Laboratory Perforation and Flow Testing

Using Reservoir Wellcore

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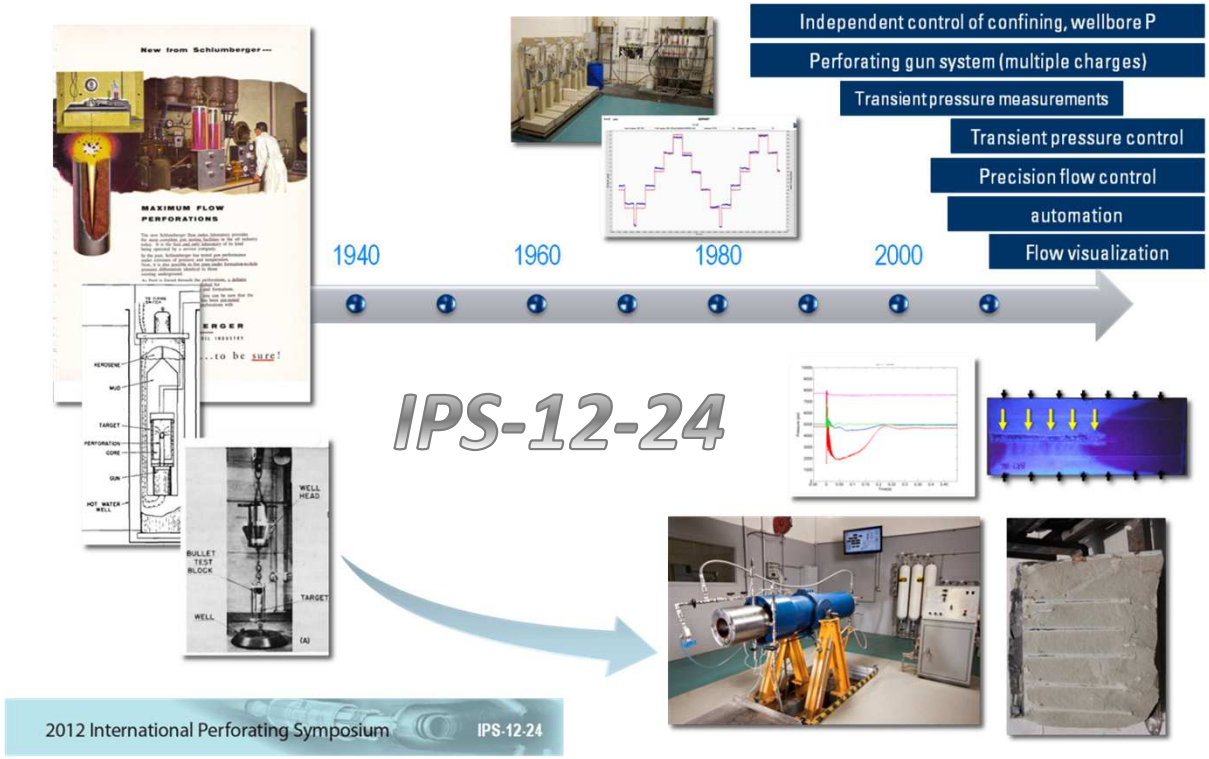
Agenda

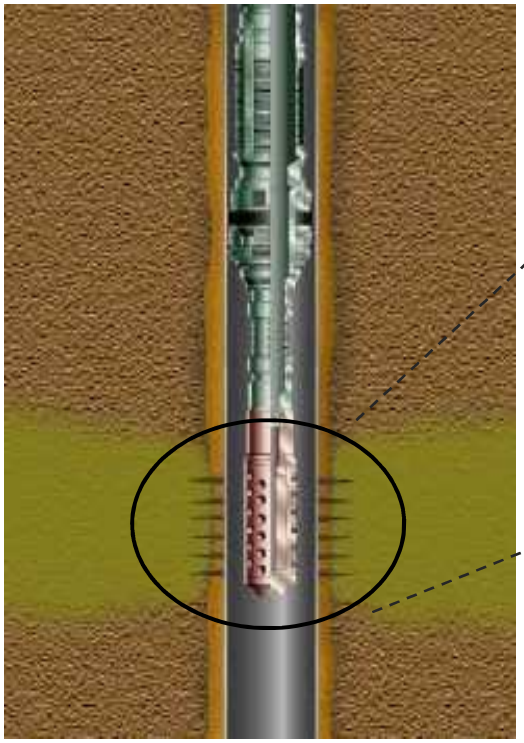
- Brief intro to the perforating laboratory
- Overview of “typical” test programs
- Survey of programs based on actual reservoir wellcores

Perforating Laboratory: Brief Introduction

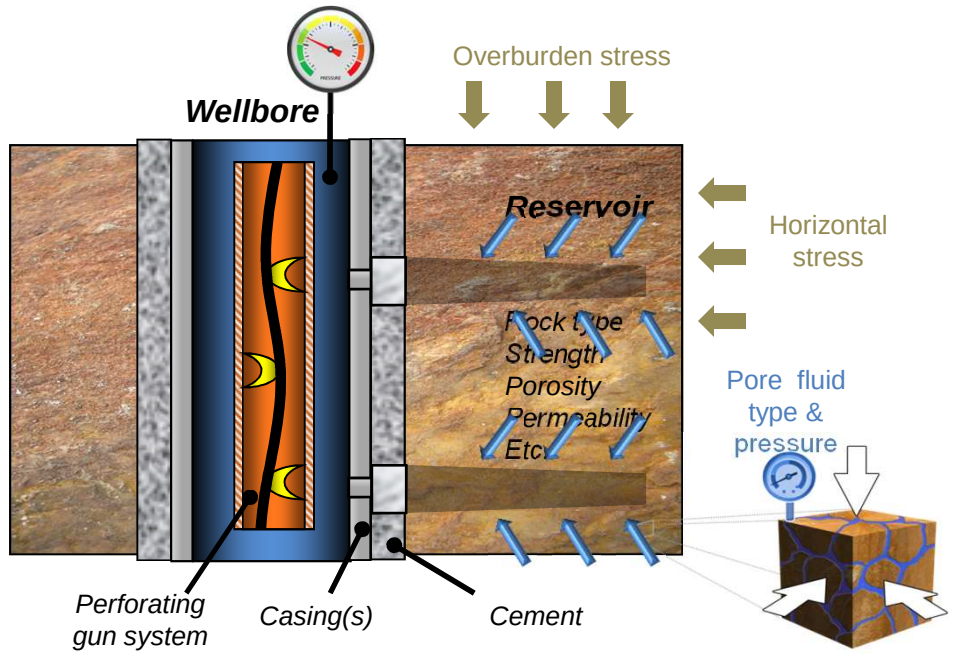
- Originated in 1953
- Fundamental and targeted studies
- Perforation depth, cleanup
- Well productivity, skin, perf for stimulation / SC

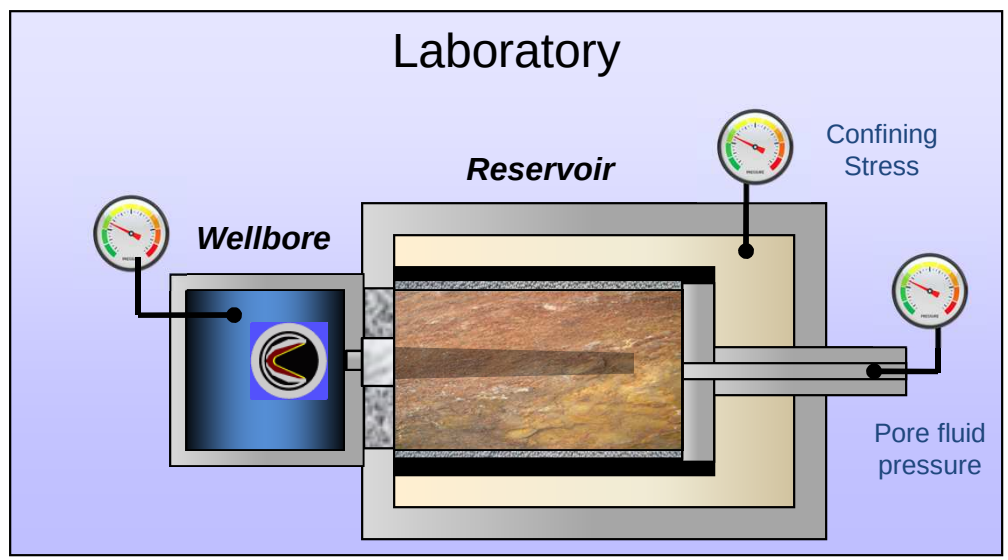


Perforating…Field to Lab



Perforating Objective: establish a highly productive flowpath between reservoir and wellbore





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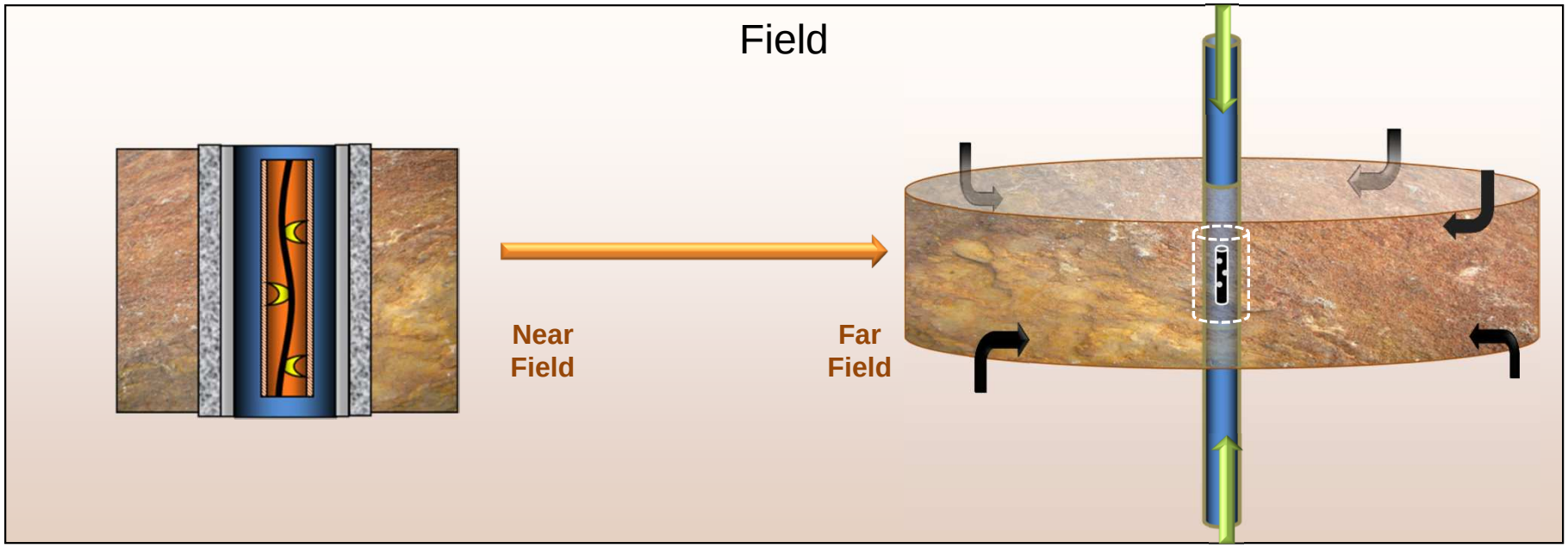
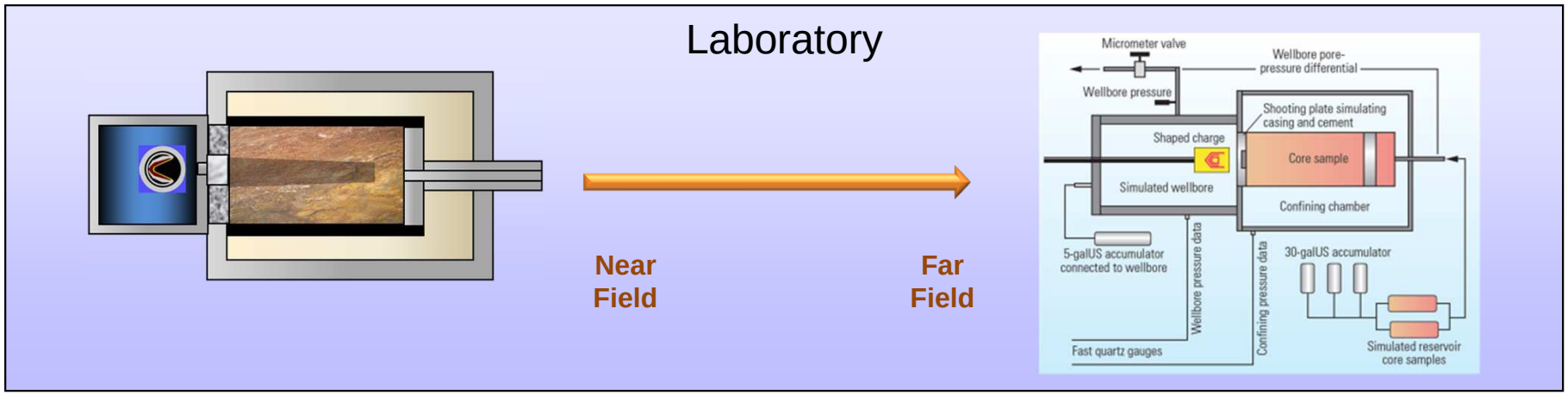


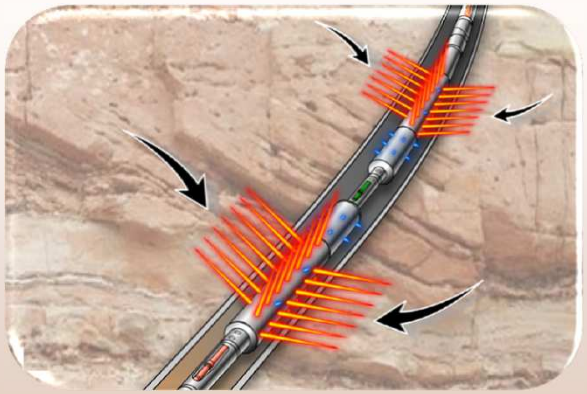


Perforating Test Programs: High Level Drivers

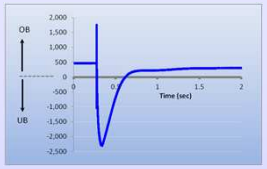
Field Objectives

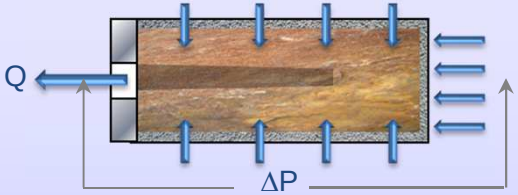
Maximize / Quantify:

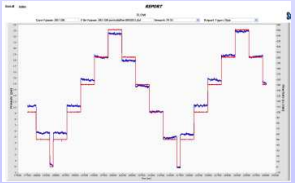
- Well productivity
- Well inflow reliability over the long term
- Operational & rigsite efficiency
- Operational & rigsite safety



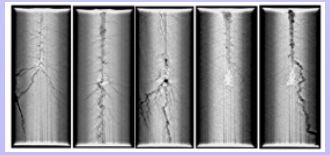
Lab Objectives





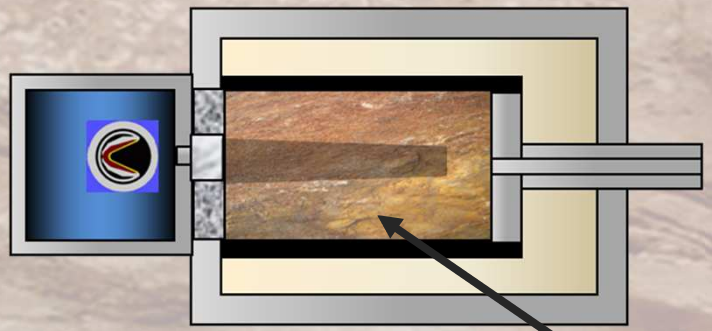


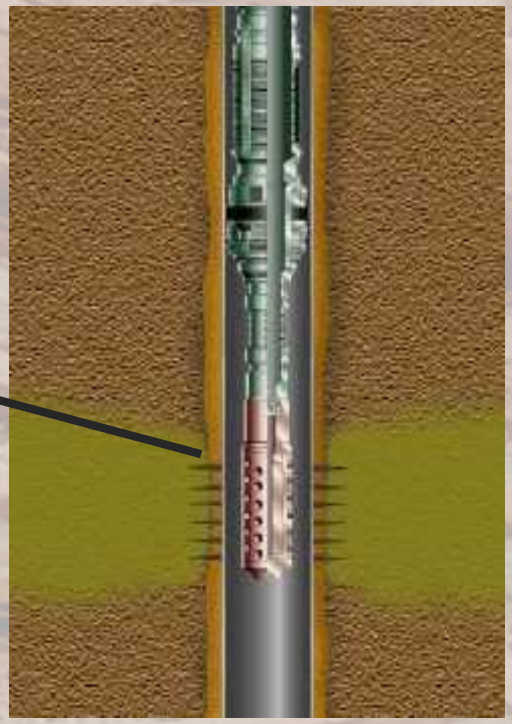
- Match critical **shot-time conditions**
  - Wellbore fluids, dynamics for perf cleanup
  - Pore fluid, and core boundary conditions
- Match **flow conditions**
  - Fluid, field rates
  - Assess flow efficiency (→well skin, PI); sanding propensity, etc.
- Investigate range of **wellbore fluid / reservoir interactions** *on full size core*
  - Stimulation – eg acidizing
  - Sand consolidation treatments
  - Well control: Non-damaging loss control fluids while perforating



Laboratory Programs Using Reservoir Cores

- Off & on since mid 1990's
- Advantages & disadvantages
- Survey of recent programs





Advantages & Disadvantages

Advantages

- The “real thing” – strength, porosity, permeability, heterogeneities
- Often no surrogate outcrop exists that matches all properties
- Most reliable indicator of actual formation response to perforating
- Especially suited to chemical/interaction phenomena (completion fluid interactions; production flow watercut, etc.)

Disadvantages

- Limited sizes; requires additional fixturing, scaling
- Heterogeneities (not really a “disadvantage”?)

Other considerations

- Coring orientation often in the “wrong direction”
- Cores often already picked over / slabbed / plugged
- Limited supply
- <u>Interpretation is key</u> for field (design, implement, produce)

Awareness

- Is completion/perforation strategy always considered early in well’s life, when cores are taken?

Brief Survey of Recent Wellcore-Based Programs

Typically fit into one of 3 main categories:

A. Shaped charge <u>penetration depth</u>
B. Perforation depth, <u>cleanup, inflow performance</u>
C. <u>Perforation stability / Sanding propensity</u> over life of well scenarios (depletion stress, watercut)

A. Wellcore Penetration Programs

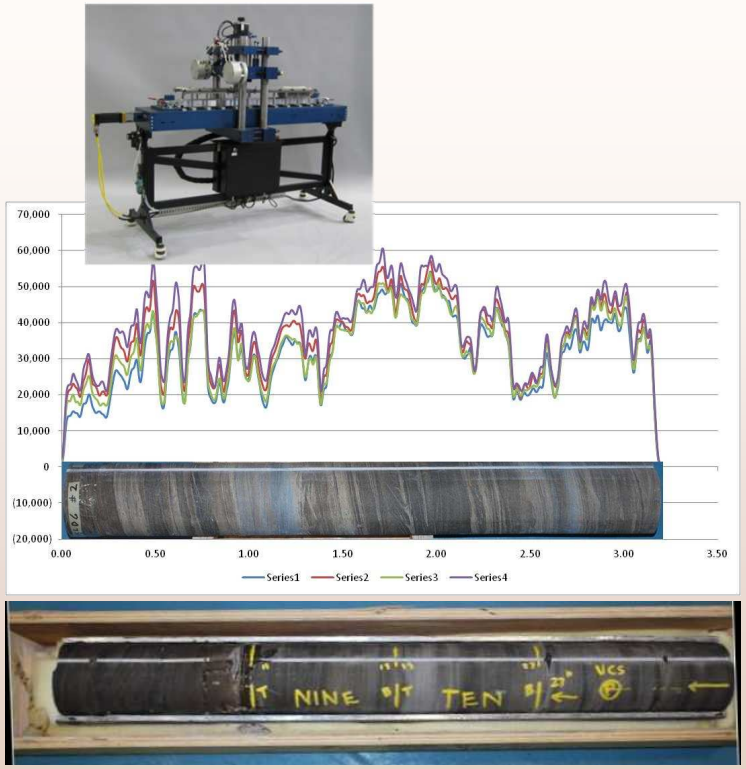
3 examples

1. Sandstone – ultrastrong / heterogeneous
2. Coal – shallow, weak, naturally fractured
3. Carbonates – moderate and high strength

Wellcore Penetration Example #1

Sandstone – ultrastrong / heterogeneous

- Driver: hydraulic frac environment; formation breakdown challenging
- Very strong formation; 20-55ksi UCS
- Obtain wellcores; map UCS profiles; stress to DH conditions, perforate
- IPS-12-04; SPE 159771



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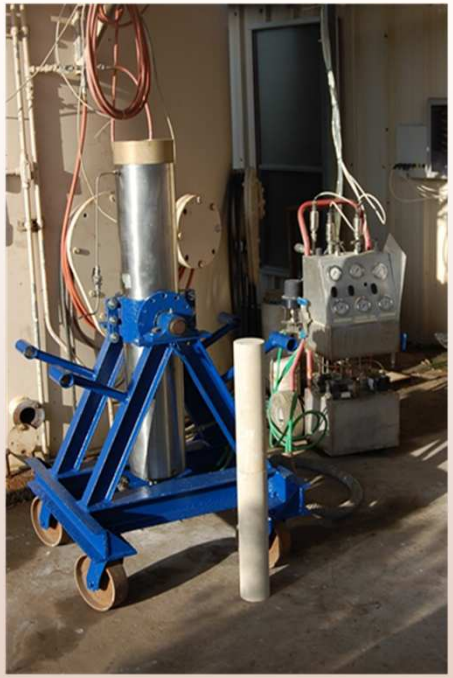
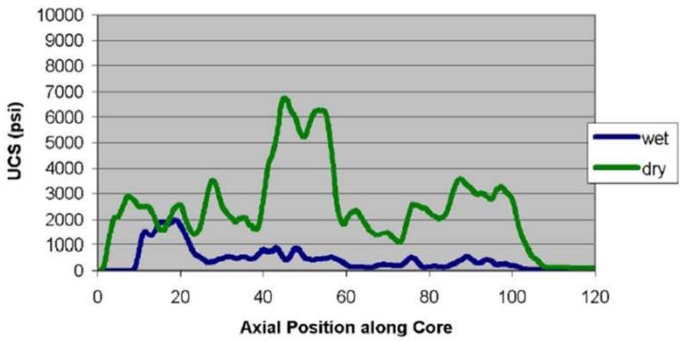
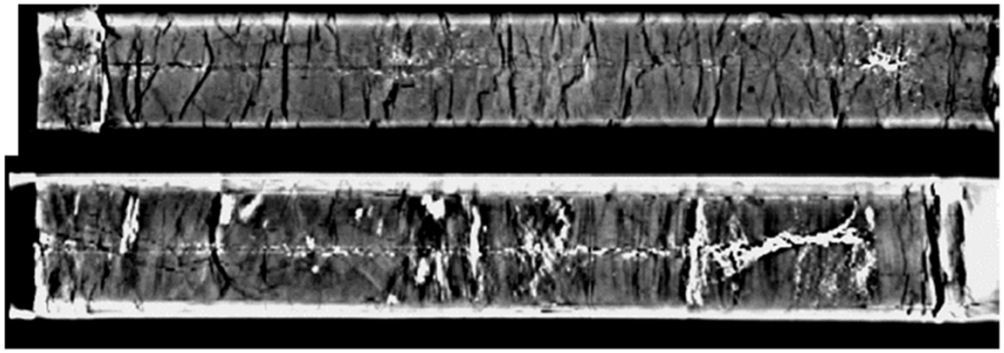


Wellcore Penetration Example #2

Coal – shallow, weak, naturally fractured

- Driver: fill gap in industry knowledge re: coal perforating fundamentals
- Obtain coal cores; map UCS profiles; stress to DH conditions, perforate
- SPE 102309





Wellcore Penetration Example #3+

Carbonates – moderate & high strength

- Evaluate candidate perforating strategies
- Confirm model predictions
- Various - unpublished

B. Wellcore Penetration, Cleanup, Inflow Performance

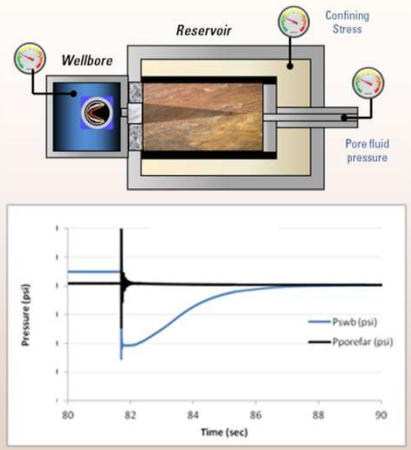
Example

- Moderate strength sandstone
- Offshore environment
- Assess penetration, cleanup, inflow performance by current and alternate perforating techniques

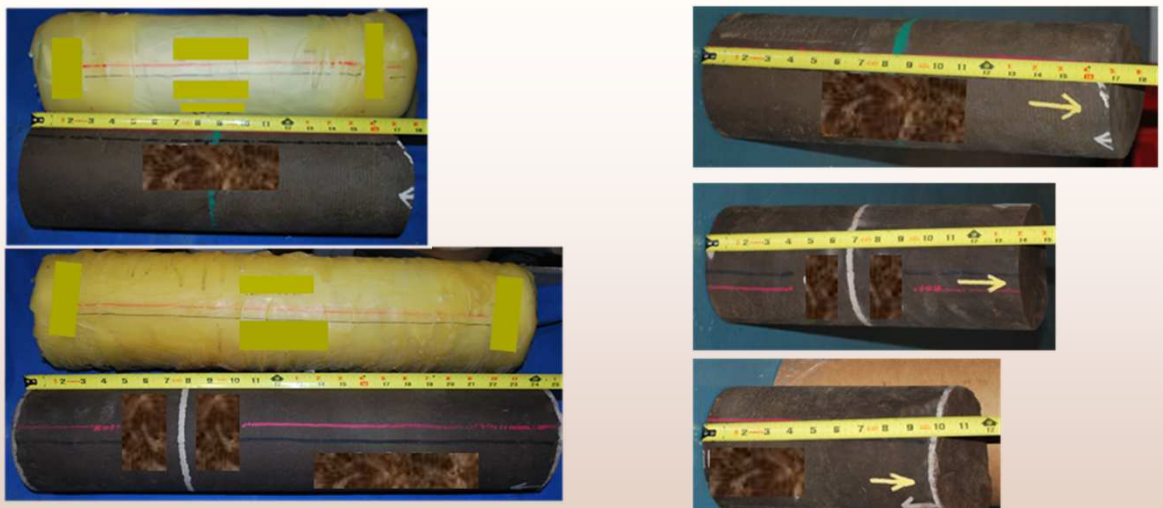
Wellcore Penetration, Cleanup, Inflow Performance

Overview (1/2)

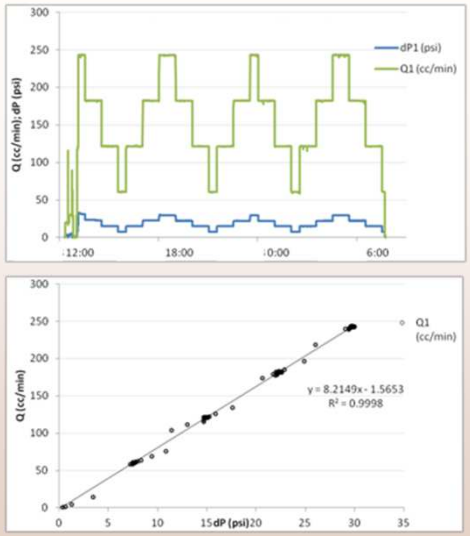
- Obtain wellcore; prepare, clean
- Assemble into test cell; establish initial permeability
- Perforate at field conditions (static & dynamic)
- Assess flow performance



Perforate



Prepare

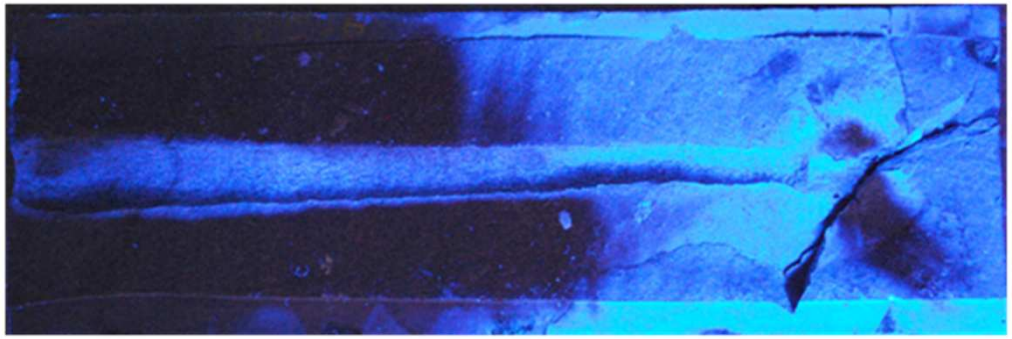


Flow

Wellcore Penetration, Cleanup, Inflow Performance

Overview (2/2)

- Obtain wellcore; prepare, clean
- Assemble into test cell; establish initial permeability
- Perforate at field conditions (static AND dynamic)
- Assess flow performance
- Establish penetration performance & flowfield



C. Tunnel Stability & Sanding Propensity Using Reservoir Wellcore

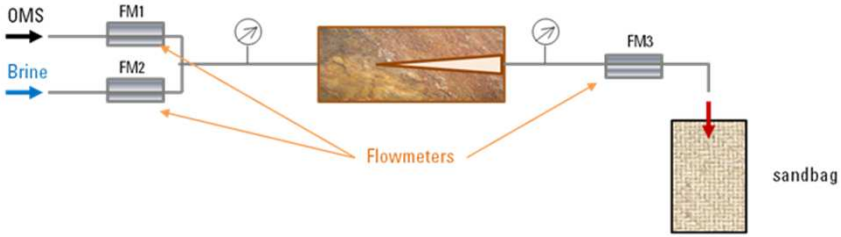
2 examples

1. Deepwater, offshore asset – oil producer
2. Deepwater, offshore asset – high rate gas producer

Wellcore: Tunnel Stability & Sanding #1

Deepwater offshore – oil producer

- Driver: assess whether C&P is feasible completion strategy
  - Is mechanical sand control required, or perf for sand prevention OK?
  - SC “insurance” can be expensive, esp. if well performance is compromised
  - What about later in well’s life: depletion stress, watercut?
  - Minimal sand production might be acceptable, if within facilities constraints
- Perforate wellcores @ DH conditions, flow, stress, watercut
- Also, drilled hole tests
- Test results + modeling + interpretation → field recommendation

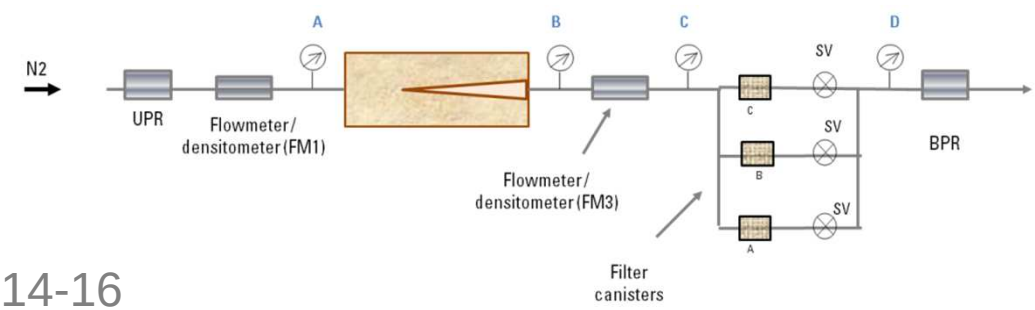


Wellcore: Tunnel Stability & Sanding #2

Deepwater offshore – high rate gas producer

- Driver: Assess whether C&P is feasible completion strategy
  - Goal = reliable, low skin completion for life of well
  - Goal = zero sand tolerance
- Perforate wellcores @ DH conditions (gas in pores)
  - high-rate flow (gas) *
  - increase rate & stress to simulate depletion
  - Collect any sand produced in fine mesh filters
- Test results + modeling + interpretation → field recommendation

* *Scaling lab rates ← → field rates critical; taking into account reservoir P, T (incl. at depletion)*



Summary

- Perforating Flow Laboratory entering 7th decade
- Reservoir wellcores can
  - be a useful part of a perforating laboratory program
  - provide guidance on completion strategy, in ways outcrop cannot
  - be the best way to assess how the actual reservoir will respond (eg to depletion stress, watercut, etc.)
- It's ideal, though not absolutely necessary that cores are:
  - as large as possible
  - not yet slabbed
- Perforating / completion concerns should be considered early in reservoir's lifecycle, when cores are first taken
- Interpretation can be key to translating results to the field