UPDATE ON ANTON IRISH CONFORMANCE EFFORTS

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Abstract
Over the last 5 to 7 years, the Anton Irish field has undergone extensive work on severe conformance problems within its CO2 flood. This work has involved considerable diagnostics, which has generated an improved wellbore and reservoir understanding. This new perspective is very different from the original assumptions about the field. Based on these new understandings conformance treatments have been designed and executed which have resulted in significant economic return. Past work has presented the results of 5 producer well treatments and recent efforts are focusing on injection wells. This paper is an update to SPE paper # 103044, and as such utilizes some of the same basic information and structure to set the ground work for this update. In addition we will update the progress and results from all efforts and discuss future expectations for continued work.

Basic Field History
The Anton Irish field, a carbonate reservoir located in West Texas was discovered in 1945. The field was then unitized for a produced gas pressure maintenance project in 1950 and converted to a waterflood in 1969. CO2 flooding began in 1997 and currently accounts for approximately 85% of the unit production. Current production is approximately 8,000 BOPD; 38.0 MMCFPD of recycled CO2, and 40,000 BWPD.

Basic Problem / Justification
The conformance problem at Anton is the rapid breakthrough of injection fluid (either water or CO2) from the injection well to the producer. This rapid breakthrough leads to excessive cycling of the injection fluid through conduits rather than sweeping the reservoir matrix. This excessive cycling prevents efficient CO2 flooding and waterflooding of a pattern. This problem cannot be ignored at Anton while on CO2 due to limited processing at the gas plant and some high gas rate wells becoming uncompetitive (even with relatively high oil rates) on a gas handling basis. In order to maintain projected recovery factors for the area, a solution had to be found to address the excess cycling and premature breakthrough problems.

This effort is complicated by many factors, but a major issue has been our ability to modify conformance in wells with open hole completions. Open hole complications (bridges, ledges, washouts) have also presented a challenge in diagnostic work and fully understanding our treatment options and results.

Conformance Project Progression:
In 2003, an effort was made to gather knowledge from past conformance experiences, identify shortcomings, and formulate a plan to better understand conformance issues at Anton. In this effort, historical data was used to identify key understandings and uncertainties, diagnostic tests were planned and executed to gather needed data, and the data was analyzed to further the Anton Conformance problem model. Then treatments were designed and executed, and the results of these jobs were utilized to modify the understanding of the problem and the design of future treatments. It is important that our process includes the ability to learn from treatments as they are executed and apply that knowledge in our understanding of the conformance problem and next solution design.

Early Conformance Efforts:
Prior to this effort to better understand the conformance problem in the Anton field, the problem was perceived to be high permeability streaks and/or small relatively near wellbore features. With this perspective, original solutions were designed as small volumes to treat near wellbore flow. The results of these solutions failed to control gas and fluid movement in the reservoir and thus the conformance problems persisted.

Improved understanding of the problem came through extensive review of additional reservoir monitoring, including, production and injection pattern rate analysis, interwell tracers, re-evaluation of core samples, ultrasonic image logs, Hall plot analysis, step rate tests, and downhole camera inspections. Examples of this data were presented in SPE#103044. This data led to a new perception of the problem, namely large void space conduits, whose origination was suspected to be induced fractures with later enhancements by rock dissolution and/or erosion caused by the flooding process. Two significant challenges accompanied this new perspective. The first was convincing all parties working the project of the suspected massive nature of the features, and the second was trying to figure out how we might control or at least significantly influence these features.

Solution Design (Initial Treatments - Producers)
As stated, establishing the size of these features was a significant unknown, and along with this comes the question of how much of the volume must be filled or blocked to effectively influence the flow. Ultimately the solution design came down to simply filling as much of the void as we felt we
could achieve within economic and logistic constraints. We believe that the more volume we could fill, the more effective and longer lasting the treatment would be. We decided on a novel treatment that would treat the producing wells rather than the injecting wells, due to evidence from an inter-well tracer survey that showed possibly 7 injectors tied to 2 high gas rate producers.

Our first treatments designs had the focus of filling the conduit void with as much product of sufficient strength (especially nearest the wellbore) while remaining within our economic and logistic constraints. The final design was to pump 8,000 Bbls of “chrome cross-linked” gel for void fillage immediately followed by 2,000 Bbls of foamed cement for near wellbore strength. A total 10,000 Bbls of void filling material was designed to prevent or greatly limit any flow back into the producer along void conduit. (More details provided in SPE #103044 and Table 1).

First two Treatments (Wells 251 & 252):
Since ultimate fillup volumes and pressure response was unknown, initial designs were pumped through a cement retainer to enable us to unsting at relatively any time in the treating process. The first large volume conformance treatments were executed in late 2003, and put on production in early 2004. These designs were the first successful conformance solutions to be placed in the Anton Irish field, and have remained fairly effective as exhibited by production plots in Figure 1.

Improved Solution Design (Wells 282, 284, and 292):
After the AICU 251 and 252 treatments we understood that the conformance problem consisted of massive conduit volumes (> 10,000 Bbls) with limited pressure resistance during treatment. This improved problem understanding led to further improvements in our treatment designs for wells 282, 284, and 292. To confirm and better understand the conformance problem in this area an inter-well tracer program was designed and executed. The results of the tracer study are provided in Figure 2. These three treatments were executed in 2005, and the design pumped shown in Table 2. Due to cement produced back in the separators of 251 and 252 we needed more near wellbore strength. The design changes included increasing both the molecular weight and concentration of the chrome cross-linked gel, increasing the strength of cement, and elimination of pumping through the cement retainer. Since the cement retainer was eliminated, job preparation only involves pulling the current completion, and installing a retrievable packer and workstring several hundred feet above the casing shoe and pumping the job away. This change allows the job to be pumped without a rig on the well and thus decreases rig costs and simplifies logistics. These modifications ultimately resulted in lowering the overall average treatment cost by approximately $50M/treatment, while at the same time improving the overall strength of the system.

The production results for these wells are shown in Figure 3. Overall performance, both initial and extended have exceeded our original expectations. Personal experience with producer well treatments led us to believe these treatments would not last much past 2 yrs before returning to pretreatment performance. At this time we have two wells with > 4 years of production performance that are still better than pre-treatment rates and 2 out of three wells with ~ 2 yrs performance better than pre-treatment rates. Recent production changes in well 284 have indicated that this well may be breaking down or potentially developing a new bypass conduit and we are reviewing alternatives for retreatment. In addition, more candidates are being reviewed for additional producer treatments and based on current results some consideration is being given to reduce treatment volume in an attempt to enhance economic benefit.

Next Step (Injector Treatments)
Given the positive results for these producer treatments the next obvious step is to implement solutions focused on injector wells which are clearly tied to multiple producers. Again tracer data and offset production performance is key to selecting the best candidates. At this time two injection well treatment candidates have been selected and are being evaluated and executed at this time. (More details provided in SPE #103044 and Table 1).

Injector Diagnostics (Injector # 63)
To continue improving our understanding of the extent and overall impact of our conformance problems, additional diagnostics were attempted on two injectors to build a pre-treatment base line of information. In each of our two selected injection wells we wanted to collect the following data: Step Rate Test, Downhole Video Inspection and a current Injection Profile. Step rate tests have been completed and the data is presented in Figures 4 and 5, suggesting that at the rates pumped and pressures observed must be flowing into fracture features and void spaces. As is the case in many field operations the realities of wellbore conditions have limited our success with both the Downhole Video and post Injection Profiles. We were unable to obtain a video image of the section that was taking 100% of injection. However, the Downhole Video Inspection of the wellbore above this depth leads us to believe this feature must be a large fracture similar to images in Figure 6.

Solution Design (Injector #63)
As in the case of the producers some key design issues continue to come forward. First, how much volume of the void conduit do we need to fill to effectively influence recovery, and second what can we reasonably expect to execute or pump from both an economic and operational standpoint. After a prudent review of the alternatives we decided to attempt to fill the void conduit in AICU injector #63 with a swelling poly-crystalline material where we have seen some benefit of using the product in smaller features. The first treatment was pumped with the intent to place 30,000#/s of swelling polycrystals at a mix ratio of 0.25 #/gal. The carrying fluid was designed as a 9.5 #/gal brine which results in a swelling ratio of ~ 35 to 1. (i.e. 1 # of dry polycrystal material will absorb ~ 35#/s of water.) Using this ratio we anticipated that this product (once fully swollen) would occupy a void volume of approximately 3,000 bbls. With an expected pump rate of
4 to 5 BPM and 0.25 #/gal this calculated to a minimum expected pump time of 10 hours. As can be seen from the pump chart for this treatment in Figure 7, we were pleased to see a steady increase in pressure during the job, possibly indicating we were filling the void or conduit feature.

**Initial Injector Treatment Results (Wells 63):**
After initial completion of the treatment and 36 hours of Shut-in, we were unable to achieve any injection into the well. The well was cleaned out with CT, and injectivity after the cleanout can be seen in Figure 8. Attempts to establish post treatment profiles have been blocked by obstruction in the tubing. We are currently waiting on a rig to pull completion and cleanup the wellbore and evaluate the post treatment profile. However, the lack of injectivity reduction has us preparing to execute a large (~1000 Bbl or greater) cement squeeze with foamed cement.

**Solution Design (Injector #104):**
After the difficulty with limited injectivity improvements on AICU #63 and a desire to be more confident and effective on our next solution, AICU injector #104 has been selected for a scab liner. This well historically takes injection on vacuum (offset injectors do not). We have positive production and injection rate analysis evidence that AICU #104 communicates directly to offset producer AICU #204. The injection profile reveals a large % of the injection in the upper portion of the well which will benefit from additional mechanical isolation. One thing that will be different for this liner is the plan to cement the liner in place with ~1000 Bbls of foamed cement. It is our belief that although the liner will provide a near wellbore pressure isolation from the injection fluids, it will do little or nothing to repair the deep formation conduit. The large cement volume will also help in establishing a good cement job in the liner. Based on our understanding of the problem, we still believe the most significant conformance improvement will come from filling the large void conduit with sufficient material to effectively divert injection into unswept rock.

**Future Conformance Work at Anton**
The conformance effort at Anton will continue and treatments generated based on our improved understanding. Efforts to lower the cost by trying to limit the treatment volumes will be attempted, but the overall longevity and total cost effectiveness will take time to evaluate. We continue to monitor the results of past treatments so that we can continue to optimize the size, strength, and placement techniques of these solutions.

This conformance work at Anton, has had impact outside of Anton. Specifically, experience and knowledge gained from the diagnostic efforts have been used in other Oxy assets in the Permian Basin. At this time several fields have executed successful solution treatments based on filling large void conduit systems. However, with the wide range of conformance problems at specific fields, each case must be diagnosed and treated with a custom solution. What we hope is learned from Anton is the methodology, and ability to search beyond the initial perceived problem solution.

**CONCLUSIONS**
- Working beyond initial perceptions at Anton resulted in a greatly improved understanding of the problem. This led to a novel and bold solution design.
- Knowledge gained from these treatments were used to update the understanding and further improve the solution design.
- A well-defined process of diagnosing a problem, executing a solution, followed by updating the problem and solution is a valuable format to follow.

**Acknowledgement**
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Table 1 - First Producer Conformance Treatments (Wells 251, 252)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Void Filler</th>
<th>Type</th>
<th>Specs</th>
<th>Volume (Bbls)</th>
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<tr>
<td>1A</td>
<td>Gel</td>
<td>Chrome Cross-Linked</td>
<td>3000 PPM</td>
<td>6,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Medium MW (13 MM)</td>
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<tr>
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<td>Gel</td>
<td>Chrome Cross-Linked</td>
<td>5000 PPM</td>
<td>2,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Medium MW (13 MM)</td>
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<td>Cement</td>
<td>No N₂</td>
<td>80/20% Poz/Prem</td>
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</table>

Note: Job pumped through cement retainer

Total: 10,000

Figure 1: AICU 251, 252 Combined Production Plot (Normalized to Treatment Time)
Figure 2: Inter-well Tracer Summary
### Table 2 - Revised Producer Conformance Treatments (282, 284, 292)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Void Filler</th>
<th>Type</th>
<th>Specs</th>
<th>Volume (Bbls)</th>
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<td>500</td>
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<tr>
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<td>5% N₂ Foamed</td>
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<td>60/40% Poz/Prem, + Fiber</td>
<td>200</td>
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</table>

Note: Job pumped under a packer, overflushed 70 bbl Total: 10,000

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Figure 3: AICU 282, 284, 292 Combined Production Plot (Normalized to Treatment Time)
Figure 4: AICU 104 Step Rate Test

Figure 5: AICU 104 Step Rate Test
Figure 6: Fractures in AICU 63 Wellbore

Figure 7: AICU 63 Polycrystal Bottom Hole Treatment Pressure
Figure 8: AICU 63 Injectivity