CAERUS OIL & GAS

DATE: November 27th, 2017

Company: Caerus Oil & Gas

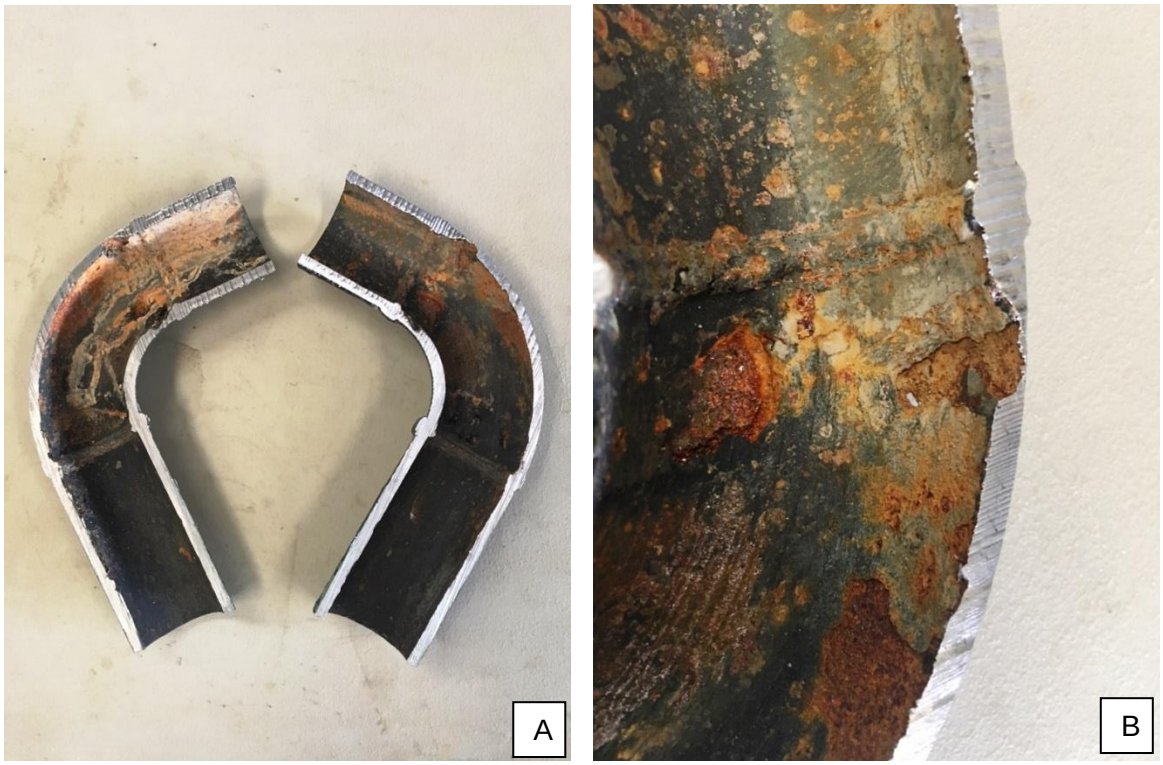
Field: Piceance Basin, Colorado

TO: Jake Janicek

SUBJECT: 17L-794 Flowline Failure Analyses

EXECUTIVE SUMMARY

Nalco Champion received a section of 2" pipe from the flowline off the 17L-794 well. Caerus Oil & Gas personnel noticed a leak at a bend in the flowline and the age of the pipe was deemed to be less than a year old. The damaged section was cut out and given to Nalco Champion where it was then split length wise for analysis. The internal portion of the pipe was noted as having a dark coating covering the metal surface along with pitting and two visible breaches through the pipe wall. The majority of the damage was at the bend in the flowline between the welds. This report lines out the analysis and findings of the failure to the pipe.



Picture A & B – 2" Pipe sample from the 17L-794 Well flowline before cleaning

FAILURE ANALYSIS

Nalco Champion performed a failure analysis with the goal of determining the mechanism behind the corrosion damage. The sample was initially swabbed to test for active and dormant microbiological activity via Nalco Champion's AccuCount testing system. An initial inspection of the pipeline sample revealed that there was no corrosion seen on the exterior of the pipe. There was pitting on multiple spots throughout the pipe walls interior surface and two holes that breached the pipe from the inside out. A section of the pipe was cleaned with 15% hydrochloric acid (HCl) which exposed more pitting on the internal surface.

MICROBRIAL ACTIVITY

As soon as Nalco Champion received the pipeline sample, the damage was swabbed 2 times for microbiological activity; one swab on the actual breach of the pipe and one swab on the multiple pitting spots. The swabs were then processed through Nalco Champion's AccuCount system to analyze the amount of active and dormant microorganisms and the numbers are reported below.

Data Set Name:	Value:
17L-794 (Swab 1) – tATP	205,542.1 ME/mL
17L-794 (Swab 1) – tAMP	0 ME/mL
17L-794 (Swab 1) – AMPi	0
17L-794 (Swab 1) – tAMP + tATP	84,124.25 ME/mL
27L-794 (Swab 2) – tATP	146,892.66 ME/mL
27L-794 (Swab 2) – tAMP	0 ME/mL
27L-794 (Swab 2) – AMPi	0
27L-794 (Swab 2) – tAMP + tATP	139,775.67 ME/mL

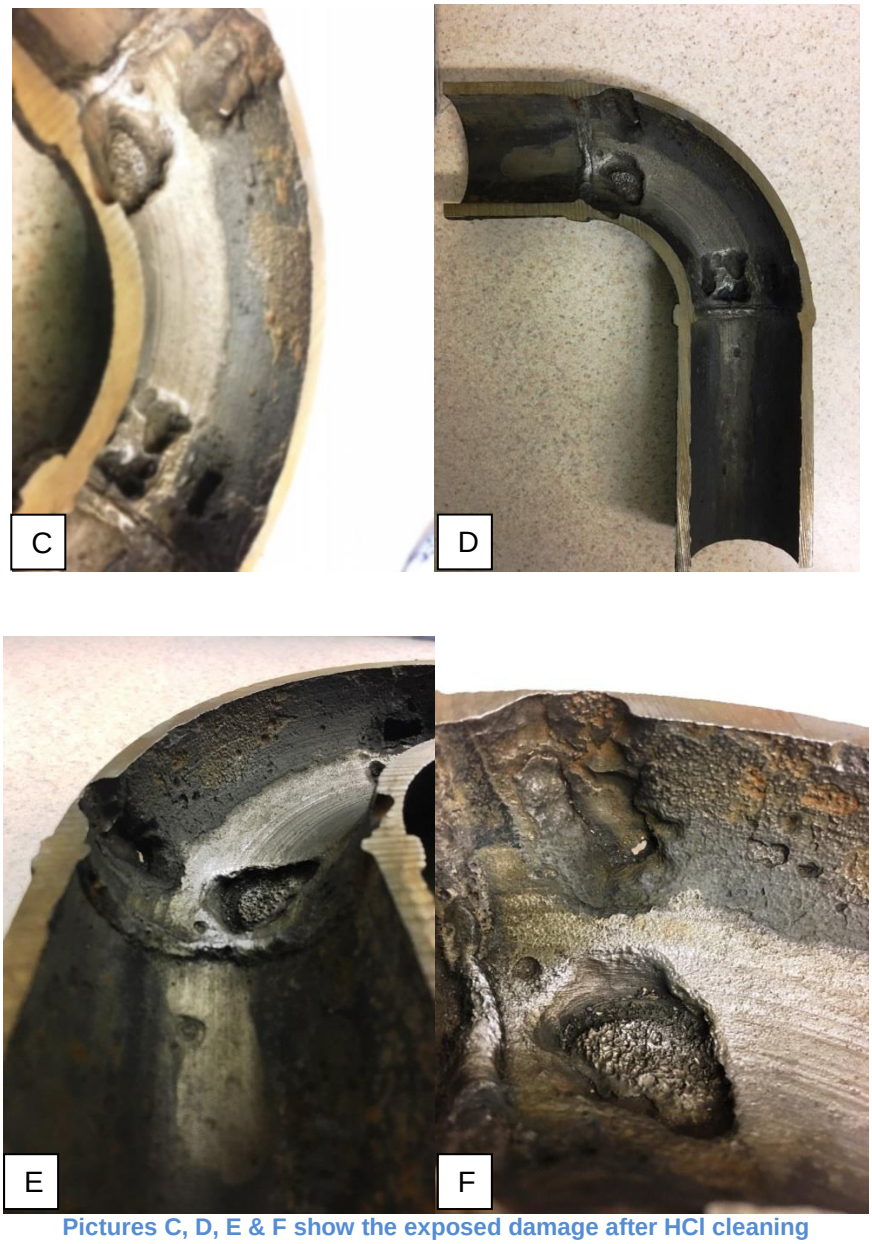
Total ATP (**tATP**) represents the total amount of active microorganisms in the sample, which translates into the **direct threat**. tATP results are reported as Microbial Equivalents (**ME's**) based on knowledge that 1 E. coli-sized bacteria contain 10-15 g of ATP.

AMP Index (**AMPi**) represents the relative proportion of metabolically-dormant to living cells in a given sample. Although metabolically-dormant cells do not pose an immediate microbiological contamination risk, changing process conditions can cause them to become metabolically active without warning. AMPi is therefore an indication of the **indirect threat**.

With the ATP & AMPi counts recorded, it is deemed that moderate quantities of active microorganisms and low proportions of dormant microorganisms were found present on the inner surface of the pipe sample.

ACID CLEANING

An internal section of the pipe was cleaned using a solution of 15% hydrochloric acid (HCl) and a wire brush to expose the pitting. As soon as the HCl was applied, it immediately started to effervesce and release H2S that was detected at ~15 ppm with an H2S monitor. It was then determined that the dark coating on the surface was iron sulfide due to the reaction with the HCl and also iron carbonate (FeCO3). After the surface was cleaned, a visual inspection of the corrosion damage was conducted. The corrosion was comprised of numerous pits with a “hill and valley” texture in certain spots and a “honeycomb” pattern in others. There were also deep gouges between the flat surfaces indicating “Mesa Attack” corrosion which typically occurs where some areas of the metal surface have a good protective coating and some do not.



Pictures C, D, E & F show the exposed damage after HCl cleaning

CONCLUSION

The damage and pitting observed on the pipe is indicative of carbon dioxide (CO_2) corrosion. CO_2 is an acid gas that is absorbed in brines and can cause severe corrosive attack to steel. The combination of the damage and pitting being on a bend and close to welds, appear to be the contributing factors of the failure. In this case, it is referred to as “Flow-enhanced” corrosion. Flow-enhanced corrosion usually occurs when a change of direction in the flow of fluids occurs, such as near an elbow. Typically, the mechanism follows a deposition of a protective FeCO3 film with rubbing off the film by the flow of fluids, and sometimes solids. After the protective coating is abraded off, a new surface is exposed which then immediately starts to corrode. The corrosion product is a softer surface, which is then eroded away, and the process continues until a failure occurs.

Please review and let me know if you have any questions or would like a recommendation to mitigate these types of failures. To do so, Nalco Champion would perform further testing and analysis on the production system to supply the best chemical treatment solution.

Regards,

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