Horizontal Injectors & Producers at SACROC

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1948 - discovered in Scurry County, Texas
52,000 productive acres
2.8 Billion Barrels OOIP
Canyon Reef Limestone
6,200 – 7,000 ft MD
Miscibility pressure 1,850#
5 spot & inverted 9 spot patterns
Produces 29,000 BOPD
Largest and Oldest CO2 Flooded Field
SACROC Unit - Production History

SACROC Unit – Historical Production and Injection

- **Water Injection 1954**
- **CO2 Injection 1972**
- **KM Begins CO2 Redevelopment 2000**

**Oil Production (BOPD)**

- **Water Inj**
- **CO2 Inj**
- **WTR Inj**

**Water Injection (BWIPD), CO2 Injection (MCFPD)**

Oil Production (BOPD)

Water Injection (BWIPD), CO2 Injection (MCFPD)

- 1945
- 1950
- 1955
- 1960
- 1965
- 1970
- 1975
- 1980
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010
- 2015
- 2020

- 0
- 50,000
- 100,000
- 150,000
- 200,000
- 250,000
- 300,000
- 350,000

- 1,000,000
- 1,200,000
- 1,400,000
Reservoir Differences

Shale Plays
- Unconventional reservoir: 0.001-0.01 md
- Tight, homogenous reservoir
- Low acid solubility
- **Vertical growth** desired to maximize surface area in new pay zones

SACROC
- Conventional reservoir: 3-30 md
- Porous, heterogeneous reservoir
- High acid solubility – 99%
- **Vertical conformance** desired to sweep layers in bypassed pay zones
Stratigraphic Layers in SACROCO

Top of Reef

- LCi6
- LCi5
- LCi5A
- LCi4
- LCi4A
- LCi3
- ECi1
- LLCN3_CYN3
- LLCN2
- LLCN1
- ELCN2
- ELCN1_CYN2

Green Zone

- ELCN1_CYN2
- MCN3
- MCN2
- Middle Canyon

- MCN1
- ELCN2
- ELCN1
- Lower Canyon

- MECN2
- MECN1
- EECN_CYN1

Bypassed Pay

- STRN_SHALE

Cisco

- STRN

Subsea Depth (ft)

- 3700
- 3800
- 3900
- 4000
- 4100
- 4200
- 4300
- 4400
- 4500
- 4600
- 4700

Catalina Database

HS=0
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Why Drill a Horizontal Well?

Shale Plays

- Lateral wellbore contacts low perm new pay
- Complete large surface area to maximize inflow rate
- Transverse fractures desirable for inflow
- Conductivity - very low requiring large sand frac volumes
Why Drill a Horizontal Well?

**SACROC**

- Lateral wellbore accesses bypassed pay
- Complete small surface area to control vertical conformance
- Longitudinal fractures desirable for injection
- Conductivity – naturally high requiring small acid frac volumes
Horizontal Well Design

Shale Plays

- Producers – no injectors
- Maximize completion
- Create large surface area
- High stimulation rates & volumes with 200’-800’ H
- Water based sand fracs – creates proppant based conductivity
Horizontal Well Design

SACROC

- CO2 Flood with producers and injectors
- Limit completion
- Create small surface area
- Low stimulation rates & volumes with 50’-100’ H
- Acid fracs – enhance natural matrix conductivity
Sliding Sleeves & Swell Packers

Play Video
Bypassed Pay Horizontal Injectors

- **Success Factors**
  - Single injector for multiple patterns
  - Segmented into defined intervals to create flood front
  - 2D conformance – horizontal and vertical

- **Design Factors**
  - 7” cemented casing from surface to 90°
  - 4-1/2” liner from KOP to TD, swell packers and closeable sliding sleeves to create defined intervals
  - Acid frac focused stages at center of each pattern
  - Treating rate creates height and contacts bypassed pay
155-18H

- Horizontal Injector - Successful
- Horizontal Well #6
- Located in middle of SACROC field
- 14 Sleeve Stages
- 30 BPM – 100,000 gals 15% Gelled HCl Acid
Cross Section - 155-18H Horizontal Lateral - 2014
155-18H – 4 Pattern Response

WELL 155-18H

(L1) Actual BOPD
(L2) Actual BWPD
(R1) Actual CO2IPD MCF

CO2 Injection 7/2014

VS Time
10-18H

- Horizontal Injector - Challenges
- Horizontal Well #8
- Could not get 4-1/2” liner to TD
- Located in SACROC North End
- 14 Sleeve Stages
- 40 BPM – 35,000 gals 15% Gelled HCl Acid

[Diagram showing well locations and stages, with indicators for sleeves, swells, and producers]
Cross Section – 10-18H Horizontal Lateral - 2015
10-18H – 4 Pattern Response

WELL 10-18H

(L1) 10000
(L2) 100000
(R1) 1000000

(L1) Actual BOPD
(L2) Actual BWPD
(R1) Actual CO2IPD MCF

VS Time

WELL 10-18H

7,500 BWPD
500 BOPD
28,000 MCFPD

CO2 Injection 7/2015

(L1) Actual BOPD  (L2) Actual BWPD  (R1) Actual CO2IPD MCF

VS Time
Microseismic Snapshot

Map View

View Looking North-East

View Looking South-East
Bypassed Pay Horizontal Injectors Results

- 2013 – 2016
  - 17 Horizontal wells drilled
  - 155-18H & 10-18H Injectors featured
  - 4 pattern (5000’) laterals in bypassed pay
  - Issues w/ closeable sliding sleeves
  - 30-40 BPM acid frac rate
  - Underestimated vertical K and stimulation H
  - Resulted in high GOR’s in main pay
  - 500-2,000 BOPD response – economic – suspect not always from bypassed pay
  - Changed horizontal focus to producers
Now to Producers…
30-22H-1\textsuperscript{st} Hz Producer

- IP @ high oil rates once CO2 was activated but had very high GOR.
- Underestimated vertical permeability and stimulation geometry.
- Resulted in fluid rates higher than any 7” casing ESP could handle and be able to pull BHP down (1,800 psi lowest pressure seen) due to geology and existing conformance issues.
- Shifted focus to Hz injectors at the time.
30-22H-1\textsuperscript{st} Horizontal Well

- 4 pattern Horizontal Producer
  - Drilled in Lower Canyon – MECN2,1 (NOT in EECN.)
  - Well was completed using 16 stages (2 sleeves didn’t open) using 74 Mgal 15% gelled HCl.
  - Max rate of 20 bpm.
  - Sliding sleeves using wireline tractor.
Stratigraphic Layers in SACROCO

Laterals target bypassed pay - EECN

EECN – Early Early Canyon
The Target – EECN in the Lower Canyon

The platform (northern portion of SACROC) is the location of the EECN target horizontals. This is due to the EECN having better phi-H in that area.
What is the ‘Platform’?

- SACROC Platform has the thickest pay in the field
- Very complex, heterogeneous reservoir
- Various conformance issues
What is the EECN and Why is it a Target?

- Deepest layer of the Lower Canyon Reef
- 20-30’ of 6% $\Phi$, $K=6-7$ mD
- Historically doesn’t flood well at SACROC
- Substantial Bypassed OIP remaining
- The concept of drilling a horizontal in the EECN is to think of the layer as an enclosed tank with no conduit to intervals above the layer.
- Draw down the reservoir pressure to very low pressures compared to the shallower zones to induce CO2 injection into the EECN.
15-17H – Lateral Cross Section

- 1st single zone HZ producer - Drilled in late 2017.
- Well porpoised somewhat.
- Good show and cut once in EECN porosity.
- Target OIP – 1.49 MMBO.
- Stimulation communicated with heel producer.
EECN is deepest target PAY in the Lower Canyon. It typically doesn’t flood well due to limited porosity vs. upper zones. The target is to drill this zone.
EECN is deepest target PAY in the Lower Canyon. It typically doesn’t flood well due to limited porosity vs. upper zones.
15-17H Map Trajectory View and Overall Completion

- Lateral - 3,700’ – 7 stages
- 49% of available lateral completed at pattern corners
- Packers spaced to try to limit short-circuiting from support injectors
- Plug & perf
- Stimulate w/ low volumes of 15% gelled HCl @ 17.3 gal acid/foot @ 12 bpm-hydraulic fracturing is not desirable!
15-17H overall completion

- 5 bbls of gelled HCl behind plug balls
- Top pressure called @ 2,500 psi to limit chance of fracturing
- Chemical tracers were monitored in offset producers post stimulation.
- 12 perforations per stage – limited entry design
- Monitored offset SI producers BHP during stimulations
15-17H Takeaways

- Increase lateral distance from vertical producers.
- Monitor ALL offset producers.
- Drill out w/ conventional tbg vs coiled tbg.
- Chemical tracer confirmed connection to vertical well that communicated during stimulation—continue to run chemical tracer.
- RA tracer log showed swell packers held—some ‘jump around’ but seemed to be formation related—note that the packers were swollen in drilling mud (WBM) due to issues during liner install.
- RA tracer showed more limited entry effect was needed—reduced perforation count.
- Smaller acid volumes needed.
15-17H – Well Tests

- Goal - reduce EECN BHP to allow to take CO2
- Gas analysis shows likely primary/secondary production
- Injection support being monitored (profiles). Last profiles showed little change.
- ESP down sized and allowed both the subject well and ‘communication’ well to operate.
- Oil production in vertical ‘communication’ well increased x 2.
- Both wells are being operated at lower BHP than normal producers in CO2 active areas (600 psi vs 1,500 psi.)

1006 BOPD / 1235 BWPD / 2.5MM

139 BOPD / 381 BWPD / 1.6MM
16-14H - EECN_HZ Producer #2

- 62% of lateral open to production
- Spaced further from producers
- Design of 8.8 gal gelled HCl / foot of completion w/ fewer perfs
- Higher gas/water rates than 15-17H but oil rates still @ 150 BOPD. Gas analysis shows higher CO2 %.
- Shows a connection to offset producer, though not as strong as prior horizontal
- Chemical tracer surveys did not show high chemical conc. seen in prior ‘communication’ well.
• Keeping 72% of lateral open to production
• Note the Hz injector to the left is in a zone a few hundred feet shallower than the current producer.
• Design of 4.6 gal gelled HCl / foot of completion
• Continue to run chemical tracer
Plan Ahead…TZ Laterals Are NEXT!

- TZ (transition zone) and EECN depth shift in SACROC depending on area. The next target laterals are in the TZ.
- High target OIP
- Longer laterals
- Planning on lower oil recovery due to being in TZ
- Evaluating OH completion technique by side tracking existing producer wellbore
Summary

• Capable of drilling and completing horizontal wells in SACROC.
• HZ injectors showed economic response but had conformance issues.
• HZ producers showing good initial production.
• Limited Entry desired on HZ producer stimulations.
• Volumes and rate limited.
• Run ‘small’ ESPs.
• Continue to balance distance from producers and injectors to optimize performance.
• It is possible that the wells will be seeing primary / secondary production prior to seeing tertiary response.
Backup Slide
Spectral Gamma Ray Log-15-17H

Stg 4 - Iridium

Stg 5 - Scandium

Only one pkr w/ RA material behind element was observed

Stg 6 - Antimony

Swell Packers

Toe