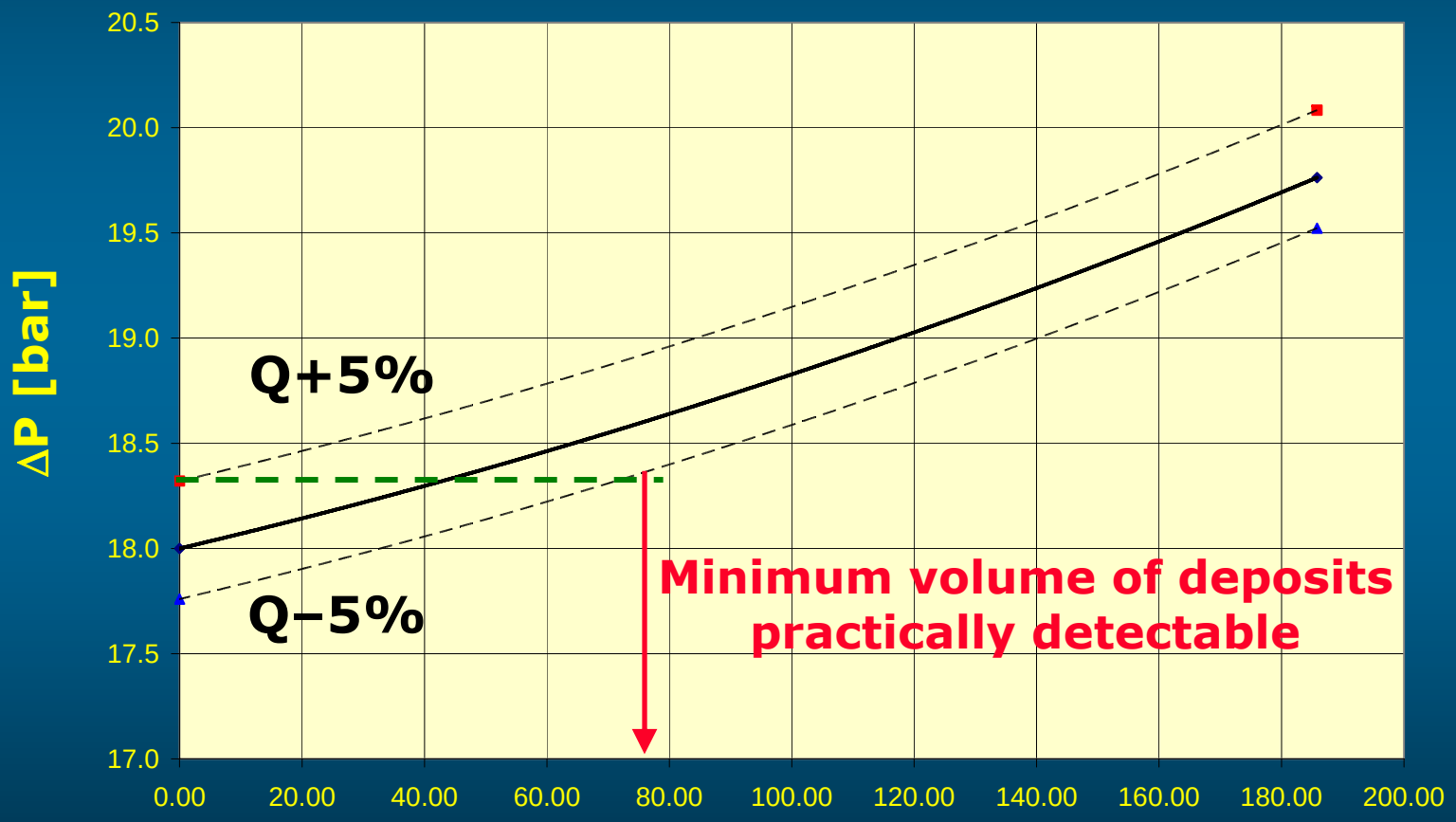
Induce a SMALL additional ΔP (<0.5 bar)

Equivalent causes: $\Delta Q < +5\%$ $\Delta\mu < 20\%$ $\Delta\rho$… ΔT…

UNCERTAINTY HIDES THE EFFECT OF SLOWLY GROWING RESTRICTIONS

STEADY–STATE MONITORING
Different states, same measurements

SENSITIVITY in DETECTING DEPOSITS



Volume of deposits [m³] uniform over 5km

STEADY–STATE MONITORING
Different states, same measurements

DEPOSITS WITHOUT PHASE-DIAGRAM PREDICTABILITY

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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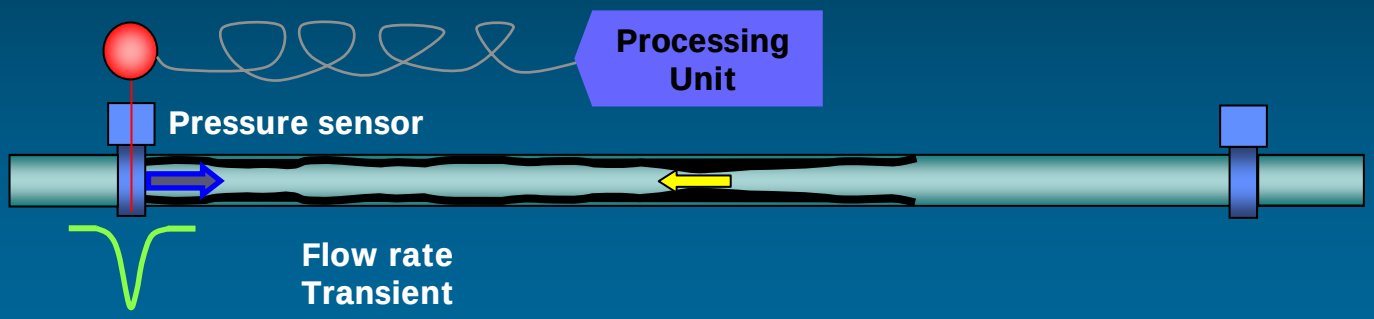
TRANSIENT-BASED INSPECTION CONCEPT

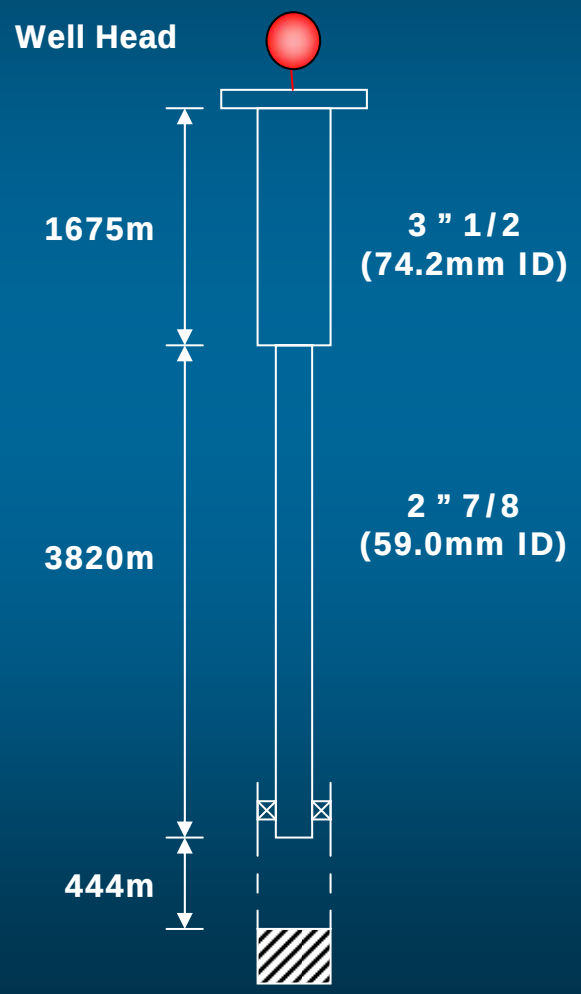


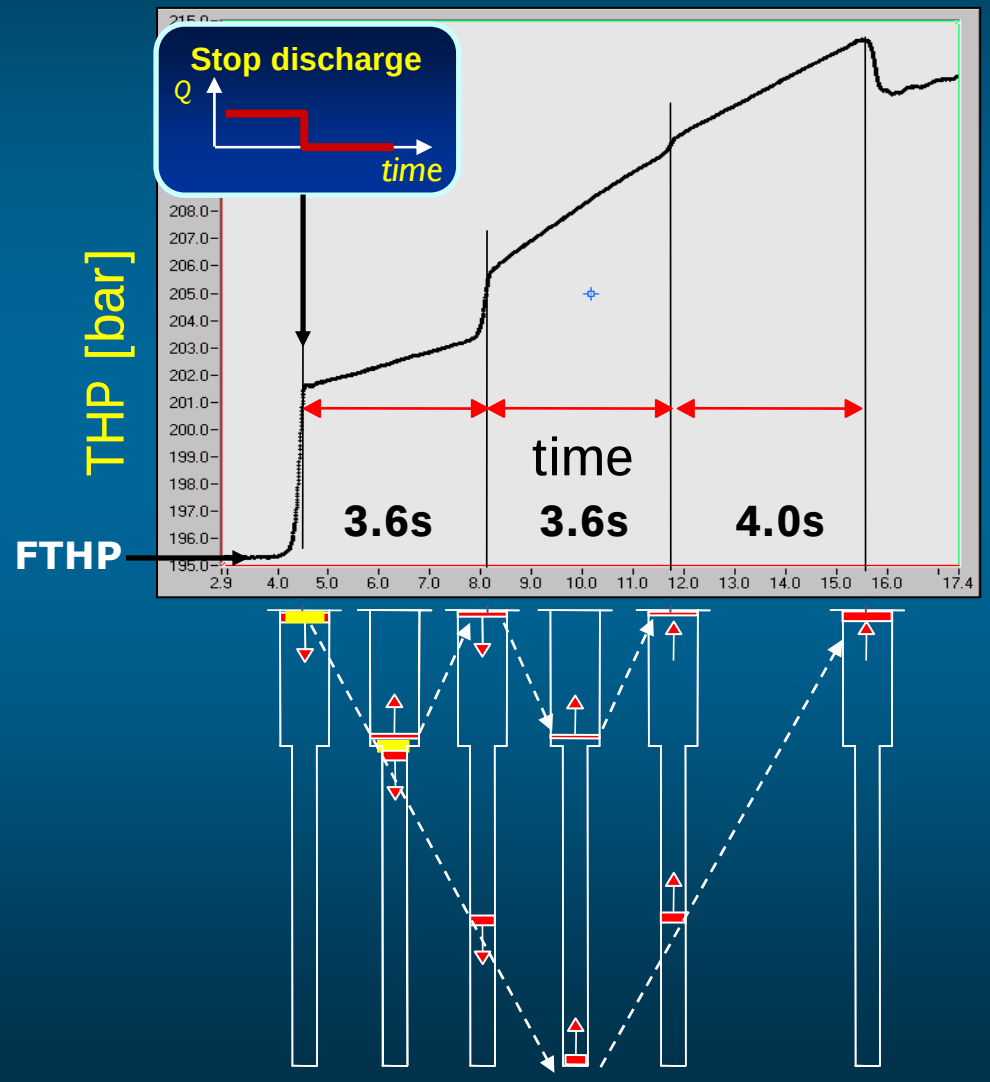
INSPECTION ACCOMPLISHED BY:

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

PATENTED

Data acquisition
In the field with operators
Portable and reliable tools

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)

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TBI
DEMONSTRATED PERFORMANCE

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 – 530km ↥

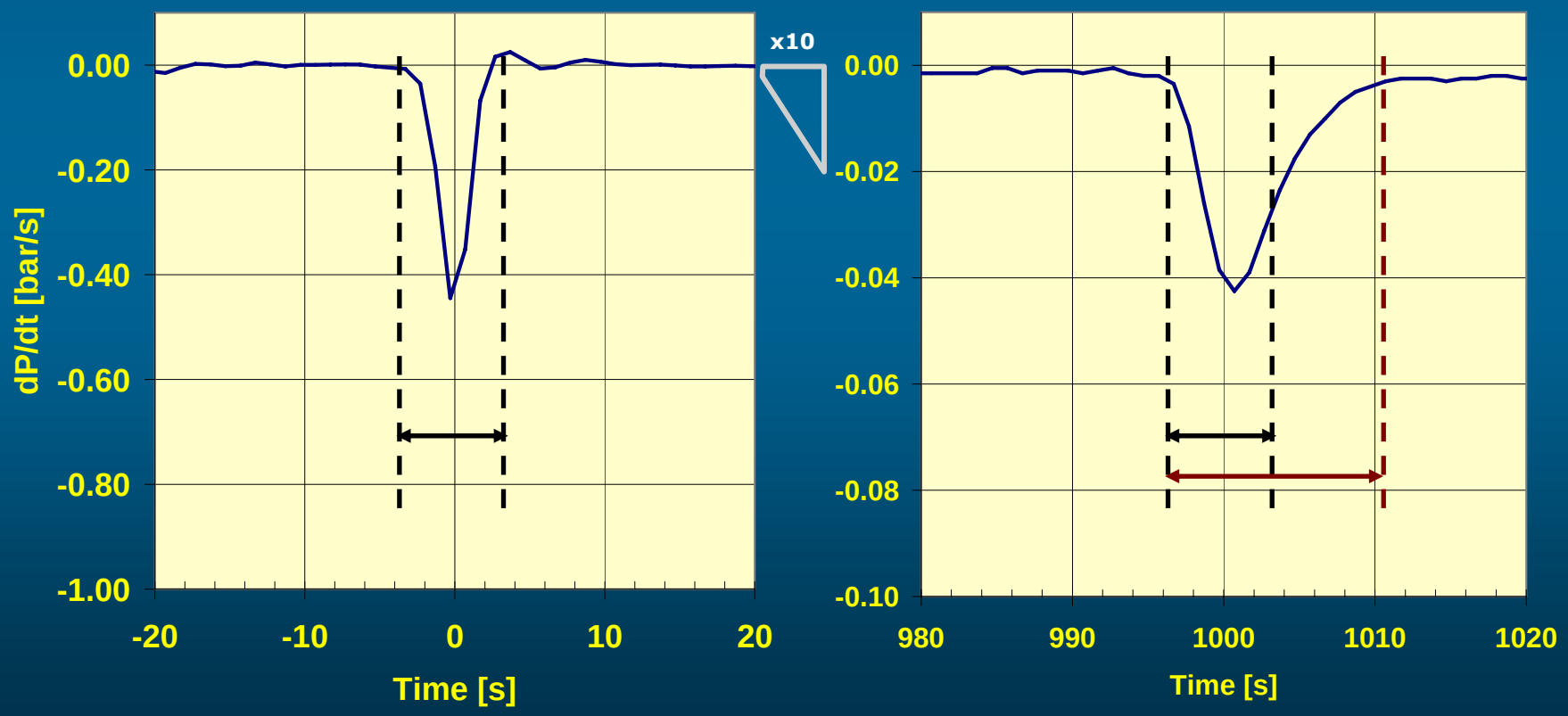
(*)

(*) Field demonstrated, not technology limit

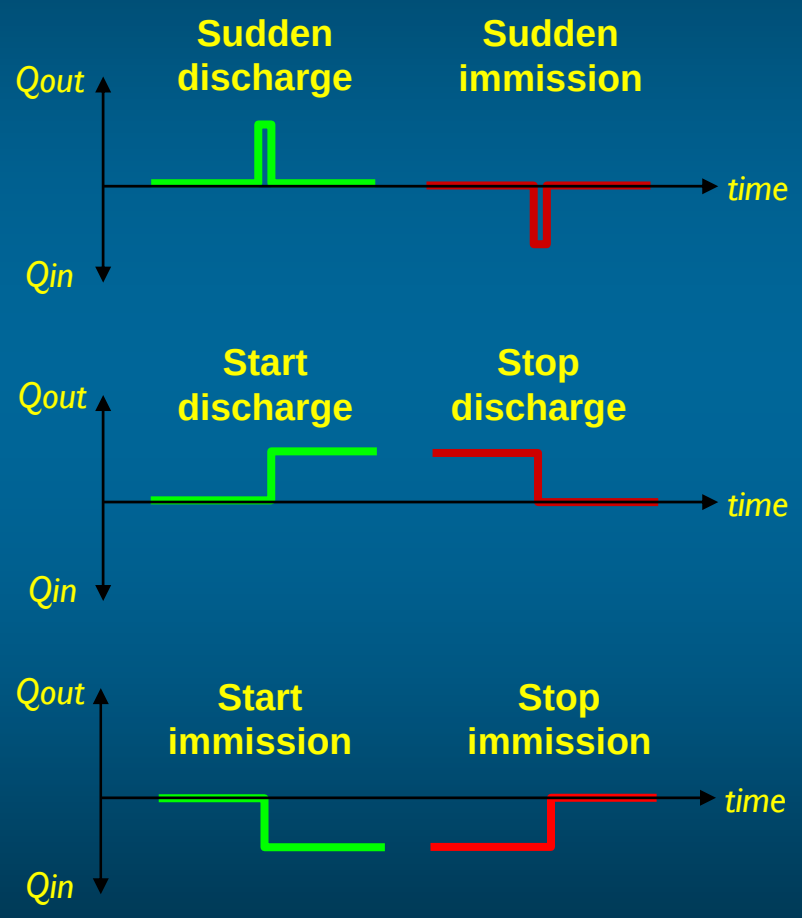
TRANSIENTS DISPERSION
EXAMPLE OF OIL PIPELINE (530km)

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

TBI SENSITIVITY

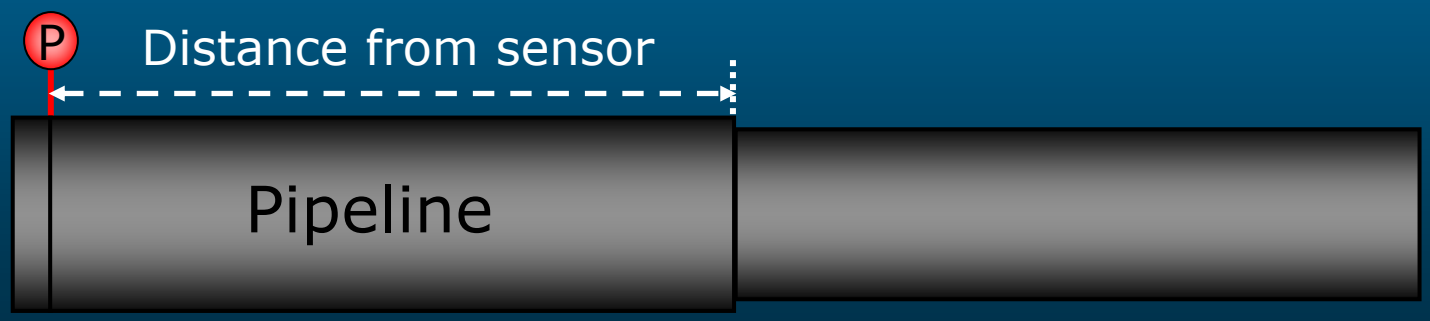
DEMONSTRATED SENSITIVITY

Light crude with μ = **2 cP**

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

Heavy crude with μ = **600 cP**

300 m far from sensor, **⅛"** / 16" diameter change



TECHNOLOGY SCOPE

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

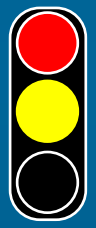
- **Gas lines**:
  - ✓ Need to shut-in long lines on both sides
  - ✓ Can only localize sharp restrictions, obstructions and interfaces

- **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

TBI
LIMITATIONS

CASES WITH LIMITED APPLICABILITY

- **Leaks**:



  - ✓ No definitive conclusions
  - ✓ <u>Probably</u> 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

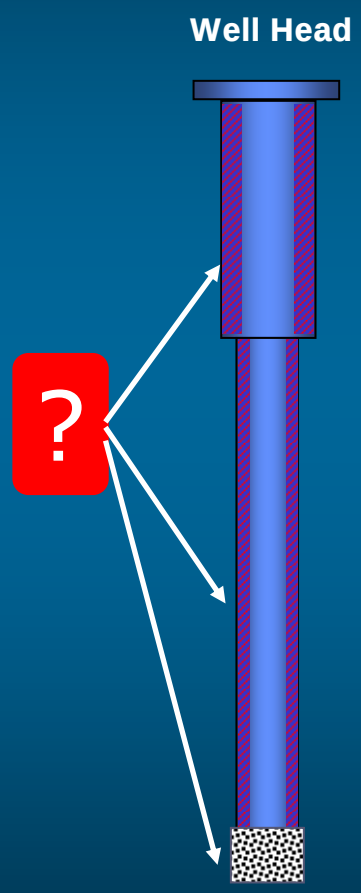
      ➔ THEFT of hydrocarbons

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

TBI APPLICATION
OIL WELL INSPECTION



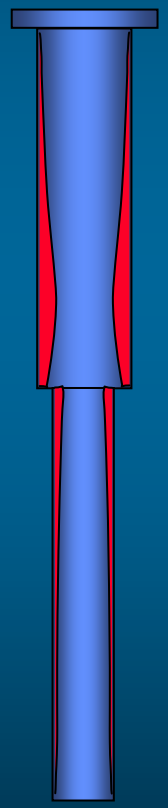
Oil well losing productivity

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

Plan best remedial technique and verify its effectiveness

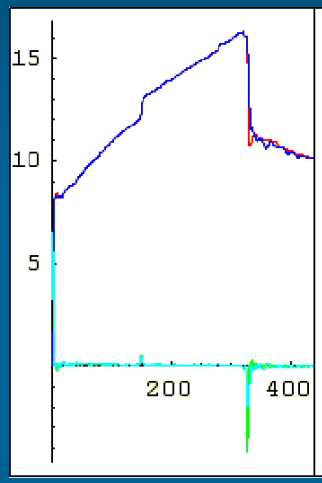
TBI APPLICATION
OIL WELL INSPECTION

Well Head

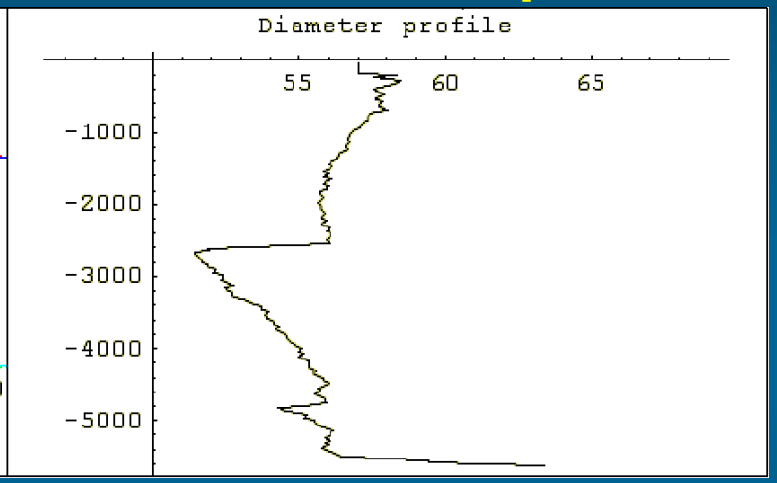


Before acid job

TBI measure

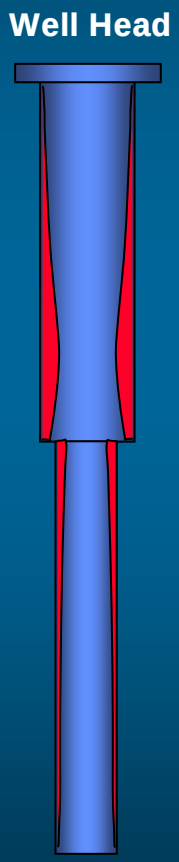


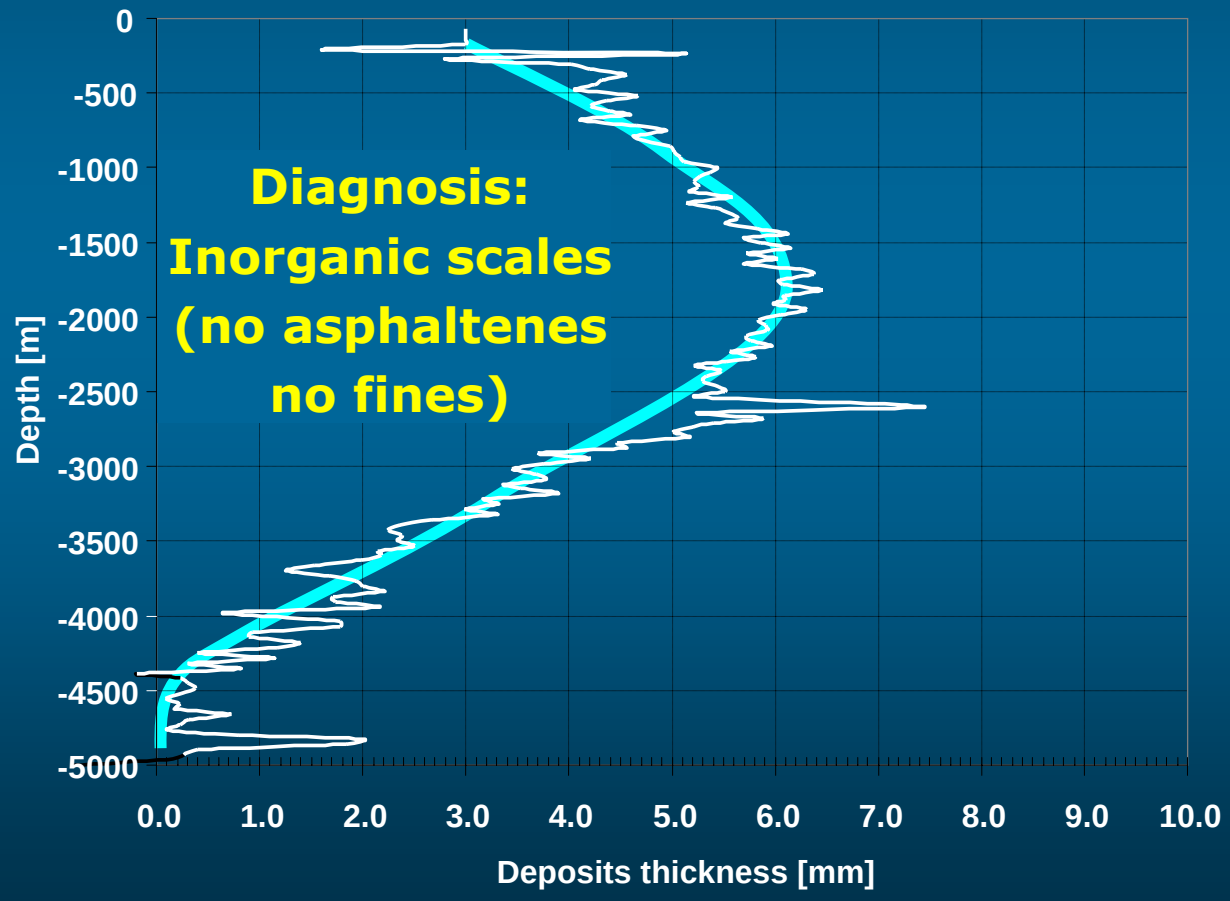
Internal diameter profile



TBI APPLICATION
OIL WELL INSPECTION

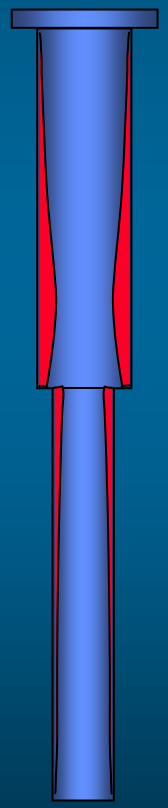
Deposits actually removed by the acid job





TBI APPLICATION
OIL WELL INSPECTION

Well Head

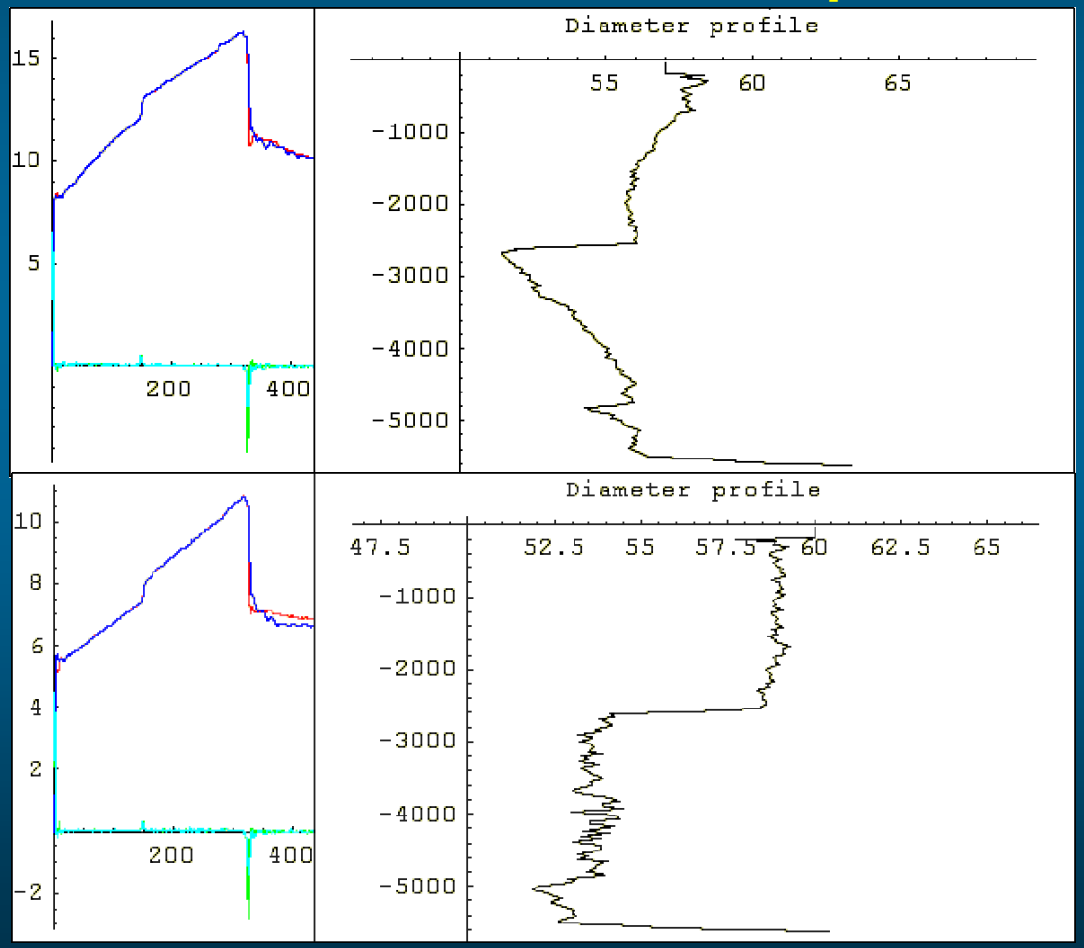


Before acid job

After acid job

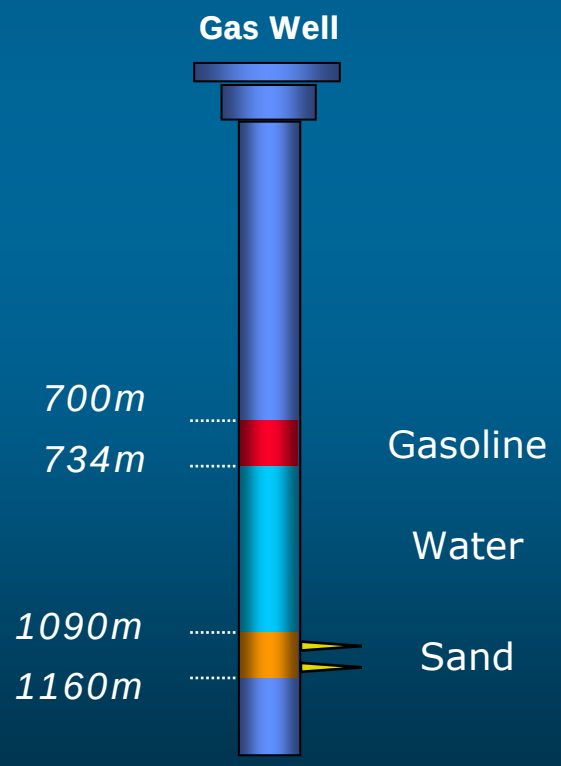
TBI measure

Internal diameter profile



TBI APPLICATION TO GAS WELLS

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



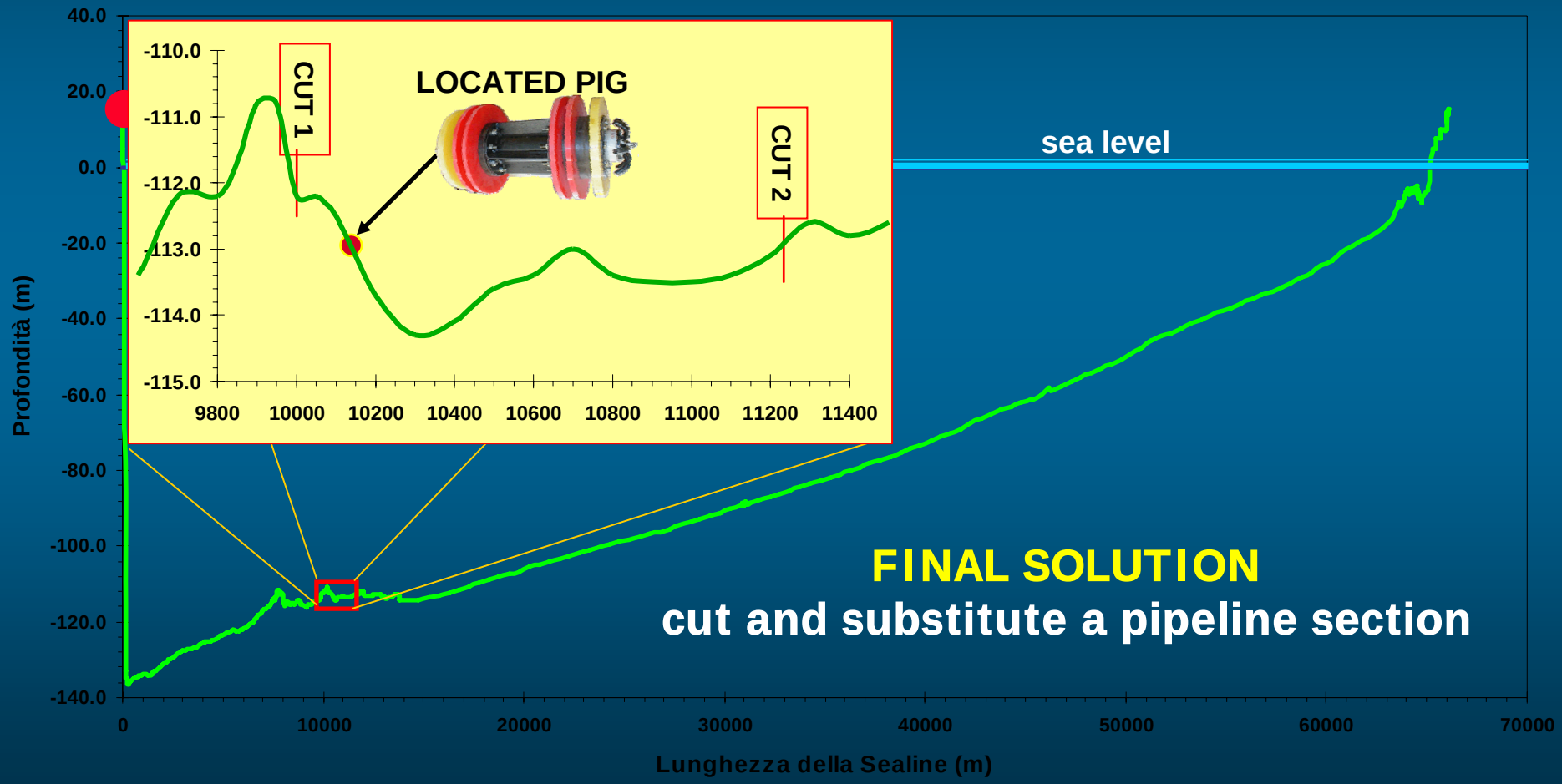
The speed of wave propagation enables the detection of interfaces and of changes in several parameters

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

E.g. "Acoustic Velocities in Petroleum Oils", Zhijing Wang et al., JPT, Feb 1990, p.192-200

TBI APPLICATION TO AN OIL SEALINE

LOCATE STUCK PIG (OBSTRUCTING)

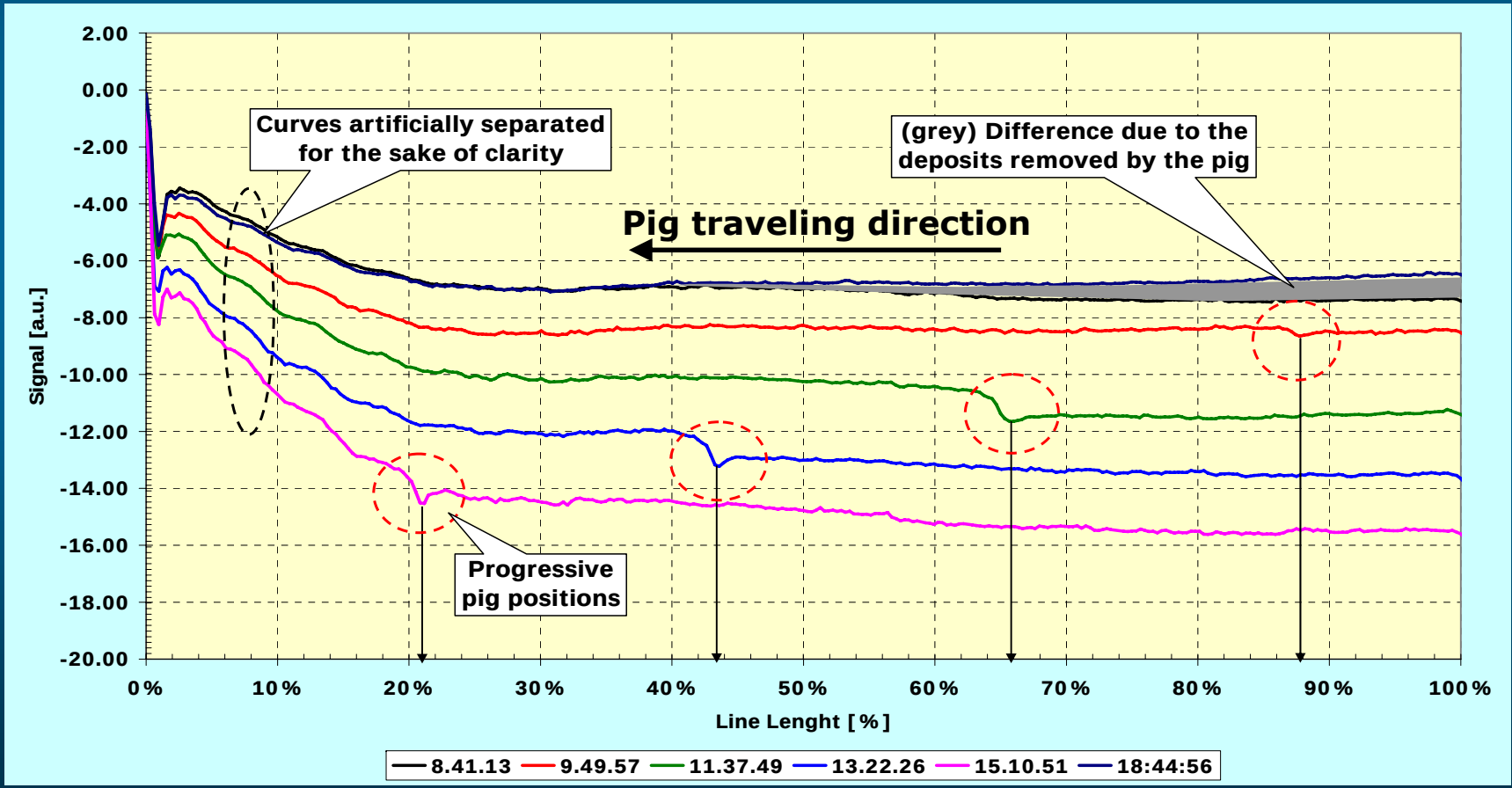


FINAL SOLUTION

cut and substitute a pipeline section

TBI APPLICATION TO PIG TRACKING

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



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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**

TBI FUTURE DEVELOPMENTS

WHAT'S NEXT FOR TBI–LIKE TECHNOLOGIES:

- **APPLY TO PRODUCTION OPTIMIZATION (e.g. gas condensate wells)**
- **TUBING + PIPELINE MONITORING**
- **NEAR-WELL FORMATION DAMAGE MONITORING**
- **MULTIPHASE FLOWING SYSTEMS**

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