Wellington KS CO2 EOR Project

• August 23, 2016
• Dana G. Wreath
• Vice President Engineering
• Berexco LLC – a private oil and gas company based in Wichita KS
• Operator of Wellington Field in southern KS
DOE Funded CO2 Research

QUARTERLY PROGRESS REPORT

To
DOE-NETL
Brian Dressel, Program Manager
Award Number: DE-FE0006821

SMALL SCALE FIELD TEST DEMONSTRATING CO2 SEQUESTRATION IN ARBUCKLE SALINE AQUIFER AND BY CO2-EOR AT WELLINGTON FIELD, SUMNER COUNTY, KANSAS

Project Director/Principal Investigator:
W. Lynn Watney
Senior Scientific Fellow
Kansas Geological Survey

Ph: 785-864-2184, Fax: 785-864-5317
lwatney@kgs.ku.edu
Wellington Field
Site of Small Scale Field Test

Top Mississippian Structure, 10 ft C.I.

20 Million Barrel Oil Field above Arbuckle Group
Kansas Geological Survey Website
http://www.kgs.ku.edu/PRS/Ozark/index.html
CO₂-EOR Technology & Carbon Management Research in Kansas

- Utilize oil and gas field Infrastructure
- Utilize comparable approaches to characterization and simulation of oil and reservoirs
- Evaluated sites for commercial scale carbon storage sites in aquifers beneath existing oil fields
- Conduct small scale CO₂-EOR injection at Wellington Field, Sumner County Kansas
- KU & partners have performed extensive research on:
  - monitoring
  - verification
  - accounting of the CO₂ over the long term
Wellington Project Current Status

• CO2 EOR Project is the first phase at 3600’ depth, then deep saline injection to follow (USEPA Class 6) at 5100’ depth.

• CO2 EOR injection began Jan 2016 and was completed June 22, 2016.

• EOR recovery, monitoring and CO2 mass balance measurement currently ongoing.

• USEPA Class 6 Injection Permit pending for saline injection phase. Timing?
Injection Well Permitting

• EOR requires Class 2 UIC Permit
• Regulator is Kansas Corporation Commission
• KCC has primacy for Class 2 wells
• Permit application is 10 page document
• USEPA has oversight function over KCC

• CO2 Disposal (not EOR) requires Class 6 Permit
• USEPA has primacy for Class 6. Class 6 program modeled from Class 1 Hazardous Waste Disposal
• Comparison of Class 2 vs Class 6
DESIGN APPROVAL

Date: JANUARY 22, 2015
Operator License Number: 34318
Operator: BEREXCO LLC
Address: 2020 N. BRAMBLEWOOD
WICHITA, KS 67206

Contact Person: BRETT BLAZER
Phone: 316-255-3311
Email: blazerg@berexco.com

Check One: ☐ Old Well Being Converted ☑ Newly Drilled Well ☑ Well to be Drilled

Surface Elevation: 1262, feet
Well Total Depth: 3615, feet
Plug Back Depth: 3770, feet
Datum of top of injection formation: 3662 (-2400), feet (reference mean sea level)

Injection Formation Description:
Name: MISSISSIPPI

Lease/Operator Name: BEREXCO LLC
Lease/Facility Name: WELLINGTON UNIT
Lease/Facility Description: SEE ATTACHMENT A

Producing Formation: MISSISSIPPI
Strata Depth: 3600 to 3800 feet
Total Dissolved Solids (if available): mg/l

Maximum Requested Liquid Injection Rate: 2000 bbls/day or
Maximum Requested Gas Injection Rate: 4,000,000 scf/day
Type of Gas: CARBON DIOXIDE

Mail to: KCC - Conservation Division, 266 N Main St, Ste 220, Wichita, Kansas 67202-1613
### Well Completion

<table>
<thead>
<tr>
<th></th>
<th>Conductor</th>
<th>Surface</th>
<th>Intermediate</th>
<th>Production</th>
<th>Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>13-3/8&quot;-43#</td>
<td>8-5/8&quot;-24#</td>
<td>6-1/2&quot;-15.5#</td>
<td>2-7/8&quot; LINED</td>
<td></td>
</tr>
<tr>
<td>Setting Depth</td>
<td>120'</td>
<td>600'</td>
<td>3815'</td>
<td>+/- 3612'</td>
<td></td>
</tr>
<tr>
<td>Amount of Cement</td>
<td>135 sax</td>
<td>300 sax</td>
<td>235 sax</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>Top of Cement</td>
<td>0'</td>
<td>0'</td>
<td>2450'</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Bottom of Cement</td>
<td>120'</td>
<td>600'</td>
<td>3615'</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

If Alternate II cementing, complete the following:

Perforations / D/H Tool at +/-2450' feet cemented to 0' feet with 400 sax.

Tubing: Type 2-7/8" PLASTIC LINED
Grade J-55
Depth +/-3162'
Annulus Corrosion inhibitor: Type TREATED FRESH WATER
Concentration 0.5%
List Logs Enclosed: CEMENT BOND LOG

### Well Sketch
(To sketch installation, darken the appropriate lines, indicate cement, and show depths.)

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SEE ATTACHED WELLBORE DIAGRAM

Static fluid level is N/A feet below surface.
APPLICATION FOR INJECTION WELL

WELLBORE DIAGRAM

LEASE: Wellington KGS #2-32

NO. 32

INJECTION ZONE: Mississippi 3662'-3687'

13 3/8" CONDUCTOR CASING
43.0 #/ft Set at 120' with 135 sx cement
Top of Cmt @ 0'

8-5/8" SURFACE CASING
24.0 #/ft Set at 600' with 300 sx cement
Top of Cmt @ 0'

5-1/2" PRODUCTION CASING
15.5 #/ft Set at 3815' with 235 sx cement
Top of Cmt @ 0'

INJECTION STRING
TUBING: 2-7/8" PLASTIC LINED
PACKER: TENSION STRADDLE PACKERS
Set at: +/-3612

TVD @ 2450' W/ 400 SX

+/-3612

PERFS 3652'-3687'

3815' TD 3815'
February 10th, 2015

Bereixo LLC
2020 N. Bramblewood
Wichita, KS 67206

RE: Application for Design Approval
Permit # E-52147 assigned to the application
Wellington KGS #2-32
32-31S-1W
Sumner County

Dear Bereixo LLC,

Technical staff of the Underground Injection Control Department reviewed your proposed completion plans for the above referenced well that was filed on January 23rd, 2015. Based on the information in your application, we approve your proposed design pending protests being received during the thirty (30) day notice period. If a protest is received, an evidentiary hearing on your application may be necessary. Following the hearing the Commission may approve or not approve your application based on the evidence presented. Work on the proposed well prior to the expiration of the protest period is at your own risk.

Until you provide all of the necessary completion information, and until the well has passed a Commission approved mechanical integrity test, you do not have the authority to use the well for injection activities. Please submit the following data and proof of the successful mechanical integrity test to my attention:

- Cementing verification for all casing strings (i.e. cement tickets, job log, bond log);
- Tubing and packer setting depth, if present;
- Copies of geophysical logs, if performed;
- Copy of satisfactory Mechanical Integrity Test;
- Cement Bond Log

You do not currently have the authority to use the above well as an injection well. K.A.R. 82-3-400 states you must receive a written permit granting your injection application prior to any injection activities. Use of the well prior to being issued a written permit is punishable by a monetary penalty and the well must be shut-in until compliance is achieved and a permit issued.

Sincerely,

Brandon Milner
UIC Department

cc: District #2
UIC Docket File
KGS 2-32 Drilling Phase

3/20/15  Spud well 7:00 am, 3/20/2015. TD 17-1/2” conductor hole @ 140’ KB, 3/20/2015. Survey 1° @ 140’. Ran 3 jts 13-3/8” 48# conductor casing- set @ 137’ KB. Cemented with 145 sx Class A cement with 1/4# flakes and 3% CC. Finished cementing 1:15 pm, 3/20/2015. Cement circulated to surface.

3/21/15  Drilling @ 465°. TD 12-1/4” surface hole @ 650’ KB, 3/21/15. Survey 1° @ 650’. Ran open hole logs in surface hole- LTD @ 653’ KB. Log showed base of conductor @ 142’ KB. Ran 15 jts 8-5/8” 24# surface casing. Set @ 647’ KB. Cemented with 175 sx 60/40 POZ 6% gel 1/4# flakes 3% CC tailed with 150 sx Class A with 1/4# flakes and 3% CC. Plug landed 8:15 pm, 3/21/15. Cement circulated to surface.

3/22/15  Drilling out of surface casing.

3/23/15  Drilling @ 1470°. Survey 3/4° @ 1164’.

3/24/15  Drilling @ 2325°. Surveys 1/2° @ 1670, 3/4° @ 2179°.

3/25/15  Drilling @ 3135°. Surveys 3/4° @ 2624”, 1/4° @ 3134°. Displaced mud system at 2815°.

3/26/15  Conditioning hole for coring. Reached core point @ 3654’ KB 6:15 am, 3/26/2015. Survey 1/2° @ 3654’. TIH w/ coring tools. Cored from 3654’ to 3669’ and core barrel jammed. TOH w/ Core #1. Recovered 15’ of core. TIH and resumed coring- core barrel jammed @ 3691’. TOH w/ Core #2. Recovered 22” of core.

3/27/15  Coring @ 3691°. Cored to 3751’. Recovered 60’ of core. Ran DST #1:
- DST #1, 3671’-3751’, Mississippi
- IFP: 51-235#  FFP: 231-392#
- ISIP: 955#  FSSIP: 950#
- Recovery: 300’ VSOSMW (Tr O, 95% W), 120’ VSOSWM (Tr O, 35% W), 120’ M;
- Chlorides 95,000 ppm

3/28/15  Drilling @ 3675°. TD well @ 3860’ 2:00 pm, 3/28/15. Survey 1/4° @ 3860’.

3/29/15  Running open hole logs- LTD @ 3860’ KB. Lay down drill pipe and drill collars. Ran 95 jts 5-1/2” 15.5# casing. Tag TD @ 3860’ KB and set casing @ 3858’ KB. Circulated halfway into hole and on bottom. DV @ 2515’ KB. Baskets @ 3732’, 3608’, on jt below DV tool and at 1000’. Ran centralizers every other collars up to 3000’ and on joints above and below DV tool.

3/30/15  Cemented bottom stage with 95 sx A-Con w/ 1/4# flakes and 2% CC mixed at 2.01 cu ft/sx tailed with 195 sx AA-2 thixotropic cement with 5% Calseal, 1% C-44 Gas Blok CO2 resistant additive, 10% salt, 1/4# defoamer, 1/4# flakes 1/2% fluid loss, 0.3% CFR-2, and 6# gylonite. Plug landed 2:10 am, 3/30/15. Opened DV tool and circulated 4 hours. Saw cement from bottom stage circulate to surface. Cemented top stage with 465 sx A-Con w/ 1/4# flakes 2% CC at 2.01 cu ft/sx and 50 sx AA-2. Plug landed 7:20 am, 3/30/15. Cement circulated to surface. Plugged mouse and rat holes with 50 sx A-Con. Rig released 3/30/15

3/31/15  Waiting on completion.
KGS 2-32 Completion

4/22/15  MIRU BX Rig #13. TIH w/ 4-7/8” bit, 3- 3-1/8” drill collars and 2-7/8” workstring. Tag DV @ 2515’ KB. Drill out DV tool. Tag PBTD @ 3820’ KB. Circulated hole clean with fresh water. SOH w/ tubing, drill collars and bit. Shut down.

4/23/15  FOH w/ tubing and bit. Ran CBL- PBTD @ 3815’ KB. Good bond from TD to surface. Pressured casing to 2500#- held. TIH w/ 4-7/8” bit, 5-1/2” casing scraper and 2-7/8” workstring to 3780’ KB. Shut down.

4/24/15  Swab casing fluid level down to 3150’ from surface. TOH w/ bit, scraper and tubing. Perforate Mississippi Chert from 3664’-3706’ KB, 4 SPF. Shut down.

4/25-26/15  Shut down.

4/27/15  Ran 5-1/2” X 2-7/8” Arrowset PKR. Set @ 3638’ KB. Ran swab- fluid level 1800’ from surface, 100’ free oil on top. Recovered 10.8 BW on swab down. Had 700’ fill up after 1 hour. Acidized Mississippi perf 2500 gallons 10% NEFE-HCl and 250 ball sealers. Treated 3 BPM @ 1300# initially, increased to 5.7 BPM @ 700# towards end. ISIP 50#, 30 seconds to vacuum. TLTR 90 BTF. Ran swab-fluid level 1100’ from surface. Recovered 44.7 BW on swab down. Next hour recovered 20.8 BTF with trace oil. Shut down.

4/28/15  Ran swab- fluid level 2000’ from surface, 50’ oil on top. Swabbed 26.7 BTF. Release PKR and run across perf to remove any remaining ball sealers. Reset PKR @ 3638’ KB. Ran swab. Recovered 16.8 BTF on swab down.

| 1st Hour | 19.1 BTF, fluid level 2800’ from surface |
| 2nd Hour | 23.4 BTF |
| 3rd Hour | 16.7 BTF |
| 4th Hour | 13.4 BTF |
| 5th Hour | 13.4 BTF |
| 6th Hour | 20 BTF. Fluid level stayed 2800’ from surface. Caught fluid samples. |

Shut down.

4/29/15  Run swab- fluid level 2000’ from surface, 75’ free oil on top. Injected 2 BPM for 10 minutes- took fluid in vacuum. Injected 4 BPM for 10 minutes- stabilized pressure 150#. TOH w/ tubing and PKR. RDMO BX Rig #13.

5/12/15  Waiting for pulse test scheduled for the week of May 10.

5/27/15  Too muddy to move in rig/injection tubing.

6/8/15  MIRU Contract WS Rig. TIH w/ nickel coated Arrowset-1X PKR with Viton rubber and 1.875” stainless steel profile nipple for X-style blanking plugs. nickel coated on-off tool and 110 it’s TK-70XT coated tubing. Pump packer fluid and set PKR @ 3636’ KB. Annulus held 150#. RDMO Contract WS Rig. Will MIT well 6/10/15.

6/10/15  MIT well to 350#- held. Witnessed by Jonathan Hill of KCC District #2 office.

6/23/15  Permit for carbon dioxide injection now approved by KCC.
INJECTION PERMIT FOR ENHANCED RECOVERY

Operator: Berexco LLC

Address: 2020 N. Bramblewood

City: Wichita

State: KS

Zip Code: 67206

Permit #: B-32,147

Pilot Well Name & No.: Wellington KGS 42-32

Location: 2700' PSL 750' EEL.

Sec. 32 Twp 31 S Rge 1 E (W) W (W)

County: Sumner

Field Name: Wellington

Date Approved: June 18, 2015

Project Acreage: NE NW NE SE Section 32-31S-1W

After reviewing the operator’s application for an Enhanced Recovery Injection Well Permit dated January 23rd, 2015, the Conservation Division grants a permit for the injection of produced saltwater or other fluids approved by the Conservation Division. Each additional permitted well is subject to the specifications and requirements of this permit including any attachments or any attached amendments.

- The injection formation is known as the Mississippi.
- The depth of the permitted injection interval is from 3662' to 3687', (PF), (OH)
- The maximum authorized injection rate is 2000 barrels of fluid per day.
- The maximum authorized injection pressure is 1200 PSIG.
- The maximum authorized injection rate for CO2 is 4,000,000 scf per day.
- The maximum authorized injection pressure for CO2 is 1500 PSIG.
- Authorized rates and pressures are subject to temporary or permanent modification during or as the result of any investigation conducted by Commission Staff.

Attachment YES, NO

Complete casing information for the Pilot well is as follows:

<table>
<thead>
<tr>
<th>Conductor</th>
<th>Size</th>
<th>Seat Depth</th>
<th>Interval Depth</th>
<th>Sacks Cements</th>
<th>Used</th>
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<tbody>
<tr>
<td>Surface</td>
<td>8.625&quot;</td>
<td>600'</td>
<td>0' to 600'</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>5.5&quot;</td>
<td>3815'</td>
<td>2450' to 3815'</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>Tubing</td>
<td>2.875&quot;</td>
<td>3636'</td>
<td>' to '</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional Cementing: DI tool set at 2450 and cemented to surface with 400 sacks.

Packer type and setting depth: Arrowset set @ 3636'

In addition to the specific permit conditions and requirements set out above or on the attachment hereon, this permit is subject to all of the provisions of K.A.R. 83-3-400 et seq. Injection authority cannot be transferred without approval of the Conservation Division.

See attached for leases supplying fluid for disposal.
<table>
<thead>
<tr>
<th>Lease Operator</th>
<th>Lease Name</th>
<th>Lease Description</th>
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</thead>
<tbody>
<tr>
<td>Heresco LLC</td>
<td>Wellington Unit</td>
<td>S/2 Section 20; Section 29, W/2 &amp; W/2 SE/4 Section 28; E/2 &amp; E/2 NW/4 Section 32; Section 33, 31S-1W, SE/4 Section 6, W/2 &amp; NE/4 &amp; N/2 SE/4 Section 5, E/2 &amp; NW/4 &amp; E/2 SW/4 &amp; NW/4 SW/4 Section 4, NE/4 Section 7, and NW/4 Section 8 and W/2 NE/4 Section 9-32S-1W</td>
</tr>
</tbody>
</table>
Class 2 Permit Features

- Protects Useable Drinking Water – surface casing covering USDW cemented to surface.
- Requires production casing be cemented well above injection perfs, but not necessarily to surface.
- Area of review completed by State regulators to confirm no improperly plugged wells or conduits
- MIT testing required
- Monitoring of annulus required and well can be inspected by state regulators at any time
- USEPA oversight of State’s Class 2 program
- You can actually get a Class 2 permit
Wellington KS Class 6 Permit Application Timeline

• Berexco and KS Geological Survey Team started work on permit application Oct 2012
• First internal draft January 2013
• Internal simulation modeling completed February 2014
• Permit application submitted to USEPA May 2014. 1468 page document, including appendices
**EPA Form 7320-9 (Rev. 12-11)**

**Underground Injection Control Permit Application**

(*Collected under the authority of the Safe Drinking Water Act. Sections 1442, 1421, 40 CFR 144*)

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### II. Owner Name and Address

<table>
<thead>
<tr>
<th>Owner Name</th>
<th>Berexco LLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street Address</td>
<td>2020 North Bramblewood Dr.</td>
</tr>
<tr>
<td>City</td>
<td>Wichita</td>
</tr>
<tr>
<td>State</td>
<td>KS</td>
</tr>
<tr>
<td>Zip Code</td>
<td>67206</td>
</tr>
</tbody>
</table>

### III. Operator Name and Address

<table>
<thead>
<tr>
<th>Owner Name</th>
<th>Berexco LLC</th>
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<tbody>
<tr>
<td>Street Address</td>
<td>2620 North Bramblewood Dr.</td>
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<tr>
<td>City</td>
<td>Wichita</td>
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<tr>
<td>State</td>
<td>KS</td>
</tr>
<tr>
<td>Zip Code</td>
<td>67206</td>
</tr>
</tbody>
</table>

### IV. Commercial Facility

- [ ] Yes
- [ ] No

### V. Ownership

- [ ] Private
- [ ] Federal
- [ ] Other

### VI. Legal Contact

- [ ] Owner
- [ ] Operator

### VII. MC-Code

- [ ] 1311, 1321, 1381, 1382

### VIII. Well Status (Mark "x")

- [ ] Operating
- [ ] Proposed

### IX. Type of Permit Requested

(Mark "x" and specify if required)

- [ ] A. Individual
- [ ] B. Area

#### A. Class(es) (enter code(s))

- [ ] Geologic Sequestration

#### B. Type(s) (enter code(s))

- [x] Other (Class VII)

#### C. If class is "other" or type is code "x", explain


### X. Class and Type of Well (see reverse)

#### A. Well Class

- [ ] 1

#### B. Well Type

- [ ] Geologic Sequestration

### XI. Location of Wells or Approximate Center of Field or Project

<table>
<thead>
<tr>
<th>Township</th>
<th>Range</th>
<th>Sec.</th>
<th>Rgs.</th>
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</thead>
<tbody>
<tr>
<td>37</td>
<td>19</td>
<td>10.1</td>
<td>26</td>
</tr>
</tbody>
</table>

### XII. Indiana Lands (Mark "x")

- [ ] Yes
- [ ] No

### XIII. Attachments

(Complete the following questions on a separate sheet(s) and number accordingly; see instructions)

For Classes I, II, III, (and other classes) complete and submit a separate sheet(s) Attachments A–U (pp 2-6) as appropriate. Attach maps where required. List attachments by letter which are applicable and included with your application.

### XIV. Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on the information of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref: 40 CFR 144.22)

**A. Name and Title**

Dana Wreath, Vice President

**B. Phone No.**

(316) 337-8331

**C. Signature**

[Signature]

**D. Date Signed**

May 23, 2014

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OMB No. 2040-0042  Approval Expires 1/30/2014
Permmitting Timeline

- Construction of 3 shallow wells at EPA's request to prove absence of USDW
- Installed Wellington Seismic Array
- Water Quality Testing and Analysis at shallow wells
- Wellington Seismic Action Plan prepared in response to EPA's concern about induced seismicity
- Conduct analytical studies to demonstrate absence of USDW at site
- Conduct modeling for 26,000 tons and prepare new report
- Prepared Site Structure and Induced Seismicity Report
- Work with EPA to prepare permit Attachments
- Respond to Request For Information on all sections of permit
- Permit reformatted and resubmitted using new GS Tool
- Conduct Water Quality Testing and Analysis at 2 domestic wells
- Prepare Quality Assurance and Surveillance Plan (QASP)
- Operation Plan for Safe and Efficient Injection (OPSEI) prepared as a monitoring response plan.
- Conducted STOMP simulations to assist EPA in AoR evaluations
- At EPA’s request, prepare plan for monitoring pressures in Mississippian reservoir

Planned permitting efforts as budgeted and tasked in PMP

Unplanned efforts requested by EPA to address induced seismicity, USDW determination, and detailed operation/monitoring to address EPA “lessoned learned” from legal and technical challenges
Status of Attachments in the Wellington Permit

- Permit details are in the following 9 attachments
- 7 Attachments near completion

A. SUMMARY OF OPERATING REQUIREMENTS
   - Draft Prepared

B. AREA OF REVIEW AND CORRECTIVE ACTION PLAN
   - Awaiting confirmation of Area of Review by EPA modelers

C. TESTING AND MONITORING PLAN
   - Draft Prepared

D. WELL PLUGGING PLAN
   - Draft Prepared

E. POST-INJECTION SITE CARE AND SITE CLOSURE PLAN
   - Awaiting confirmation of Area of Review by EPA modelers

F. EMERGENCY AND REMEDIAL RESPONSE PLAN
   - Draft Prepared

G. CONSTRUCTION DETAILS
   - Draft Prepared

H. FINANCIAL ASSURANCE DEMONSTRATION

I. STIMULATION PROGRAM
   - Draft Prepared

Costs for three out of four cost categories finalized. KGS preparing a response document to lower cost of one emergency scenario. Berexco needs to inform EPA of the preferred financial instrument to guarantee financial obligations.
Class 6 – Where are we now?

• Some fundamental issues pending.
• USEPA modeling results and related area of review determination.
• Post Injection Site Closure duration and terms still pending. Relates to financial assurance requirements.
• May have a draft permit to be made public in 6-12 months, but are not sure.
• After that, still have public comment period and potential for litigation.
Wellington EOR Project

• Small scale CO2 injection in portion of large successful waterflood.
• Mississippian carbonate formation – dolomite and lime.
• Oil response and CO2 also arriving at producing wells.
• Measurement of CO2 injected and recovered, material balance calculation of CO2 stored.
Wellington CO2 Project
Wellington KGS 2-32 Neu-Den Log
Mississippian Reservoir

- Java web app (freeware);
- archive well data as LAS 3.0

http://www.kgs.ku.edu/software/PFEFFER-java/
Company: Berexco LLC  
Well: Wellington KGS #2-32  
Field: Wellington  
Location: Sumner County, Kansas  
File: HOU-150357  

Sample Number: 1  
Sample Depth, feet: 3685.20  
Permeability to Air, md: 10.1  
Klinkenberg Permeability, md: 8.98  
Porosity, fraction: 0.252  
Initial Water Saturation, fraction: 0.158  
Effective Oil Permeability at Swi, md: 7.36
<table>
<thead>
<tr>
<th>Date</th>
<th>CO2 Injected</th>
<th>Rate</th>
<th>Location</th>
<th>Remarks</th>
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<tr>
<td>5/30/16</td>
<td>1502 BBL</td>
<td>166#</td>
<td>TP</td>
<td>E. Nelson 27 BO.</td>
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<td></td>
<td>permanently 4:00 pm, 6/22/16. Killed well</td>
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<tr>
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<td></td>
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<td>with 40 BW and left shut in.</td>
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Injection Well Downhole Equipment

• Lined tubing
• Packer equipped for CO2 service
• Profile nipple and on/off tool
• If needed, can set wireline plug in profile nipple and then sting out with tubing leaving plugged packer in bottom of the well.
Injection Tubing Lining - NOV

**TK®-70XT**

TK-70XT is a tough, flexible; thick-film coating that has been modified for enhanced abrasion resistance. Laboratory testing has shown it to be 11x more abrasion resistant than standard TK-70. This thermoset coating is suitable for CO₂ injection, oil and water service, including rod pumping applications where excellent mechanical performance is required. Hydrocarbons can cause problems with certain corrosion control solutions in water handling. TK-70XT is hydrocarbon resistant and provides outstanding protection during systematic acidizing. This coating can be applied to new or used pipe, holiday free, which results in a smooth surface that provides increased hydraulic efficiency and deposit mitigation.

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<th>Specifications</th>
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<td>Pressure</td>
<td>Yield strength of pipe</td>
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<td>Applied Thickness</td>
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<td>Primary Applications</td>
<td>New and used tubular goods</td>
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<tr>
<td>Primary Services</td>
<td>Subsurface CO₂ and water handling systems, salt solutions, crude oil production (rod pumping), and mild mineral acids</td>
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<tr>
<td>Limited Service</td>
<td>Should be limited to low concentrations of H₂S</td>
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</table>
Injection Packer

Wellington KGS 2-32. The pkr. is a 5 ½ x 2 7/8

Nickel coated AS1 with viton rubber kit (rubbers, o-rings and seals), the on off tool is a DT-2

Nickel coated with viton seal kit and stainless steel stinger.

Packer sets last motion up, ¾ turn to the right at the tool, stack out 15000# then pull 15000#
tension (do this 2-3 times) you can now leave tool in tension compression or neutral.

Packer releases by stacking out weight on pkr. ¼ turn to the right and pickup tubing to release.

On off tool releases from pkr. by stacking out weight on pkr. ¾ turn to the left and pick up tubing, on off tool latches back to pkr. by setting weight on it.

The profile size is 1.875X
ASI-X PACKER

The ASI-X Single String Double-Grip Production Packer is the most versatile of the mechanically set retrievable packers and may be used in any production application. This packer is suited for treating, testing, or injection applications, in pumping or flowing wells, either deep or shallow. This packer can be left in tension or compression depending on well conditions and the required application.

A large internal by-pass reduces swabbing when running and retrieving. The by-pass closes when the packer is set and opens prior to releasing the upper slips when retrieving to allow pressure equalization. The J-slot design allows easy setting and releasing; 1/4 turn right-hand set, 1/4 turn right-hand release.

The standard ASI-X Packer is designed for differential pressures up to 7,000 PSI (unless noted otherwise). This packer is also available in an HT version which is designed for differential pressures up to 10,000 PSI (unless noted otherwise). The HT version allows this packer to be utilized in completions where high pressure treating operations are performed and it is desirable to leave the tool in the well for production.

Special Features

- By-pass below upper slips to wash debris when valve is opened
- By-pass is opened before upper slips are released
- Can be set with tension for shallow well applications
- Can be left in tension, compression or neutral
- 1/4 turn right-hand set, 1/4 turn right-hand release
- Additional J-Slot arrangements available

Product Specifications

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<th>Size (inches)</th>
<th>Weight (lbs/ft)</th>
<th>Recommended Hole Size (inches)</th>
<th>Gage OD (inches)</th>
<th>Max OD (inches)</th>
<th>Tool ID (inches)</th>
<th>Thread Connections</th>
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1Maximum OD is across retracted drag blocks.
2Utilized for testing.
3Designed for differential pressures up to 10,000 PSI.

Builder: Trim Engineering (oilfield tooling, Inc) with a DIL sales association: PDN, Wills, ECNE/IM/HK, EN/M/Sl, EPQM

NOTE: All pricing includes standard Nitride trim. Other sizes, connections, and rubber options available upon request.
Wellington Results

• CO2 Accounting
• Total 374,461 MCF Injected (21,784 US tons)
• Required 1,101 Truckloads, each about 20 US tons.
• Incremental Oil Production about 4,200 bbls as of 7/31/2016.
• Approximately 11% of CO2 injected has been produced (vented) as of 7/31/2016
Wellington Scale Comparisons

• Average CO2 injection rate: 2,500 MCFD

• A 45 MMGPY ethanol plant emits about 7,500 MCFD CO2. CO2 volume is linear to MMGPY.

• Wellington project injected about 22,000 US tons of CO2 (Approx 20,000 Metric Tons).

• EPA.GOV states “A typical passenger vehicle emits about 4.7 metric tons of CO2 per year”

• $20,000/4.7 = 4,255$ cars (for one year)
CO2 Injection Begins 1-09-16

Pause in CO2 Injection

CO2 Injection Ends

Sustained High Volume Water Injection Begins 7-14-16

Oil Recovery Starts 2-26-16

Legend

- CO2 Purchased Daily (MCF)
- CO2 Produced Daily (MCF)
- Cumulative CO2 Produced (MCF)
- Incremental Oil Daily (bbls)
- Cumulative Incremental Oil (bbls)
- Cum. Ratio Produced/Purchased CO2
- Daily Ratio Produced/Purchased CO2
- Daily Water Injection (bbls)

CO2 Injected and Recovered; Oil Produced Through 7/31/16
Wellington Unit Oil Production

Decline Chart for: ('WELLINGTON UNIT- EAST NELSON', 'WELLINGTON UNIT- NELSON WEST', 'WELLINGTON UNIT- PEASEL', 'WELLINGTON UNIT- SOUTH ERKER')
CO2 Produced Gas Measurement

• Cameron MC-III EXP Flow Measurement
• Installed at wellhead vent, or 2 phase separator at well.
• Separators needed to stop liquids flowing up annulus making a mess as gas volumes increase.
• CO2 Content Sensors for low volume gas venting.
NUFLO Gas Turbine Meters

Overview

NUFLO GT gas turbine flowmeters feature a transducer that utilizes a lightweight, low-inertia rotor to sense gas velocity. It offers an output frequency that has a linear relationship to gas velocity over a wide flow range.

The meter tracks the flow rate continuously, offers little resistance to flow, and has a unique cartridge design that allows removal of all internal parts as one assembly. The meter also exhibits little sensitivity to gas density above two atmospheres pressure. The low inertia of the rotor and vee bearings allows over-ranging of the meter to twice its rated capacity without damage for intermittent flow variations.
## CO2 Measurement Data

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Wellington Oil Well Configuration
2 Phase Separator
CO2 Measurement at Tank Battery
Conclusions

• EOR projects with Class 2 permitting can accurately measure CO2 injected, recovered and stored in the reservoir
• EOR projects WILL produce CO2, including after CO2 injection ceases
• Need to differentiate between reinjected and vented CO2 from producers and tank batteries

• Thanks and Credits to DOE/NETL, Kansas Geological Survey, Berexco LLC.