SPE Distinguished Lecturer Program

The SPE Distinguished Lecturer Program is funded principally through a grant from the **SPE Foundation**.

The society gratefully acknowledges the companies that support this program by allowing their professionals to participate as lecturers.

Special thanks to the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) for its contribution to the program.

Appropriate Hydraulic Fracturing Technologies for Mature Oil and Gas Formations

Tony Martin
BJ Services

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

Today's Talk

- Understand the Reservoir First
- Get Value for Money
- Techniques for Mature Assets

+ Case Histories

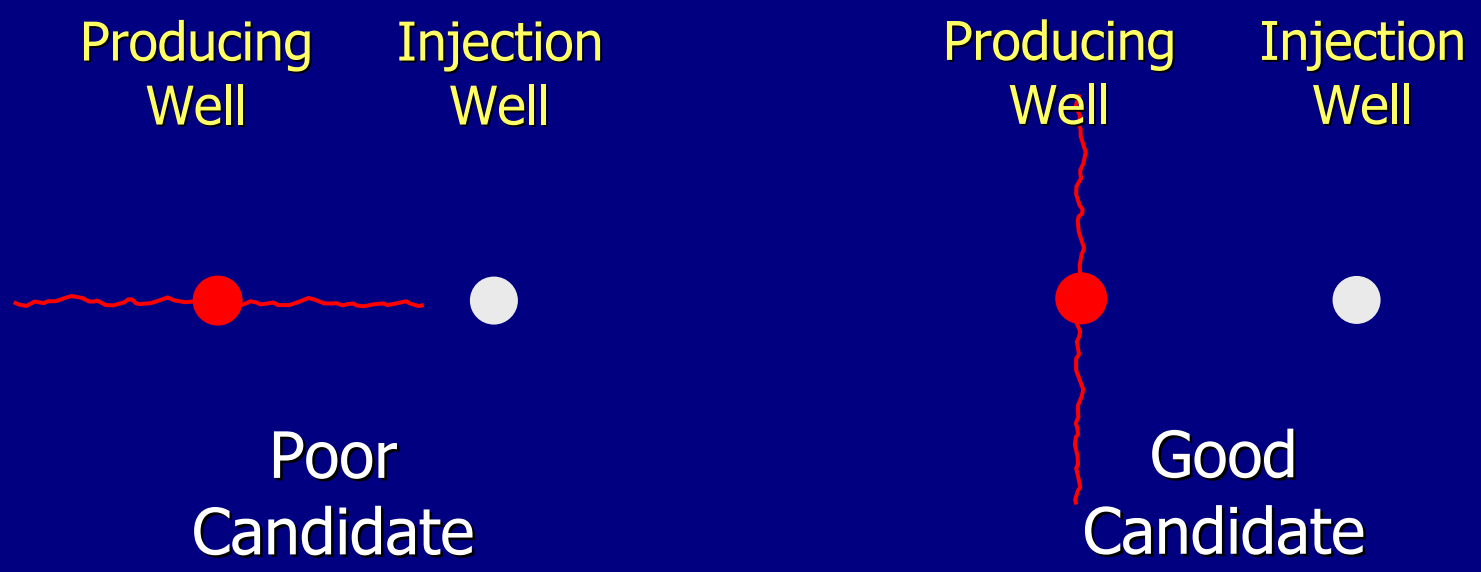
Understand the Reservoir

Understand the Reservoir

- Reservoir Engineering is a Necessary Part of any Mature Field Redevelopment
- Field Studies
  - Recoverable reserves
  - Economic justification
  - Fracture azimuth
  - Extent of water, steam or gas flooding
  - Potential for infill drilling

Understand the Reservoir

- Importance of Understanding Fracture Azimuth:-



Understand the Reservoir

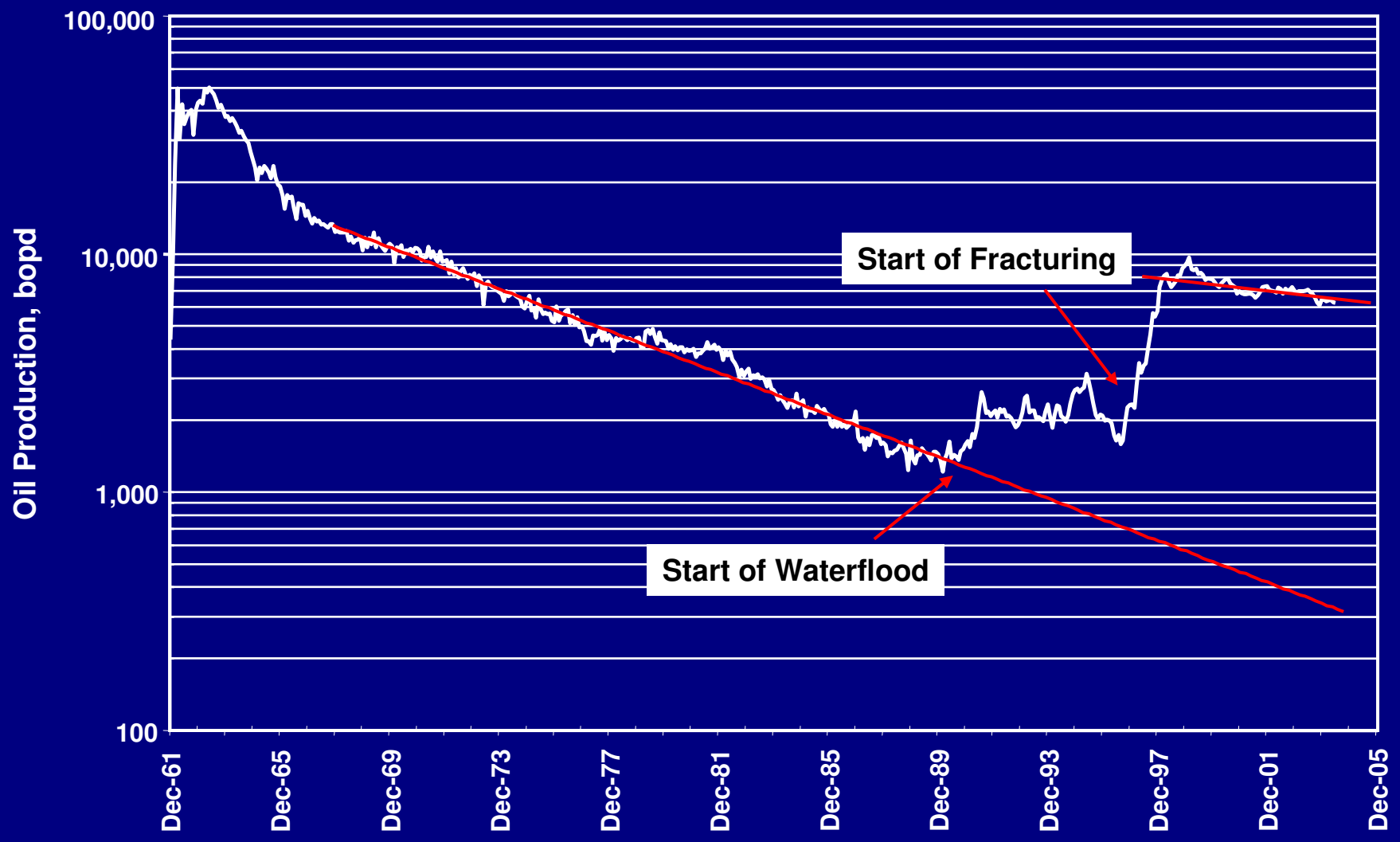
- Production Well Studies
  - Reserves behind pipe, pressure
  - Potential for water production
  - Permeability!
- Establish Candidate Selection Criteria
  - Review and adjust regularly
- Injection Wells can be Fractured to Improve Sweep Efficiency
  - Economic justification usually harder

Case Study #1

- Tanjung Field, S. Kalimantan, Indonesia (from SPE 88604)
  - Mature oil field, first production 1961
  - Low pressure, medium permeability, shallow, multi-zone, ESP's
  - Fracturing used to redevelop field
  - Extensive reservoir engineering
  - Systematic approach to candidate selection
  - Simple, low-tech frac treatments

(ESP = Electric Submersible Pump)

Case Study #1



(after SPE 88604)

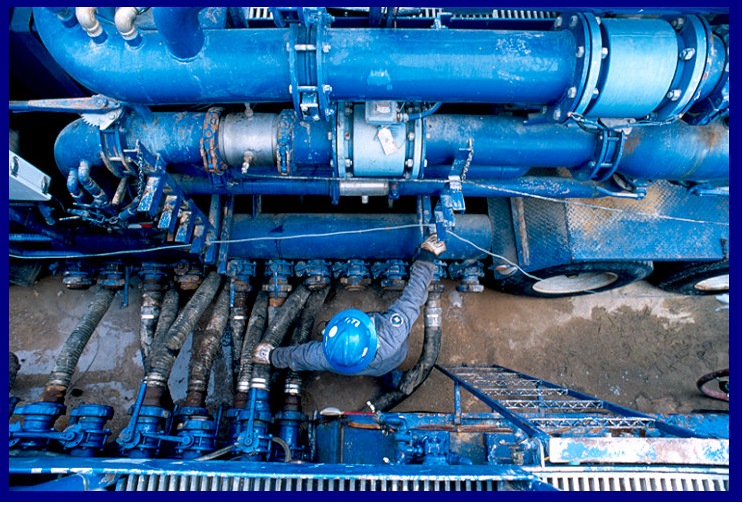
Get Value for Money

Get Value for Money

- Plan on a Field-Wide Basis, rather than Well by Well
  - High Volume = Low Unit Cost = High Value
  - Reduced per frac costs
  - Reduced day rate

Get Value for Money

- Get Appropriate Technology and Equipment
  - Use the right technology, not necessarily the latest technology.
  - State-of-the-art frac equipment = state-of-the-art pricing!
  - Keep it simple



Get Value for Money

- Pump the Right Sized Treatment
  - Don’t pump large volumes of proppant just because you can
  - We need the right combination of length and width - too much propped width means wasted proppant

Get Value for Money

- Avoid False Economies
  - Use artificial proppant rather than frac sand
  - Be prepared to re-perforate
  - Get downhole pressure data
  - Be prepared to minifrac
  - Use clean fluid systems - Filtration!

Get Value for Money

- Give the Service Company a Reliable Scope of Work
  - The easier it is for the Service Company to plan ahead, the lower the cost of fracturing
  - Uncertainties increase Service Company risk and hence add to costs

Get Value for Money

- Low Cost Workovers
  - To get maximum effect from hydraulic fracturing, it is usually necessary to perform some sort of workover prior to fracturing
    - Zonal isolation
    - Removal of ESP's etc
    - Completion unsuitable for fracturing operation
    - Fishing

Get Value for Money

- Most Successful Mature Field Projects have had Access to Low Cost Workovers
  - Cost effective, readily available and reliable workovers can dramatically alter the project economics.
  - Doing a workover can also dramatically increase the effectiveness of the treatment (e.g. zonal isolation)

Techniques for Mature Assets

Skin Bypass Fracturing

- Small Scale Frac Treatments Designed to Produce a Conductive Path Through the Skin Damage
- Cost Effective, Easy to Perform
- More Suitable for Medium and High Permeability Formations
  - Higher *k* formations tend to have greater skin factors and so get more benefit from bypassing skin damage

Skin Bypass Fracturing

- Production Increase Based on Reducing Skin Factor to Zero or Slightly Lower
  - Will not produce as much stimulation as “full scale” treatment.
  - Better stimulation than matrix acid treatment
- Treatments can be Performed by Cement Units

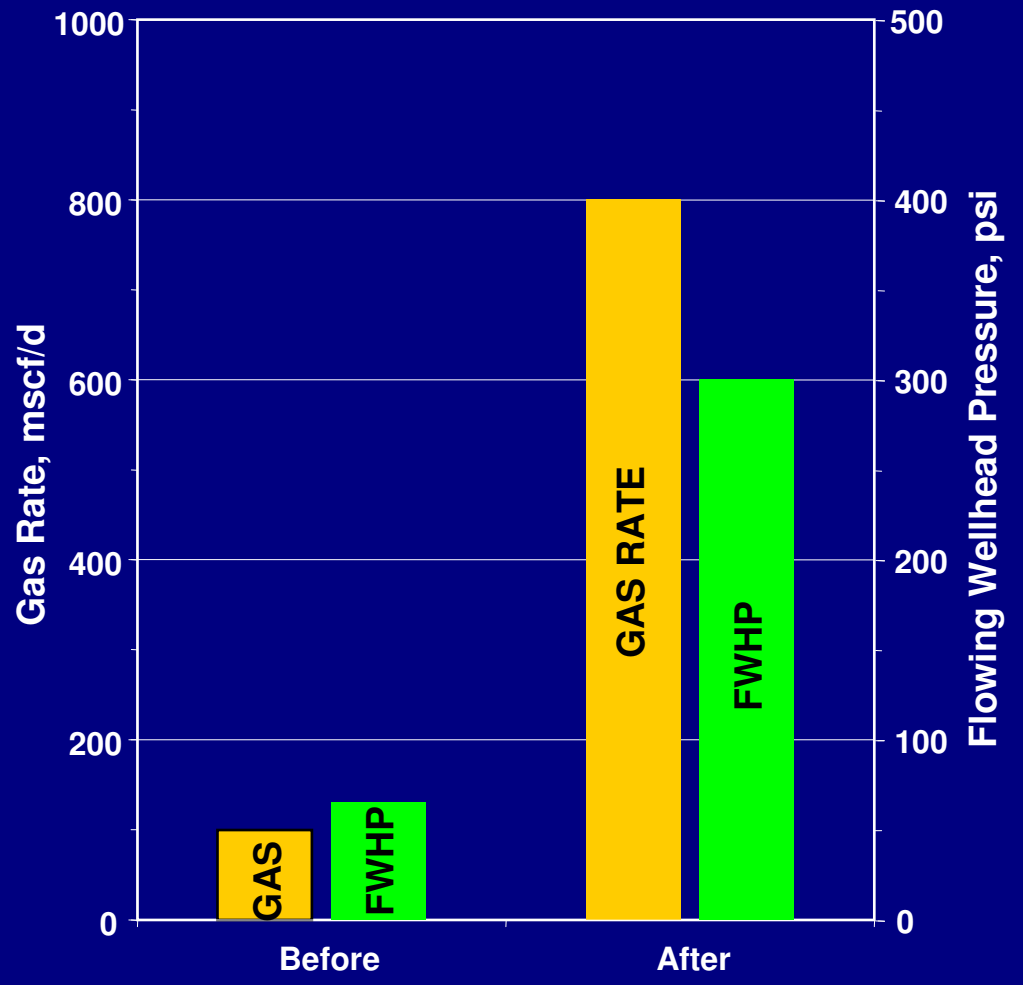
Case Study #2

- SPE 56473 - South Texas
  - Gas well
  - Permeability 0.1 md
- Skin Bypass Frac Treatment
  - 14,000 lbs 20/40 Low Density Ceramic
  - 9.6 bpm maximum rate
  - VES fluid system

(VES = Viscoelastic Surfactant)

Case Study #2

- Gas Production
  - From 100 mscfd
  - To 800 mscfd
- Flowing Wellhead Pressure
  - From 70 psi
  - To 300 psi

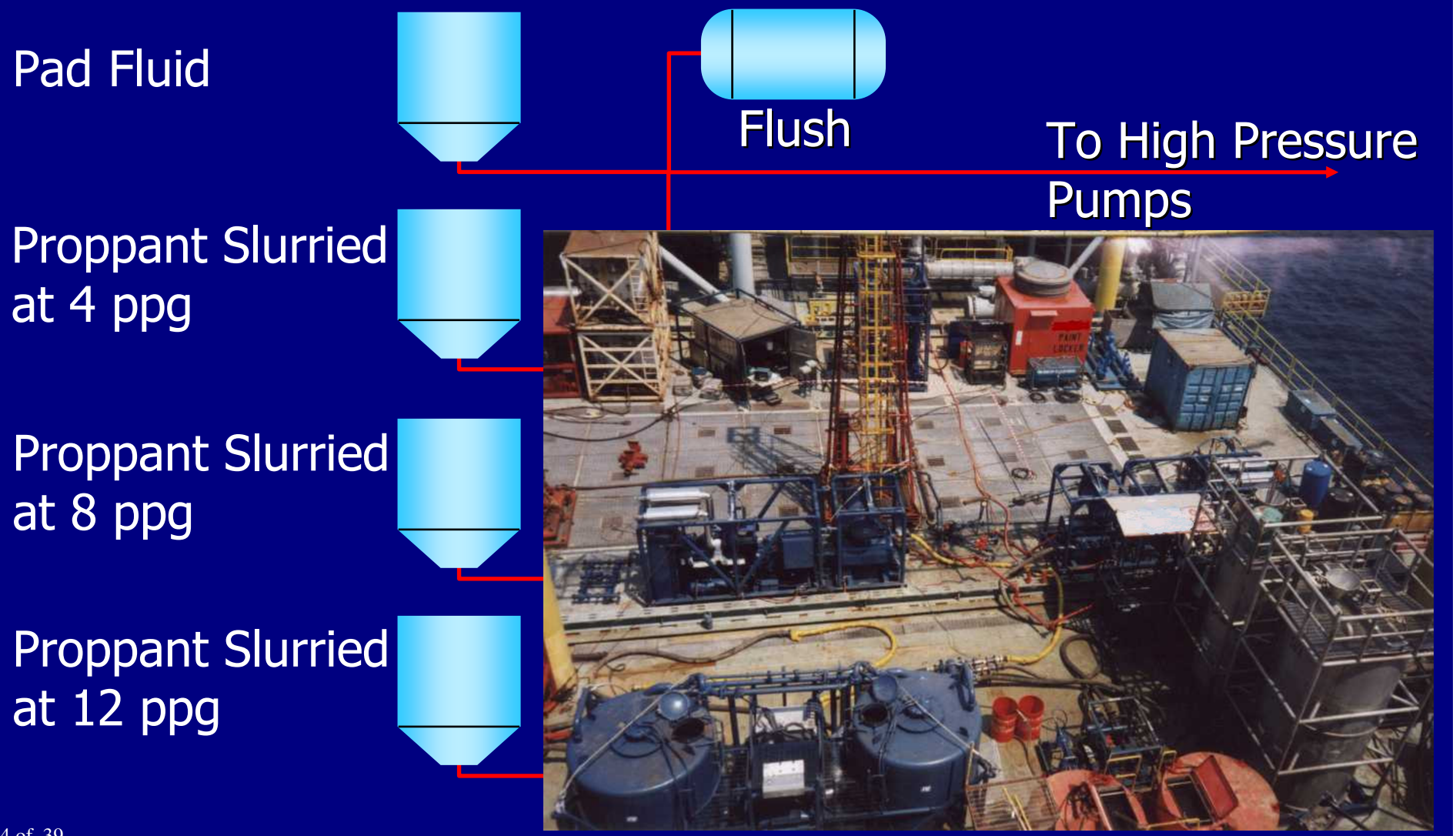


Batch Fracturing

- Eliminates the Need for Complex Blending Equipment
- Proppant is Pre-Slurried in Batch Tanks
  - All QC performed before going downhole
- Gel Type and Quality Critical

(QC = Quality Control)

Batch Fracturing



Proppant Partial Monolayer

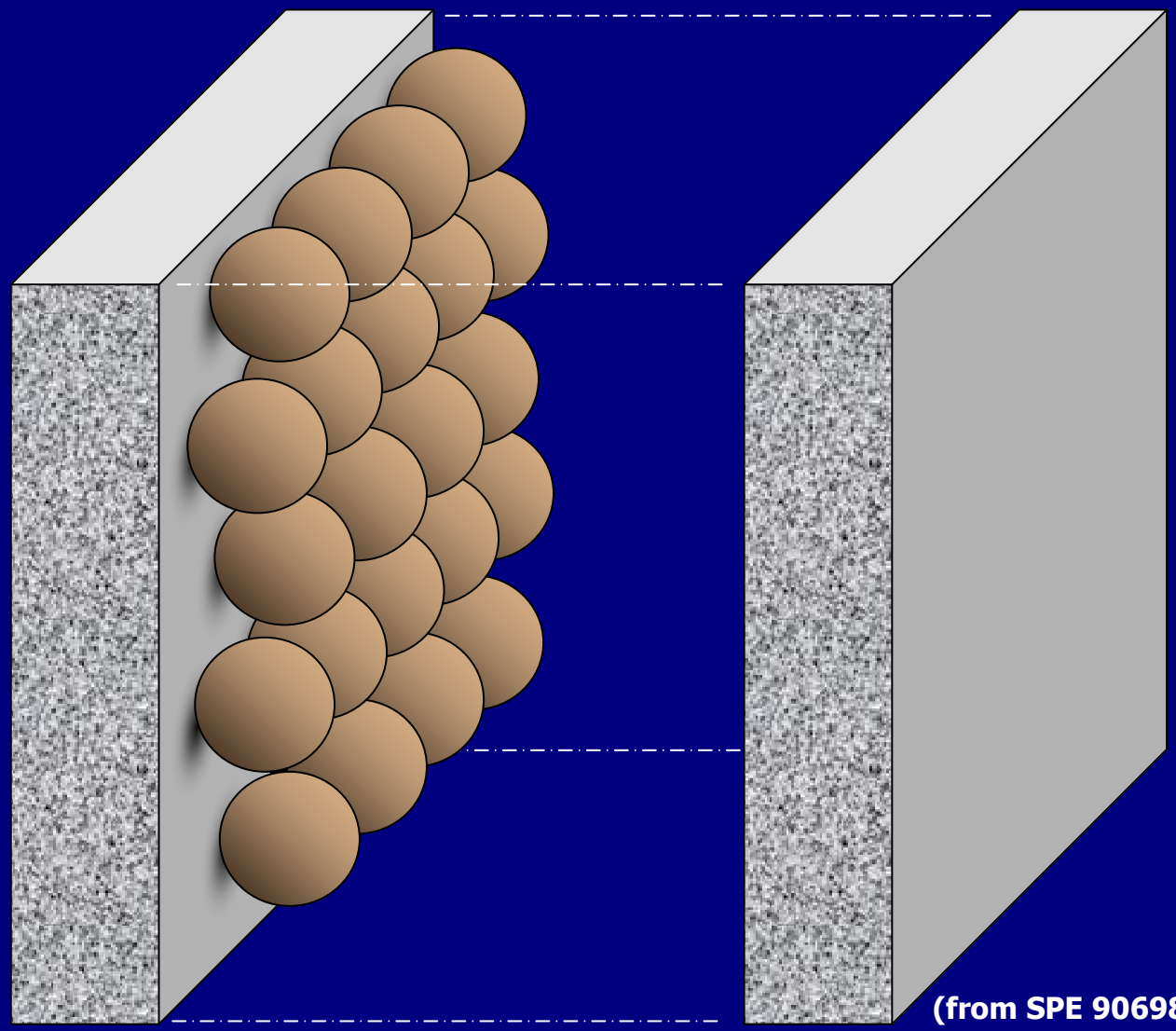
Darin and Huitt (SPE 1291)

- Very Low Concentration of Proppant Produces Same Effects as Higher Concentrations
  - 0.09 lbs/ft^2 gives the same frac conductivity as +/- 4 lbs/ft^2.
  - Applicable for lower permeability formations
  - Low closure stress formations only

Proppant Partial Monolayer

Full Monolayer

A complete coverage of the fracture face, one proppant grain thick

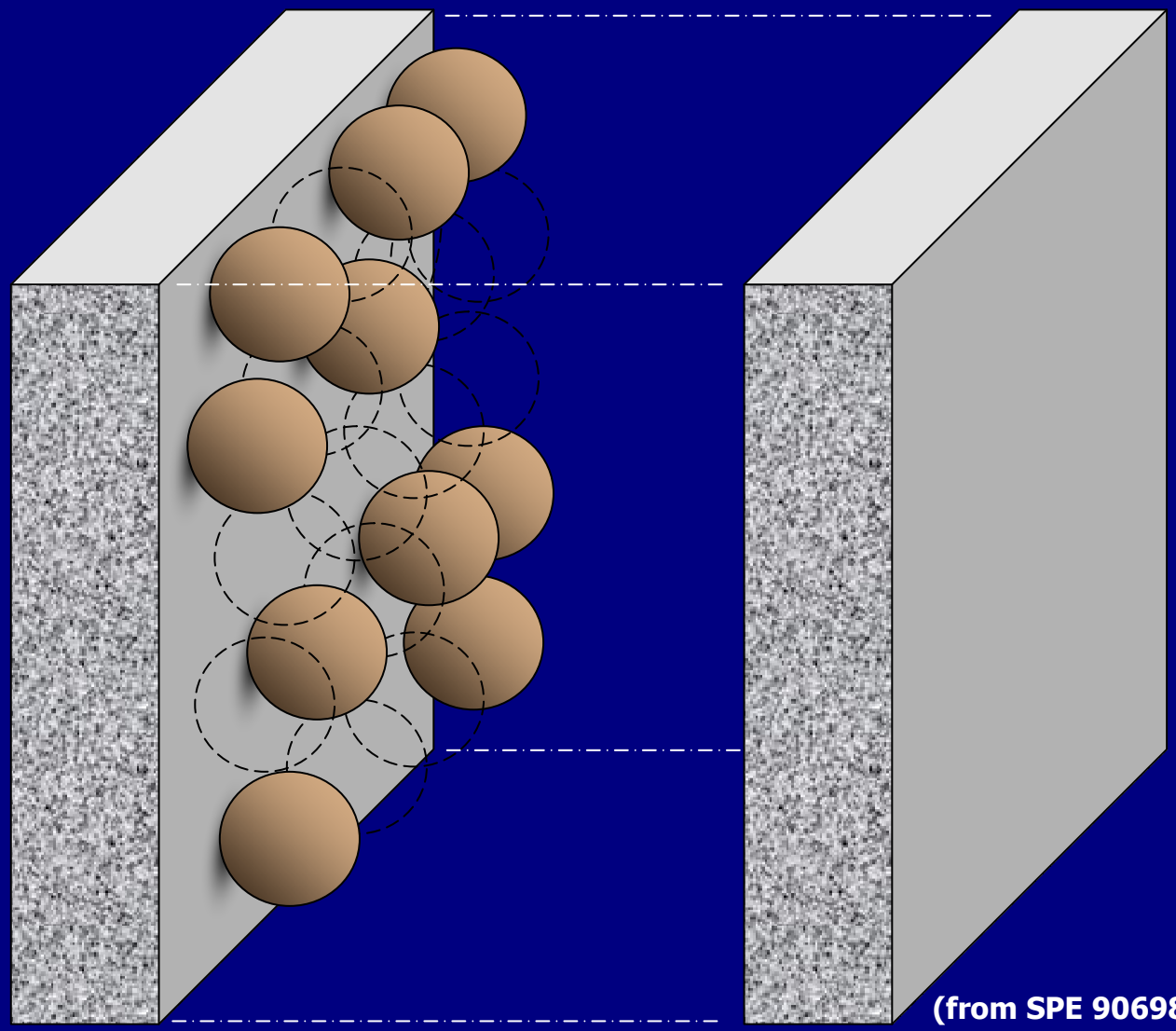


(from SPE 90698)

Proppant Partial Monolayer

Partial Monolayer

Increased permeability due to spaces between proppant grains. Mono-Layer keeps the same fracture width



(from SPE 90698)

Neutral Density Proppant

- Neutral Density Proppant does not Require Viscosity to keep it Suspended in the Fracturing Fluid
  - Fluid Costs Dramatically Reduced
- Proppant Can be Batch Mixed into Fluid Prior to Treatment
  - Sophisticated Blending and Metering Equipment not Required

Neutral Density Proppant

- Therefore, Neutral Density Proppant can Dramatically Reduce the Costs, Logistics and Complexity of Fracturing Operations
  - Current limited by depth and closure pressure
  - Some temperature limitations

Neutral Density Proppant

Proppant Type	Specific Gravity
Neutral Density	1.08 – 1.25
Resin-Coated Sand	2.45 – 2.55
Frac Sand	2.65
Low Density Ceramic	2.71
High Density Ceramic	3.27
Sintered Bauxite	3.55

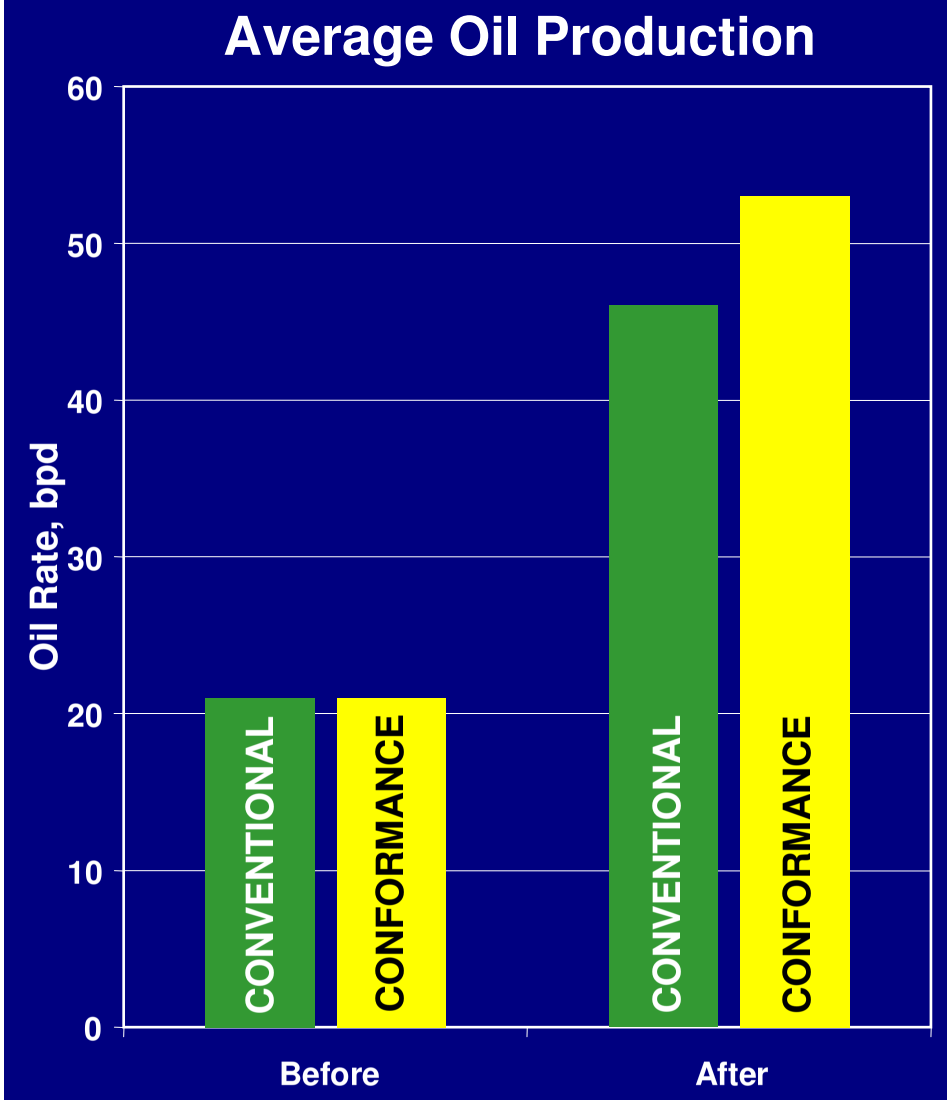
Water Conformance Fracturing

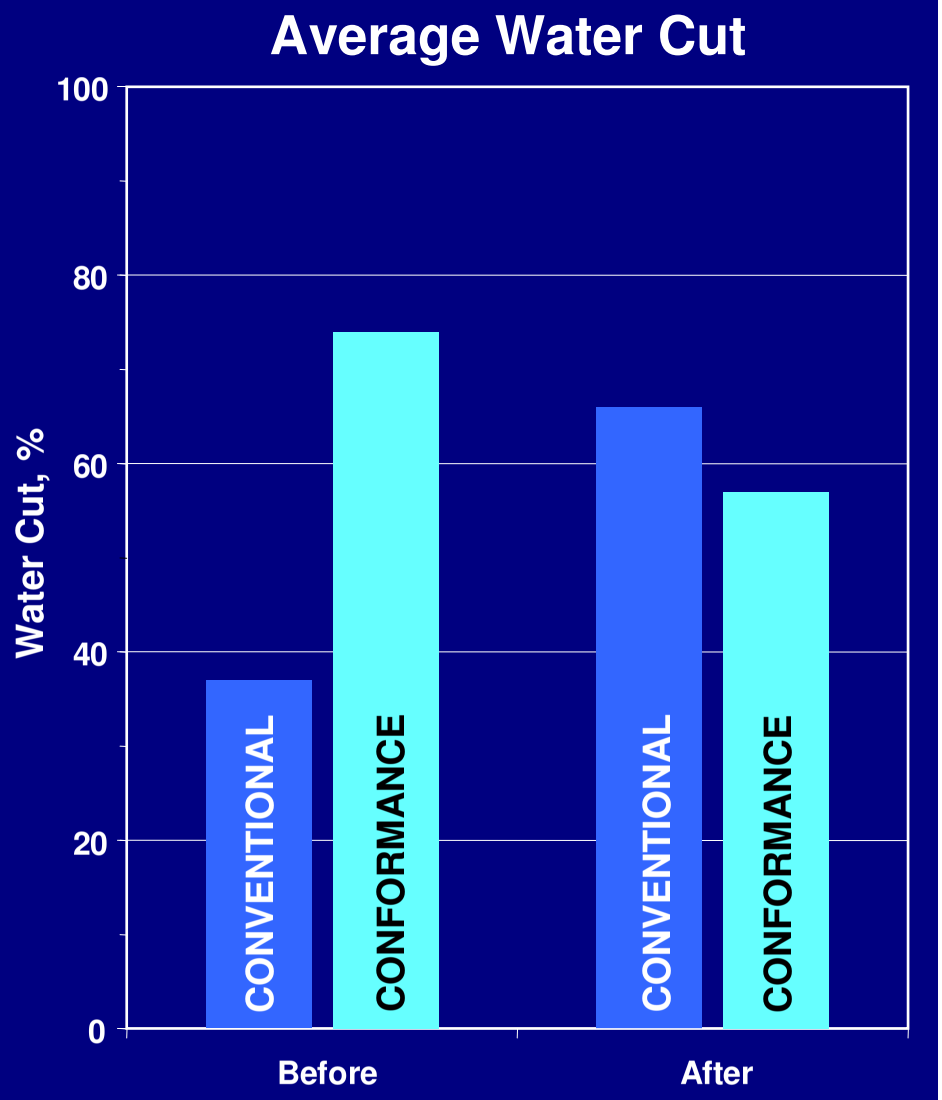
- Hydraulic Fracture Treatments Performed with Relative Permeability Modifier (RPM) as part of the Treatment Fluid
  - RPM works by affecting the wettability of the formation grains
  - RPM makes it harder for water and easier for oil to flow
  - Effective in gas formations as well
  - Medium to high permeability only

Case Study #3

- SPE 101019
  - 5 Water Conformance Fractures
  - 3 Offset Conventional Fractures
  - Mature Oil Field in South Sumatra, Indonesia

Case Study #3


Average Oil Production
Oil Rate, bpd
60
50
40
30
20
10
0
CONVENTIONAL
CONFORMANCE
CONVENTIONAL
CONFORMANCE
Before
After

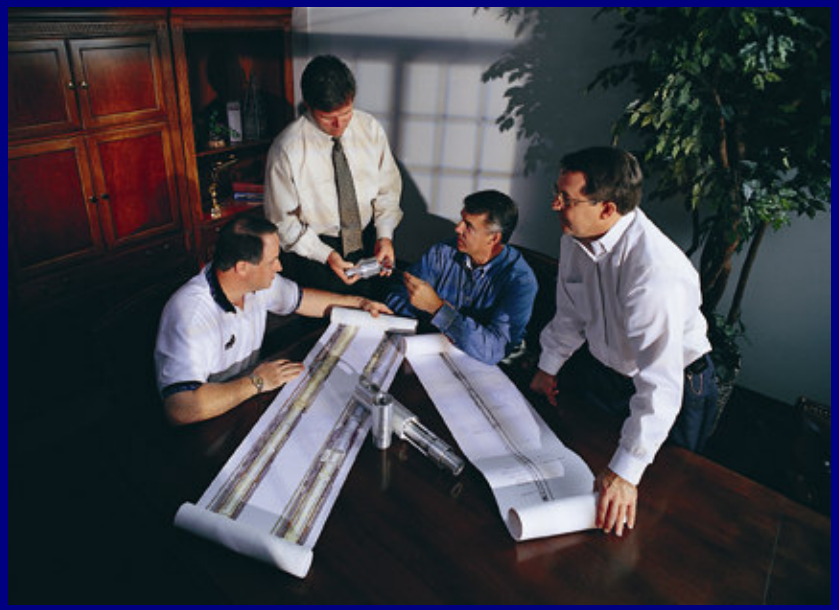

Average Water Cut
Water Cut, %
100
80
60
40
20
0
CONVENTIONAL
CONFORMANCE
CONVENTIONAL
CONFORMANCE
Before
After

Refracturing

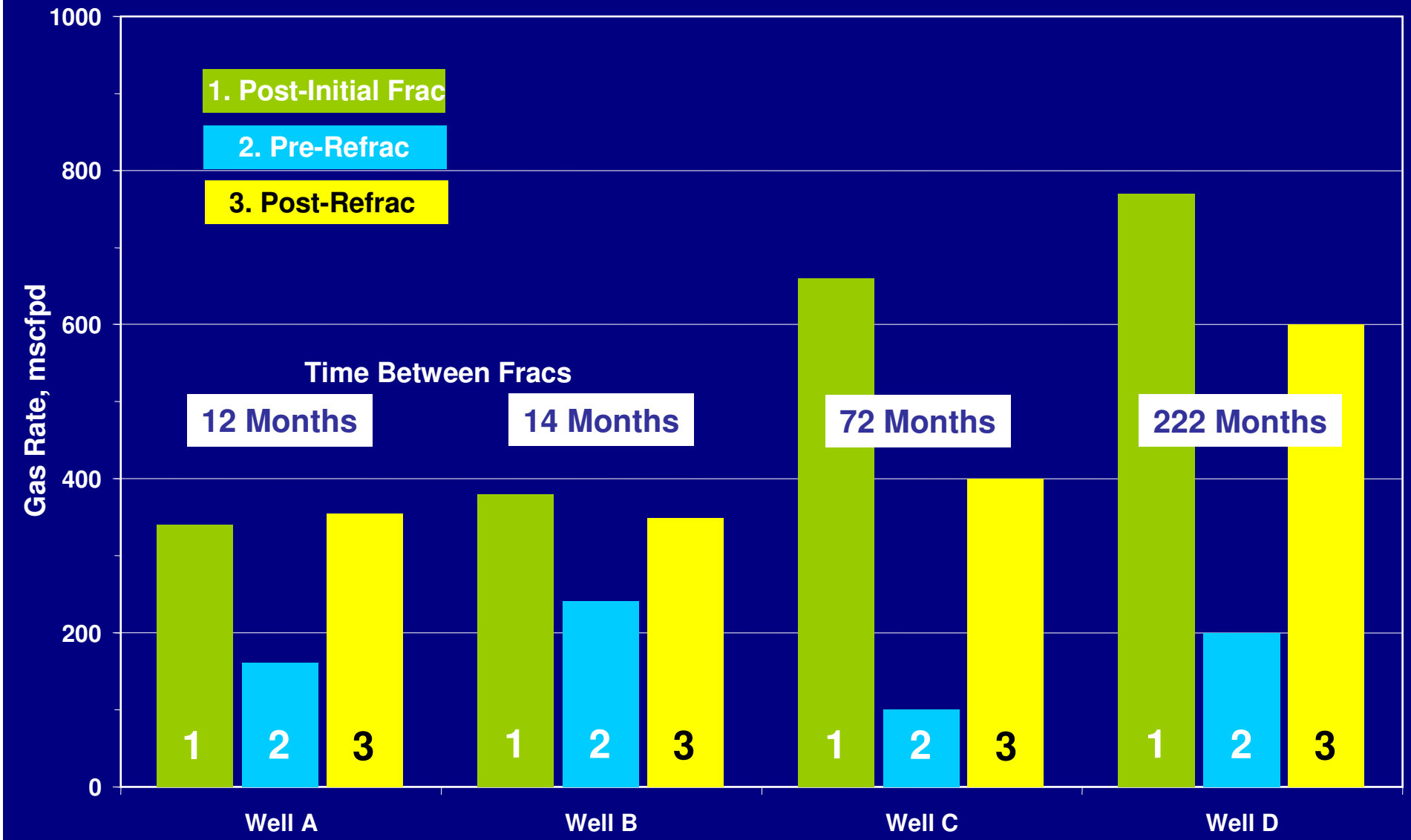
- Don't Ignore a Field because the Wells Have Already Been Fractured
  - Refracturing is a highly successful and established technique
- By Definition, it is Always Used on Mature Assets
  - Reservoir depletion is necessary to re-orient fracture
- Updated Technology

Case Study #4

- SPE 101026 - Wyoming, USA
  - Refracturing Tight Gas
  - Frontier Formation



Case Study #4


1000
800
600
400
200
0
Gas Rate, mscfpd
1. Post-Initial Frac
2. Pre-Refrac
3. Post-Refrac
Time Between Fracs
12 Months
14 Months
72 Months
222 Months
1
2
3
Well A
Well B
Well C
Well D

Summary of Techniques

- Skin Bypass Fracturing
- Batch Fracturing
- Proppant Partial Monolayer
- Neutral Density Proppant
- Water Conformance Fracturing
- Refracturing

Techniques Can Be Combined!

Mature Field Redevelopment with Hydraulic Fracturing

- Understand the Reservoir First
  - Permeability, reservoir pressure, reserves, fracture azimuth
- Get Value for Money
  - Appropriate technology
  - Economies of scale
  - Avoid false economies

Thank You

Any Questions?