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Eagle Ford Shale Cemented-Liner Refracs: Analysis of Reserves and Economics

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ABSTRACT

Casto Petroleum Engineering (CPE) analyzed the reserves and economics of 114 horizontal Eagle Ford Shale wells that were re-fractured ("refrac'd") using cemented liner technology provided by Nine Energy Service (NES). These wells, which are located across eight counties in Texas, were originally completed using multi-stage hydraulic fracturing, and produced via the original completion for an average of eight years. At the end of the original completion period for each well, a casing liner was ran and cemented in place, sealing off the original perforations. Each well was then refrac'd using new perforations placed throughout the liner. The wells were then flowed back and turned back into production.

CPE used decline curve analysis (DCA) to evaluate the estimated ultimate recoveries (EURs) of oil for three different segments of each well's production history. The EUR is the sum of the cumulative production to date and the estimated future production. First, the EUR associated with the original completion was determined by forecasting using only the production prior to the refrac. Second, the EUR associated with the full pre- and post-refrac production history was determined by forecasting using all production to date. Third, the incremental EUR associated only with the refrac was determined by subtracting the first EUR from the second EUR. Typical results for the oil EUR per 1,000 feet of lateral (oil EUR/1,000') were as follows:

- Original Completion Oil EUR/1,000': 50 Mbbl (thousands of barrels)
- Full Pre- and Post-Refrac Oil EUR/1,000': 80 Mbbl
- Incremental Refrac Completion Oil EUR/1,000': 30 Mbbl

For the typical lateral length of 5,000 ft, this represents an original completion EUR of 250 Mbbl, a full pre- and post-refrac EUR of 400 Mbbl, and a refrac completion incremental EUR of 150 Mbbl.

CPE also developed type curves for oil, gas, NGL, and water to represent the typical monthly production associated with a refrac on a 5,000 ft lateral. This incremental production was burdened with capital, operating expenses, and all other required economic parameters in order to determine key economic metrics associated with refracs. For a base case assuming $2.5 million capex, the internal rate-of-return (IRR) was 137% and payout was approximately 9 months after turn-in-line. It should be emphasized that these economics are only based on incremental refrac production, and not the "wedge" of production that would have been produced anyway if the refrac never occurred.

CPE and NES view these results as highly promising for the continued expansion of refracs throughout the Eagle Ford Shale and other U.S. shale plays. Other aspects of refrac philosophy and application continue to be studied by CPE and NES, such as candidate selection, refrac completion design, parent-child considerations, application in gas reservoirs, etc. CPE and NES encourage interested parties to contact us for more specific consultation.

INTRODUCTION: CEMENTED-LINER REFRACS

Refracturing a horizontal well using a cemented liner involves running a smaller diameter casing string inside the original production casing and cementing it in place to seal off the perforations associated with the original completion. Prior to running the liner, a clean-out run is performed on a work string in to remove sand, debris, perforation burrs, etc. from the wellbore. Once the liner is run, the narrow annulus between these casing strings is cemented to isolate the original perforations from one another and from the refrac perforations. After the liner is set and tested, the well is stimulated using multi-stage hydraulic fracturing methods just like in the original completion. For most of the wells in this data set, the original production casing is 5.5 inch diameter and the refrac liner is 4 inch. NES has shown consistent success running either 3.5 inch or 4 inch liners inside of 4.5 inch, 5 inch, and 5.5 inch production casing in several U.S. shale plays. To date, NES has run liners as long as 10,628 ft and to a measured depth as far as 20,693 ft.

To learn more about Nine Energy Service's suite of refrac tools and technology, contact Nick Pottmeyer, President of U.S. Completions, at nick.pottmeyer@nineenergyservice.com.

DATA SET

The data set for this analysis includes 114 horizontal Eagle Ford Shale wells in Atascosa, Bee, Dewitt, Dimmit, Karnes, La Salle, Live Oak, McMullen Counties of Texas. These are all wells that used NES's refrac liner technology.

Publicly available oil, gas, and water production data for these wells was downloaded from Enverus. Data pertaining to the original completion for each well was also obtained from Enverus, and the mean values for various high-level completion parameters are summarized below:

- Year Completed = 2013
- Lateral Length = 4,989 ft
- Stage Spacing = 288 ft
- Proppant Intensity = 1,420 lbs/ft
- Fluid Intensity = 27 bbl/ft

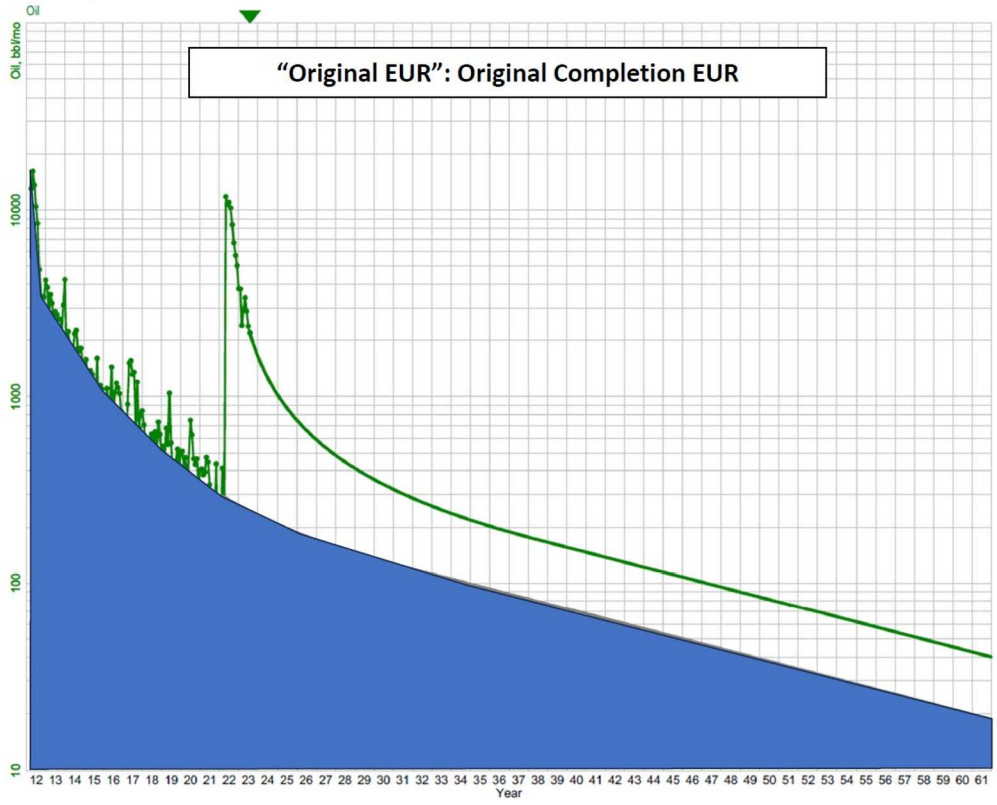
The wells are located in what are considered the Volatile Oil and Condensate thermal maturity windows of the Eagle Ford Shale and their primary product is oil or condensate. In this analysis, both oil and condensate are considered oil. The average gas-oil ratio (GOR) for all wells was approximately 3.5 Mcf per barrel.

ANALYSIS & RESULTS

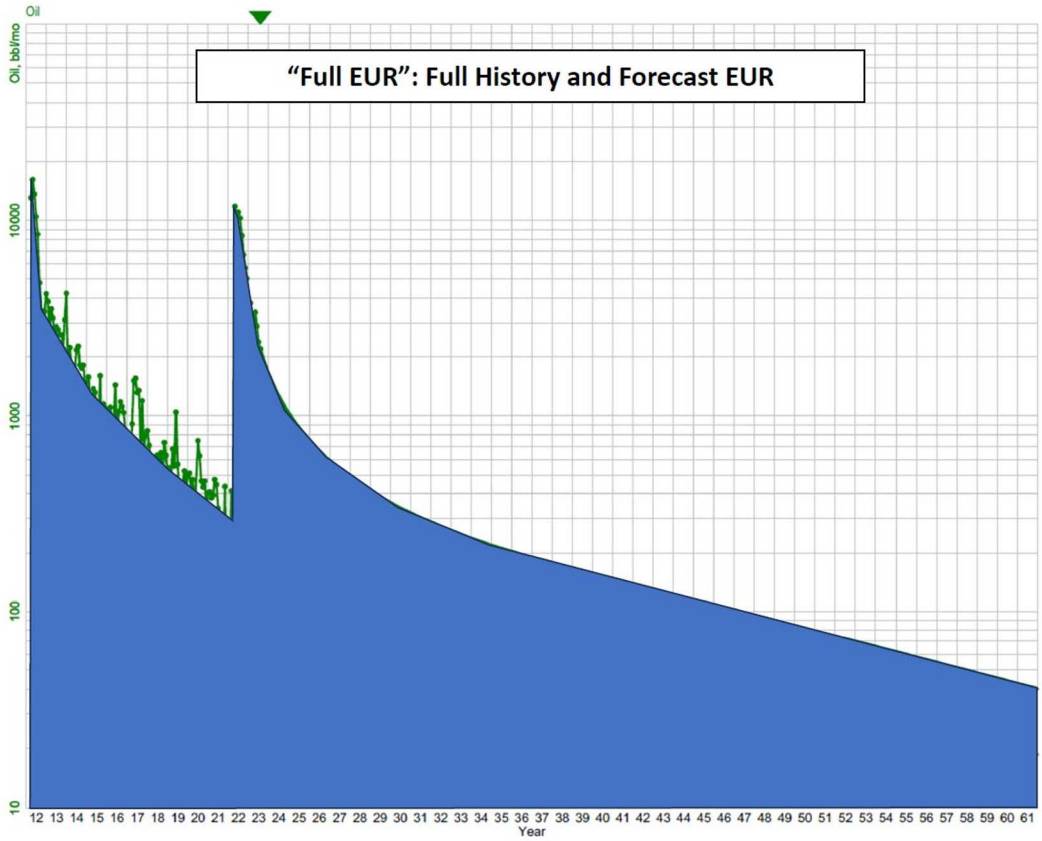
A. EUR Analysis

The oil, gas, and water production histories were loaded into the ARIES petroleum software for decline curve analysis. Three different EURs were determined for each well, as illustrated in the graphics below. The area under the curve (integral of flow rate vs. time) shaded in blue comprises the EUR.

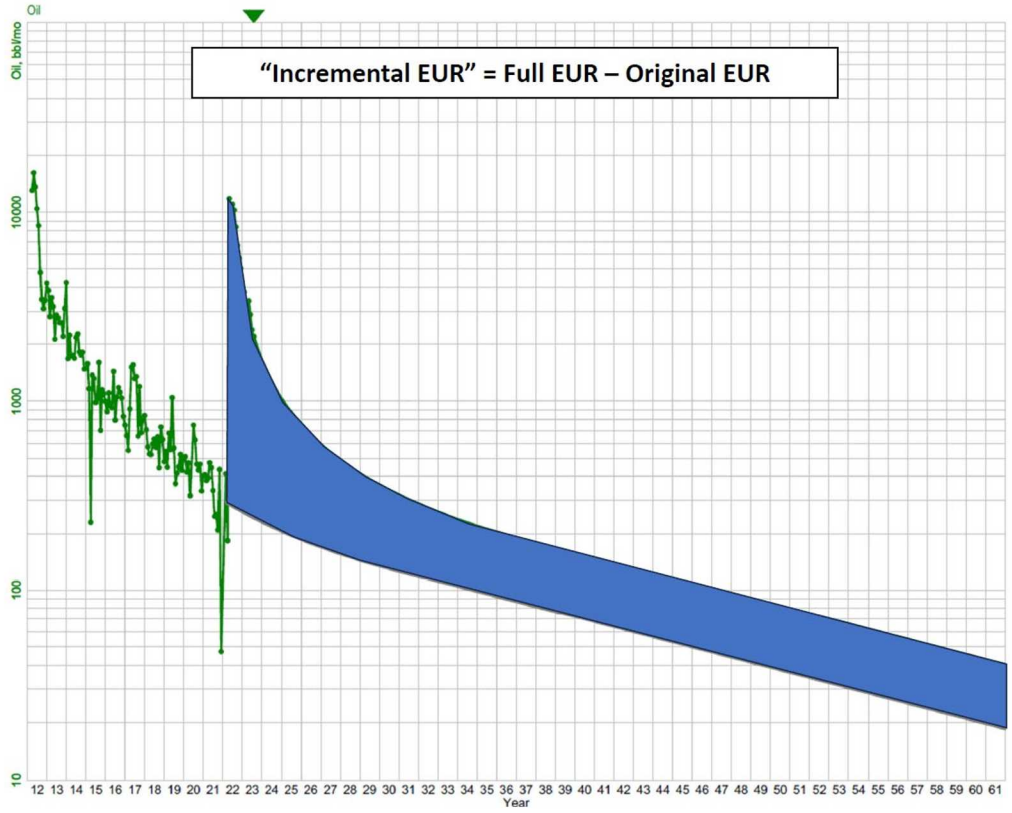
1. Original Completion EUR



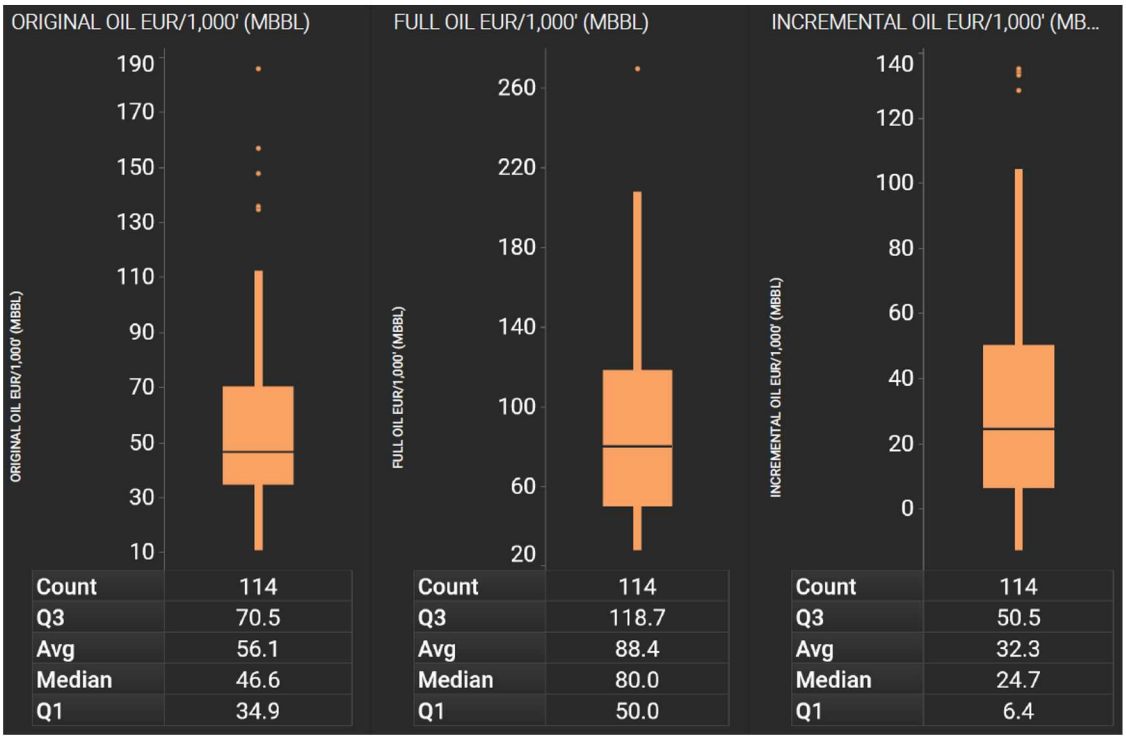
2. Full Pre- and Post-Refrac EUR



3. Incremental Refrac Completion EUR



CPE loaded the well data and EURs into the Spotifre program for statistical analysis of the original, full, and incremental oil EUR/1,000' values.

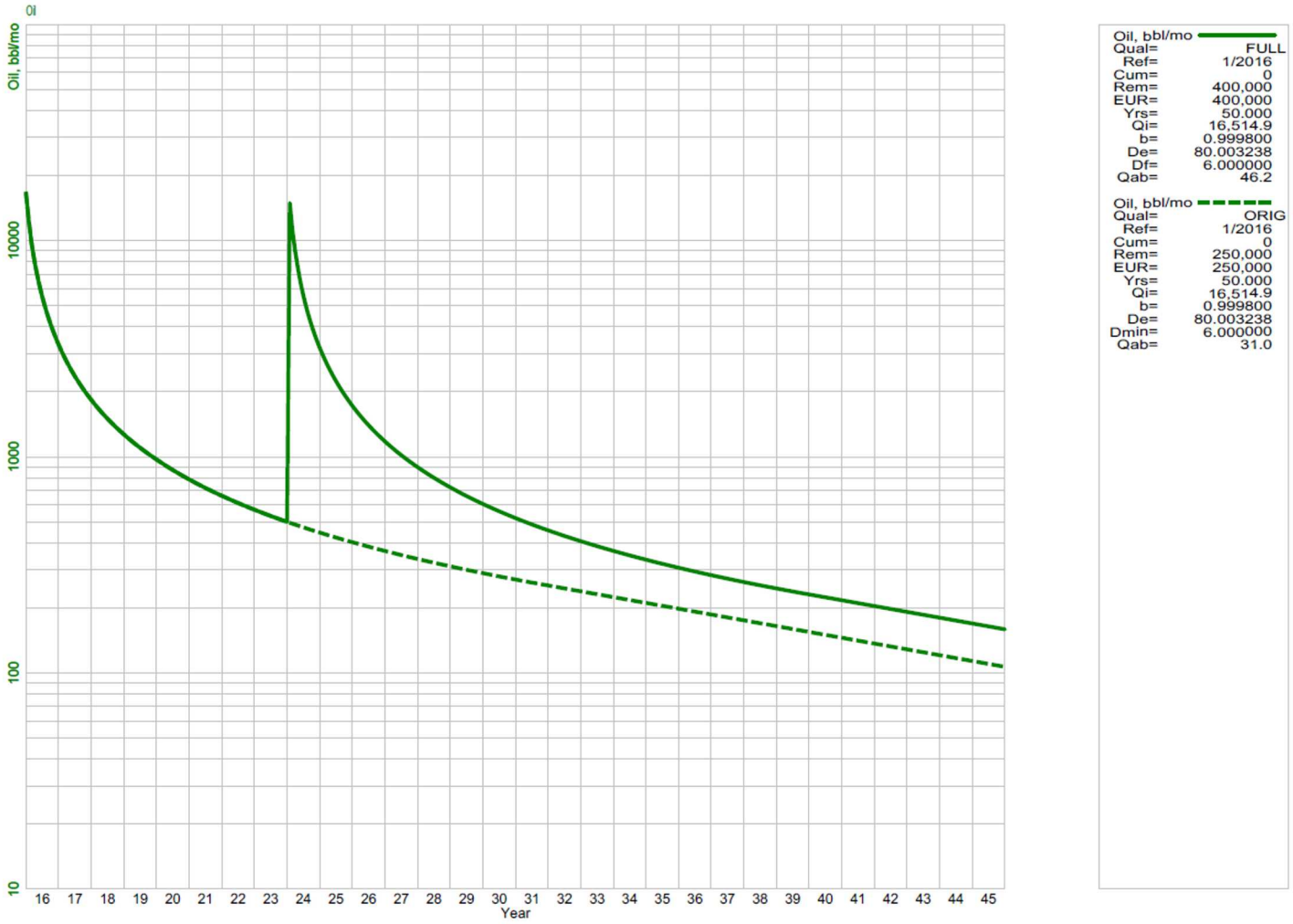


"Typical" (roughly between the mean and median) results for the oil EUR per 1,000 feet of lateral (oil EUR/1,000') were as follows:

- Original Completion Oil EUR/1,000': 50 Mbbl (thousands of barrels)
- Full Pre- and Post-Refrac Oil EUR/1,000': 80 Mbbl
- Incremental Refrac Completion Oil EUR/1,000': 30 Mbbl

B. Type Curve Reserves & Economics Analysis

Type curves were created in ARIES for a well of typical lateral length (5,000 ft), typical original completion oil EUR/1,000' (50 Mbbl) and typical full pre- and post-refrac oil EUR/1,000' (80 Mbbl).



For the typical lateral length of 5,000 ft, this represents an original completion EUR of 250 Mbbl, a full pre- and post-refrac EUR of 400 Mbbl, and a refrac completion incremental EUR of 150 Mbbl.

The type curve parameters are summarized below:

- Original Completion
  - Oil EUR = 250 Mbbl
  - Oil IP = 16,515 bbl/month
  - Hyperbolic b-Factor = 1.0
  - Initial Decline Rate = 80%
  - Terminal Decline Rate = 6%
  - Well Life = 50 years
- Refrac Completion
  - Oil EUR = 150 Mbbl
  - Oil IP = 14,935 bbl/month
  - Hyperbolic b-Factor = 1.0
  - Initial Decline Rate = 80%
  - Terminal Decline Rate = 6%
  - Well Life = 50 years

The Arps decline parameters are based on trend analysis of the wells in the data set. The eight-year period of production from the original completion before the refrac is based on the average from the data set. The post-refrac initial production rate (IP) was back-extrapolated using the other known or assumed decline parameters. CPE reviewed the original completion IP's and post-refrac IP's of the wells in the data set and found that the type curve is consistent with the data.

Outputs of the monthly oil volumes for each type curve were generated and the difference between the two was considered the monthly incremental refrac oil volumes. An economic model was generated and applied only to these incremental volumes. The assumptions used in the economic model are summarized below:

- Working Interest = 100%
- Net Revenue Interest = 80%
- Gas-Oil Ratio = 3.5 Mcf/bbl
- Water-Oil Ratio = 0.4 bbl/bbl
- NGL Yield = 75 bbl/MMcf
- Shrink = 85% Remaining
- Post-Processing Gas BTU = 1.060
- Operating Expenses = $10/bbl Oil
- Water Hauling & Disposal = $6.00/bbl
- Gas Gathering, Processing & Transportation = $2.00/Mcf
- Ad Valorem Tax = 2.5%
- Oil Severance Tax = 4.6%
- Gas Severance Tax = 7.5%
- West Texas Intermediate (WTI) Oil Price = $80.00/bbl Flat
- Henry Hub (HH) Natural Gas Price = $3.00/MMBtu Flat
- Oil Price = 90% of WTI

- Gas Price = 85% of HH
- NGL Price = 35% of WTI

The results of this analysis are represented by two key economic metrics, internal rate of return (IRR) and payout period, and are presented below at a range of capital expenditure (capex) amounts:

CAPEX ($MM)	IRR (%)	PAYOUT (MONTHS)
$2.000	262%	6
$2.250	186%	8
$2.500	**137%**	**9**
$2.750	104%	10
$3.000	80%	12

For a lateral length of 5,000 ft, a $2.5 million capex corresponds to $500/ft. Assuming the refrac completion uses 300 ft stage spacing, straddling the stages of the original completion, that would mean there are 17 stages in the refrac. $2.5 million over 17 stages implies a cost of $147,000 per frac stage. In CPE's judgement, this is an appropriate base case cost assumption including the cost of the liner, pressure pumping, and other expenses associated with the refrac. Admittedly, more work is to be done on the estimation of capex associated with refracs. However, the table above shows that refrac economics are competitive with new-drill economics across a broad range of capex amounts.

An oil price sensitivity assuming $2.5 million capex and all other assumptions held constant was also performed. The results are shown in the table below:

WTI OIL PRICE ($/BBL)	IRR (%)	PAYOUT (MONTHS)
$100	311%	6
$90	213%	7
$80	**137%**	**9**
$70	81%	12
$60	40%	20
$50	13%	46

Again, these results support the refrac of existing wells as an alternative or complement to a drilling development program.

CONCLUSION

CPE and NES view these results as highly promising for the continued expansion of refracs throughout the Eagle Ford Shale and other U.S. shale plays. Other aspects of refrac philosophy and application continue to be studied by CPE and NES. These topics include:

- Refrac Candidate Selection
- Refrac Completion Design
- Mechanism of Action for EUR and Rate Improvement
- Parent-Child and Well Spacing Considerations
- Application in Gas Reservoirs
- EUR Improvement in terms of Recovery Factor
- Economics of Reserves Acceleration via Refrac Apart from Incremental EUR

CPE and NES encourage interested parties to contact us for a discussion of these findings and more specific consultation.

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