

Engineering Report

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Corrosivity of Multiphase Systems

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1 Background

Background Very little work has been carried out to examine the effect of water cut and water/oil mixture velocity on corrosion in multiphase oil and water pipelines. World-wide, some rules-of-thumb exist based on limited experience. For example, it has often been suggested that, in a horizontal pipe, a mixture velocity of about 3 feet/second is sufficient to produce enough turbulence to ensure that the water phase is maintained as a dispersed phase in a continuous oil medium. If this were true, then the water would not wet the internal steel surfaces, and corrosion would not occur. Unfortunately, the oil industry has experienced failures at water cuts as low as 1-2%. More specifically, in Saudi Aramco's Hawtah field we experienced repeated failures soon after crude production started; we used this as a justification to initiate Phase I of this study.

In Arab Heavy production in a Safaniya field pilot program we have documented several failures of gas lift mandrels in 18-30 months of production. This resulted in work-over costs of \$750M per well. With the potential of up to 500 oil wells going on gas lift starting in approximately 2005, we targeted this issue as Phase II of this project. Three wells failed due to erosion-corrosion of the gas lift mandrels, and were re-completed using 13Cr mandrels at the recommendation of CSD. This work was justified on the basis that we had to confirm that 13Cr is suitable for this service.

The Engineering Services Technology Program funded this work as item CSD-08/96-T. In 1996 the Program did not require a Field Partner. However, it did require a Beneficiary; for this project, the beneficiary were identified primarily the Saudi Aramco Engineering Standards (SAESs), Pipelines and Projects.

This Executive Summary will provide only the main findings. The reader is referred to each individual report for specific details. In the Findings Section (below) are included the main findings distilled from the data and observations conducted during the test programs.

The following are the Sections of the original proposal:

- 1) **Statement of Problem/Opportunity:** The purpose of this study is to determine the Corrosivity of multiphase systems containing Saudi Aramco crudes mixed with carbon dioxide. The study will be conducted to identify the potential corrosion problems in systems carrying Arab Super Light (ASL) crude (Phase I); and to select materials of construction for gas lift mandrels used in Arab Heavy crude produced with sand, which fail prematurely (Phase II).
 - 2) **Scope:** For ASL, will conduct thirty-six tests in a flowing multiphase loop at Ohio University (this scope was later changed to strictly study the behavior of water separation from Saudi Aramco crude oils at various flowing velocities and water cuts, based on the preliminary findings). For Arab Heavy, will conduct tests in a mini-loop with sand added to the fluid(s) at Tulsa University.
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- 3) **Objective/Deliverables:** Develop the effect of corrosion inhibitor and flow pattern(s) for Arab Super Light crude (this was later re-defined as the water cut at which water separates from crude oil at various flowing velocities). For Arab Heavy, identify a suitable material of construction for the gas lift mandrels to prevent additional premature failures of oil producing wells.

2 Recommendations

Phase I - Separation Behavior of Produced Water from Saudi Aramco Crudes

- 1) Implement new velocity guidelines in SAES-L-32 as appropriate.
- 2) Implement new corrosion inhibition requirement guidelines in SAES-L-33 as appropriate.
- 3) Perform a new study to determine the separation behavior of water at various water cuts, flowing velocities, and inclination angles. We recently visited Ohio University to discuss this proposal, and have determined that the cost will be approximately \$45M for the initial phase, plus travel. We will request funding through a separate proposal, to be submitted for approval to TQS.

Phase II - Materials of Construction for Gas Lift Mandrels in Arab Heavy Crude Oil Production

Use 13Cr as the most cost-effective material of construction.

3 Findings

Phase I - Separation Behavior of Produced Water from Saudi Aramco Crudes

The main finding is that the old rule-of-thumb of water being entrained in the crude oil at velocities greater than 3 feet/second has been confirmed to not be true. For each crude the following are the findings:

Arab Super Light (ASL)

- 1) Up to approximately 10% water cut the water is entrained in the oil. This means that the water is entrained or dispersed in the crude oil.
 - 2) At 12% water cut the water separates from the ASL crude, and is able to wet the internal steel surfaces. As the liquid velocity is increases, the water becomes more uniformly dispersed in the oil, but water content is still higher near the bottom of the pipe than near the top.
 - 3) A minimum flowing velocity of 5 feet/second (1.5 meter/second) is required to keep the water fully entrained in the crude oil at water cuts higher than 12%.
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- 4) At water cuts higher than 12% corrosion can be expected at velocities lower than 5 feet/second (1.5 meter/second). As a result, corrosion inhibition is required.
- 5) Corrosion rate increases with an increase in liquid velocity at constant total pressure.
- 6) The shear stress increases with an increase in liquid velocity at all water cuts, but increases only negligibly with an increase in water cut.

Arab Light

- 1) At water cuts greater than 15% the concentration of water near the bottom of the pipe is high, and significant corrosion can result.
- 2) At mixture velocities of 5 feet/second (1.5 meter/second) and lower, more water is present at the bottom of the pipe, and higher corrosion results and can be expected.
- 3) Above a velocity of 6.5 feet/second (2 meters/second), the flow is fully-dispersed, homogeneous.

Arab Heavy

- 1) At 10% water cut and a velocity of 3.3 feet/second (1 meter/second) the flow is almost homogeneous, and is fully homogeneous at 5 feet/second (1.5 meter/second). This means that the all the water is fully dispersed in the crude oil.
- 2) At 15% and 20% water cuts the water is almost fully dispersed at a velocity of 5 feet/second (1.5 meter/second).
- 3) At all water cuts and mixture velocity greater than 5 feet/second (1.5 meter/second) the flow is fully dispersed.
- 4) At 1.3 feet/second (0.4 meter/second) and 20% water cut the corrosion measured was 17 mils per year. This tells us that we must avoid such low velocity in this crude.

Phase II - Material of Construction for Gas Lift Mandrels in Arab Heavy Production

- 1) Corrosion in the 4140 steel used for the gas lift mandrels was extremely high, confirming the Safaniya field experience. However, the erosion component was much lower than we expected. We are following this up with Tulsa University. Any new findings will be incorporated in a revised version of this SAER.
 - 2) The 13Cr material tested did not suffer any corrosion or erosion. Therefore, 13Cr should be the material of choice.
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- 3) Communicate these findings to Drilling and Production Engineering, for permanent inclusion into their completion practices.

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Revision Summary
New document.