Rocky Mountain E & P Technology Transfer Workshop

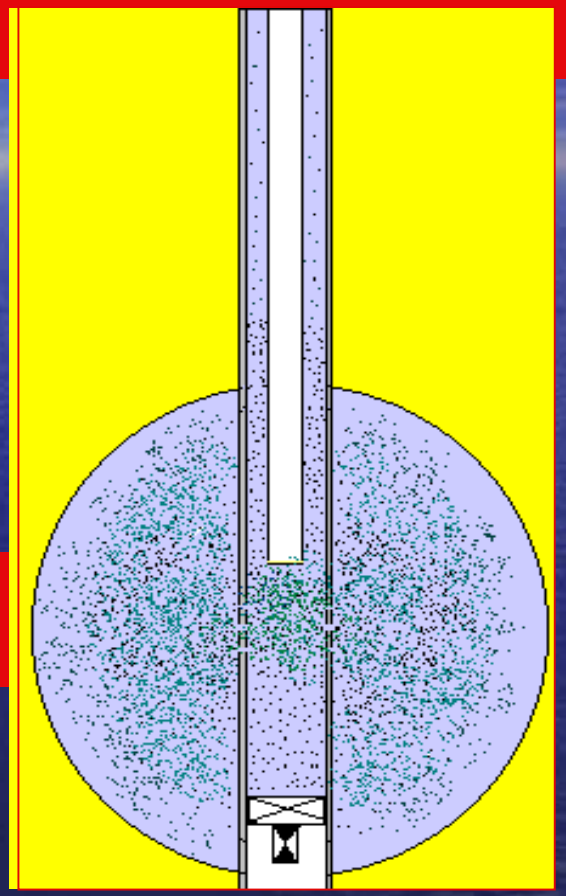
August 2002

Real-time Enhanced Downhole-mixed Reservoir Stimulation Fracturing

Presented by
George L. Scott III

QUESTION:

What is real-time downhole-mixed reservoir fracturing?



ANSWER:

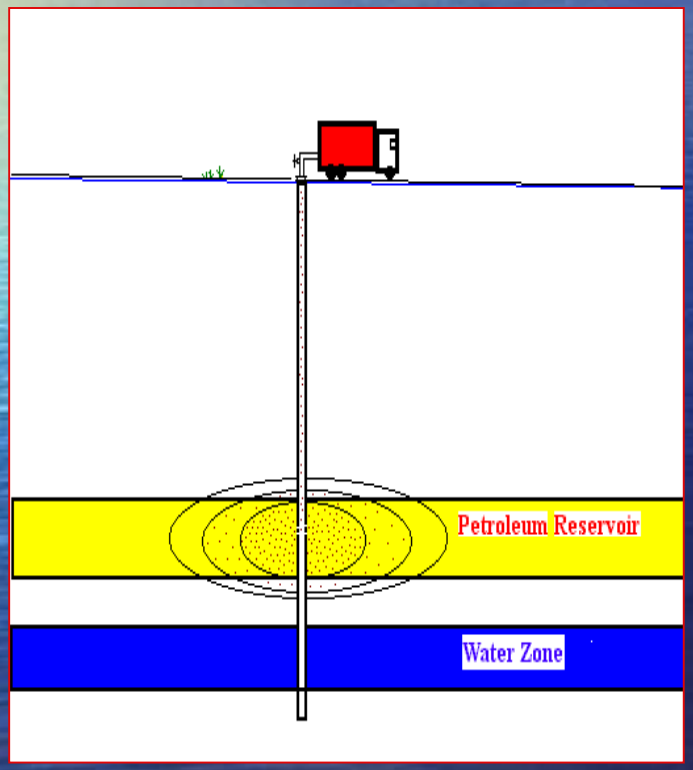
Simple completion system for real-time reservoir stimulation control of fracturing & proppant concentration

INTRODUCTION:

Downhole-mixed Stimulation Fracturing

- Proven reservoir stimulation system for control of both proppant concentration & placement in reservoir fractures
- Numerous advantages provided by downhole mixing of composite fracturing fluids, including less fluid-pipe friction, lower pump treating pressures, and reduced stimulation costs.
- Downhole blending of gases (CO_2 & N_2) and gel mixes a composite stimulation fracturing fluid that is comparable in efficiency to frac foams mixed at the surface.
- Real-time advantages × reserve recovery.

Downhole-Mixed Real-time Stimulation



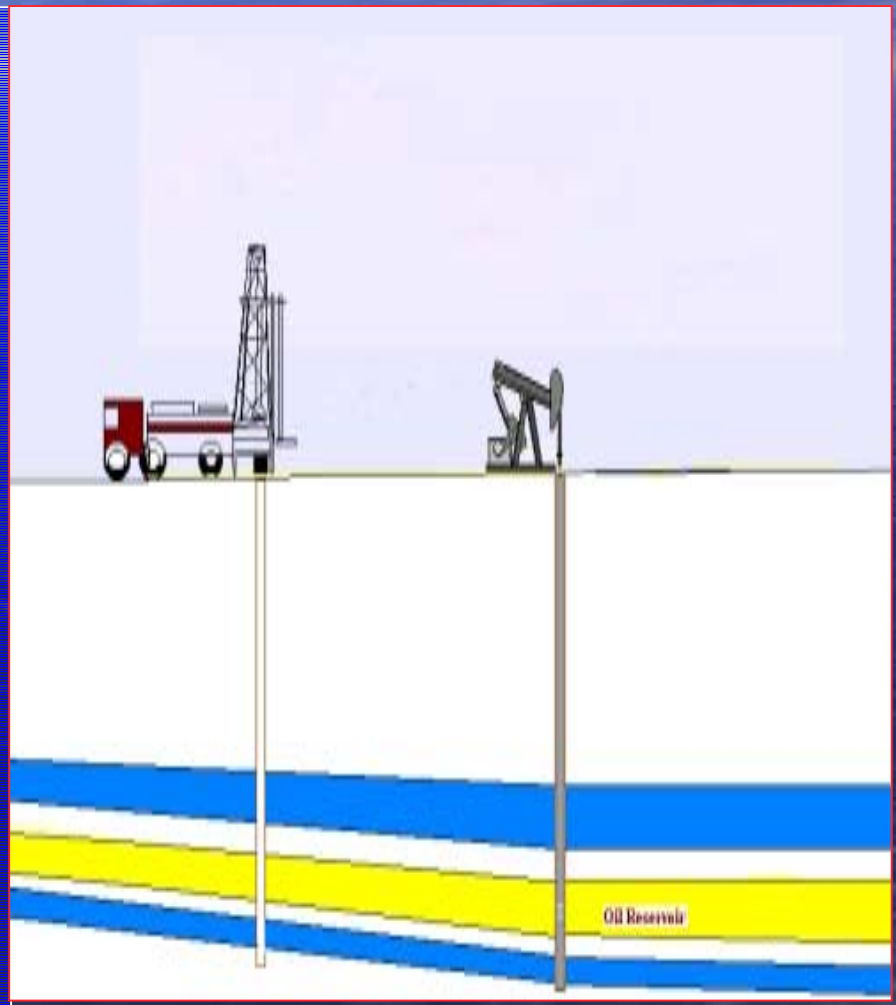
- Real-time control of fracture geometry, frac fluid properties & proppant concentration
- Minimizes fluid friction & reduces treating pressures
- Real-time enhanced fracture stimulation system provides simple methods for avoiding premature screenout and treatment out of zone

The Premature Screenout Problem

Premature Screenout results when excessive fracturing fluid bleedoff into the reservoir zone occurs, thus resulting in proppant packoff in the induced fracture (and an abrupt end to the stimulation treatment). Usually as a result, the entire frac job isn't pumped & the reservoir zone is understimulated, which often results in an ultimate loss of reserve recovery.

Chronic Well Completion Problems

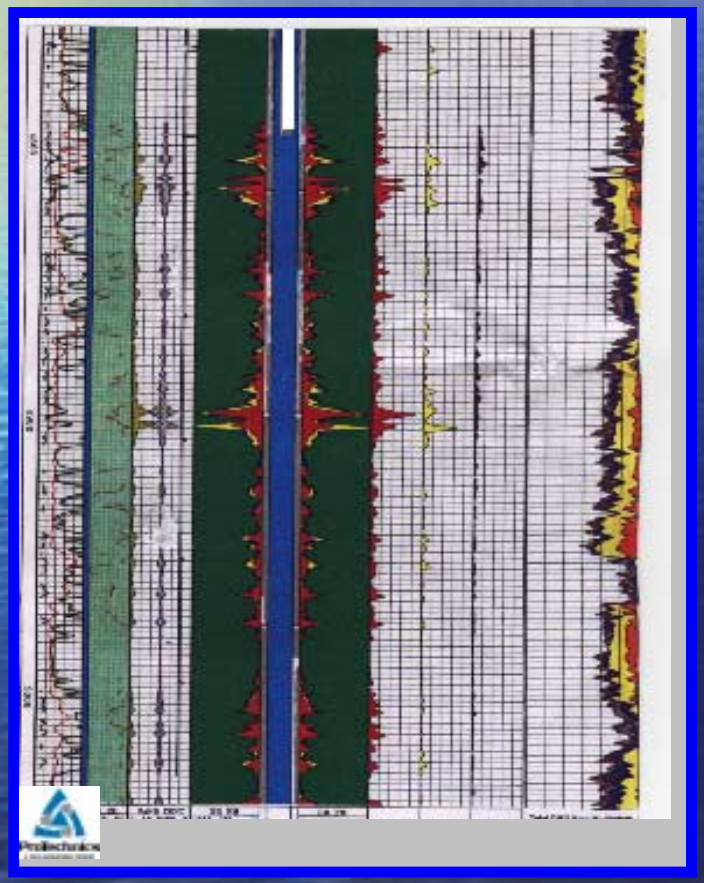
- Zonal isolation
- Excessive water production due to fracturing out of zone
- Poor proppant placement in reservoir
- Excessive treating pressures



Significance of Treating Out of Zone?

- Treatment out of zone = ruined or permanently damaged well (rare exceptions)
- Poor completions in the initial test well often results in writing off reserves & reduction of further field well drilling.
- Significant loss of reserves due to ineffective reservoir fracturing (usually irreversible when frac-induced damage)
- Produced water reduces profitability

Poor Zonal Isolation = Excessive Produced Fm. Water and/or Dry Hole

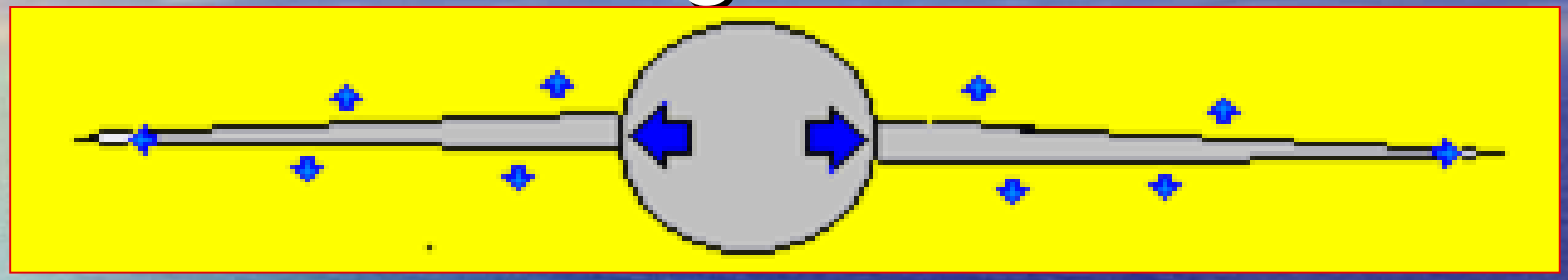


Delaware Sandstone Reservoir - Permian Basin, N.M. Sand-frac @ 15 BPM. Post-fracture tracer log indicates minimum fracture height over 250 feet.
Production result:
90% water cut

More Common Stimulation Problems

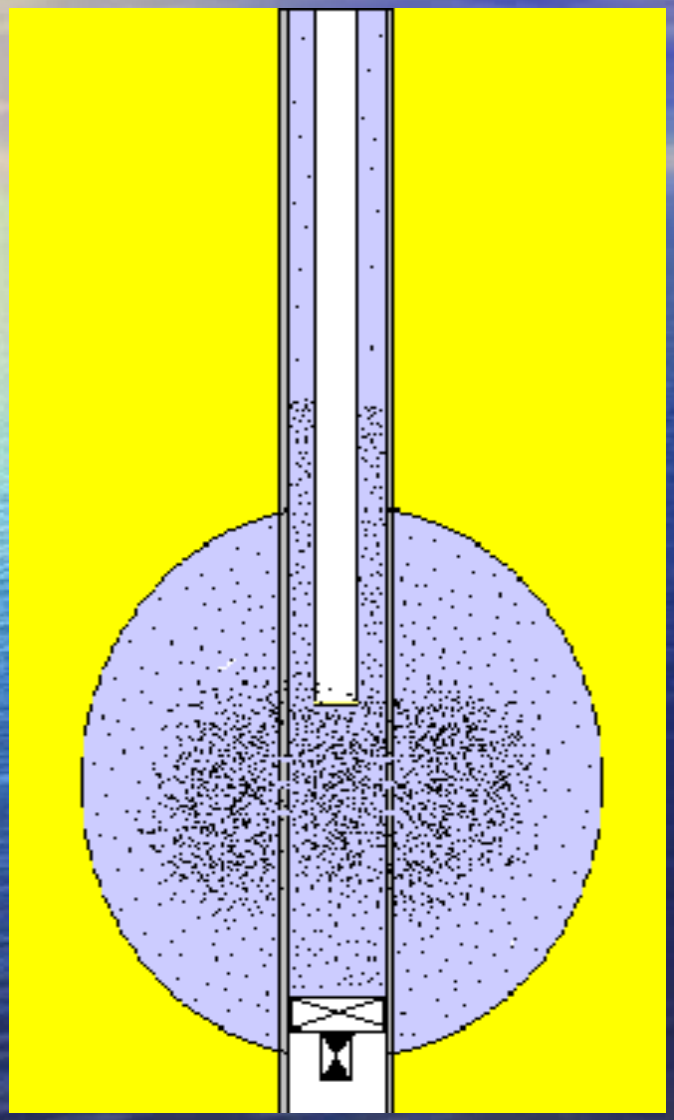
- Excessive fluid loss to formation results in premature screenout & gel-fluid-clay skin damage
- Other limitations inherent to present surface-mixed completion methods:
  - Cased wells
  - Openhole stimulation
  - Horizontal fracturing

Real-time Fracture Diagnostics



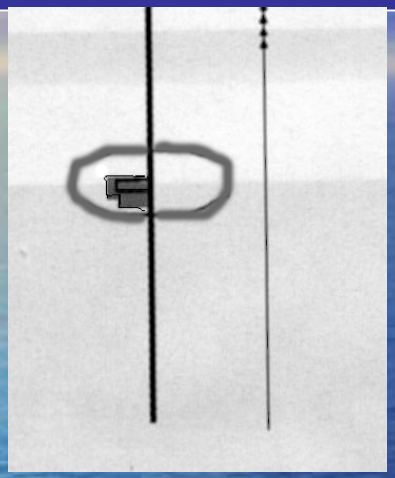
- BHTP
- Seismic
- Tracers

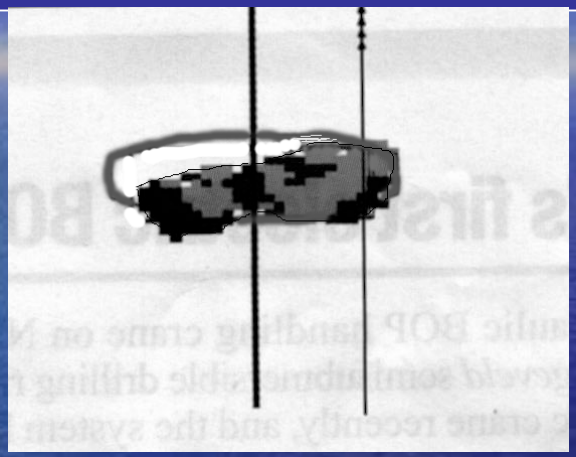
Most BHTP Data isn't Really Real-time

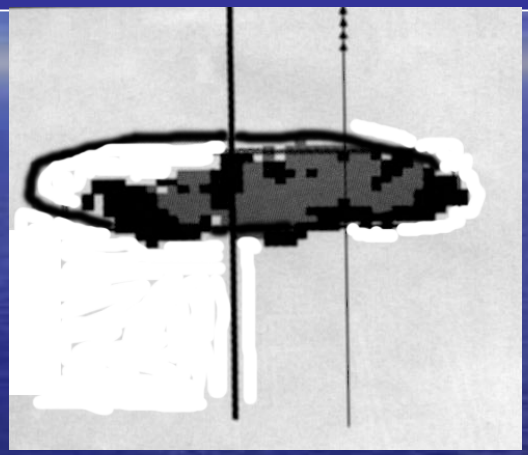


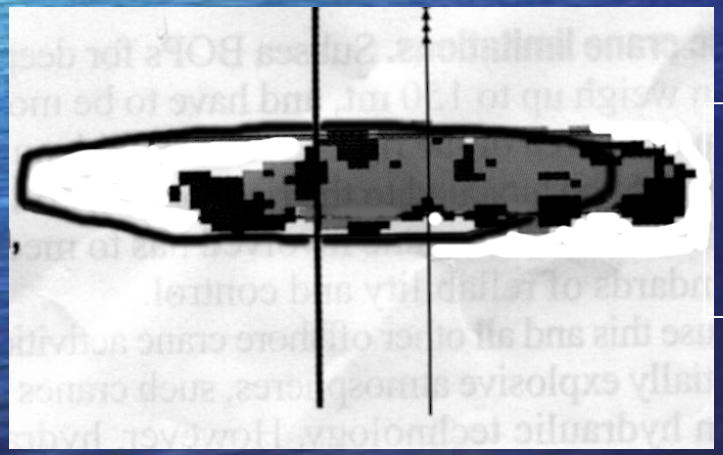
BHTP Data indicates when fracturing is evident and if premature screenout is pending or imminent, but data is limited when fracturing with gases. Nolte plots are commonly used in industry, however, this data is of limited real-time utility.

Evaluation of fracture stimulations with real-time microseismicity data





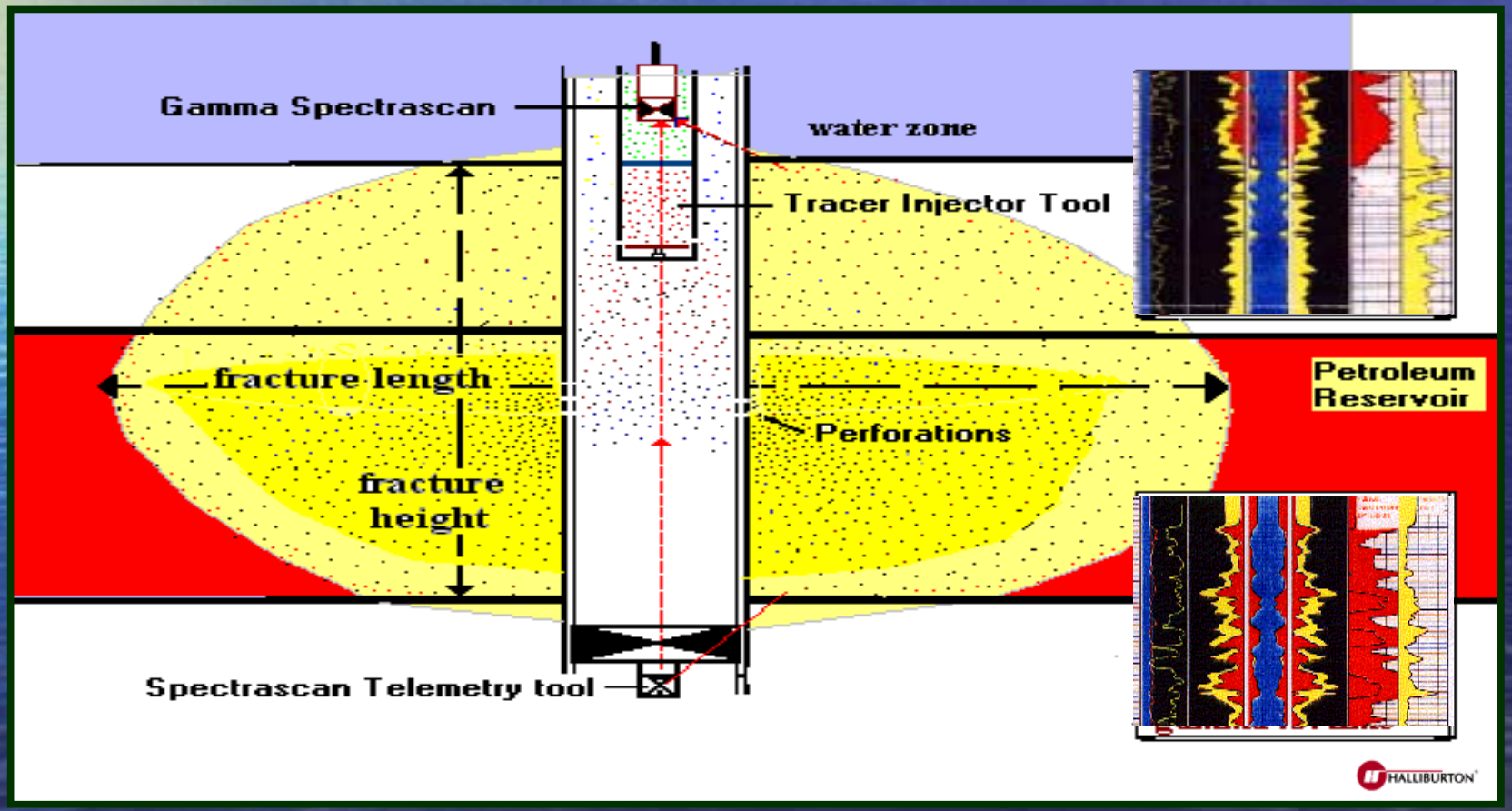




Modified from World Oil, May 2002, "Evaluating fracture stimulations with microseismicity",T.I. Urbancic, et al

Evaluation of fracture stimulations with real-time tracer diagnostics

(RTZ, NETL, HES)



Needed: Real-time Stimulation process for real-time diagnostics

To Optimize:

- Fracture propagation
- Proppant placement
- Reservoir productivity
- Ultimate reserve recovery & R.O.I.

To Minimize:

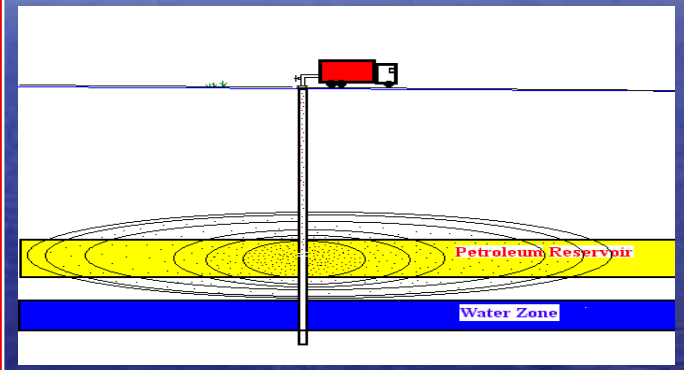
- Fluid-pipe friction
- Pump pressures
- Pump HP, equipment & treatment cost
- Problems including premature screenout & treating out of zone

Downhole-Mixed Real-time Fracturing

- Provides enhanced stimulation success
- Optimized reservoir drainage efficiency
- Cost-economic completion testing of reservoir zones and best methods stimulation w/ gelled fluids in water-sensitive zones (such as borate gel w/ CO_2)
- Real-time prevention of chronic well completion problems that otherwise typically result in economic loss

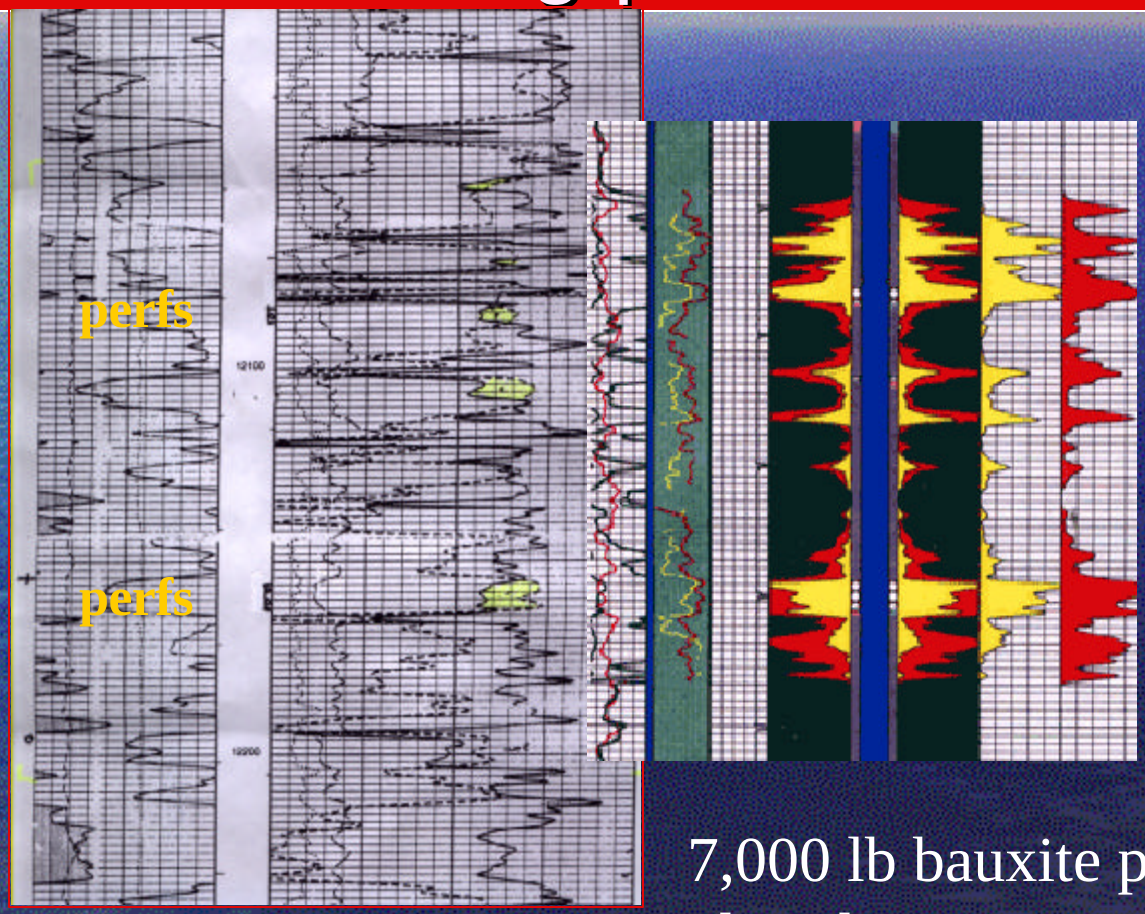
Downhole-Mixed Real-time Fracturing

-Downhole-mixed fracturing facilitates lower fluid-pipe friction pressure
-Lower friction pressures result in lower treating pump pressures
-Lower treating pressures are safer and save HP & $$$



In deeper well fracture treatments, lower pressures are desirable for finishing stimulation per design

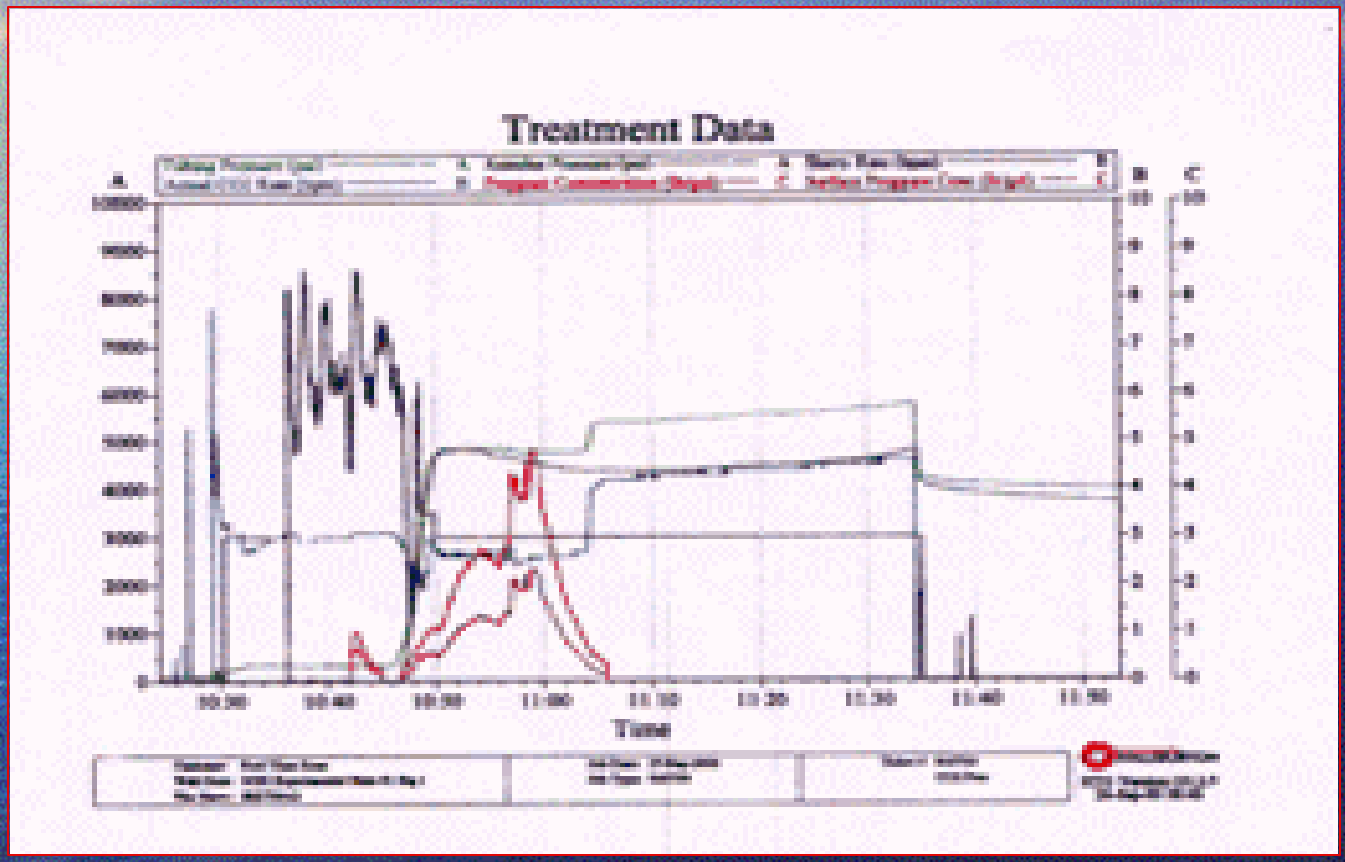
Morrow Example of Downhole-mixed reservoir fracturing process



Porosity log section

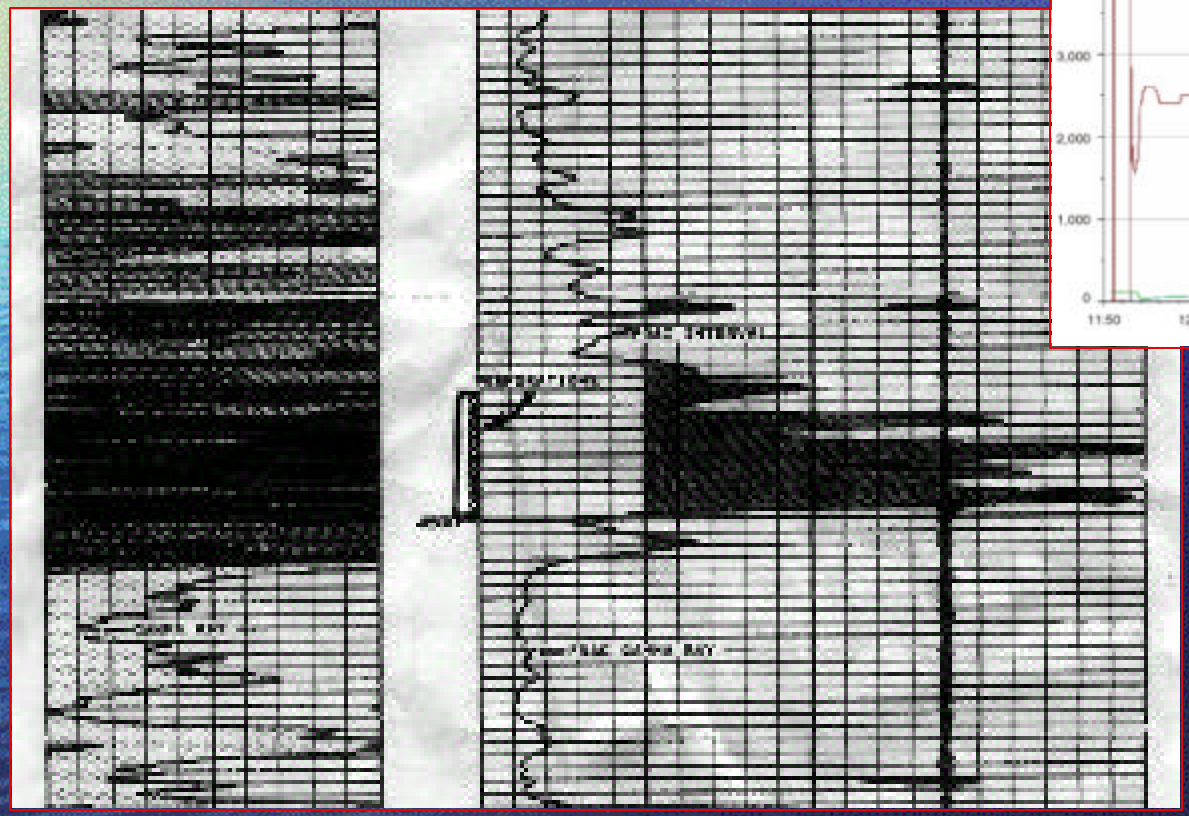
7,000 lb bauxite proppant placed in reservoir

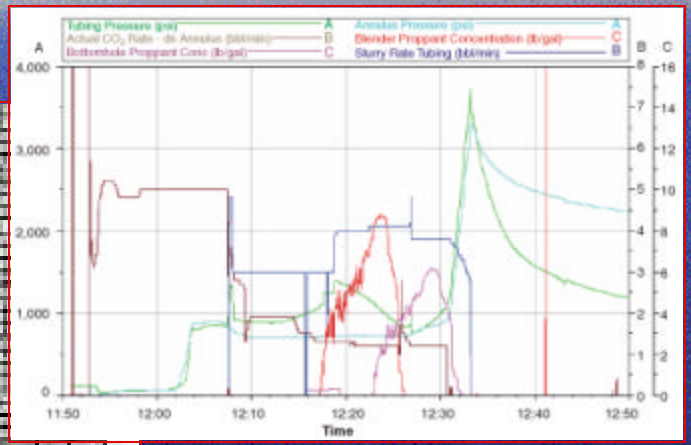
Downhole-mixed Fracture Treatment Pressure Chart



Treating Pressure Data for Morrow fractured reservoir, 12,300 feet

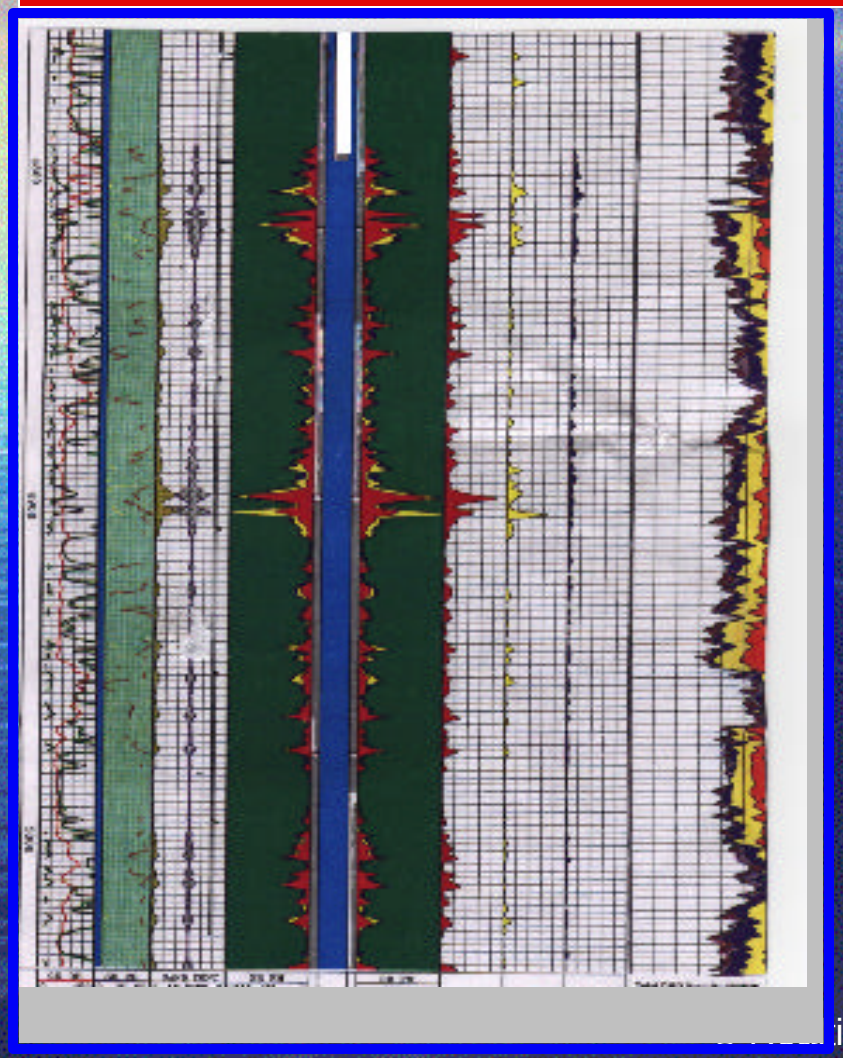
Tracer Survey Showing Delaware Downhole-mixed Frac Treatment

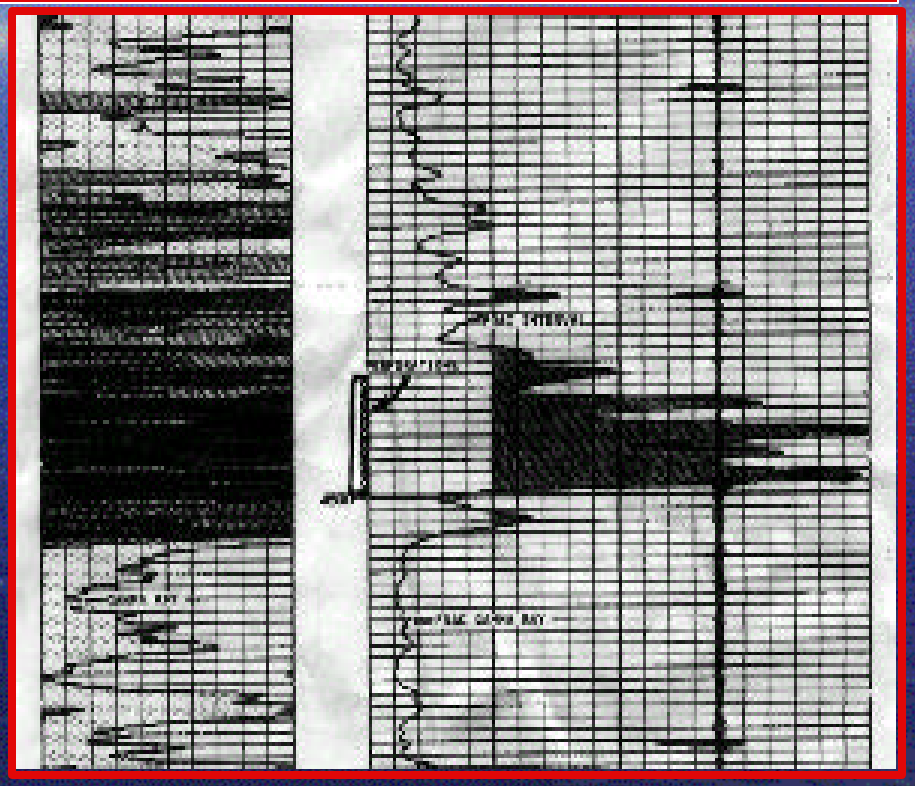




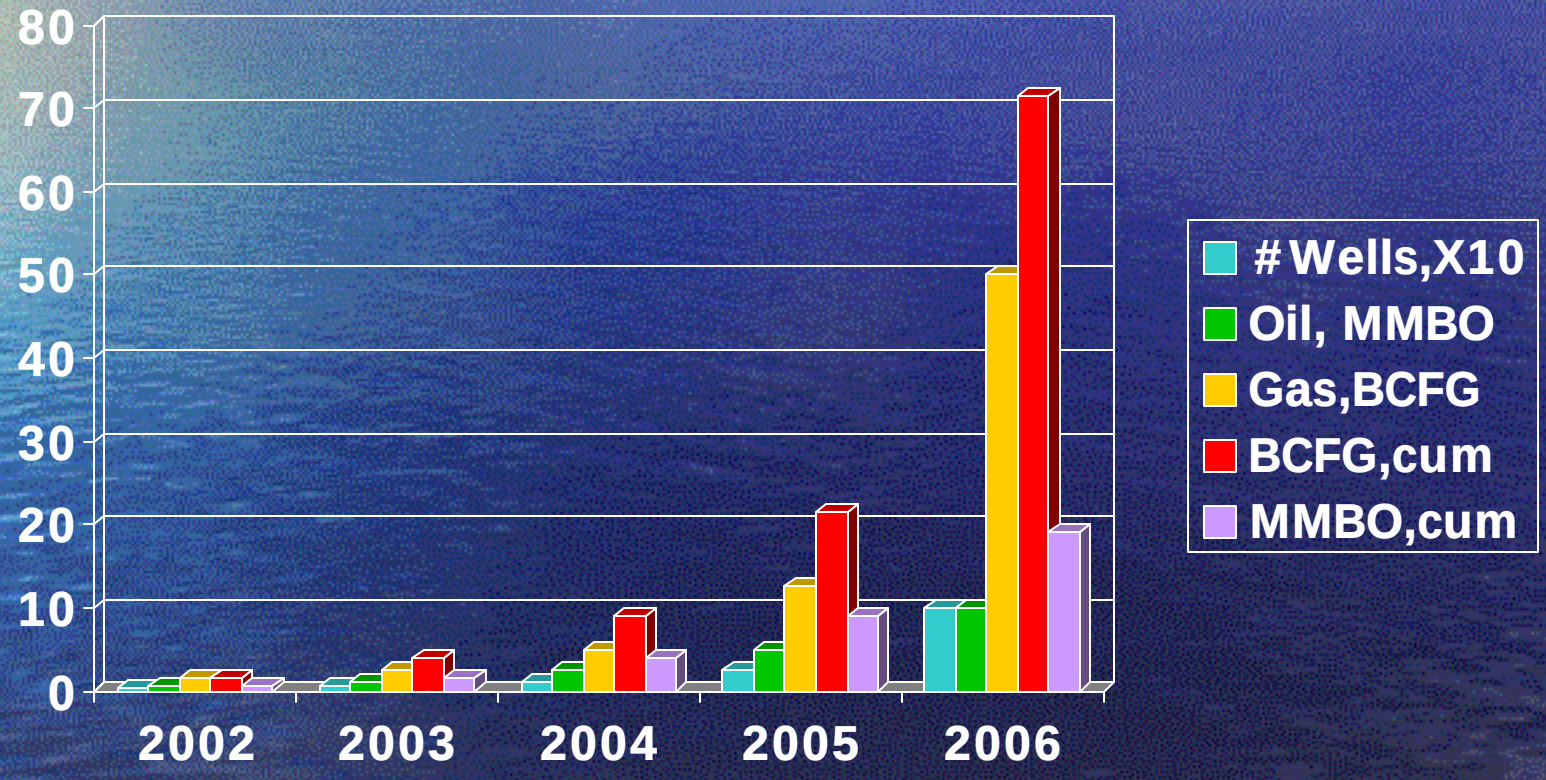
Total min. frac height Est. from Tracers: 25’

Tracer Survey Showing Delaware Treatment Out of Zone vs. In Zone

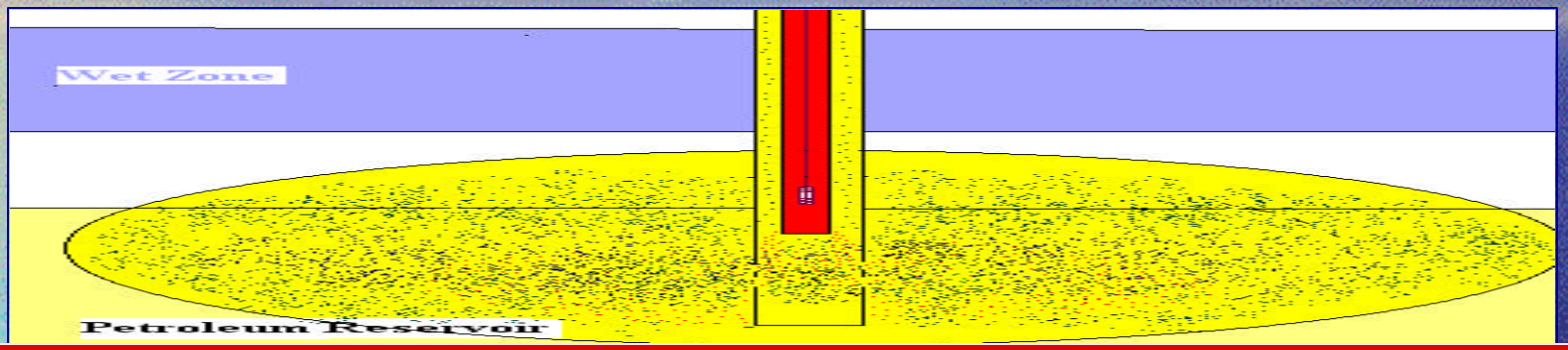




Real-time Enhanced Recovery of Oil & Gas Projected Reserves-Permian Basin, N.M.



Downhole-mixed Real-time Fracture Stimulation System



- Real-time modification of reservoir fracture geometry.
- Real-time control of proppant concentration.
- Real-time focus of proppant distribution in reservoir fracture(s).
- Minimized likelihood of well completion mishaps and liability

SPE 77676

Real-Time Downhole-Mixed Stimulation Fracturing Process

George Scott III, Realtimezone, Gary Covatch, NETL, and Art Carrasco, Halliburton

This paper was prepared for presentation at the SPE Annual Technical Conference and Exhibition held in San Antonio, Texas, 29 September–2 October 2002.

Abstract

A field-tested reservoir fracturing process comprised of carbon dioxide (CO2), fluid, and proppant was mixed downhole to generate a composite fracturing fluid that was modified in real time at the reservoir. This fracturing system provides numerous advantages over present industry fracturing practices, including reduced friction pressures and lower pumping-treatment pressures. In addition, this downhole-mixing process improves wellsite safety, reduces equipment horsepower requirements, and enables the operator to alter treatment mixture and proppant concentrations concurrent with the reservoir fracturing stimulation procedure in real time.

The first field application of this fracturing process was performed in September 2000 in an abandoned 12,300-ft Morrow gas well in the Sand Point field of Eddy County, New Mexico. The fracturing treatment consisted of methanol gel with 7,000 lb of bauxite proppant that was pumped down the annulus and blended above the perforations with 40 tons of liquid CO2, which was pumped down the tubing. A post-fracture tracer log showed that the treatment was placed in the objective reservoir as designed. Initial production from the well was approximately 250 Mcfd.

A common problem during fracturing is high surface treating pressures, which may prevent the pumping of fracturing treatments in their entirety. Typically, surface-mixed fracturing treatments are pumped at pressures that may exceed 10,000 psi. At these higher pressures, the stimulation treatment is aborted prematurely unless extra-strength tubulars are deployed. However, during the first downhole-mixed treatment, tubing pressures were observed at less than 6,000 psi, and casing pressures at less than 5,000 psi.

A second field application of the downhole-mixed fracturing system was performed in March 2002 in a stripper oil well (Delaware formation). Gelled lease oil, proppant, and CO2 were mixed downhole in an attempt to improve production from this well while avoiding fracturing out of zone. The detailed results from both test wells are presented in this paper.

Introduction

A real-time enhanced reservoir fracturing technology is currently under development and final field-testing.1,2 This real-time stimulation process involves the mixing of separate fluid types in the downhole region of the well to create a composite fracturing fluid that can be modified on the fly to alter various rheological properties and proppant concentrations. Additionally, different fracturing-fluid phases can be created to induce real-time viscosity interfingering in the reservoir fracture(s).3 The

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