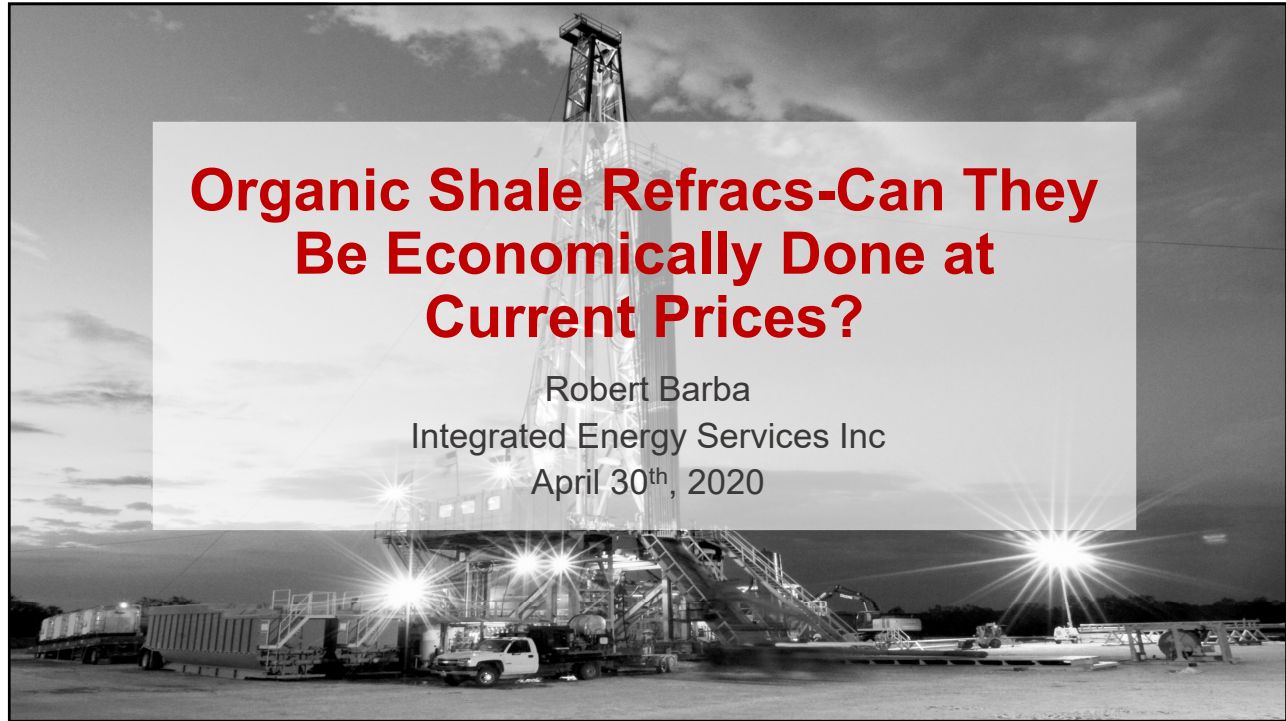


Organic Shale Refracs-Can They Be Economically Done at Current Prices?

Robert Barba
Integrated Energy Services Inc
April 30th, 2020



Executive Summary



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- With the current low price environment, significantly lowering completion costs while maximizing recovery is critical to economic survival
- Refracking organic shale primary wells presents a unique opportunity to produce more hydrocarbons at less cost and deliver superior returns than new well drilling and completions
- Our study shows the potential to significantly improve field economics through the use of Extreme Limited Entry and mechanical isolation using expandable liners
- Biggest opportunities
 - Pure gas plays of Haynesville, Marcellus and downdip Eagle Ford
 - Oil window of the Eagle Ford and in the Southern Midland Basin

What do refracs and Rodney have in common?

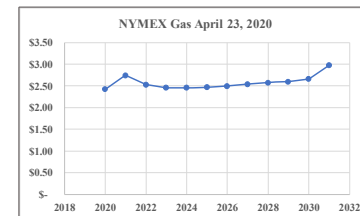
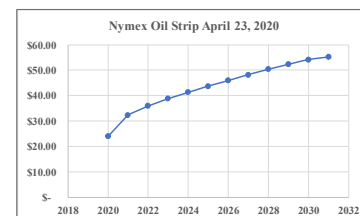
- Last two down cycles (2009 and 2015) saw a huge increase in refrac discussion and conferences
- Poor results from the extensive use of diverters rightfully earned refracs very little respect
- From 2017 on mechanical isolation methods were finally accepted, results now very consistent



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“Current Prices” = NYMEX Strip 4/23/20

- Economic analysis involves calculating the present value of future cash flows vs. the investment
- Current spot prices not relevant to the bulk of this net present value
- Marcellus producing life accepted by Range Resources financial auditors 55 years!
- IES EUR analysis of Marcellus wells cut off at 30 years, most wells still strong positive cash flow



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Post Coronavirus Refrac Slogan:

Make America's
Old Gas
Wells Great Again!



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Executive Summary (contd)



- Analysis of organic shales in the Eagle Ford (oil and gas), Marcellus (gas), and Permian Wolfcamp oil strongly suggests that the P50 recovery factors for close cluster completions (+/- 15 ft) with high cluster efficiency can be just below the established numbers for conventional solution gas drive oil reservoirs (13.5% vs. 15%) and low perm depletion drive gas reservoirs (59% vs. 70-80%)
- Analyses in all four areas indicate numerous economic refrac opportunities exist even at the current depressed NYMEX strip pricing

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Executive Summary (contd)



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- If the original recovery factors are less than half of these numbers the potential exists to have two refracs produce more than a single new well at a lower total cost and have better economics than drilling and completing new wells
- Opportunities are especially rich in the two pure gas plays (downdip Eagle Ford and all of the Marcellus) and Haynesville given their 2010-2012 vintage with huge original cluster spacings (as much as 90 ft in the early wells vs. +/- 15 ft proposed now)
- Numerous opportunities exist in the oil window of the Eagle Ford and in the Southern Midland Basin in the Permian even with the closer cluster spacings used in these more recent plays
 - The earlier wells with larger cluster spacings do have the best potential initially though and should be highest on the list

Permian Recovery Factor vs. Cluster Spacing

Actual results from 2020 study (green dot), curves from extensive University Lands simulation study

Eagle Ford oil P50 12%, Eagle Ford gas and Marcellus 59% P50

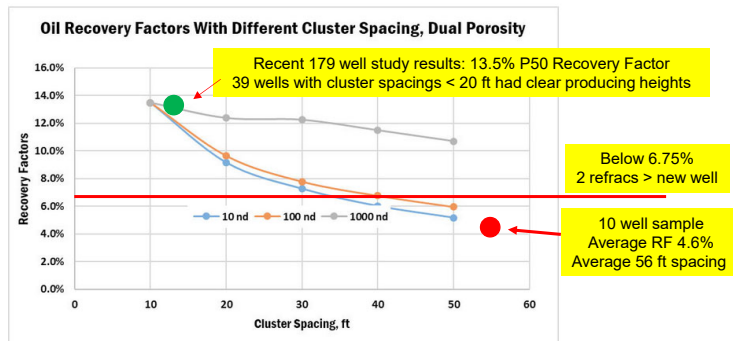


Fig. 10—Recovery efficiency based upon the dual-porosity model at the end of year 30.

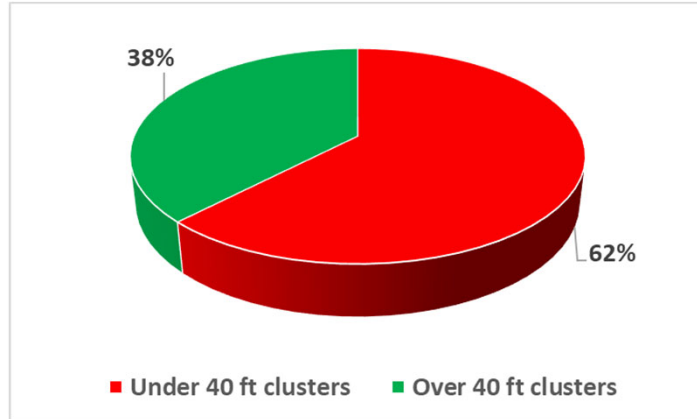
Xiong SPE 199721 2020 HFTC

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Size of the Prize-Southern Midland Basin Sample

Over 40 foot spacing wells have the highest probability of having less than a 6.75% recovery factor

Need to also consider OIP within the drained height, must be high enough with a 13.5% post refrac recovery



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Historical Cluster Spacing (2011 Survey)

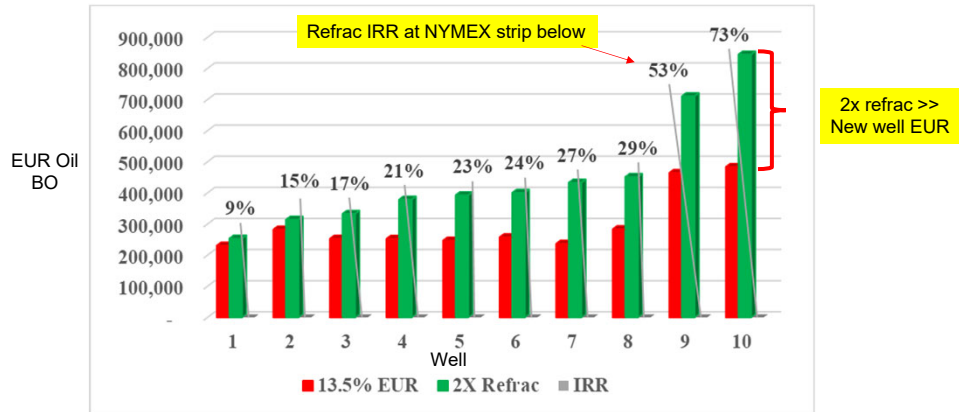
Play	Cluster Spacing	Clusters Per Stage	Stage Spacing	Average Thickness
Woodford	130	4.2	546	170
Barnett	183	3.3	604	350
Fayetteville	120	4.3	516	110
Eagle Ford	72	2.8	202	200
Haynesville	87	4.5	392	250
Marcellus *	50	5.2	260	125
Average	107	4.1	420	201

* CHK/STO Marcellus project August 2011: over 450 wells producing with 90 ft cluster spacing
 Petrohawk 2010 wells in Eagle Ford 90 ft spacing
 "Best Practices" now +/- 15 ft

SPE 144326 (2011)

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S Midland Basin New Drill EUR vs. 2X Refrac EUR



4/23/2020	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 on
Nymex Oil	\$ 24.01	\$32.33	\$ 35.98	\$ 38.81	\$ 41.37	\$ 43.76	\$ 46.01	\$ 48.19	\$ 50.36	\$ 52.36	\$ 54.18	\$55.21
Nymex Gas	\$ 2.42	\$ 2.75	\$ 2.53	\$ 2.46	\$ 2.46	\$ 2.47	\$ 2.50	\$ 2.54	\$ 2.57	\$ 2.60	\$ 2.66	\$ 2.97

Seven Well Refrac Project vs. Seven New Wells

Seven refracs at \$3 million vs. seven new wells at \$6 million:

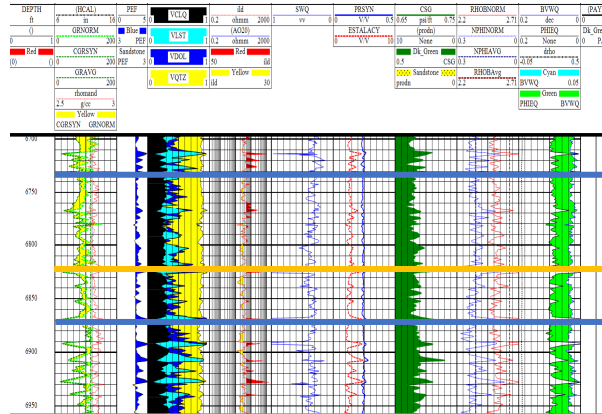
Refrac program higher IRR and NPV

Organic Shale New Well Economic Analysis 7 Well Program			
Updated April 23 2020			
Assumes		IP Oil	2689.4
		EUR Oil BO	2,227,222
NRI	75.0%	EUR Gas MCF	23,586,900
Disc Rate/IRR	10%	Total Cash Flow undisc	\$ 109,378,375
LOE/Well	\$ 2,500	Total Cash Flow disc	\$ 65,756,951
LOE Esc	3.0%	Payout (undiscounted)	54
Oil severance	4.60%	Payout (discounted)	82
Gas severance	7.50%	Undisc Net/Invest	2.60
MMBTU ADJ	1200	Disc Net/Invest	1.57
		NPV	\$ 14,792,567
		Refrac Cost	\$ 42,000,000
		IRR	17%

Organic Shale Refrac Economic Analysis 7 Well Program			
Updated April 23 2020			
Assumes		IP Oil	2181.8
		EUR Oil BO	1,806,845
NRI	75.0%	EUR Gas MCF	19,134,991
Disc Rate/IRR	10%	Total Cash Flow undisc	\$ 88,522,302
LOE/Well	\$ 2,500	Total Cash Flow disc	\$ 53,228,324
LOE Esc	3.0%	Payout (undiscounted)	26
Oil severance	4.60%	Payout (discounted)	31
Gas severance	7.50%	Undisc Net/Invest	4.22
MMBTU ADJ	1200	Disc Net/Invest	2.53
		NPV	\$ 25,006,471
		Refrac Cost	\$ 21,000,000
		IRR	37%

4/23/2020	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 on
Nymex Oil	\$ 24.01	\$32.33	\$ 35.98	\$ 38.81	\$ 41.37	\$ 43.76	\$ 46.01	\$ 48.19	\$ 50.36	\$ 52.36	\$ 54.18	\$55.21
Nymex Gas	\$ 2.42	\$ 2.75	\$ 2.53	\$ 2.46	\$ 2.46	\$ 2.47	\$ 2.50	\$ 2.54	\$ 2.57	\$ 2.60	\$ 2.66	\$ 2.97

Well Number 10 (Top Candidate) Petrophysical Analysis



78 FT Cluster Spacing

Top 6730

6821 lateral

Base 6870 A quality

prop/ft	BBL/ft	Clust Spc	RF CONT	OIP	Cum Oil	Cum Gas	13.5% RF	Refrac EUR	Orig EUR
965	27.1	78.0	2.3%	3,582,778	61,104	643,543	483,675	422,571	83,037

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Well Number 10 (Top Candidate) Economic Analysis

Organic Shale Refrac Economic Analysis Well 10		IP Oil																			
Updated April 23 2020		510.3																			
Assumes		EUR Oil BO		4/23/2020	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 on					
NRI	75.0%	EUR Gas MCF	4,475,144	Nymex Oil	\$ 24.01	\$32.33	\$ 35.98	\$ 38.81	\$ 41.37	\$ 43.76	\$ 46.01	\$ 48.19	\$ 50.36	\$ 52.36	\$ 54.18	\$55.21					
Disc Rate/IRR	73%	Total Cash Flow undiscc	\$ 19,844,616	Nymex Gas	\$ 2.42	\$ 2.75	\$ 2.53	\$ 2.46	\$ 2.46	\$ 2.47	\$ 2.50	\$ 2.54	\$ 2.57	\$ 2.60	\$ 2.66	\$ 2.97					
LOE/Well	\$2,500	Total Cash Flow disc	\$ 4,663,532																		
LOE Esc	3.3%	Payout (undiscounted)	13	15																	
Oil severance	4.60%	Payout (discounted)	240	16																	
Gas severance	7.50%	Undisc Net/Invest	6.61	6.0																	
MMBTU ADJ	1200	Disc Net/Invest	1.6	3.7																	
		NPV	\$ 0	\$6,832,985																	
		Refrac Cost	\$ 3,000,000	\$3,000,000																	
NGLs captured in MMBTU adjustme		IRR	73%	68.0%																	
IP GOR								NRI	NRI	NRI	NRI	WI	WI	WI	WI						
								75.0%	75.0%	75.0%	75.0%	100.0%	100.0%	100.0%	100.0%						
		Oil	Gas	Oil	Gas	Gas	Oil	Oil	Gas	0.046	0.075	Operating	Future	Cum	Disc Future	Cum Disc					
		Rate	Rate	Rate	Rate	Price	Price	Revenue	Revenue	Severance	Severance	Per Well	Net Cash	Cum Cash Flow	Net Cash	Cum Cash Flow	Decline				
		BOPD	MCFD	BOPM	MCFM	\$/MMBTU	\$/BBL			Oil	Gas	Expense	Flow \$	\$	\$	\$	Oil				
		Count															Decline				
Month	Well	Rate	Rate	Rate	Rate	Price	Price	Revenue	Revenue	Oil	Gas	Expense	Net Cash	Cum Cash Flow	Net Cash	Cum Cash Flow	Decline				
Jun-20	1	510	1276	15532	38831	\$ 2.42	\$24.01	\$279,684	\$70,612	\$ 12,865	\$ 5,296	\$ 2,500	\$329,634	\$ 329,634	\$ 310,839	\$ 310,839	0				
Jul-20	1	418	1264	12723	38486	\$ 2.42	\$24.01	\$229,102	\$69,983	\$ 10,539	\$ 5,249	\$ 2,506	\$280,791	\$ 610,425	\$ 249,684	\$ 560,522	0.81915				
Aug-20	1	357	1253	10860	38144	\$ 2.42	\$24.01	\$195,555	\$69,362	\$ 8,996	\$ 5,202	\$ 2,513	\$248,207	\$ 858,632	\$ 208,124	\$ 768,647	0.85357				
Sep-20	1	313	1242	9524	37806	\$ 2.42	\$24.01	\$171,500	\$68,747	\$ 7,889	\$ 5,156	\$ 2,519	\$224,683	\$ 1,083,315	\$ 177,657	\$ 946,304	0.87699				

Very low initial recovery factor (2.3%) with high OIP top refrac candidate in S Midland basin study

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Organic Shale Refracs-Can They Be Economically Done at Current Prices?

Work Flow and Course Content:

1. Overview of the refrac optimization process
2. Estimate original oil or gas in place for the refrac candidate from petrophysics
3. Estimate drainage height from integrating landing zone with rock properties
4. Estimate incremental ultimate recovery from local recovery factor analysis
5. Estimate monthly production decline from incremental oil/gas and type curve
6. Analyze economics of refrac using the current NYMEX price strip
7. Estimate refrac cost portion of the economic analysis with “best practices.”
 - Run expandable liner: Lowest possible total refrac cost vs. cemented liners (+/-20% less)
 - Extreme Limited Entry (XLE) perforation design 2500 psi pressure drop or higher
 - Close cluster spacing (+/- 15 ft) to maximize stimulated reservoir volume
 - One hole per cluster minimizes near wellbore friction energy loss creating single fracture
 - Rate per cluster optimization based on rock mechanical properties and 3D frac modeling
 - ✓ May need to increase rate per cluster to break through stress barriers above and below lateral

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Organic Shale Refracs-Can They Be Economically Done at Current Prices?

Work Flow and Course Content:

1. Overview of the refrac optimization process

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Organic Shale Refrac Main Value Drivers

- Access and contact significant volumes of unstimulated rock from cluster spacings wider than 15 ft and low frac fluid and proppant loadings
- Increase production at the minimum possible cost implementing “best practices” for cluster spacing, proppant loading, and fluid loading, must compete for capital with new well completions
- Enhance and protect production of primary wells while avoiding up to 40% losses in infill well once pad operations resume
- Anything less than a full volume preload (several hundred thousand barrels) or a refrac will result in significant NPV losses

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Refrac Primary Execution Challenges

- Control fracture entry points to stimulate as close to 100% of the new rock and recharge 100% of the depleted intervals
 - Recharge not critical for all wells if no primary-infill issues but restricting flow into old clusters important for new rock stimulation
- Execute a premium optimized frac at the lowest cost per barrel or MCF possible using “best practices”
- XLE and expandable liners will maximize SRV at the lowest cost
 - Higher pump rates with the larger ID expandable liners can result in longer stage lengths and fewer stages
 - Once liner is installed the refrac treatment is identical to a new well completion and conventional plug and perf operations can begin
 - XLE will ensure high cluster efficiency (85-90%) even with longer stages (see next slide from SM fiber optic study)

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25% Stage Length Increase vs. Active Clusters

Conclusions

- Stage spacing increased 25% with no evidence of performance degradation
- Optimal initial perforation friction is 2,000 – 3,000 psi ($C_d = 0.7$)
- Equal-entry hole perforating charges performed as advertised
- Intrastage diverter drops do not create new fracture initiation points, but can effectively redistribute fluid and proppant among active clusters

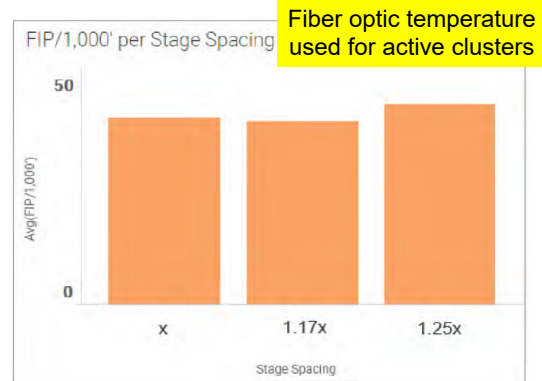
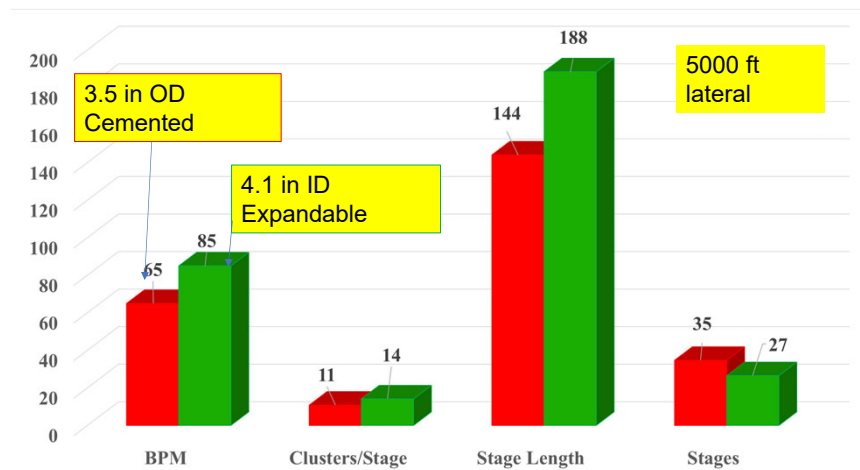


Figure 8—Average fracture initiation points normalized per 1,000' of lateral for different stage spacing designs.

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SPE 199712 SM 2020 HFTC

Expandable vs. Cemented Liner Comparison

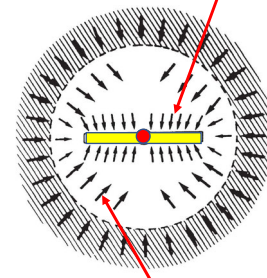


This is the value proposition for expandable liners fewer stages without sacrificing SRV

Organic Shales vs. Conventional Reservoirs

- Nanodarcy organic shales have a different drainage mechanism than millidarcy conventional reservoirs shown in the cartoon below
- Millidarcy conventional reservoirs the frac results in an extension of the effective wellbore radius that provides a shorter path for hydrocarbons in the matrix to the wellbore:
- Organic shale matrix not productive, must be hydraulically fractured to flow
- Horizontal multistage fracs create permeability, no frac almost zero flow
 - 100 days for gas molecule to travel 1m in 100 nd rock

Conventional reservoir
Matrix drains into planar fracture



Conventional reservoir
Planar fracture extending effective wellbore radius

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Eagle Ford Pressure Monitor Well Data

Producing Well Gen I Frac 50 ft Cluster Spacing

Cluster



Pressure Monitor Well 70 ft Away Drilled +/- 4 yrs later (based on frac gen)



■ = depleted area in offset pressure monitoring well (width of SRV)

7.5 ft of lateral drainage (SRV width) observed in monitor well
85% of rock producing almost zero with 50 ft cluster spacing

Ref: COP presentation Oct 2018 SPE/Icota Refrac Workshop (slides not released)

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6 Month Cum. Production vs. Cluster Spacing

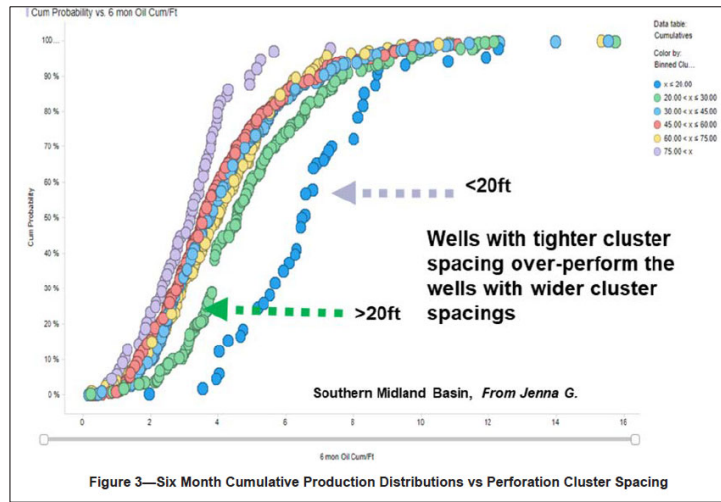
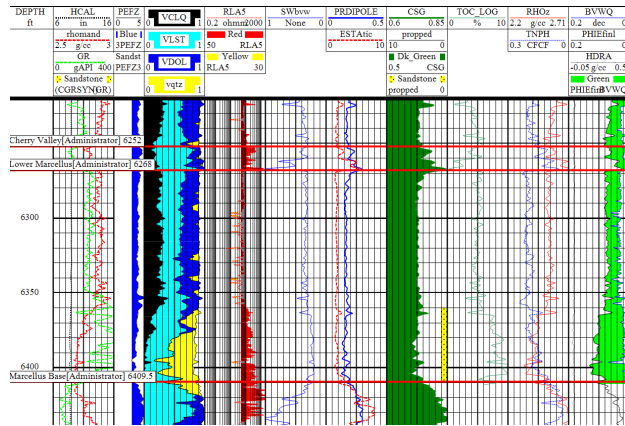


Figure 3—Six Month Cumulative Production Distributions vs Perforation Cluster Spacing

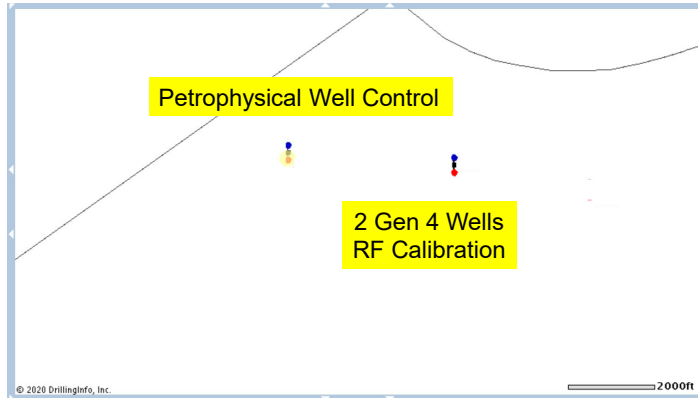
Xiong et al SPE 199721 2020 HFTC

Marcellus Gen 4 Example Bradford County 58.7% RF



First Prod	Last Prod.	Cum Gas	GPI	EUR	Acres	EUR/ac	MCF/ac	Lb/Ft	BBL/ft	Stg Length	RF	EUR
Apr-18	Jan-20	2,518,548	5238	8,019,470	105.8	75,785	125383	1532	27	131	60.4%	
Apr-18	Jan-20	2,775,317	5576	8,057,029	112.6	71,525	125383	1506	28	133	57.0%	
											58.7%	

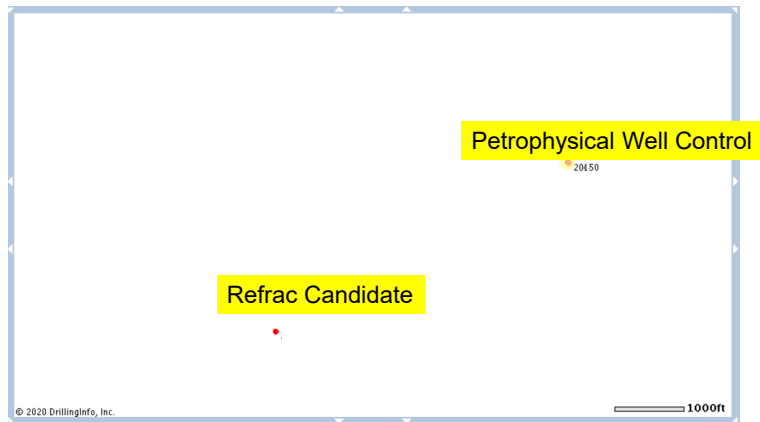
Marcellus Gas Refrac Recovery Factor Model Wells



First Prod	Last Prod.	Cum Gas	GPI	EUR	Acres	EUR/ac	MCF/ac	Lb/Ft	BBL/ft	Stg Length	RF EUR
Apr-18	Jan-20	2,518,548	5238	8,019,470	105.8	75,785	125383	1532	27	131	60.4%
Apr-18	Jan-20	2,775,317	5576	8,057,029	112.6	71,525	125383	1506	28	133	57.0%
											58.7%

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Marcellus Refrac Candidate Bradford County Economics



First Prod	Cum Gas	GPI	EUR	Lb/Ft	BBL/ft	Stg Length	RF EUR	RF Cum	Stages	GIP	59% RF	Refrac EUR
Jan-12	5,252,805	6538	8,205,266	680	17	467	40.8%	25.9%	14	20,092,028	11,854,296	6,658,925

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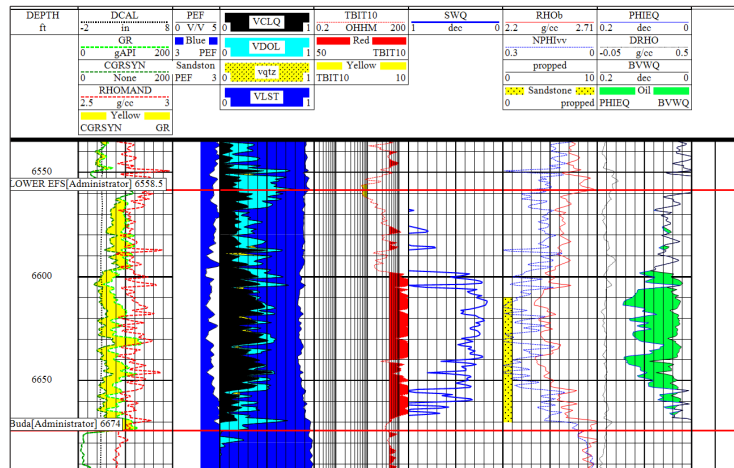
Marcellus Refrac Candidate Economic Analysis

Organic Shale Refrac Economic Analysis Marcellus				
Updated April 23 2020			IP Gas	3755.0
Assumes				EUR Oil BO
NRI	75.0%		EUR Gas MCF	6,658,925
Disc Rate/IRR	10%		Total Cash Flow undisc	\$ 12,138,696
LOE/Well	\$ 2,500		Total Cash Flow disc	\$ 7,064,722
LOE Esc	3.0%		Payout (undiscounted)	20
Oil severance	na		Payout (discounted)	23
Gas severance	0.00%		Undisc Net/Invest	4.05
MMBTU ADJ	1200		Disc Net/Invest	2.35
LOE includes PA impact fee			NPV	\$ 4,064,722
			Refrac Cost	\$ 3,000,000
			IRR	42%

4/23/2020	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 on
Nymex Gas	\$ 2.42	\$ 2.75	\$ 2.53	\$ 2.46	\$ 2.46	\$ 2.47	\$ 2.50	\$ 2.54	\$ 2.57	\$ 2.60	\$ 2.66	\$ 2.97

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Eagle Ford Gen 4 Oil Example P50 12% RF



Top	Base	Ft Pay	Porosity	Sw	BVW	BOIP/Acre	BOIP 640
6598	6662.5	56.5	0.103	0.331	0.03409	23,414	14,984,830

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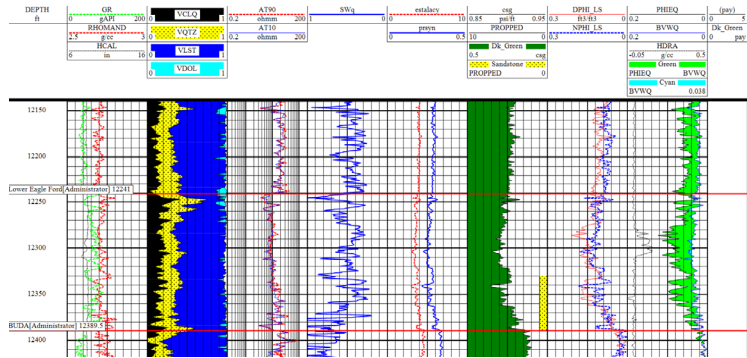
Eagle Ford Oil Example Offset Producers

Well	OIL EUR	GAS EUR	Lateral	Acres	EUR/ac	OIP/ac	RF
1	168,850	556,880	6977	105.7	1597	23414	6.8%
2	292,370	292,700	7744	117.3	2492	23414	10.6%
3	274,560	790,330	6873	104.1	2637	23414	11.3%
4	306,540	290,300	7612	115.3	2658	23414	11.4%
5	266,090	536,770	5954	90.2	2950	23414	12.6%
6	318,920	979,440	6465	98.0	3256	23414	13.9%
7	256,480	489,870	4993	75.7	3390	23414	14.5%
8	395,930	355,670	7628	115.6	3426	23414	14.6%
						P50	12.0%

Recent completions engineered perforating

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Eagle Ford Gas Webb County Gen 4 Example

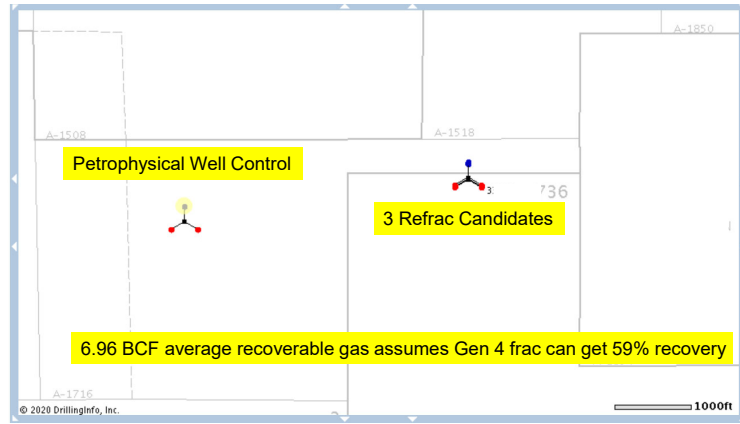


Top	Base	H	PHI	SW	Free Gas MCF/Acre	Sorbed MCF/acre	Total MCF/acre
12241	12384	116	0.075	0.441	65,961	28,957	94,917

GAS EUR	Lateral	Acres	EUR/ac	GIP/ac	RF
8,863,940	7901	159.62	55,533	94917	58.5%

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Eagle Ford Gas Refrac Candidate Evaluation



Well	GPI	FirstProd	GPI	EUR	Ac	EUR/ac	MCF/ac	lb prop	bbl fluid	lb/ft	RF EUR	bbl/ft	RF EUR	Cum Gas	Cum/ac	RF Cum	eur/ft	EUR/RF (GIP)	Refrac RF	Refrac EUR
Refrac 1	6191	4/1/2013	6191	2,297,845	125.1	18,372	121,954	4038760	91934	652	15.1%	15	15.1%	1,965,670	15716	12.9%	371	15,252,873	46.1%	7,033,525
Refrac 2	6065	4/1/2013	6065	2,335,870	122.5	19,064	121,954	3865600	88247	637	15.6%	15	15.6%	1,970,633	16083	13.2%	385	14,942,445	45.8%	6,845,409
Refrac 3	6071	4/1/2013	6071	2,471,595	122.6	20,152	121,954	4040300	92992	666	16.5%	15	16.5%	1,818,416	14826	12.2%	407	14,957,227	46.8%	7,006,348
Gen 4 1	6720	5/1/2019	6720	11,665,895	135.8	85,932	121,954	15064665	360627	2242	70.5%	54	70.5%	3013565	22198	18.2%	1,736			6,961,761
Gen 4 2	6797	5/1/2019	6797	7,304,662	137.3	53,197	121,954	15318475	361170	2254	43.6%	53	43.6%	2678031	19503	16.0%	1,075			

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Average

Eagle Ford Gas Refrac Candidate Economics

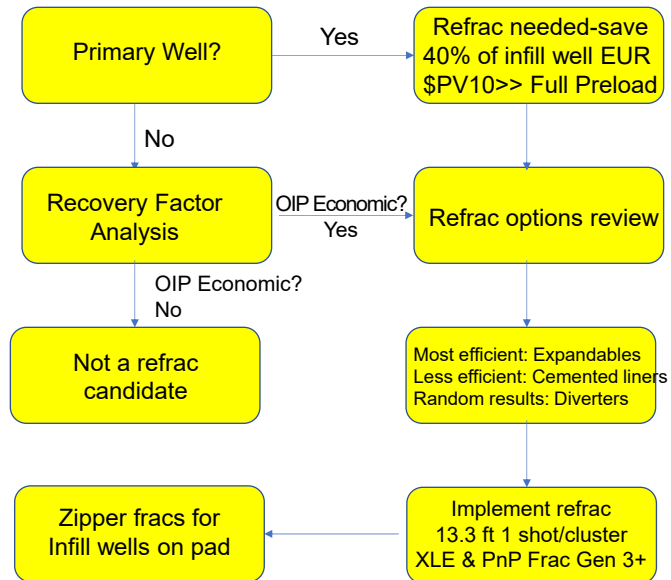
Organic Shale Refrac Economic Analysis Eagle Ford			
Updated April 23 2020		IP Gas	15512.4
Assumes		EUR Oil BO	
NRI	75.0%	EUR Gas MCF	6,961,760
Disc Rate/IRR	10%	Total Cash Flow undisc	\$ 12,265,960
LOE/Well	\$ 500	Total Cash Flow disc	\$ 8,999,441
LOE Esc	3.0%	Payout (undiscounted)	6
Oil severance	4.60%	Payout (discounted)	6
Gas severance	7.50%	Undisc Net/Invest	4.09
MMBTU ADJ	1200	Disc Net/Invest	3.00
		NPV	\$ 5,999,441
		Refrac Cost	\$ 3,000,000
		IRR	141%

Above numbers assume a 59% recovery factor for a new Gen 4 close cluster well
 Refrac EUR is the difference between the 59% and the current 12.7% average
 Breakeven PV10 28.4% recovery factor total
 (12.7% current plus 15.7% incremental)

	4/23/2020	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 on
Nymex Gas	\$	2.42	\$ 2.75	\$ 2.53	\$ 2.46	\$ 2.46	\$ 2.47	\$ 2.50	\$ 2.54	\$ 2.57	\$ 2.60	\$ 2.66	\$ 2.97

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Organic Shale Refrac Process Flow Chart



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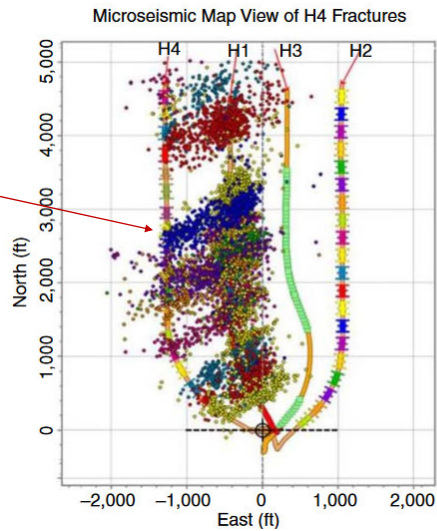
Horizontal Organic Shale Refracs

- As more infill wells were completed it became apparent that there were issues involved with Fracture Driven Interactions (FDI's or "frac hits")
- Initially the focus was on avoiding production losses in the primary wells as infill well FDIs often damaged or killed the primary wells
- As production was established it became apparent that the recovery factors of the initial infill wells were lower than what should be expected from the OIP and offset recovery factors normalized to the frac vintage
- Recent work done by Elliott (2019) suggests that the only viable options for primary well protection are refracs and full volume preloads with water
- The full volume preload requires replacement of a large % of the oil and water produced from where it was produced to restore original pore pressure

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Infill/Child well

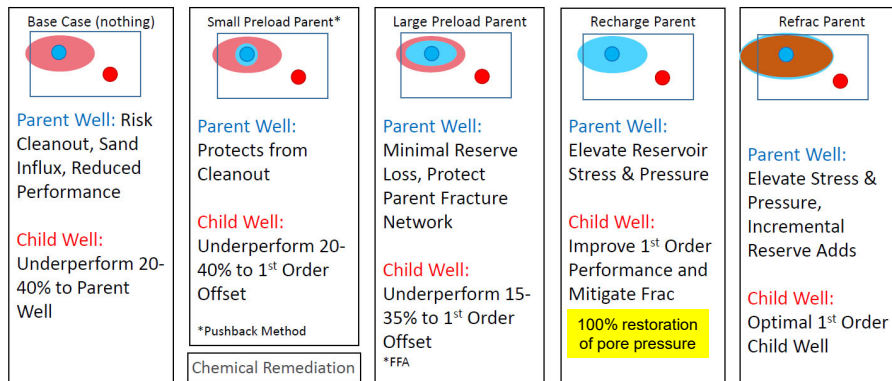
- Infill/child well (H4) asymmetric frac
- Very few events on distal side
- H1 primary/parent well
- Bakken formation



Dohmen, et al SPE 186096

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Depletion Mitigation Opportunities

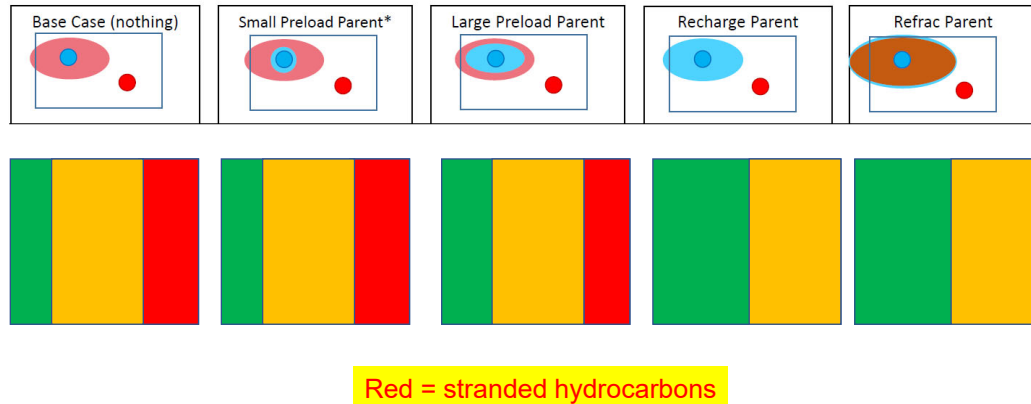


Increasing Cost and Planning Complexity →

Elliott, Brendan, Well Completions for Unconventional Resource Development Optimization and Parent Child Interaction Workshop, April 2019

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Depletion Mitigation Results



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Primary Well Refrac Issues

- The refrac treatment needs to recharge the existing clusters to prevent infill well asymmetric fractures
- The treatment should access as much “new rock” as possible to increase primary well production as much as economically possible
- Both mechanisms require complete isolation of the existing perforations to effectively stimulate both the new and existing clusters
- Mechanical isolation is strongly recommended vs. attempting to divert with chemicals, fiber, or ball sealers
- The two viable options for mechanical isolation are expandable liners and cemented casing

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Refrac Isolation Options

- There are several options available for executing refracs using either diverters or mechanical isolation
- For mechanical isolation the two main options are cemented or expandable liners
 - The combination of Extreme Limited Entry and expandable liners provides a means for:
 - ✓ Fewer stages than cemented liners via higher pump rates allowing for more clusters per stage
 - ✓ Lower cost of stimulation than cemented liners
 - ✓ Lower cost per barrel of oil produced than cemented liners
- The process has similar benefits for new well completions

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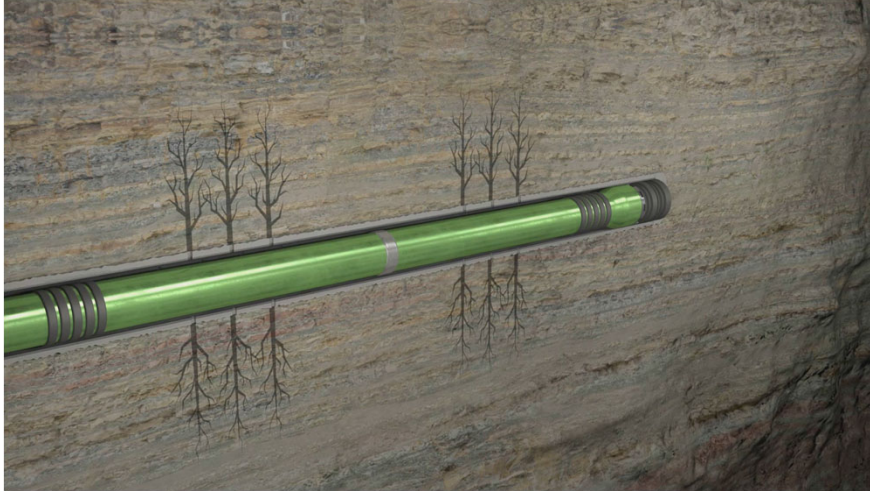
Refrac Execution

- Extreme limited entry (XLE) provides a mechanism to stimulate short spaced clusters (13.3 ft spacing proposed) with high cluster efficiency (85%)
 - Higher SRV=higher EURs 100% of the time
- If the number of perfs per cluster are limited (one is proposed) and the hole size is uniform stage lengths can be increased without decreasing the overall SRV with a 1500 psi pressure drop across perfs post erosion (typically requires +/- 2800 psi pre-erosion)
- 85 BPM with an expandable liner can frac a 7500 ft lateral with 38 stages vs. 47 stages required if the max rate is 65 BPM with a 3.5 in cemented liner
- While the expandable option up front AFE is higher than a cemented liner the elimination of 8 frac stages results in 2 fewer pumping days and a return on the incremental investment in the expandable of 6.5 to 1

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Expansion Process Video



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Perforating Best Practices Horizontal Wells

- Latest advances in fiber optic technology have validated the minimum pressure drop across the perforations to maximize cluster efficiency, SRV, and production
- Two studies (SPE 189880/184834) have shown that 2000 psi is the minimum number for the pad and 1500 psi at the end of the job after perf erosion
- Designing the completion for the 1500 psi post erosion target is recommended and this will typically result in an initial pressure drop greater than 2000 psi (2700 psi +/-)
- Perforations need to be uniform size, conventional charges not used due to irregular hole sizes and unpredictable pressure drops
- A critical rate of 6 BPM/cluster is proposed and this typically overrides the number of clusters from the delta p calculation and larger holes are needed
- May need higher pressure drop if primary well highly depleted

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Volume to 1st Response in Offset

SPE-199731-MS

7

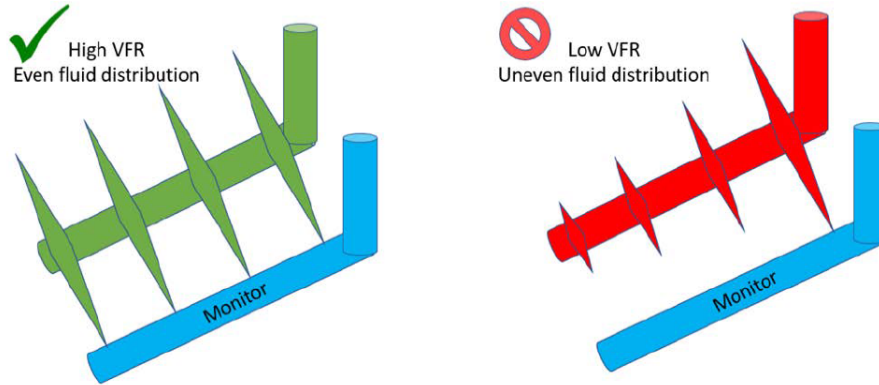


Figure 3—Volume to First Response (VFR) impact on fracture geometry.



XLE Validation with Offset Pressure Monitoring

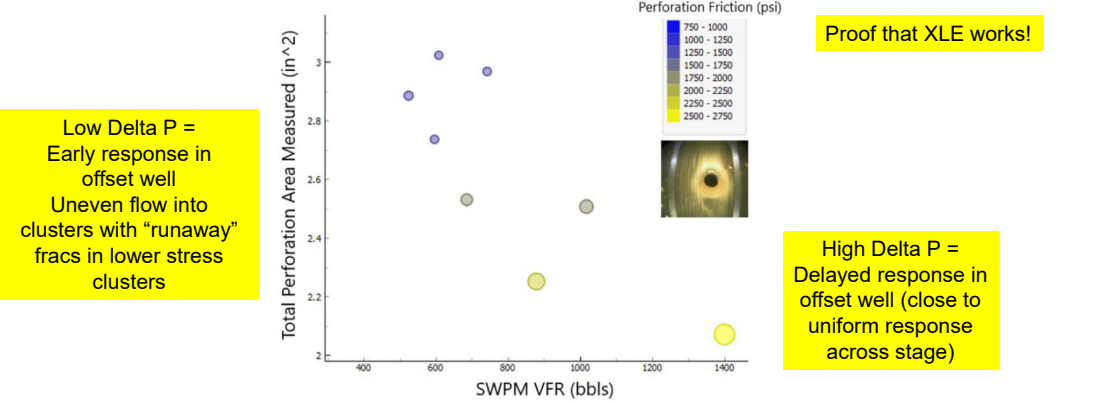


Figure 9—Cross-plot of total perforation area versus volume to first response (VFR) from Sealed Wellbore Pressure Monitoring (SWPM). Each point represents one stage. Points are sized and colored by perforation friction, all of the stages are from one well. The perforation friction is calculated using measured diameters.

SPE 199731



XLE vs. Conventional Perf Cluster Efficiency

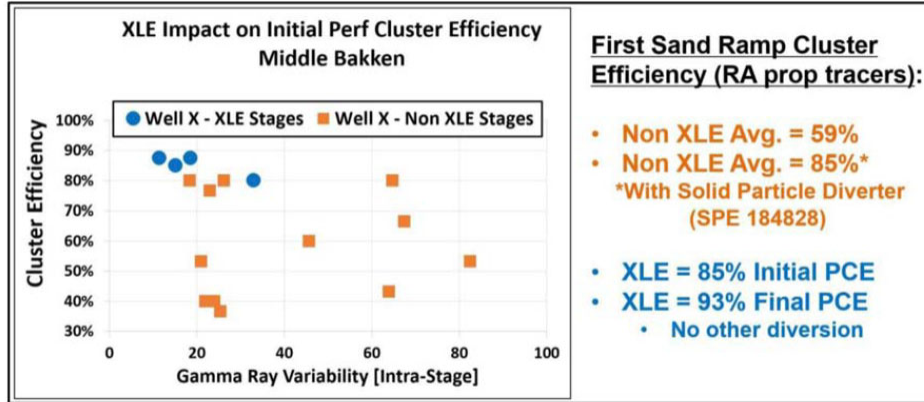


Figure 9—Perforation cluster efficiency (PCE) comparing stages with XLE vs non-XLE stages for Well X.

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SPE 189880

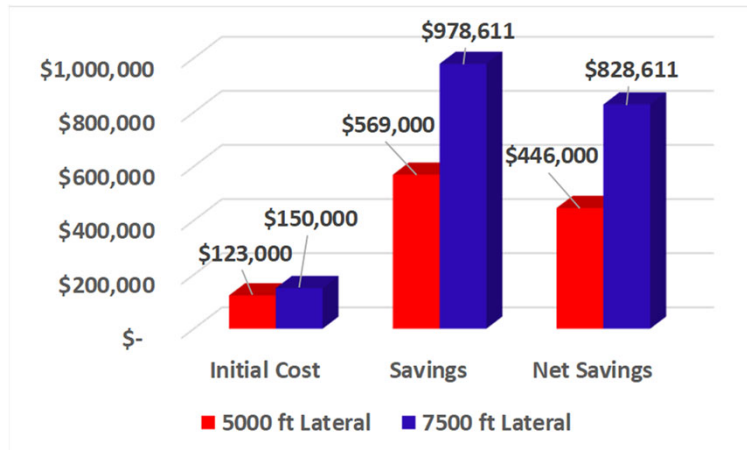
XLE Optimization Spreadsheet

EXTREME LIMITED ENTRY PRESSURE DROP CALCULATION		
Stage length vs Pump Rate		
Vary total number of perfs to obtain 1500 psi post erosion Delta P		
Number of clusters limited by 6 BPM critical rate to avoid screenouts		
		Post
Part 1 Number of Perforations to Obtain 2000 psi Delta P	Initial	Erosion
Rate BPM (input)	90	90
6 BPM/cluster allowable clusters	15	15
fluid density lb/gal (input)	8.44	8.44
Total number of perfs (variable to change in goal seek)(input)	16	16
Number of holes per cluster (recommend keeping this number)	1	1
Perf cluster efficiency (input)	0.85	0.85
Number of perfs active (calculated)	14	14
Perf diameter inches (input)	0.5	0.5
Coefficient of discharge (input)	0.70	0.95
Delta P perfs (use Goal Seek Alt-T-G 2000 psi or higher target)	2859	1500
BPM/perf (calculated)	6.62	6.51
Cluster spacing (input)	13.33	
Number of clusters	16	
Stage length	213	
Lateral length	5000	
Number of stages	23.4	

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Detailed Economic Summary

	5000 ft lateral	5000 ft lateral	Expandable	7500 ft lateral	7500 ft lateral	Expandable
Expandable vs:	Added Up Front Cost	Benefit	ROI	Added Up Front Cost	Benefit	ROI
3.5 cemented	\$ 123,000	569,000	4.6	\$ 150,000	\$ 978,611	6.5
4 in FJ Cemented	\$ 98,000	162,734	1.7	\$ 120,000	\$ 279,603	2.3



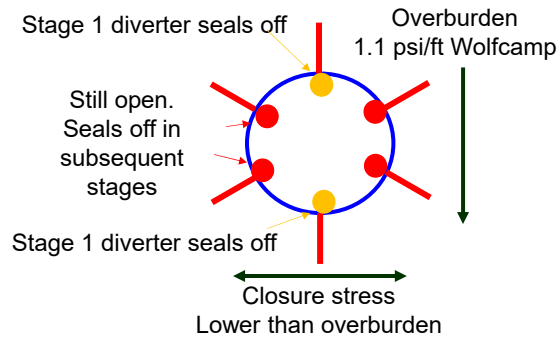
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XLE vs. Diversion and Engineered Completions

- While all three options have similar published cluster efficiencies in the 85% range, XLE is recommended over the other options
- While intra-stage diversion is fine for new well completions, in a refrac they can prematurely plug off significantly depleted clusters and create an asymmetric fracture at that cluster
 - With typically large primary well cluster spacing (50 ft +/- Gen 1 wells) this can be significant and infill well EUR losses can occur
- For engineered completions the cluster spacing needs to be a maximum of 13-15 ft to avoid gaps in the SRV and to ensure proximity to depleted clusters
- Can probably increase the spacing to 20 ft for new wells in the Permian since recharging existing clusters is not needed

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Diverter Mechanics with 6 SPF 60 Degree Perforations



Explains why different stage tracers are often seen in the same perf clusters
Severe overflushing occurs after pressure increase and diversion of subsequent stage

SPE 155485

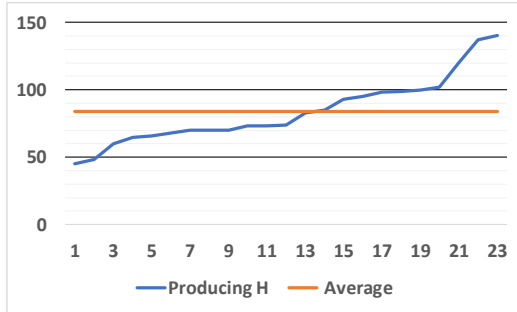
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Critical Rate vs. Optimum Rate and Accessing “New Rock” Above and Below the Lateral

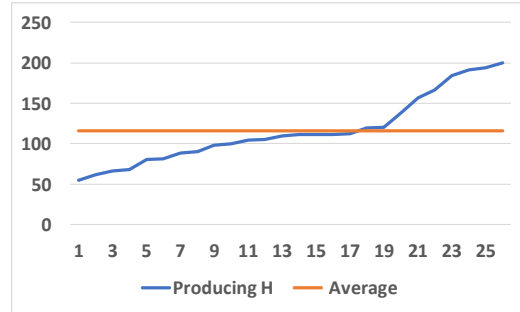
- Pump rates per cluster need to be high enough to prevent screenouts, 6 BPM per cluster is the minimum recommended for screenout prevention
- In all 49 of the 187 wells studied where producing heights were reliable (depending on the relationship between the lateral and the stress barriers) the production was clearly coming from the intervals between the barriers
- The original frac treatment should be reviewed and modeled with a 3D frac model on an individual cluster basis to estimate created height
- This should be validated with production data using the appropriate recovery factor for the cluster spacing used
- If there is pay above or below the barriers that most likely stopped the initial frac the refrac should be modeled using higher rates per cluster and increasing viscosity with HVFR, higher rates can be achieved with fewer clusters
- It is possible that “new rock” can be accessed above and below the original producing zones as well as with the new rock perforations along the lateral

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Producing Height Distribution Midland Basin



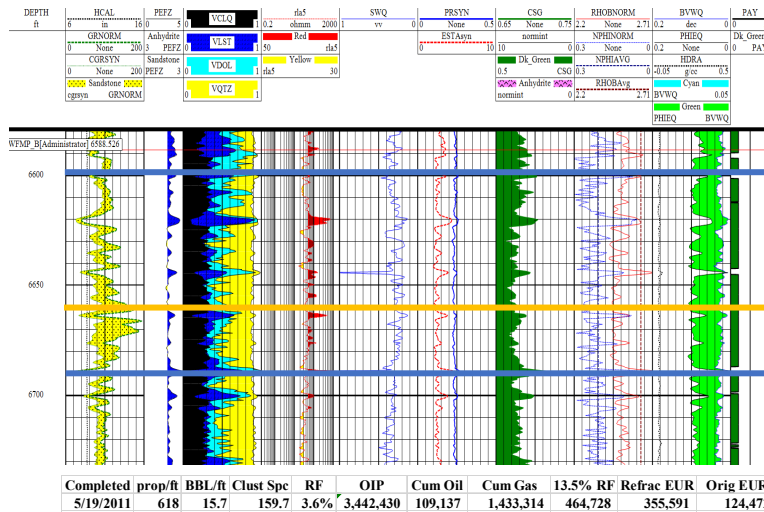
23 wells with clear barriers
Average "h" 84 ft
Southern Midland Datsaset



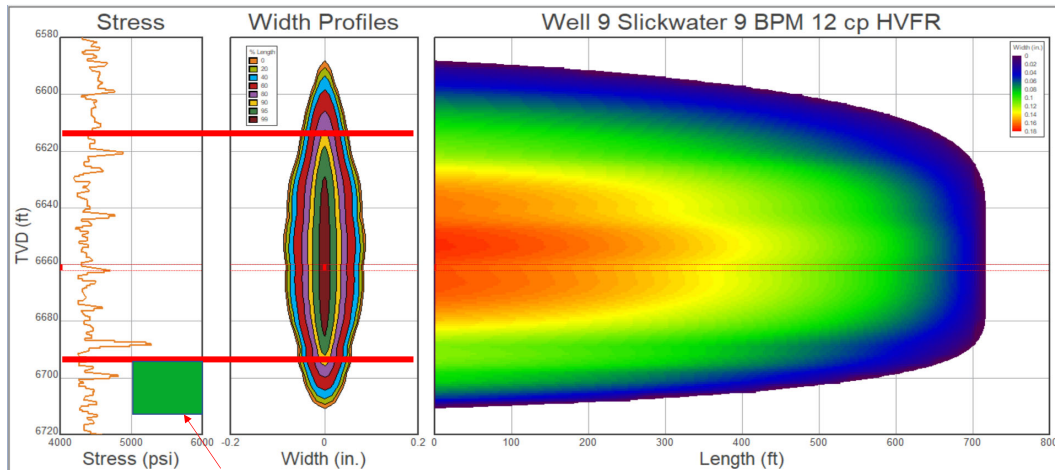
26 wells with clear barriers
Average "h" 116 ft
Northern Midland Datsaset

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Well 9 Rock Properties Plot



Well 9 MFRAC 9 BPM /Cluster 12 cp HVFR



Added 20% to OIP/acre

Bookable Reserves from Refracs

- Should be a clear indication that the reserves added were incremental and not an acceleration of existing production
- Should establish a reasonable certainty that the refrac operation would be successful
- Should generate a large enough number of successful refracs to establish confidence in the process

Holroyd, Samantha "Refrac Integration in the Capital Deployment Plan," Dec 10-11 2015, Houston Energy Forum.

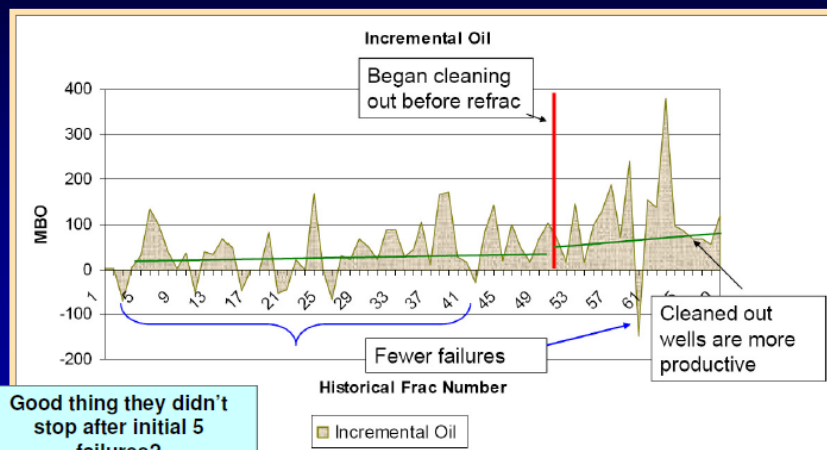
54

How Many Refracs Are Needed to be Able to Book Behind Pipe Reserves?

- SPE 30745 (Beliveau Shell Canada 1995)
 - Six horizontal wells needed to generate consistent results
 - Statistically shown to be relevant to other technology introductions
- Fracknowledge Canadian refrac study
 - Several projects-5 wells typically needed to refine process
- XTO/Exxon Bakken 70 well refrac program
 - First five wells failed, rest were successful

55

Headington/XTO/XOM implemented >70 refracs in similar candidates between 2006 and 2011.



McCrary et al 2011 Tight Reservoir Completions ATW Banff 2011 from Mike Vincent 2015 Refrac AW keynote

Summary and Conclusions

- Refracting organic shale primary wells is critical to DSU economics and can presents a unique opportunity to increase production more efficiently than new well completions if current recovery factors are less than half of the optimized completion numbers
- If an infill well frac hits the primary well depleted zone asymmetric fracs = 40% EUR loss in the infill
- “Preload” treatments do not prevent this loss unless a very large percentage of the fluid removed from the reservoir is replaced
- While mechanical isolation with expandable liners, short cluster spacing, and XLE is more expensive on the front end than cemented liners the return on the incremental up front investment ranges from 1.7 to 2.3 vs. 4 inch flush joint cemented and from 4.6 to 6.5 for 3.5 inch cemented liners

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Summary and Conclusions (cont'd.)

- Refrac programs have the potential to produce more hydrocarbons at less cost and be superior to new well drilling and completion programs
- Case in point 7 well refrac program in S Midland Basin on following slide
- IRR and NPV both higher if the refracs cost \$3 million each and new wells \$6 million
- The potential to book behind pipe reserves with refracs presents a huge opportunity to increase asset value at a relatively low cost per barrel or MCF

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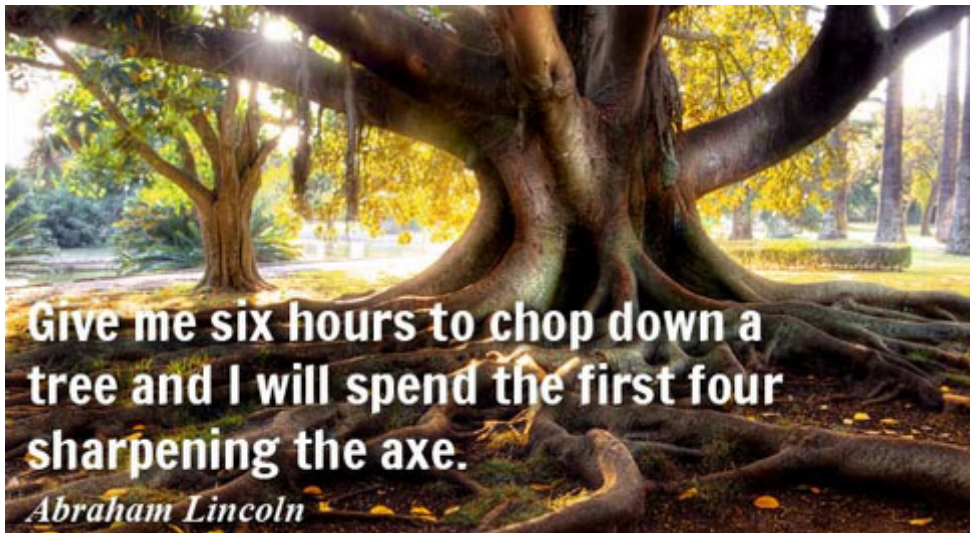
Seven Well Refrac Project vs. Seven New Wells

Seven refracs at \$3 million vs. seven new wells at \$6 million: Refrac program higher IRR and NPV

Organic Shale Refrac Economic Analysis 7 Well Program			
Updated April 23 2020			IP Oil
			2181.8
Assumes			
NRI	75.0%	EUR Oil BO	1,806,845
Disc Rate/IRR	10%	EUR Gas MCF	19,134,991
LOE/Well	\$ 2,500	Total Cash Flow undisc	\$ 88,522,302
LOE Esc	3.0%	Total Cash Flow disc	\$ 53,228,324
Oil severance	4.60%	Payout (undiscounted)	26
Gas severance	7.50%	Payout (discounted)	31
MMBTU ADJ	1200	Undisc Net/Invest	4.22
		Disc Net/Invest	2.53
		NPV	\$ 25,006,471
		Refrac Cost	\$ 21,000,000
		IRR	37%

Organic Shale New Well Economic Analysis 7 Well Program			
Updated April 23 2020			IP Oil
			2689.4
Assumes			
NRI	75.0%	EUR Oil BO	2,227,222
Disc Rate/IRR	10%	EUR Gas MCF	23,586,900
LOE/Well	\$ 2,500	Total Cash Flow undisc	\$ 109,378,375
LOE Esc	3.0%	Total Cash Flow disc	\$ 65,756,951
Oil severance	4.60%	Payout (undiscounted)	54
Gas severance	7.50%	Payout (discounted)	82
MMBTU ADJ	1200	Undisc Net/Invest	2.60
		Disc Net/Invest	1.57
		NPV	\$ 14,792,567
		Refrac Cost	\$ 42,000,000
		IRR	17%

4/23/2020	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 on
Nymex Oil	\$ 24.01	\$32.33	\$ 35.98	\$ 38.81	\$ 41.37	\$ 43.76	\$ 46.01	\$ 48.19	\$ 50.36	\$ 52.36	\$ 54.18	\$55.21
Nymex Gas	\$ 2.42	\$ 2.75	\$ 2.53	\$ 2.46	\$ 2.46	\$ 2.47	\$ 2.50	\$ 2.54	\$ 2.57	\$ 2.60	\$ 2.66	\$ 2.97



Refrac optimization requires doing your homework
“measure twice cut once” applies