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# Reversible Invert Fluid Enhances OpenHole Completions



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# Reversible Emulsion Technology

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## **Definition:**

**An invert emulsion Reservoir Drill-In Fluid (RDF) system that utilizes a unique emulsifier package to enable the wettability of the filtercake to change from an oil-wet condition to a water-wet state with only a simple chemical adjustment.**



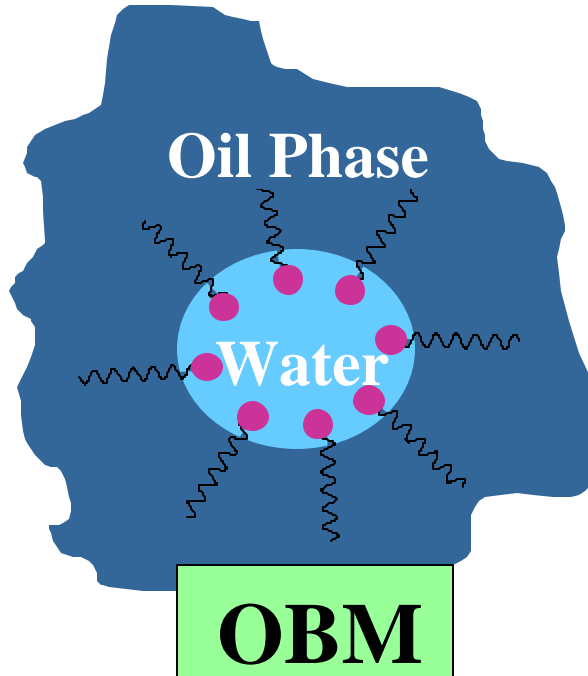
# More Definitions

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- “Flipping”** - Uncontrolled water wetting of solids in invert emulsion forming nasty greasy mess.  
May occur just prior to mud engineer being run off.  
May happen during water packing???
- “Reversal”** - Controlled chemical reaction that converts emulsifiers into water wetting surfactant during a completion operation.  
Enhances completion efficiency by readily destroying filtercake integrity and permitting dissolution of acid soluble bridging agents



# Reversible Emulsion Technology



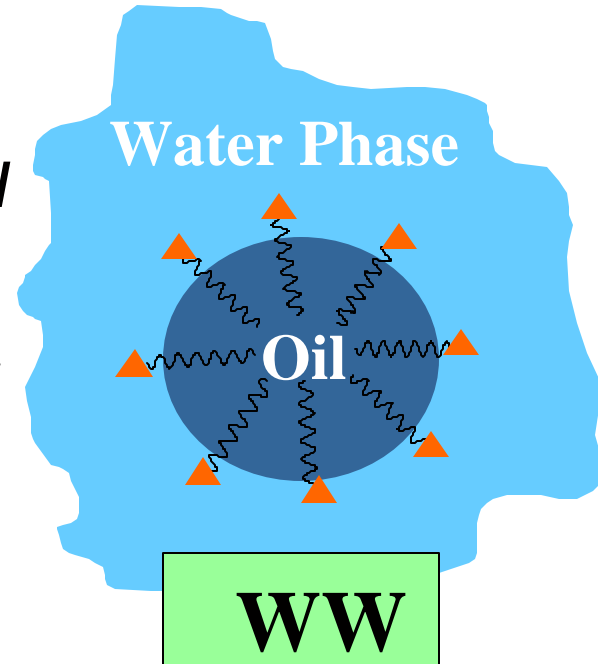
**OBM**

**Oil External Phase**

**Oil wet solids & surfaces**

**Desirable for Drilling**

*Low pH*  
→  
←  
*High pH*



**WB**

**Water External Phase**

**Water wet solids & surfaces**

**Desirable for Completions**



# Reversible Applications

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- **Where productivity/injectivity is poor due to inefficient clean up of conventional oil or water base mud filter cake.**
- **Where drilling problems e.g. shale stability, torque & drag, ROP are encountered with a water base RDF.**
- **Injection wells where no flow back for clean up is desired. (Even where it is)**
- **Carbonate reservoirs that must be drilled with Invert and must be stimulated.**



# Reversible Applications

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- **Reservoir Drill-In Fluid**
- **Open hole completion operations**
  - **Production & Injection wells**
  - **Stand alone wire wrapped or premium screens**
  - **Gravel packs**
  - **Slotted/Perforated Liner**
  - **Expandable Screens**
  - **Barefoot**
- **Cased hole injectors?**



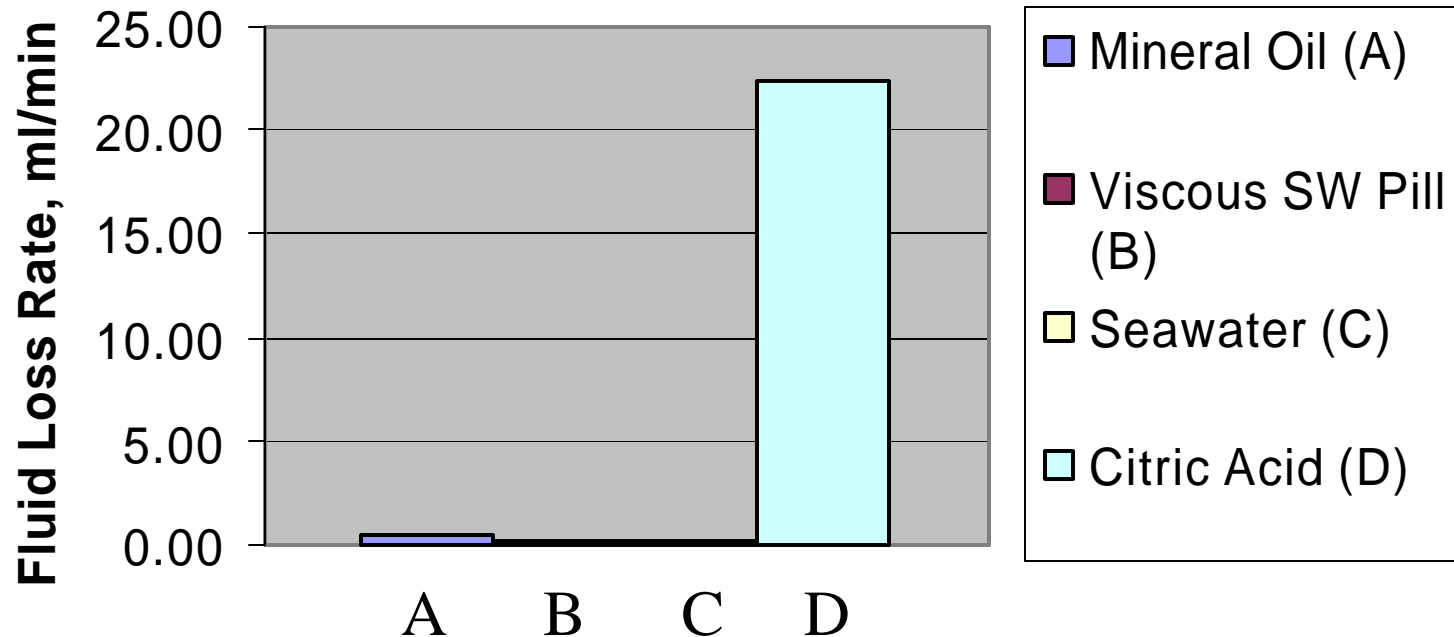
# Reversible Formulation

Component	Typical Concentrations
Base fluid (diesel, mineral oil, synthetic)	40 – 70% by vol.
Primary Emulsifier	8 – 12 ppb
Secondary Emulsifier	2 – 4 ppb
Organoclay	1 – 5 ppb
Polymeric fluid loss control additive (HT applications)	0 – 2 ppb
Internal phase (CaCl <sub>2</sub> , NaCl, NaBr, CaBr <sub>2</sub> )	30 – 60% by vol.
Lime	5 – 9 ppb
Sized bridging agents	30 – 120 ppb
Barite	If required for high density applications

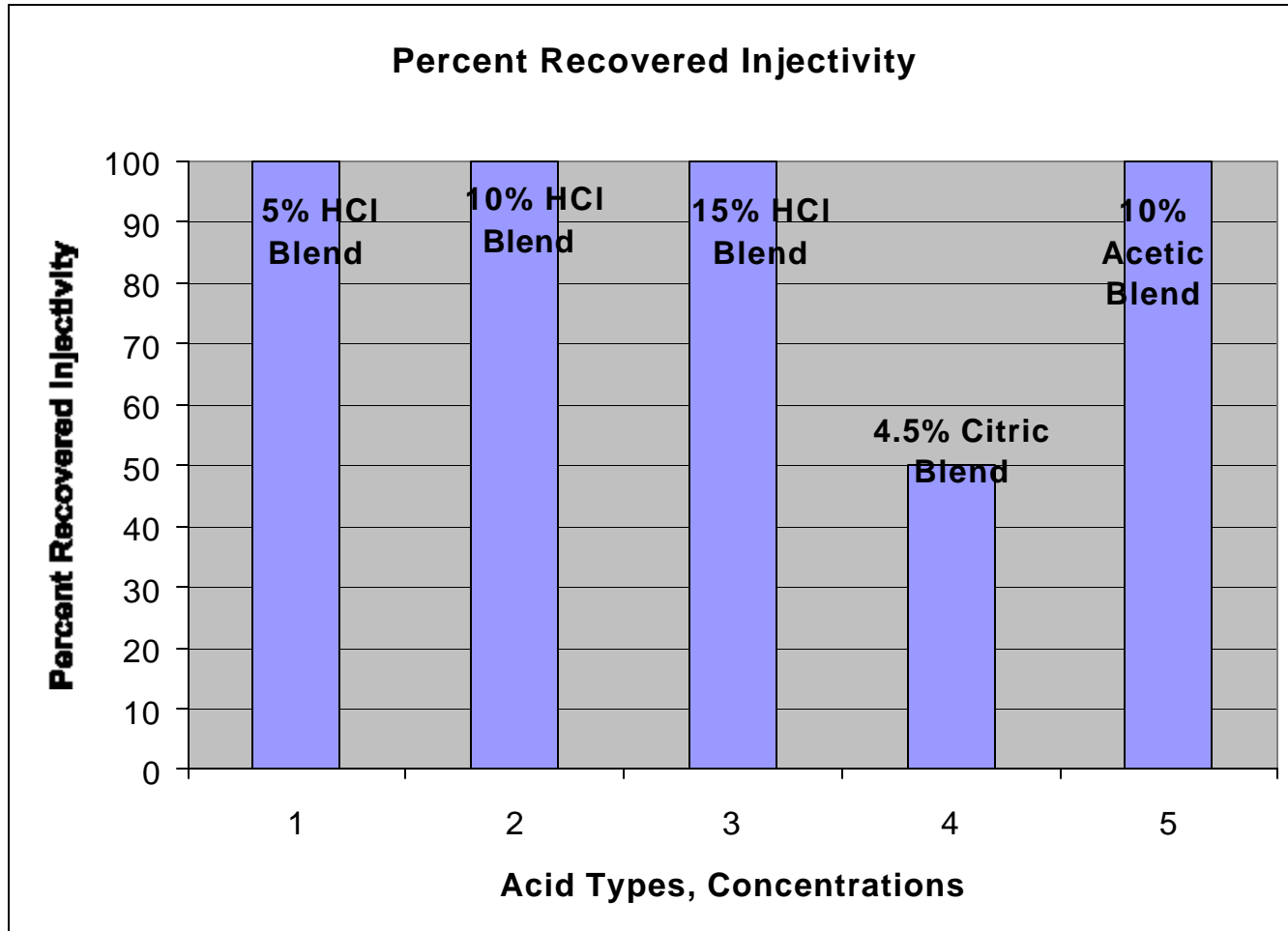


# Reversible Clean Up Filter Cake Stability

## Testing Filter Cake Breakthrough, Dynamic and Static

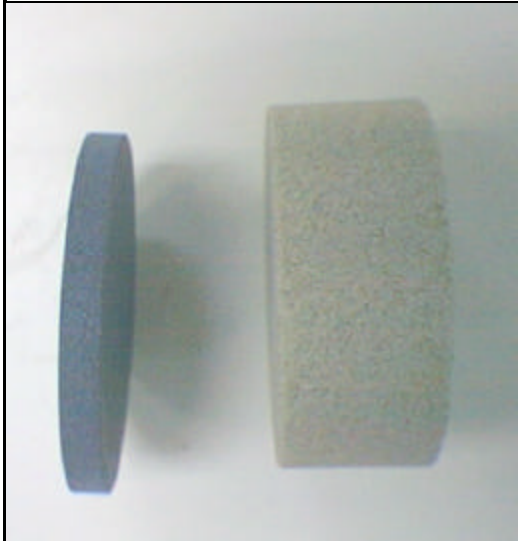
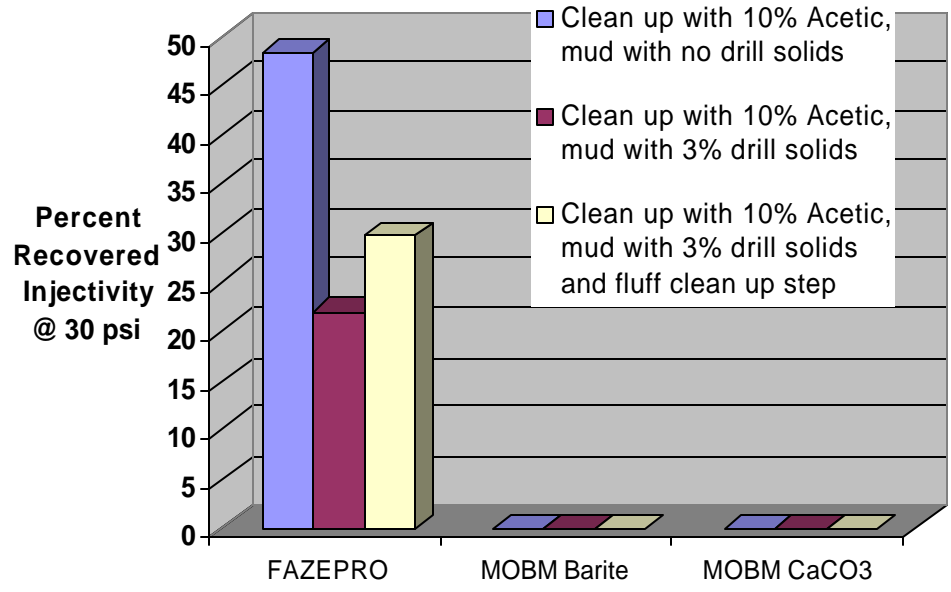


# Reversible - Acid Strength Comparision



# Filter Cake Clean-Up Testing Procedure: Non - Gravel Pack

Filter Cake Cleanup of 500 mD Berea



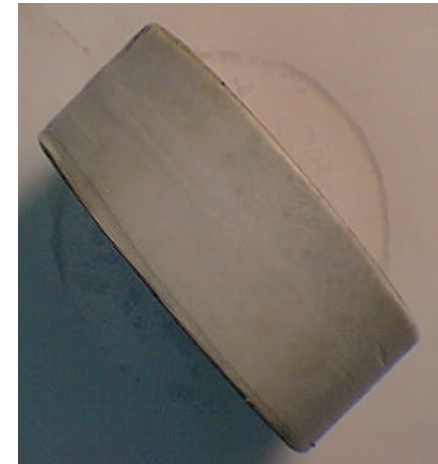
Work was performed on 1" Berea sandstone



# Reversible vs. Conventional Mineral Oil Acid Clean-up Evaluation



10% Acetic Acid  
1 hour soak @  
150°F & 200 psi



Conventional  
Mineral Oil  
Mud

**Reversible**



# Filter Cake Clean-Up Testing Procedure: Non - Gravel Pack

Pressure Drop Across Screen / Core  
*Flow Rate = 60 cc/minute*

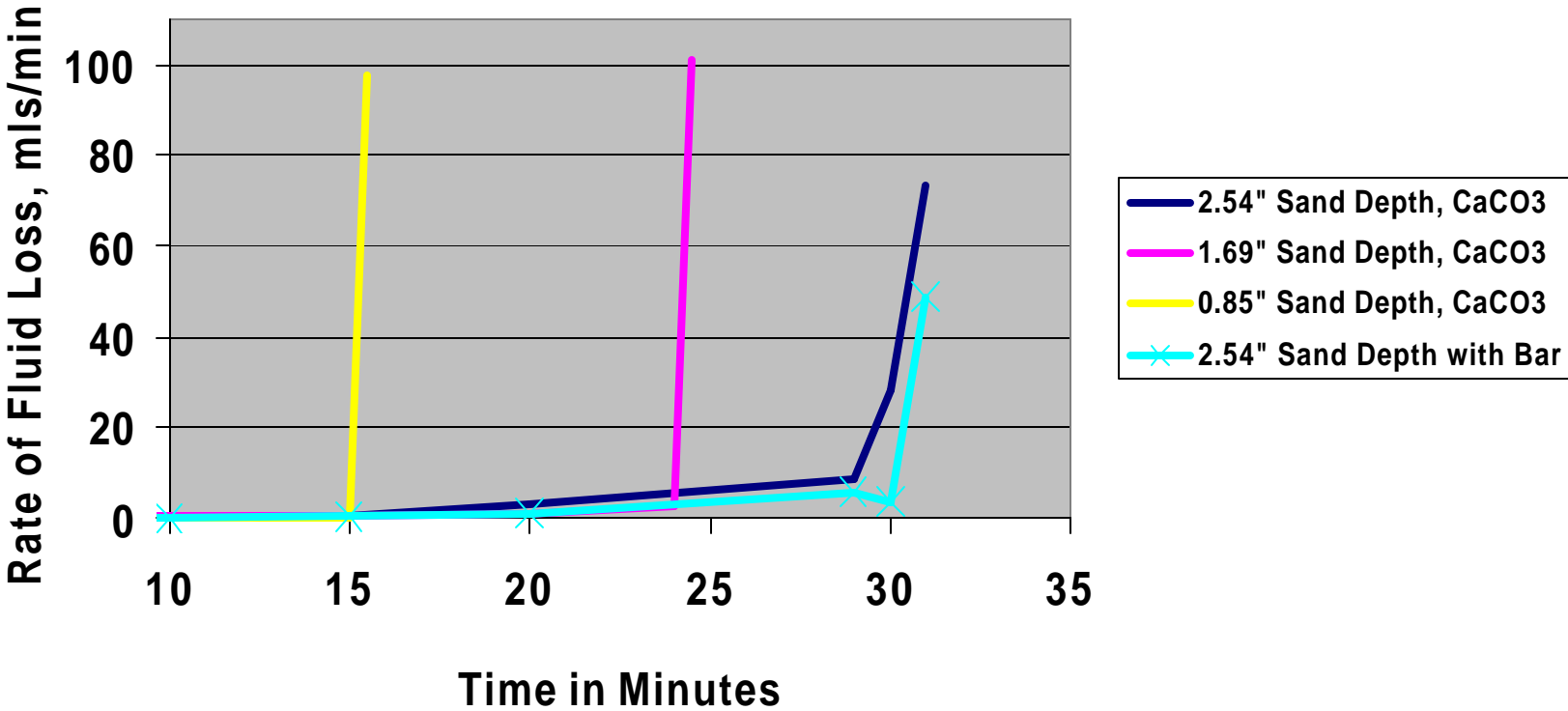
<b>FLUID TESTED</b>	Initial Pressure Drop Across Screen	Final Pressure Drop Across Screen
Conventional SBM	<b>0.1 psi</b>	<b>&gt;&gt; 300 psi</b>
Reversible	<b>0.1 psi</b>	<b>0.3 psi</b>
	Initial Pressure Drop Across Core	Final Pressure Drop Across Core
Conventional SBM	<b>2.30 psi</b>	<b>2.77 psi</b>
Reversible	<b>2.34 psi</b>	<b>2.85 psi</b>

**These results show that both fluids yielded similar core return permeability (82% - 83%), however; the Reversible filter cake did not damage the screen whereas the SBM filter cake plugged the screen.**



# Filter Cake Clean-Up Testing Results - Gravel Pack

## Reversible Filter Cake Clean Up Through 40/60 Gravel Pack



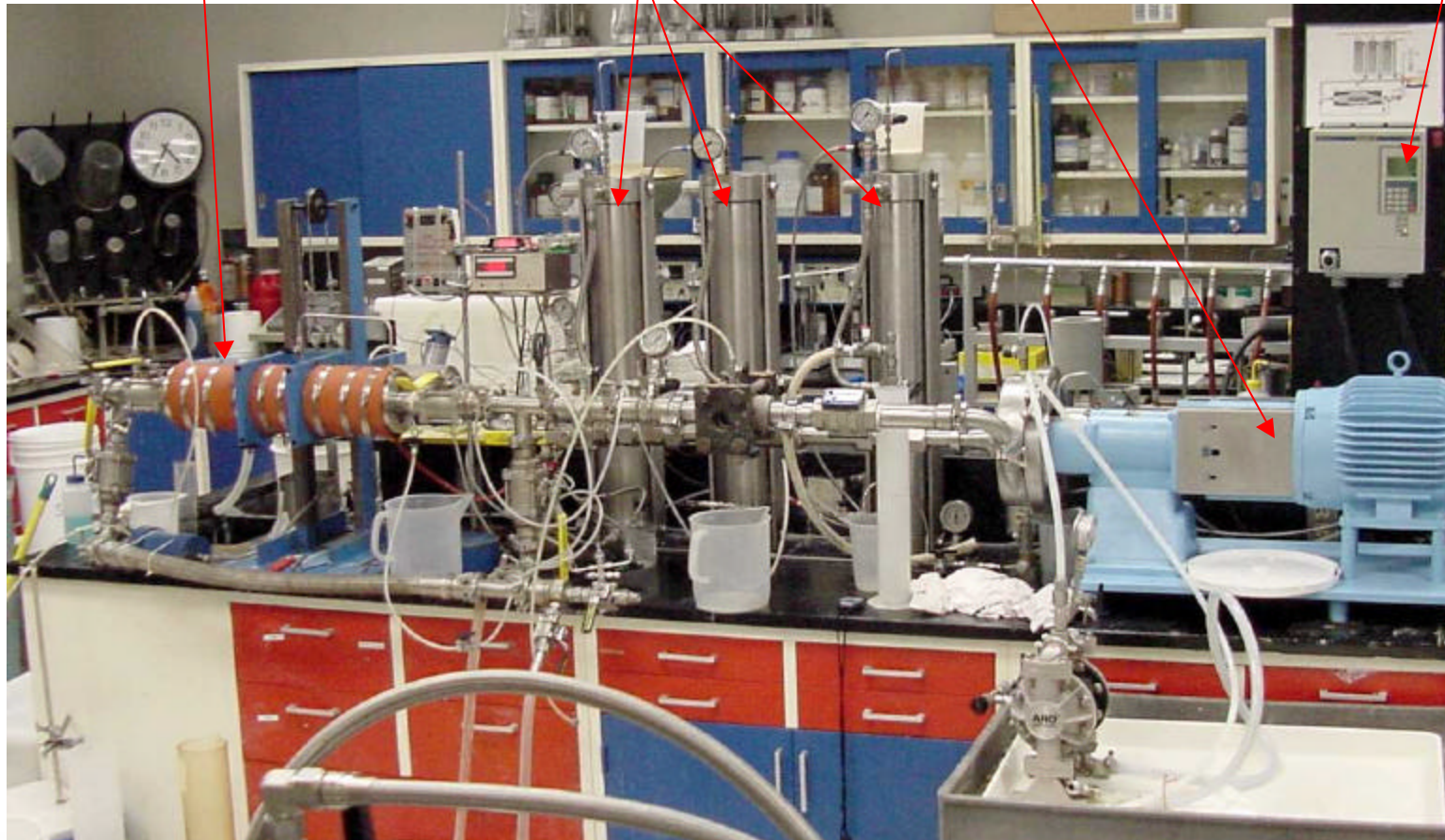
# Joint Operator Radial Flow Tests

Cell Chamber

Accumulators

High Volume Centrifugal Pump

Pump Control



# Joint Operator Radial Flow Tests Procedures

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- A 10.3 lb/gal MOBMs and Reversible w/ $\text{CaCO}_3$  and 35 lb/bbl Rev Dust.
- Initial injection flow-through was established with seawater.
- The RDF was then circulated for 2 hours at 150°F with an annular flow velocity of ~175 ft/min, under 500 psi differential pressure through 3" ID x 4 3/8" OD x 6" L aloxite (10 micron) core while monitoring leak-off.
- The cell was then shut-in for 18 hours under differential pressure and temperature.
- RDF was then circulated for one hour, to re-establish dynamic mud deposition prior to displacement steps.



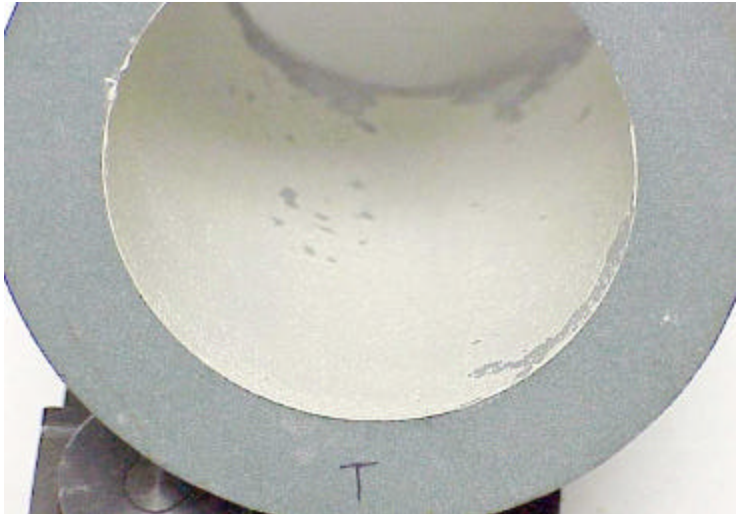
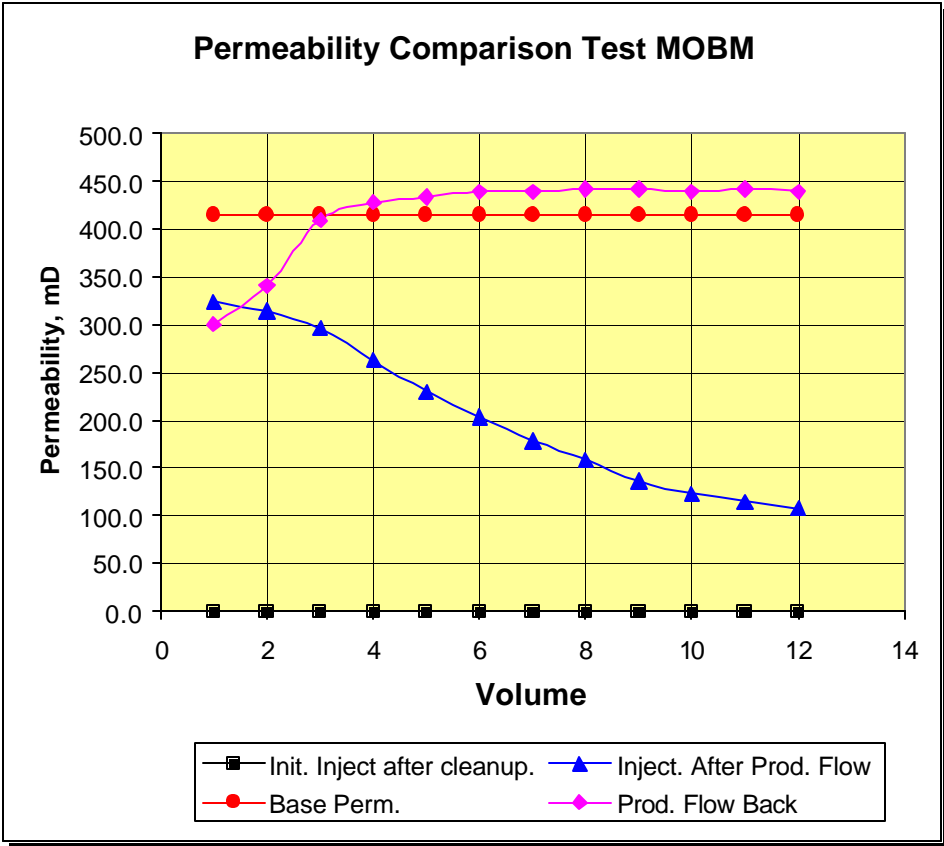
# Joint Operator Radial Flow Tests Procedures

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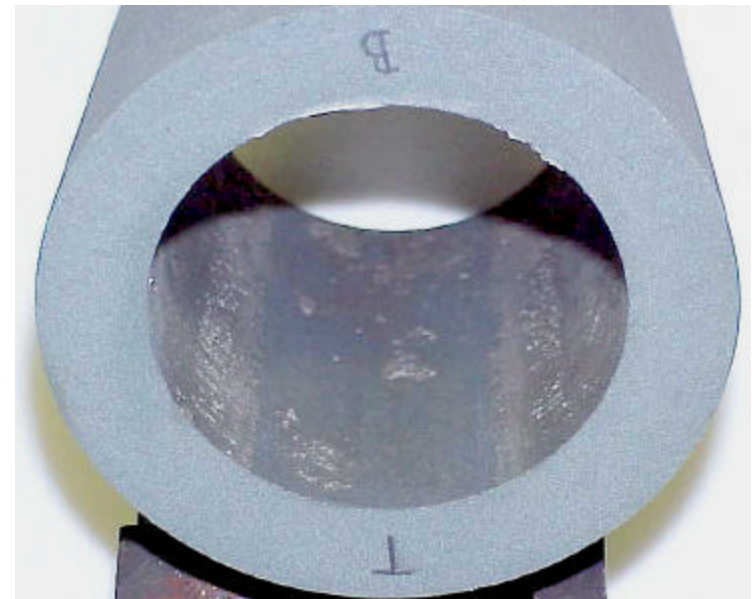
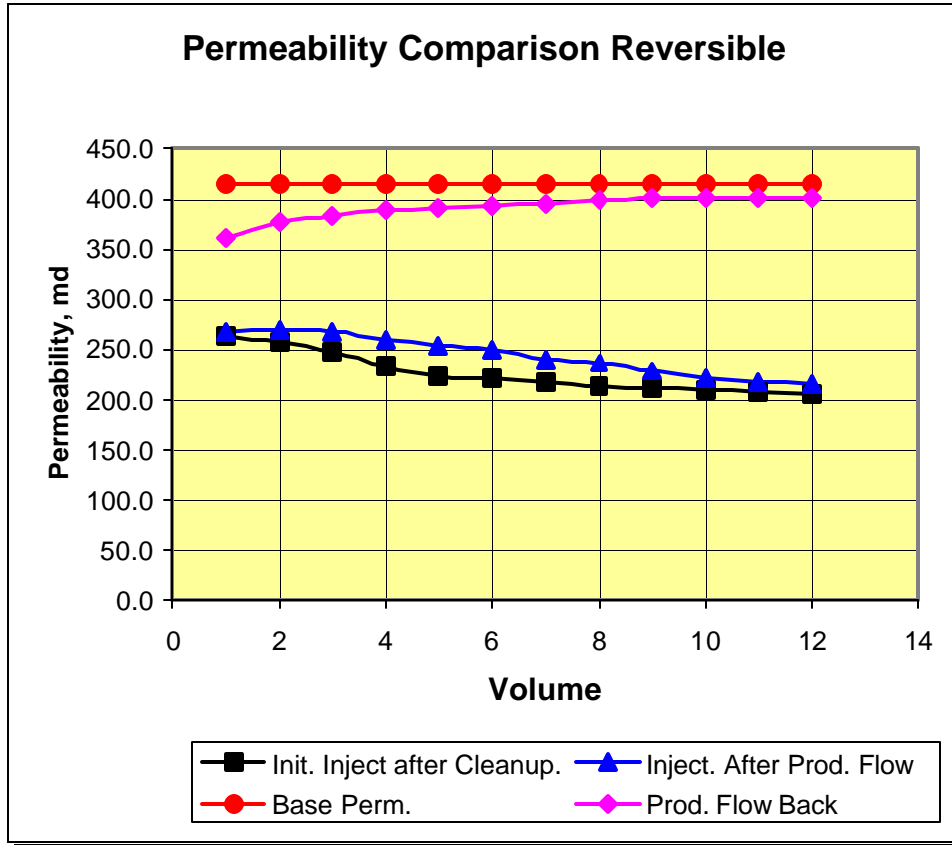
- The RDF was displaced to base oil at an annular velocity of ~300 ft/min for a total of 5 - 10 minutes.
- Base oil immediately followed by a solvent/surfactant clean-up system for 15 minutes at 300 ft/min.
- For the Reversible test, the solvent/surfactant was substituted by 10% acetic acid containing 5 vol% mutual solvent and 0.25 vol% corrosion inhibitor.
- Clean-up package soaked for 1 hour before a final injection to seawater was established.
- After injectivity results were obtained, seawater was produced-back through the core until production-direction permeability had stabilized.
- A second injectivity-permeability measurement was then obtained.



# Joint Operator Radial Flow Tests Results - MOBM



# Joint Operator Radial Flow Tests Results - Reversible



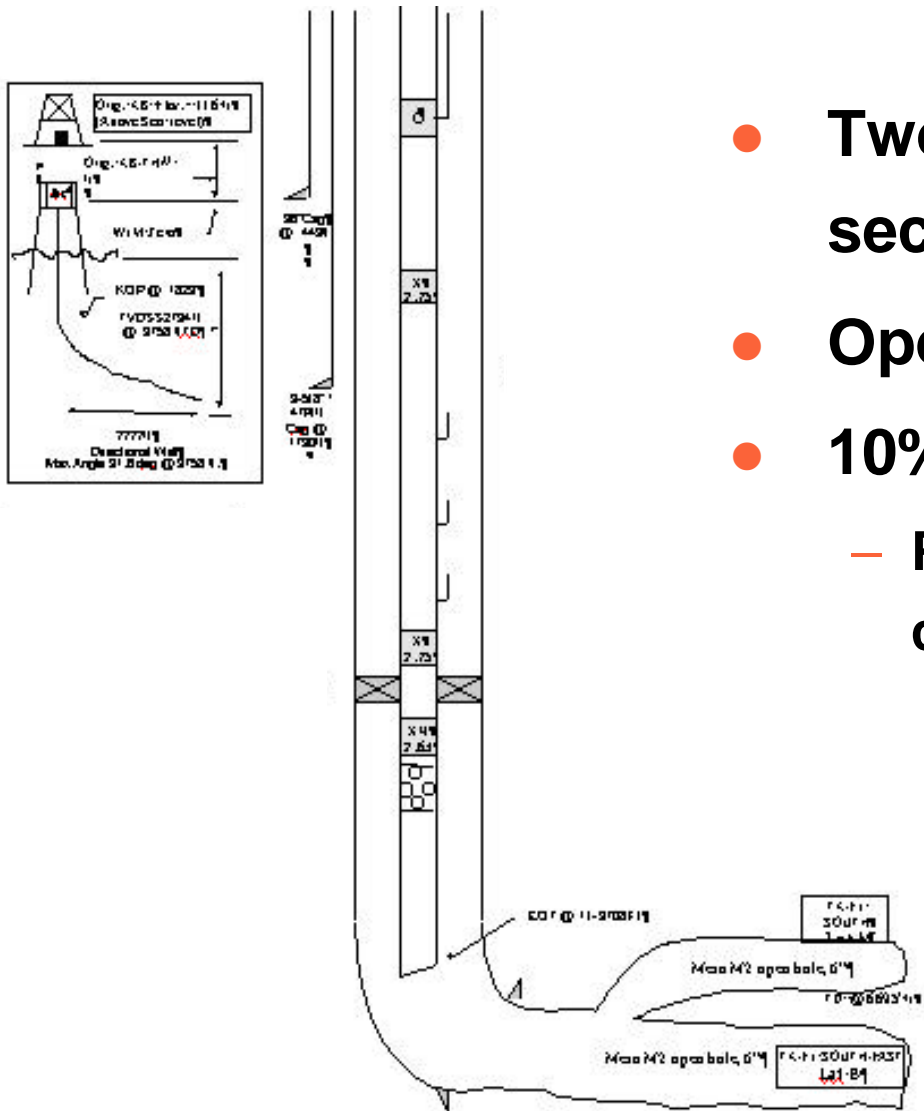
# Reversible Experience

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- ✓ **Open hole completions - 60**
- ✓ **Injectors – 36**
- ✓ **Producers - 24**
  
- ✓ **Barefoot - 42**
- ✓ **Pre-drilled liners – 1**
- ✓ **Expandable Screen - 1**
- ✓ **Stand-alone screen completions – 11**
- ✓ **Open hole Gravel Packs – 5**



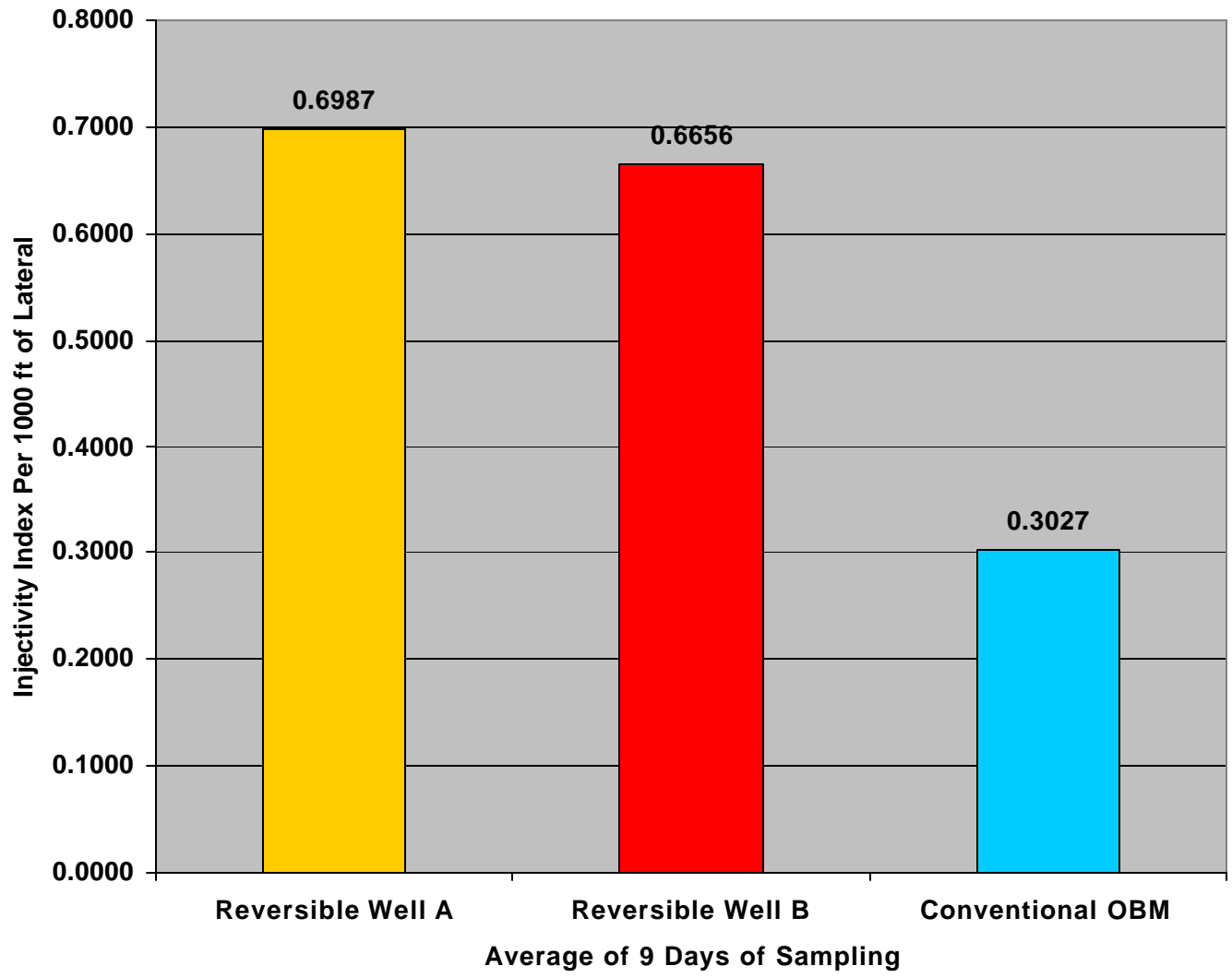
# Injector Well Details



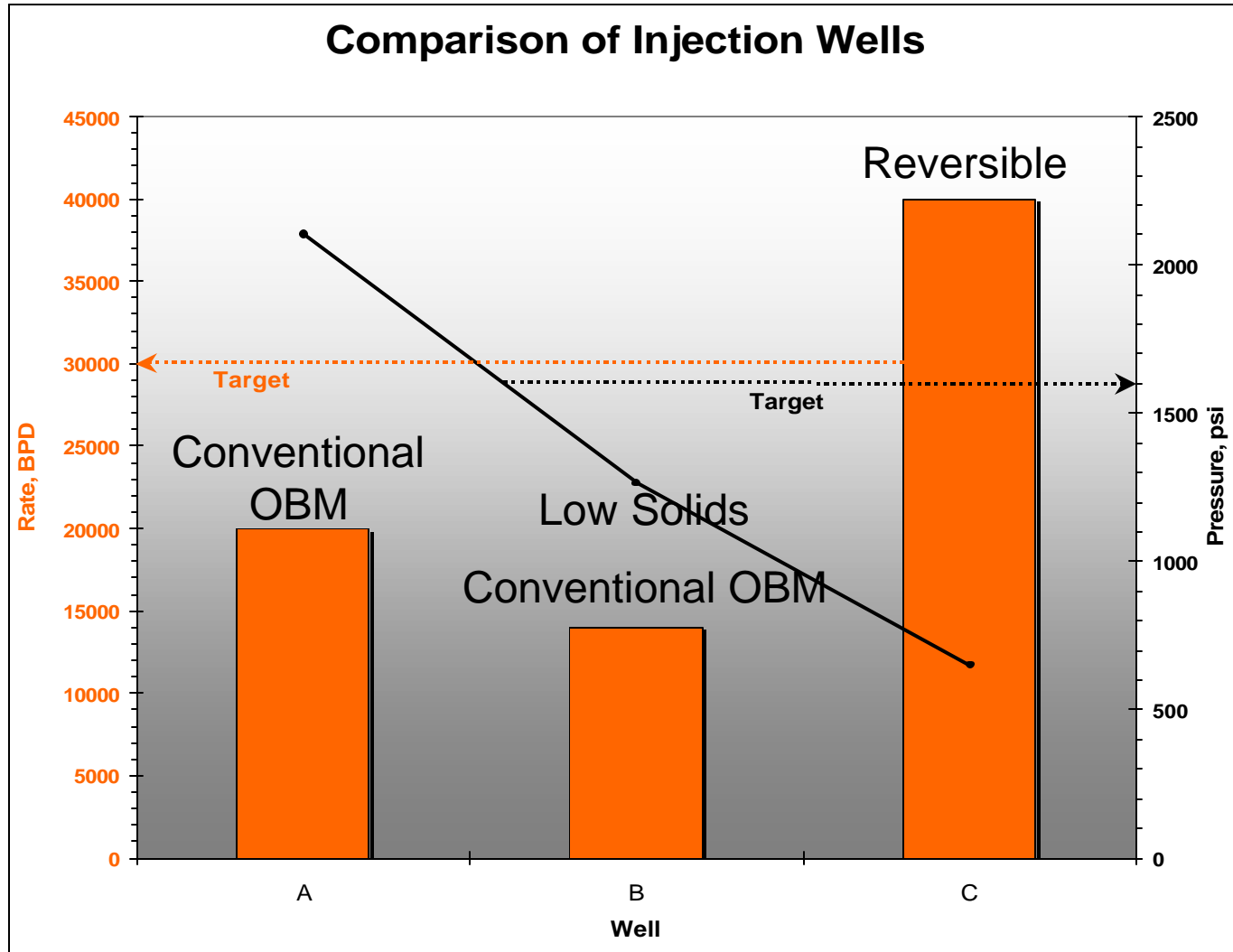
- Two » 3500 ft bi-lateral hole sections
- Open hole “bare-foot” completion
- 10% HCl acid blend clean up
  - Pumped as spacers with 5 minutes contact time

# Reversible - Injectivity Field Results

Comparison of Injectivity Index Using OBM and Reversible



# Reversible – Case History



# Reversible – Oil Based Gravel Packing

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## One Application

- **Formation calcium sensitive**
  - ✓ High rate gas producer
  - ✓ BHT 149 °F (65 °C)
- **Horizontal interval 754 feet (230 meters)**
- **9 ½” x 11 3/8 “ drill / underream – 7.5 hours**
- **Displaced open hole and top 1000 feet to SF**
- **Open hole gravel packed > 100% theoretical**
- **Breaker - internal phase of gravel pack fluid**
- **Well cleaned up and one of operator’s best Producers**



# Reversible - Waterpacking

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## Four Applications

- **Concentric Annular Pack System**
  - ✓ **Solid Liner / Slotted liner “Shroud”**
  - ✓ **20 gauge screen inserted**
  - ✓ **Multistage displacement to completion fluid post liner**
    - » **Solid liner**
    - » **Riser – Seawater / Completion fluid**
    - » **Scraper Trip**
    - » **Slotted Liner / Open hole**
    - » **Acid integral spacer**
  - ✓ **Gravel packed – 1 acid breaker/ 3 delayed breaker**
  - ✓ **Producing at/above expectations**

