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State of the Art in Open Hole Sand Control Completions: Advancements & Gaps

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Schlumberger

Society of Petroleum Engineers
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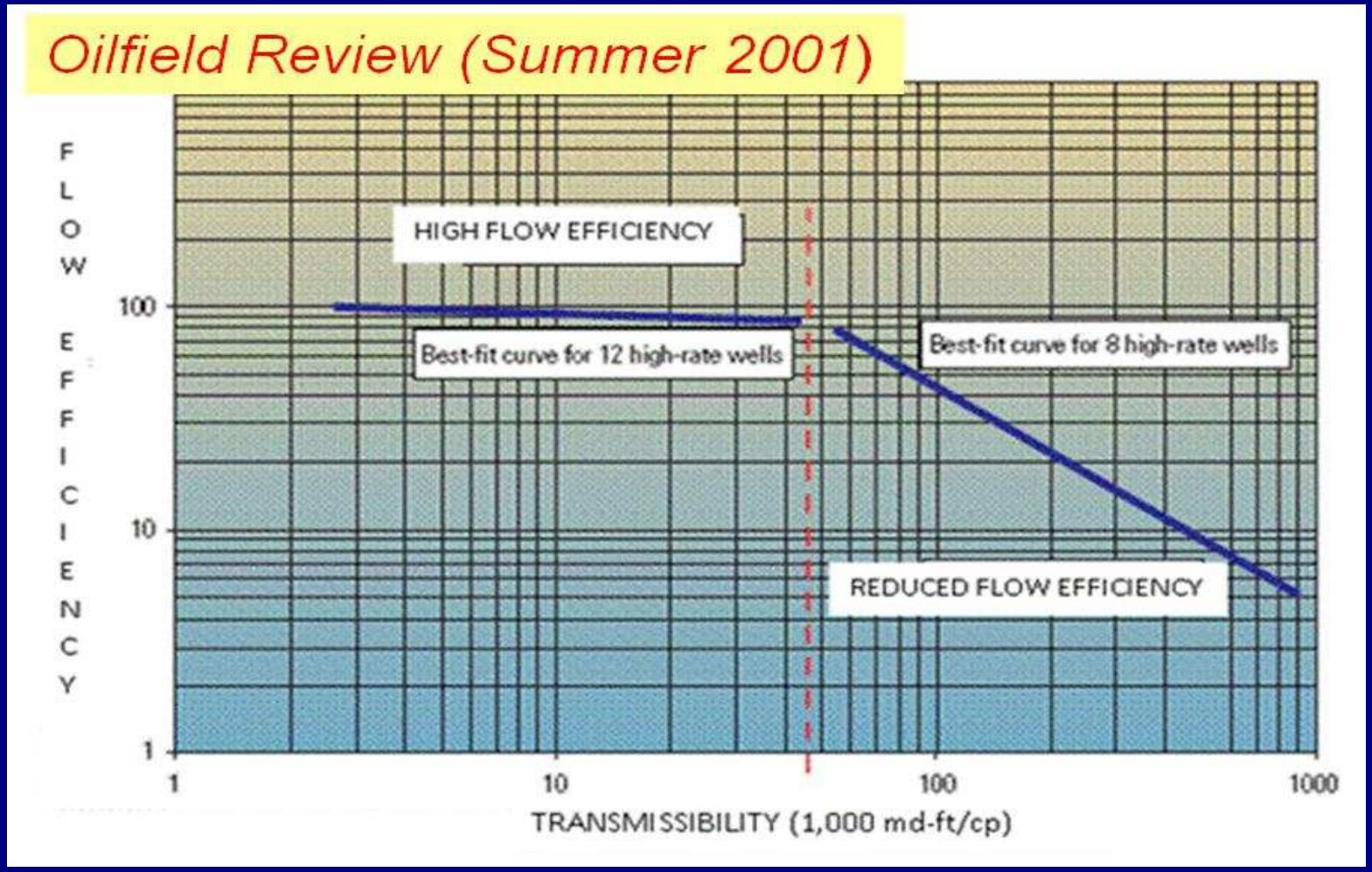
Outline

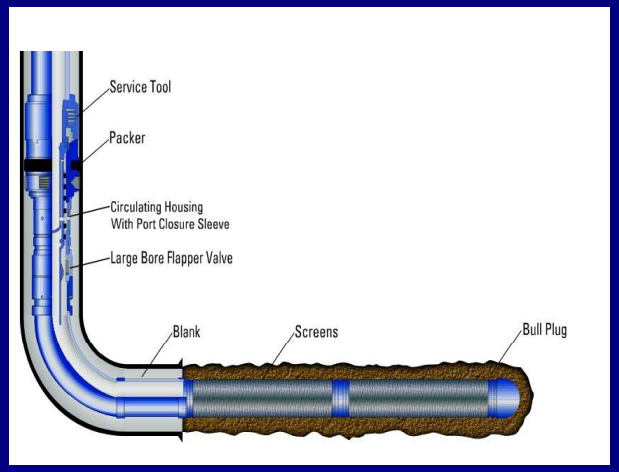
- Openhole Sand Control Techniques
- Technique Selection Criteria
- Past Challenges & Advancements in each
  - Open Hole Sand Control Technique along with
    - Inflow Control Devices
    - Zonal Isolation
    - Intelligent Completions
- Gaps
- Conclusions

Productivity Driver for Open Hole

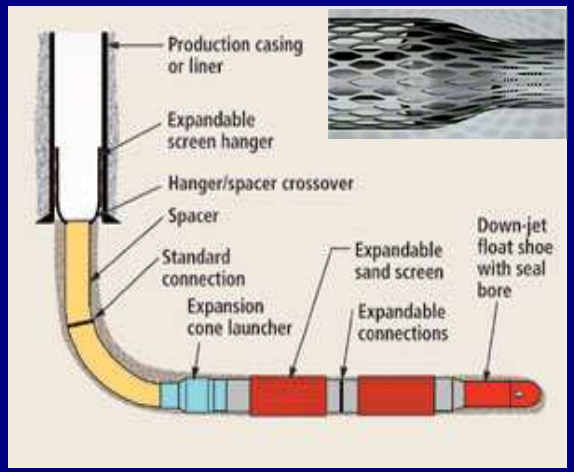


CASED HOLE FRAC-PACKS

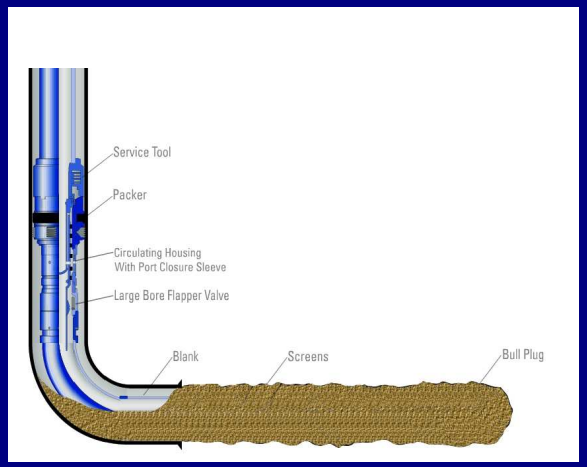
Open Hole Sand Control Techniques



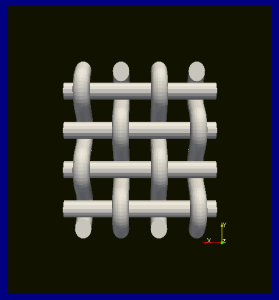
Stand Alone Screen
(SAS)
(WWS, Metal Mesh)



Expandable Screen
(ES)
(Compliant, non-Compliant)



Gravel Pack
(GP)
(α/β, Alternate Path,
α/α, β-only)

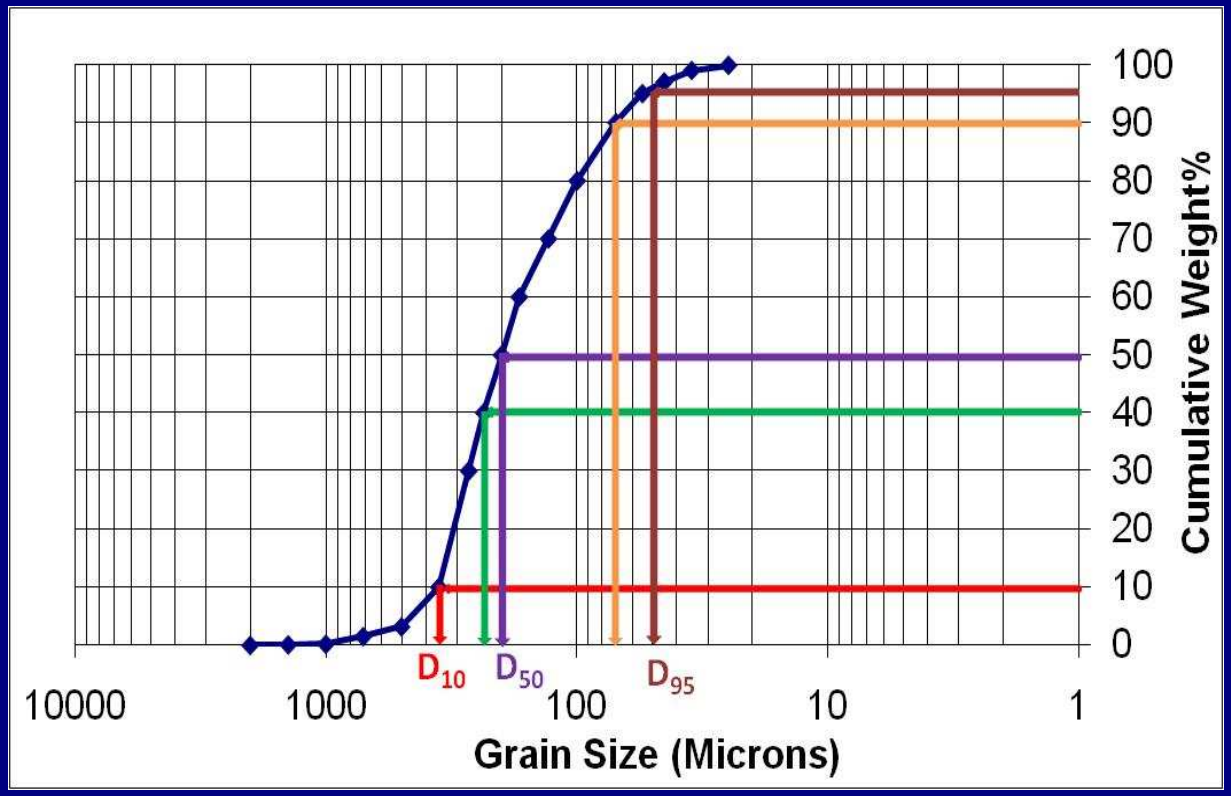


Open Hole Frac Pack?
(SPE 73757, 84416, 135441)

Selection Considerations

- Technical
  - PSD, rock strength, shale breaks & frequency, zonal isolation
  - Limitations of each technique
  - Laboratory testing
- Tolerance to solids production
  - Surface facilities, disposal, erosion
- Economics, Risk, Logistics
  - Total completion cost & cost of failure
- Comfort (Perceived Risk) Factor

Particle Size Distribution & Its Representation



D_{50} , C_U = D_{40}/D_{90} **, C_S** = D_{10}/D_{95} **,**

% Fines (< 44 μ)

Commonly Used Criteria

SPE 39437, Tiffin et al.

- **C_S** (= D_{10} / D_{95}) **< 10 ➔ SAS**
  - **C_U** (= D_{40} / D_{90}) < 3 **and Fines** < 2% ➔ WWS
  - 3 < **C_U** < 5 **and 2% < Fines** < 5% ➔ Mesh
- **C_S > 10** or **C_U > 5** or **Fines > 5% ➔ GP**

•Adapted by Price-Smith et al. (*SPE D&C, Sep. 2003)*

•Challenged by

- •Mathisen et al. citing field experience (*SPE 107539)*
- •Chanpura et al. thru lab evidence (*SPE 127931)*

Standalone Screens (SAS)

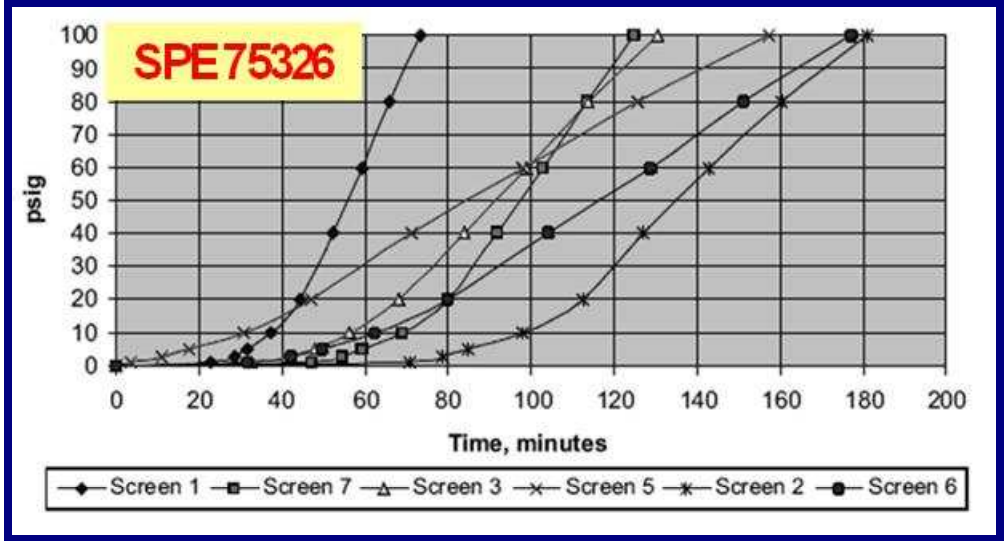
- Bad taste from early stages of learning curve
  - Screen plugging when screens installed in
    - not well-conditioned mud
    - well-conditioned mud but mixing of formation sand with mud (where sanding occurs on Day 1)
    - wells where no mud cake cleanup performed, with mixing of mudcake & formation sand (sanding occurs on Day 1)

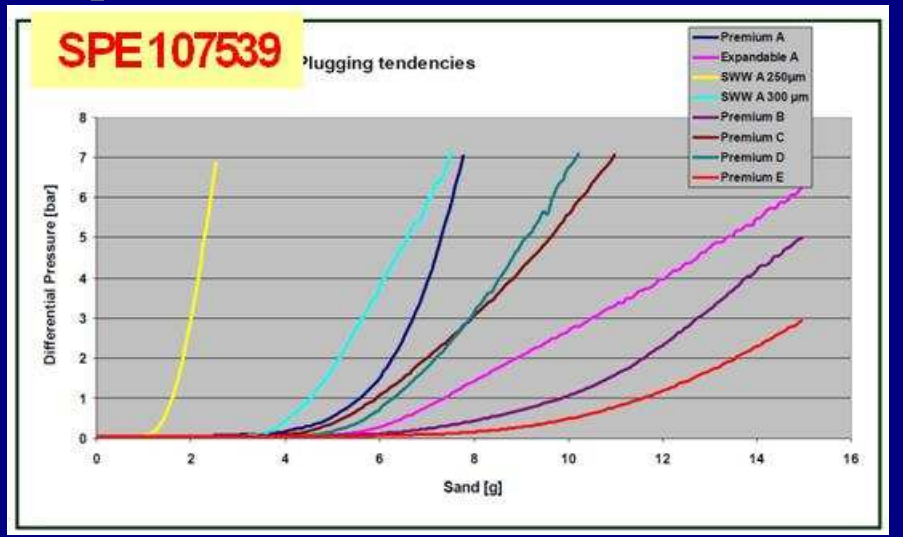
Screen Testing for SAS

	Slurry Tests	Prepack Tests
Simulates	Gradual failure	Hole collapse
Concentration	Low (<1%)	High (~ 50%)
Pack forms	During test	Start of test
Pumped at	Constant Q	Constant P

- Sand produced vs. Time *(or Sand Injected)*
  - Sand retention efficiency
- Pressure *(or Flow Rate)* vs. Time
  - "*Plugging*" tendency
- Size Distribution of Produced Solids
  - Erosion considerations

Drawbacks of Current Slurry Test Methods & Interpretation

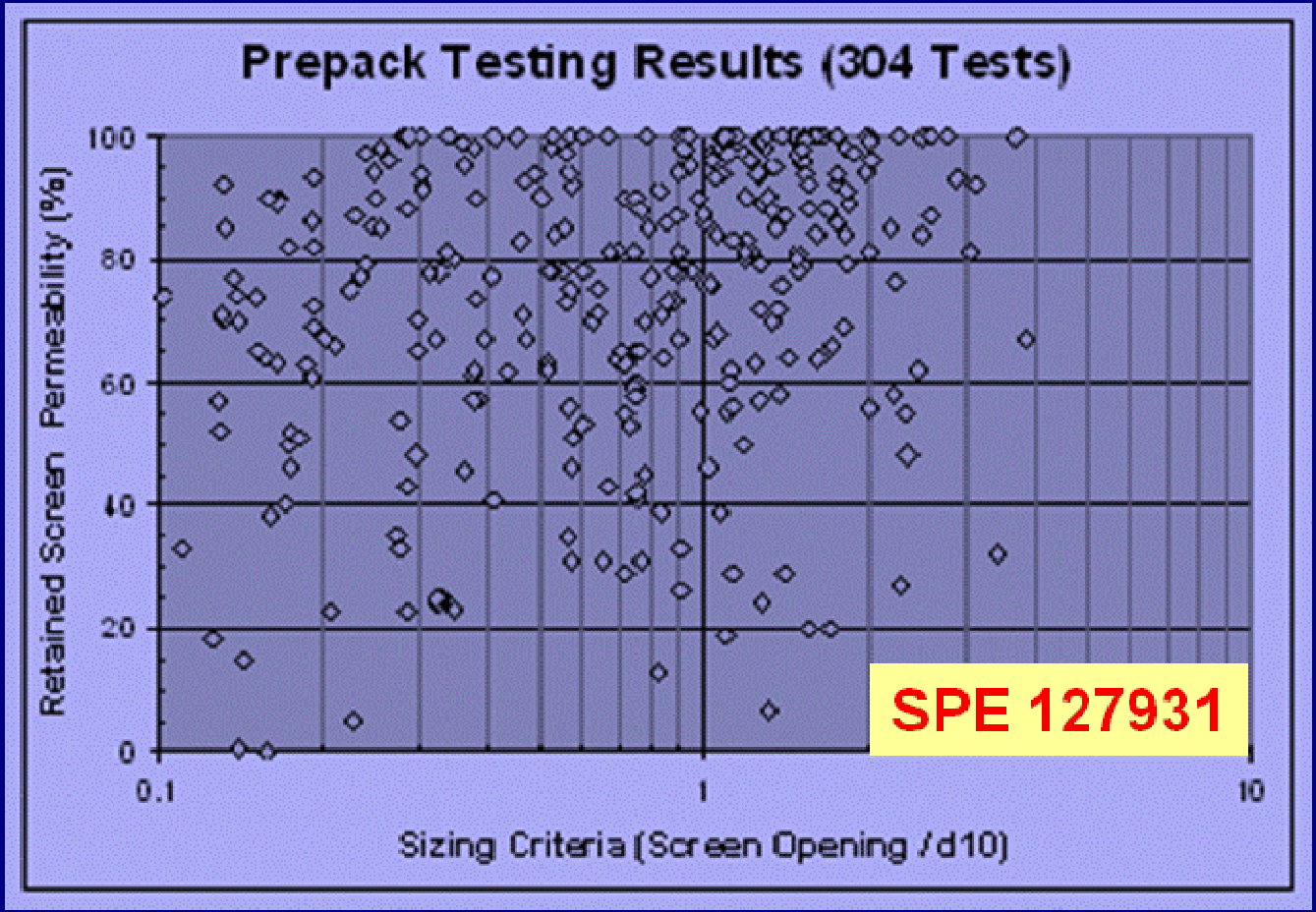




- Selection based on relative ranking, and even then NOT straight forward :
  - Tests stopped prematurely (100 psi limit)
    - Once sand production stops or stabilizes (true fines problem), slope should be independent of screen
  - Effects of open flow area, converging flow and Forchheimer flow effect
  - Flow rates ~ 1-2 orders of magnitude higher vs. Field
  - "Plugging" is OFTEN coverage of screen openings by sand.

Favors Mesh Screen vs. Wire Wrap Screen

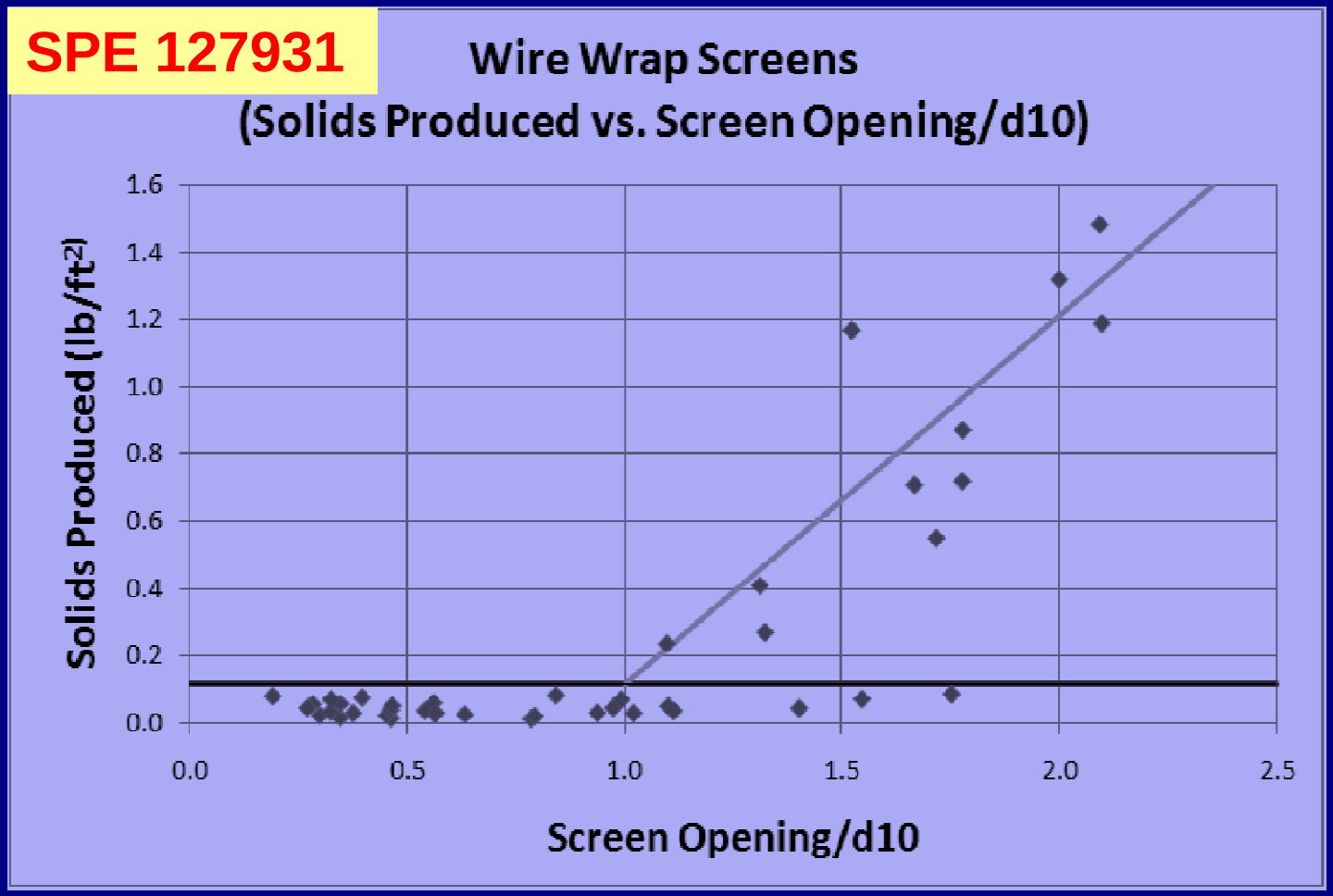
Plugging with Sand alone: Rare



Plugging due to mixing of sand with:

- Shales/Silts (annular isolation) or
- Mud/Mudcake (displacements/cleanup)

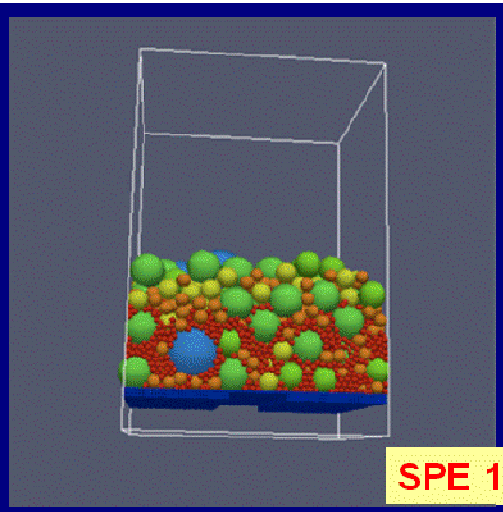
Current Criteria Too Conservative

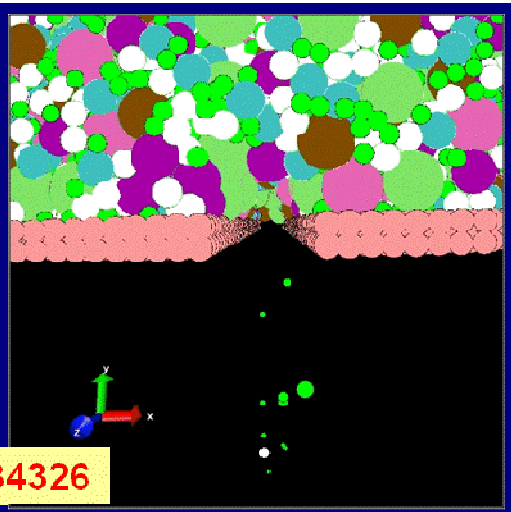


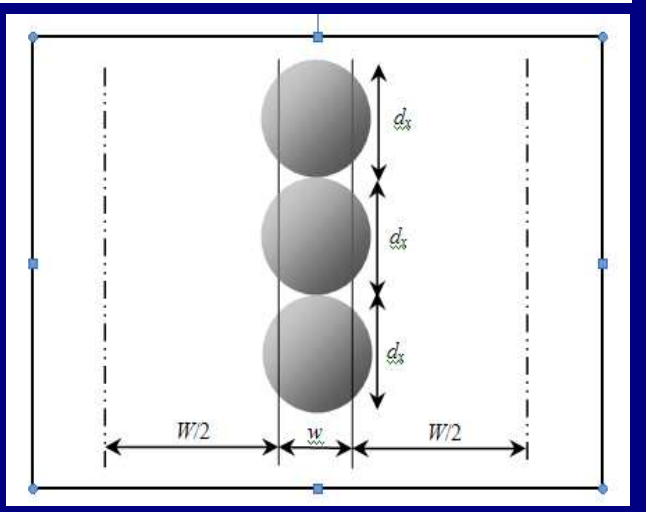
30 of 45 WWS (and 70 of 140 PMS) tests with U_C : 5 – 26 satisfied a very conservative sand retention criterion.

RECENT MODELING WORK

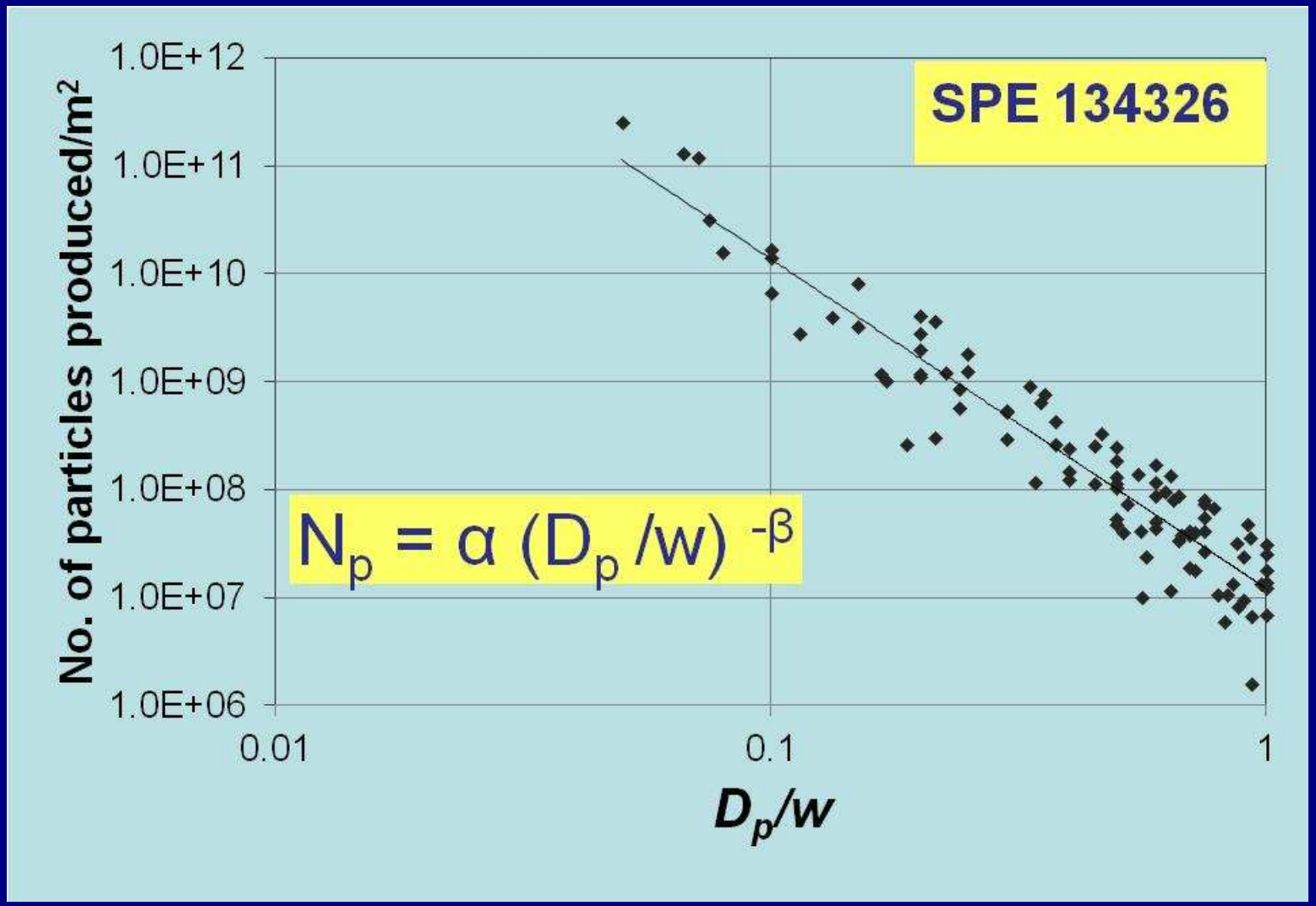
	PRE-PACK	SLURRY
SLOT GEOMETRY (Wire-Wrap Screen)	*SPE 134326*, Mondal et al. (2010)	*SPE 143728*, Chanpura et al. (2011)
MESH GEOMETRY (Metal Mesh/Premium)	*SPE 146656*, Mondal et al. (2011)	*SPE 151637*, Chanpura et al. (2012)





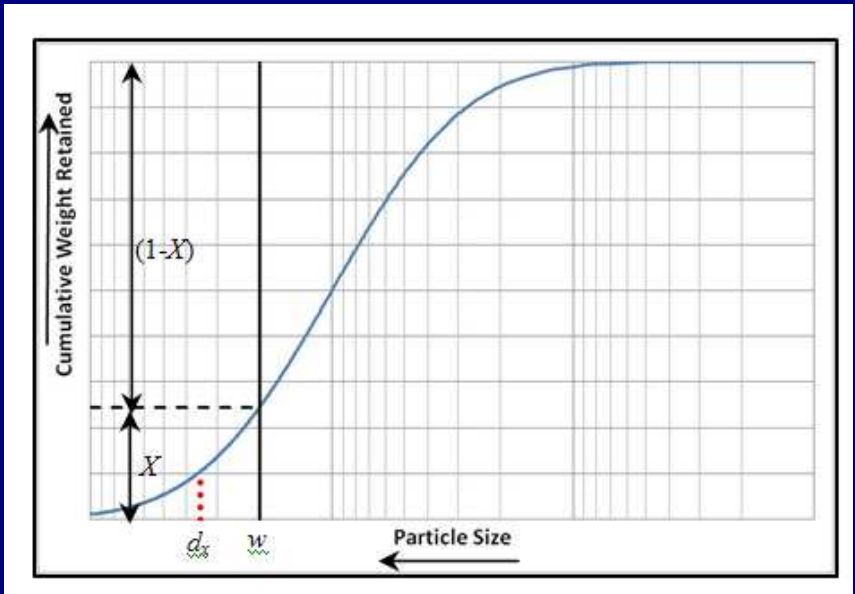


Prepack: Numerical Simulations



Slurry: Monte Carlo Simulations & Analytical Solutions

- Sand retention purely size exclusion
  - No bridging
- Given a slot opening and a PSD
  - Pick particles at random
  - Produce if smaller than slot and retain if bigger .
  - Determine sand production per unit area



$$M_{Prod} = \frac{\rho}{w}\frac{\pi}{6}\left[\left(\frac{1-X}{X}\right)d_x^2\right]\left(\frac{A_s}{A}\right)$$

$$d_x = \sqrt{\frac{X}{\sum_{i=1}^{n_b}\left(\frac{x_i}{d_i^2}\right)}}$$

Comparison to Experimental Results

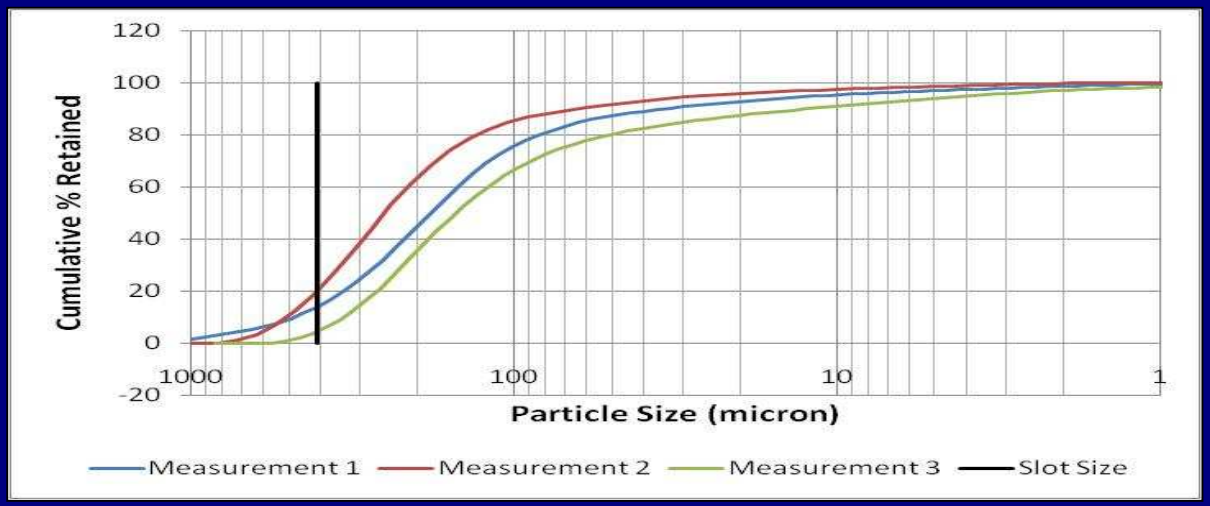
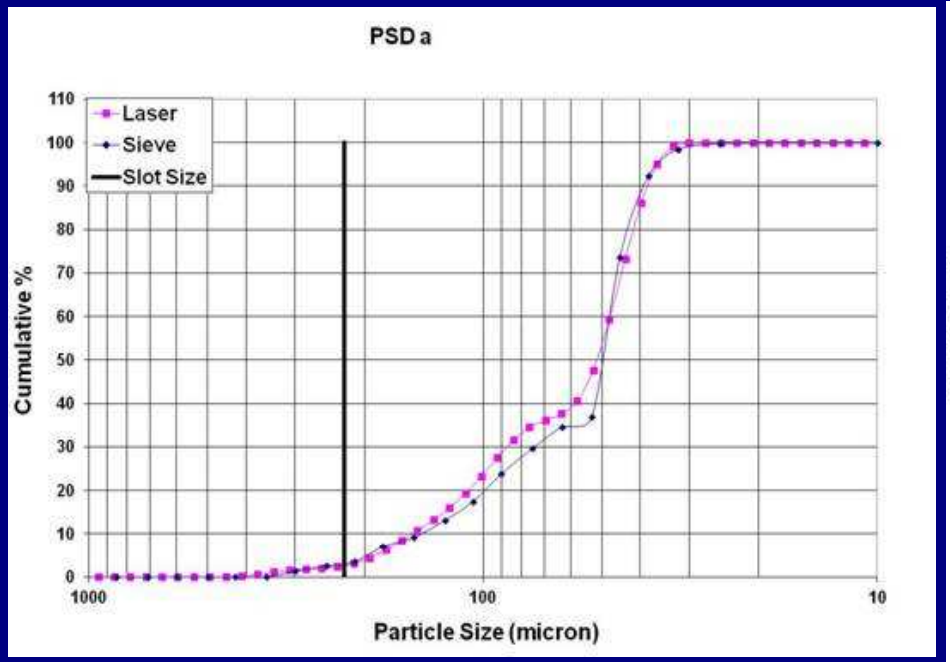
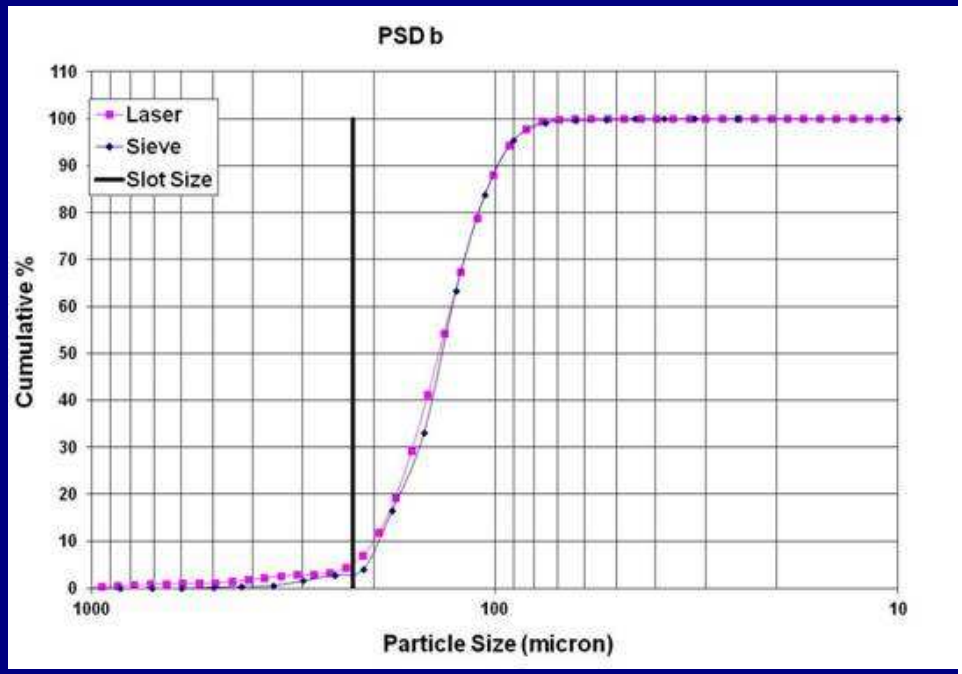


TABLE 4—COMPARISON OF SAND PRODUCTION FROM MONTE CARLO SIMULATIONS RESULTS WITH EXPERIMENTAL DATA

	MC Simulations (g/cm^2)	Data (g/cm^2)
Test1	0.0914	0.0919
Test2	0.0468	0.0907
Test3	0.2073	0.0754

Recent Experimental Data

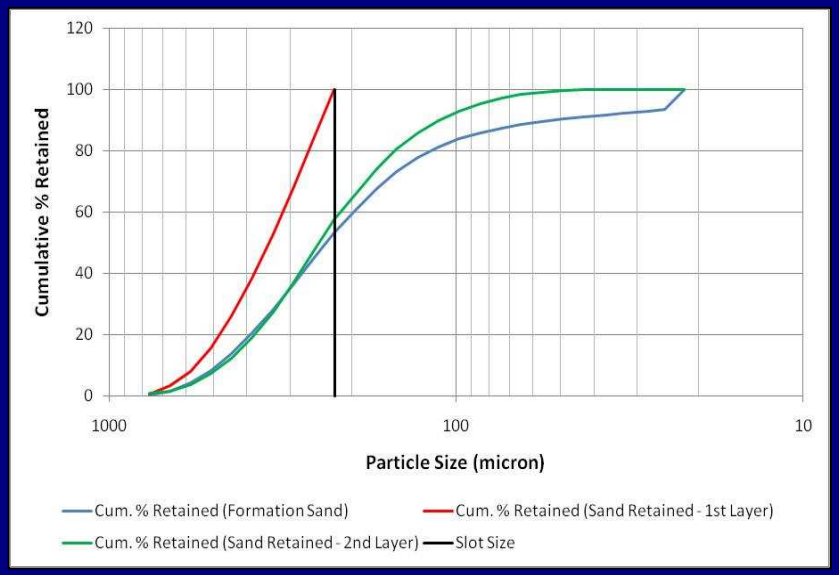




Sand Production In lb/ft^2	EXPERIMENT	MONTE CARLO	ANALYTICAL
PSD-a	0.40	0.42	0.43
PSD-b	0.26	0.26	0.26

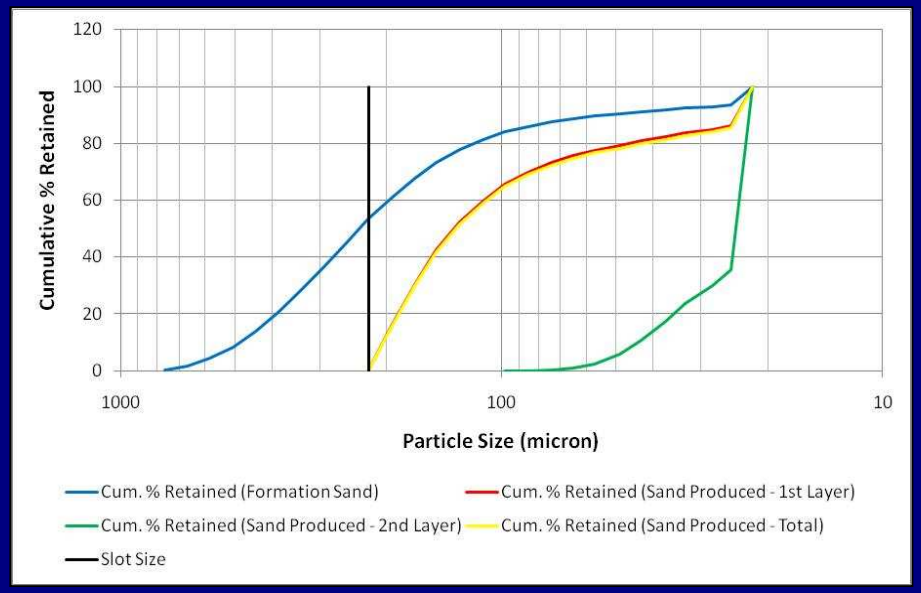
If accurate PSD ➔ MODEL IS PREDICTIVE

PSD of Retained & Produced Sand



Retained Sand

Produced Sand



Conclusions of SPE 143731

- Analytical & numerical solutions available now for prediction of slurry sand retention tests
  - Analytical solution gives > 90% of the answer because after the first layer of sand particles cover the slots sand production ~ stops and screen has NO FUNCTION.
- Conventional fines definition (<44 Microns) is IMMATERIAL to selection of screen.
- What matters is the COARSER portion of the PSD.

Expandable Screens

- Viewed as
  - Elegant alternative to gravel packing by some
    - simpler to install, and
    - up to a certain length lower cost than gravel pack
  - Expensive SAS by some others
    - Wellbore collapse at onset of hydrocarbon production
  - New technology by some others
- Had its successes & failures much like others
  - *SPE 97282*

Expandable Screens

- Technology evolved substantially to single trip installation with zonal isolation capability *(SPE 106342)*

- Compliant versus non-Compliant
  - How much of a gap is small enough?
  - Finding the right application for each?
    - Proper geomechanical work required.
      - Some of the failures associated with loss of sand control attributed to “localized collapse”

- Cased Hole Producers, especially in high transmissibility formations: Abuse of ESS technology

Open Hole is Forgiving

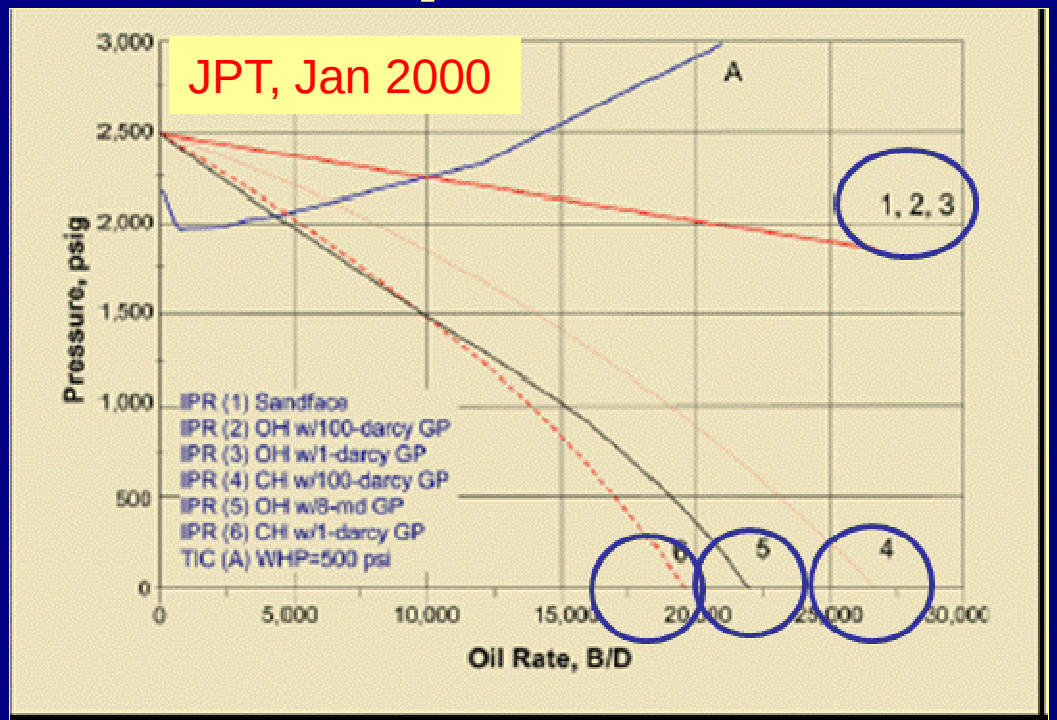


Fig. 2—Comparison of production rates from gravel-packed openhole and cased-hole completions. Open hole: 50-ft vertical interval, 1-darcy formation, 8.5-in. hole; cased hole: 12 shots/ft, 0.75-in. collapsed perforations. IPR=inflow performance relationship, TIC=tubing-intake curve, CH=cased hole, and GP=gravel pack.

Open Hole

2. 100 D
3. 1 D
5. 8 mD

Cased Hole

4. 100 D
6. 1 D

•SAS/ESS in Cased Hole NOT the best choice for "high rate producers".

Open Hole Gravel Pack (OHGP)

- Why would anyone go through additional pumping stage if Screen Only will do it?

  – Not every well is an SAS candidate
    - Frequent thin shale breaks (too many packers)
    - Zero tolerance to sand production

Challenge: No More

- Swabbing during tool movements
  - Filtercake liftoff & leakoff at start of circulation (*SPE 48976)*
  - Anti-Swab Tools *(SPE 74492)*
    - Hydraulic communication
- Post-Gravel Pack Filtercake Cleanup
  - Required Coiled Tubing
  - Tools with Post-GP Circulation capability *(SPE 50651*)

Challenge: No More

- Reactive Shales
  - Shale swelling and/or collapse before or after screen installation
    - *SPE 89815, 90758, 107297*
  - Shale dispersion in Carrier Fluid
    - *Pet. Eng. Int. (Mar. 1999)*

- Shale Stabilizers *(SPE D&C, 2008)*
  - Displacement and Carrier Fluids *(SPE 121834)*

Challenge: No More

- Reactive Shales- Contd.
  - Oil-Based Drilling
    - Oil-Based Gravel Packing
      - Viscous Packing *(SPE D&C, 2006)*
      - α/β Packing *(SPE D&C 2009)*
    - Water-Based Gravel Packing
      - Two-Trip *(SPE 48976, 73727, 89815, 90758)*
      - Single-Trip w/ Screens RIH in Oil Based Fluids
        - Conditioned OBM *(SPE 90758, 98146, 115434)*
        - Solids Free OBM in Open Hole & Brine in Cased Hole *(SPE 134319)*

Challenge: No More

- Narrow Operational Window (Fracturing)
  - Loss of circulation & premature screenout
  - Diverter Valves *(SPE 71668)*
    - World Record: 8,305 ft. in 2003 *(OTC 15281)*
  - Light Weight Gravel *(SPE 17169, 96257)*
  - Friction Reducer *(SPE D&C, Sep 2010)*
    - *These solutions can take α/β packs a long way!*
  - Alternate Path *(SPE 86532)*
    - *Transport/Packing Tubes, Nozzles, Concentric Entrance, Swell Packers*

Zonal Isolation

- Considered as the biggest disadvantage of open holes vs. cased holes
  - Hydraulically Inflated Packers
  - Hydro-Mechanically Set Packers *(SPE 77214)*
  - Swell Packers *(SPE 78312)*
  - Expandable Packers *(SPE 106342)*

Zonal Isolation

- Gravel Packing
  - Full isolation with complete pack still a matter of debate
  - Isolation packer set
    - After gravel packing *(SPE 77214)*
    - Before gravel packing *[SPE 146361, SPE 146803 (swell packers) ➔ Alternate Path]*

Inflow Profile Control

- Higher inflow near heel or high perm streaks
  - Premature water or gas breakthrough
  - Inflow Control Devices *(SPE 108700, Review)*
    - Channel Type *(SPE 78293)*
    - Nozzle Type *(OTC 19172)*
    - Hybrid Type *(OTC 19811)*
  - Many SAS Applications *(e.g., SPE 107539)*
  - 1 documented OHGP *(SPE D&C, Mar 2008)*
    - Non-ICD screen at toe
    - Some 2 trip installations
    - Ongoing developments

Inflow Profile Control

- Ability to adjust flow, including shut-off
  - Active Inflow Control Devices *(IPTC 12145, Comparison of Active vs Passive)*
  - Many applications to date injectors & producers
    - Some limitations for active flow control devices
      - Control lines
    - Open hole applications limited to ~ 2 compartments in cases when another tubing is run inside screen
    - Alternatively, sliding sleeve type solutions exist
      - Require intervention (e.g., CT run)

Intelligent Completions

- Real time measurements along sandface
  - Fiber Optic
    - Distributed Temperature Sensor
    - Pressure Gauge
    - Distributed Vibration Sensor
- Communication of Power & Data
  - Between upper & lower completion in subsea completions *(SPE D&C, June 2010)*
- Active Flow Control along sandface

Gaps

- Selection guidelines based on solid grounds
  - SAS (WWS vs PMS) vs ESS vs OHGP
  - Not only insufficient information sharing, particularly of failures, but also lack of thorough understanding why.
- Predictive models for sand production through sand control screens
  - Good results for laboratory environments, but even that part is not yet complete (accuracy of PSD measurements: Sieve, Laser ??)
  - What do these really say about field scenario?

Gaps

- Laser vs Sieve for PSD
- Particle Size Distribution Log
  - Ongoing work in various companies
- Impact of bean up (ramp up) procedures
  - How, under what conditions, why?
- Real time data during installation & execution
- Sandface measurements combined with active flow control

Conclusions

- Significant advancements made in the last decade
  - Retention by SAS being better understood & limits are deservingly being pushed
  - ESS has come a long way to single trip installation with zonal isolation
  - Many OHGP challenges overcome, wells longer than most of us interested in drilling can now be gravel packed (α/β, APS)
  - Zonal isolation, ICDs, intelligent completions
- Although some gaps do exist

Thank you for your attention.
Questions ?

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