

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

THIS BALLOT IS FOR A PROPOSED

ADDENDUM 1 TO CURRENT API 13TR1

Stress Corrosion Cracking of Corrosion Resistant Alloys in Halide Brines Exposed to Acidic Production Gas, 1st Edition (November 2017)

The following shall be added to Table of Contents with page numbers updated:

| | |
|---|----|
| Table C.1 - Chemical Composition of Alloys | 5 |
| Table C.2 - 13Cr 80 & 85 | 6 |
| Table C.3 - Alloy 13Cr(2Mo)-95 (modified chemistry) | 7 |
| Table C.4 - 13Cr(0.6Mo)-110 | 8 |
| Table C.5 - 13Cr(1Mo)-110 | 9 |
| Table C.6 - 13Cr(1.7Mo) Bar Stock | 10 |
| Table C.7 - 13Cr (2Mo)-110 | 11 |
| Table C.8 - 13Cr(3Mo)-125 | 12 |
| Table C.9 - 22Cr-125 | 13 |
| Table C.10 - 25CrW-125 | 14 |
| Table C.11 - Alloy 925 | 15 |
| Table C.12 - Alloy 945 | 16 |
| Table C.13 - Alloy 718 | 17 |
| Table C.14 - Alloy 825 | 18 |
| Table C.15 - Alloy 725 | 19 |
| Table C.16 - Alloy 2550 | 20 |
| Table C.17 - Alloy G50 | 21 |
| Table C.18 - Alloy 2535 | 22 |
| Table C.19 - Alloy C-276 | 23 |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Scope 1 – current fourth paragraph:

The current paper evaluates the SCC risks of a range of CRAs in various halide brine compositions for the case of exposure to acidic production gas ($\text{CO}_2+\text{H}_2\text{S}$). Also evaluated are SCC risks due to air exposure. However, the testing became focused on a group of martensitic stainless steels alloyed with Ni and Mo, that are collectively referred to as modified 13Cr martensitic SS, or alternatively in some publications as super (S13Cr) martensitic SSs. Most tests evaluated the as-received brine, excluding proprietary additives such as corrosion inhibitor or oxygen scavengers. For completeness and comparison, test results provided by member companies in the API program or in the publications are cited; these test protocols may be different from those in the API test protocols hence, where that occurs, significant differences are noted.

Shall be replaced with the following (changes highlighted):

This technical report evaluates the SCC risks of a range of CRAs in various halide brine compositions for the case of exposure to acidic production gas ($\text{CO}_2+\text{H}_2\text{S}$). Also evaluated are SCC risks due to air exposure. However, the testing became focused on a group of martensitic stainless steels alloyed with Ni and Mo, that are collectively referred to as modified 13Cr martensitic SS, or alternatively in some publications as super (S13Cr) martensitic SSs. Most tests evaluated the as-received brine, excluding proprietary additives such as corrosion inhibitor or oxygen scavengers. For completeness and comparison, test results provided by member companies in the API program or in the publications are cited; these test protocols may be different from those in the API test protocols hence, where that occurs, significant differences are noted. **Test results are summarized in a tabular format with color coding to designate passing or failing test results in Annex C of this technical report.**

The following Annex C shall be added:

Annex C (Informative)

Alloy/Halide Brine Compatibility

C.1 Introduction

This annex summarizes the results of the stress corrosion cracking (SCC) testing of a range of Corrosion Resistant Alloys (CRAs) in halide brine compositions contaminated with acidic production gas ($\text{CO}_2 + \text{H}_2\text{S}$) or exposed to oxygen-containing air in the brine. This Annex is in a tabular format with color coding to designate passing or failing test results. Complete test procedures and detailed test results can be found in Sections 3 through 7 as Annex A of API 13TR1.

These specific halide brines are used as completion, packer and workover fluids. Most tests evaluated the as-received brine, excluding proprietary additives such as corrosion inhibitor or oxygen scavengers. The alloys (martensitic and duplex stainless steels, and cold worked austenitic and precipitation hardened nickel-based alloys) are used in tubing and completion equipment in oil and gas production, where failure could pose a risk to health and safety or the environment.

The primary test variables were:

- Brine density and chemistry
- Temperature ($>200^\circ\text{F}$),
- Brine contaminants oxygen and CO_2
- Presence of H_2S , either directly or via thiocyanate decomposition
- C-ring stress levels

Test concentration of the acid gases, H_2S and CO_2 , were intentionally varied depending on alloy content. Most testing with martensitic stainless steels had CO_2 levels of 100 psi. Duplex stainless steels and higher alloys had levels of 500 psi CO_2 . H_2S levels was typically 0.15 psi, but when H_2S was generated in tests due to decomposition of thiocyanate (SCN), H_2S levels could not be measured directly. Users are advised not to consider specific levels of contamination as go/no-go values for individual alloy/contamination combinations.

Failure was defined as cracking with a minimum 25 microns in length. Tested samples were subjected to visual examination for the presence of cracking. Metallographic sectioning was performed at crack locations or at the center of the apex of the C-ring if no cracks were observed. Pitting within a test was not considered a failure. If severe pitting or corrosion was observed, it is noted.

Tables C.2 to C.19 were created to summarize these test results and results from literature. These tables are issued as Annex C to API TR 13TR1.

C.2 Instructions for Use of the Tables

The following are instructions for the use of Tables C.1 through C.19:

- Individual CRAs are shown on each table.
- Numerical values in the cells denote a temperature limit where passing or failing results were obtained.
- The legend for the tables is shown below. Footnotes are provided for further explanation where available.
- Some cells may have multiple colors, which indicates a pass (green) at the lower temperature, and a failure (red) at the higher temperature.

The tables in this annex provide usage information summarized from the tests undertaken by this Joint Industry Project (JIP). Additional information comes from literature surveys and sharing of data by company members. There is a table of test results for each of the alloys tested in halide brines. The resulting information in the tables uses color coding for each of the alloys tested and their compatibility with halide brines in which they were tested. This is meant to provide a high-level guide for brine usage. Details can be found in the report.

C.3 Color-coding of Tables

Below is the color-code used in the tables with the following meanings to the colors:

| |
|--|
| Legend |
| Temperature in degrees Fahrenheit |
| Blank indicates no test results. |
| Green/Red in blank cell indicates pass at a lower temperature and failures at higher temperature as expected from SCC damage mechanism |
| Green indicates tested by JIP and passed, or passed at more severe conditions, or good field experience, or from literature |
| Red indicates tested by JIP and failed, or failed under less severe conditions, or field failure reported |
| Yellow indicates conflicting test data or data with no verifiable source or bring attention to other inconsistencies worth considering (e.g., other alloys within the same family showing different passing/failure results) or results that require more testing |
| (L) Data from literature |
| (F) Data from field experience |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

The convention used with the temperatures (degrees Fahrenheit) in the table is:

265F^A indicates a footnote (A) located at the bottom of the table.

265F₂₀ indicates the test number (#20) associated with that result.

Table C.1 lists the alloy compositions used in the tests.

Table C.1 - Chemical Composition of Tested Alloys

| Alloy | Chemical Composition, % | | | | | | | | | | | |
|---------------------------------------|-------------------------|------|------|-------|------|------|------|------|------|------|-----|------|
| | C | Fe | Ni | Cr | Mo | Ti | N | V | Cu | W | Nb | Co |
| Standard 13Cr | | | | | | | | | | | | |
| 13Cr-L80 | 0.21 | 86.7 | 0.14 | 12.91 | -- | -- | -- | -- | -- | -- | -- | -- |
| Modified 13Cr | | | | | | | | | | | | |
| 13Cr(0.6Mo)-110 13-5-0.6-110 | 0.01 | 86.4 | 5.20 | 12.89 | 0.60 | 0.06 | -- | 0.05 | -- | -- | -- | -- |
| 13Cr(1Mo)-110 13-4-1-110 | 0.20 | 81.9 | 4.3 | 12.8 | 1.0 | | 0.08 | | -- | -- | -- | -- |
| 13Cr(2Mo)-95 13-6-2-95 S41426 | 0.01 | 80.0 | 5.9 | 12.1 | 1.90 | 0.08 | -- | 0.06 | 0.07 | --- | -- | -- |
| 13Cr(2Mo)-110 13-6-2-110 S41426 | 0.01 | 80.0 | 5.9 | 12.1 | 1.90 | 0.10 | -- | 0.06 | 0.07 | -- | -- | -- |
| 13Cr(1.7Mo)-110 S41425 (bar stock) | 0.02 | 79.0 | 4.68 | 13.46 | 1.67 | -- | 0.07 | | -- | -- | | |
| 13Cr(3Mo)-125 13-7-3-125 | 0.01 | 0.01 | 6.9 | 12.00 | 2.90 | 0.10 | -- | 0.04 | -- | -- | -- | -- |
| Duplex SS | | | | | | | | | | | | |
| 22Cr-125 22-5-3-125 S31803 | 0.02 | 69.2 | 5.01 | 22.05 | 3.10 | -- | 0.18 | -- | 0.50 | -- | -- | -- |
| 25CrW-125 S39274 (tubing) | 0.02 | 62.2 | 6.86 | 25.0 | 3.15 | -- | 0.29 | -- | 0.50 | 2.22 | -- | -- |
| High- Ni | | | | | | | | | | | | |
| C-276 15-60-16-135 N10276 | 0.02 | 4.0 | Bal. | 14.55 | 15.0 | -- | --- | -- | -- | -- | --- | 2.50 |
| 2535-125 25-32-3-125 N08535 | 0.02 | 39.1 | 31.4 | 25.6 | 3.2 | -- | -- | -- | 0.71 | -- | -- | -- |
| 935 (bar stock) N09935 | 0.02 | 36.0 | 35.4 | 20.2 | 3.6 | 2.04 | -- | -- | -- | -- | -- | -- |
| 718 N07718 (bar stock) | 0.02 | 23.2 | 54.1 | 18.8 | 3.0 | 0.96 | -- | -- | 0.02 | -- | -- | 0.04 |
| 825 21-42-1-120 N08825 | 0.02 | 27.0 | 43.5 | 22.4 | 2.8 | 0.93 | -- | -- | 2.60 | -- | -- | -- |
| 925 N09925 (bar stock) | 0.01 | 27.4 | 42.7 | 21.5 | 3.4 | 2.13 | -- | -- | 1.67 | -- | 0.3 | -- |
| 725 N07725 (bar stock) | 0.01 | 7.5 | 58.2 | 20.9 | 8.0 | 1.52 | -- | -- | -- | -- | 3.6 | -- |
| 2550 25-52-11-125 N06255 | 0.01 | 16.7 | 50.7 | 23.8 | 6.6 | 0.30 | -- | -- | 0.75 | -- | -- | -- |
| G50 20-54-9-130 N06950 | 0.01 | 15.1 | 52.5 | 19.8 | 9.0 | -- | -- | -- | 0.10 | -- | -- | 1.10 |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.2 - Standard 13Cr 80 & 85

| Alloy 13Cr-80 & 85 | | SCC observed at noted temperature with gas contamination | | | |
|---|-------------------|--|-----------------|--------------------------------------|--|
| No testing was done with this alloy with CO ₂ or H ₂ S added. | | | | | |
| Brine Composition | None | O ₂ | CO ₂ | CO ₂ and H ₂ S | |
| 9.7 ppg KCl | (F) | | | | |
| 10.0 ppg NaCl | (F) | (F) | | | |
| 11.6 ppg CaCl ₂ | (F) | | | | |
| 14.2 ppg CaBr ₂ | | 265 _A | | 265 _{A_C} | |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | 225 ₄ | | | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | | 225 ₂ | | 225 _{A₃} | |
| 18.0 ppg ZnBr ₂ /CaBr ₂ | 265 ₁₃ | 225 ₁ | | 265 _{A₉} | |
| NOTE The first five tests in this program were labeled with alphabetic characters A thru E. Thereafter numeric designations were used. In this table "A" & "C" in the footnote position refer to these tests. | | | | | |
| A Tested with SCN ⁻ which can potentially decompose and yield H ₂ S at high temperatures. No acid gases were added. (Tests labelled C, 3 and 9). | | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.3 – Modified 13Cr–Alloy 13Cr(2Mo)-95

| Alloy 13Cr(2Mo)-95 (modified chemistry) | SCC observed at noted temperature with gas contamination | | | |
|---|--|--------------------------------------|------------------------------------|--------------------------------------|
| Brine Composition | None | O ₂ | CO ₂ | CO ₂ and H ₂ S |
| 9.7 ppg KCl | (F) | (F) | | |
| 10.0 ppg NaCl | 265 ₂₉ | (F) | | |
| 11.6 ppg CaCl ₂ | 350 ₃₇ | 225 ₄₆ / 265 _A | (L) ^A | |
| 12.4 ppg NaBr | (L) ^B | 265 ₃₀ | 265 ₄₅ ^C | 225 ₈₇ |
| 14.2 ppg CaBr ₂ | 350 _{33a} | 265 _A ^D | | 225 ₈₈ |
| 14.1 ppg CaCl ₂ /CaBr ₂ (medium Cl ⁻) | 350 ₂₂ | | 265 ₂₃ | |
| 14.2 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | 350 ₂₅ | | 225 ₈₆ | |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | 225 ₄ | 265/(L) ^E ₃₅ | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 350 ₂₁ | 225 ₂ | 265 ₂₄ | |
| 18.0 ppg ZnBr ₂ /CaBr ₂ | 265 ₁₃ | 225 ₁ | | |
| NOTE : 14.2 ppg CaBr ₂ brine : A in numeric designation indicate one of the first test of this program | | | | |
| A Based on Piccollo data ^{13]} & Henke data ^{14]} . | | | | |
| B Failure based on literature ref Scoppio ^[24] , but conflicting results from Test #30, and good field history. | | | | |
| C Conflicting results in Tests #28 & #45. Test #28 invalid due to O ₂ contamination. | | | | |
| D Testing with SCN ⁻ at 225 °F and 265 °F passed. | | | | |
| E Based on a series of test results and literature data. Company F tests at 205 °F have failure but Test #35 is a pass at 265 °F. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.4 – Modified 13Cr–13Cr(0.6Mo)-110

| Alloy 13Cr(0.6Mo)-110 | SCC observed at noted temperature with acid gas contamination | | | |
|---|---|--|-----------------------|--------------------------------------|
| Brine Composition | None | O ₂ | CO ₂ | CO ₂ and H ₂ S |
| 10.0 ppg NaCl | 265 ₂₉ | | | |
| 11.6 ppg CaCl ₂ | 265 ₃₁ / 350 _{A37} | 225 ₄₆ / 265 _{B20} | | |
| 12.4 ppg NaBr | 265 _{65, 71} | 265 _{C30,48} | 350 ₇₂ | |
| 14.2 ppg CaBr ₂ | 350 _{33a} | 350 ₆₃ | 265 _{D70} | |
| 14.1 CaCl ₂ /CaBr ₂ (medium Cl ⁻) | 350 ₂₂ | | 265 _{23, 83} | |
| 14.2ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | 350 ₂₅ | | | |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | | 265 _{35,43} | |
| 15.5ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 350 ₂₁ | | 265 ₂₄ | |
| 18 ppg ZnBr ₂ /CaBr ₂ | | 225 (L) | | |
| <p>A Tests #31 & #32 failures at 265 °F and 350 °F, respectively. Pass at 350 °F, Test #37 with new deaeration procedure.</p> <p>B Test #46 passed at 225 °F. Test #20 failed at 265 °F. However, cell is yellow since Test #46 had 1 failure of 2Mo grade.</p> <p>C SCC in Test #30; no SCC in Test #48.</p> <p>D No SCC in Tests #41, #50a, #50b, #51, #52, & #60 at 265 °F, but SCC in Tests #68 & #70</p> | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.5 –Modified 13 Cr–13Cr(1Mo)-110

| Alloy 13Cr(1Mo)-110 | SCC observed at noted temperature with gas contamination | | | |
|--|--|--|-----------------------|---|
| | None | O ₂ | CO ₂ | CO ₂ and H ₂ S |
| 9.7 ppg KCl | (F) | (F) | | |
| 10.0 ppg NaCl | 265 ₂₉ | (F) | | |
| 11.6 ppg CaCl ₂ | 265 ₃₁ / 350 _{A37} | 225 ₄₆ / 265 _{B31} | | (L) ^C |
| 12.4 ppg NaBr | 265 ₆₅ | 265 ^D | 350 ₇₂ | 225 ₈₇ /265 ^E ₅₆ |
| 13 ppg CaBr ₂ /CaCl ₂ (low Cl ⁻) | | | 350 ₈₁ | |
| 14.2 ppg CaBr ₂ | 350 _{33a} | 350 ₆₃ | 265 ^F | 225 ₈₈ |
| 14.1 ppg CaCl ₂ /CaBr ₂ (medium Cl ⁻) | 350 ₂₂ | | 265 _{23, 83} | |
| 14.2 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | | 350 ₂₅ | 225 ₈₆ | |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | 225 ^G ₄ | 265 ₃₅ | 225 _{3, 10} |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 350 ₂₁ | 225 ₂ | 265 ₂₄ | 225 _{15a} |
| 18.0 ppg ZnBr ₂ /CaBr ₂ | 265 ₁₃ | 225 ^G ₁ | | |
| <p>A Test #31 failures at 265 °F. Pass at 350 °F, Test #37 with new deaeration procedure.</p> <p>B Test #46 passed at 225 °F. Test #31 failed at 265 °F. However, cell is yellow since Test #46 had 1 failure of 2Mo grade.</p> <p>C Based on Piccollo data ^[13] & Henke data ^[14].</p> <p>D Failed in Tests #30 and #28 before deaeration procedure modified.</p> <p>E Test #56 failed at 265 °F and 0.3 psi H₂S. Test #87 pass at 225 °F and 0.15 psi H₂S.</p> <p>F Conflicting results in Tests #50a, #51, & #52. Test #62 confirms SCC at 350 °F.</p> <p>G 1Mo-110 pass but 2Mo-110 failed in Tests #1 & #4.</p> | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.6 – Modified 13 Cr–13Cr(1.7Mo) Bar Stock

| Alloy 13Cr(1.7Mo) Bar Stock | SCC observed at noted temperature with gas contamination | | | |
|---|--|-----------------------|--------------------------------|--|
| Brine Composition | None | O ₂ | CO ₂ | CO ₂ and H ₂ S |
| 11.6 ppg CaCl ₂ | | | 265 ^A ₈₄ | (L) ^B |
| 12.4 ppg NaBr | | | 350 ₇₂ | 225 ₈₇ / 265 ^C ₅₆ |
| 14.2 ppg CaBr ₂ | | 350 ₆₃ | 265 ^D | 225 _{57b} |
| 14.2 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | | 225 _{63, 85} | 225 ₈₆ | |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | 350 ₇₆ | | |
| 17.0 ppg ZnBr ₂ /CaBr ₂ /CaCl ₂ | | | 350 ₇₇ | |
| <p>A No cracking with 100 psi CO₂ at 265 °F (Test #84); Bar passed, but Super 13Cr(2Mo) Tubular grades failed in same test.</p> <p>B Based on Piccollo data ^[13] & Henke data ^[14].</p> <p>C Test #56 at 265 °F had SCC with 0.3psi H₂S and 100 psi CO₂. Test #87 shows no cracking at 225 °F with 0.15 psi H₂S and 100 psi CO₂.</p> <p>D Conflicting results in Tests #50a, #51, & #52.</p> | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.7 - Modified 13Cr–13Cr(2Mo)-110

| Alloy 13Cr(2Mo)-110 | SCC observed at noted temperature with gas contamination | | | |
|--|--|---|--|--|
| Brine Composition | None | O ₂ | CO ₂ | CO ₂ and H ₂ S |
| 9.7 ppg KCl | (F) | (F) | | |
| 10.0 ppg NaCl | 265 ₂₉ | 265 (L) ^A | | |
| 11.6 ppg CaCl ₂ | 350 ₃₇ | 225 ^B ₄₆ | 265 ₈₄ | (L) |
| 12.4 ppg NaBr | 265 _{65, 71} | 265 ^C _{30,48} | 350 ₇₂ | 225 ⁸⁷ / 265 ^N ₅₆ |
| 12.9 ppg CaBr ₂ /CaCl ₂ (low Cl ⁻) | | | 350 ₈₁ | |
| 14.2 ppg CaBr ₂ | (L) ^D | 350 ₆₃ | 265 ^E _{41,50,52} | 225 ₈₈ |
| 14.1 ppg CaCl ₂ /CaBr ₂ (medium Cl ⁻) | 350 ₂₂ | | 265 _{23, 83} | (L) |
| 14.2 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | 350 ₂₅ | 225 ₈₅ | 225 ₈₆ | 225 ^F ₈₆ |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | 225 ^G ₄ / 350 ⁷⁶ | 350 _{35,77} ^H | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 350 ^I ₂₁ | 225 ^J | 265 ²⁴ / 350 ^K ₇₇ | |
| 17.0 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ Brine | | | 350 ^L | |
| 18.0 ppg ZnBr ₂ /CaBr ₂ | 265 ₁₃ | 225 ₁ | | (L) ^M |

A Agrees with Company A tests at 265 °F.
 B Test #46 had one (1) failure of 2Mo grade but no failures of other martensitic grades.
 C No cracking in Test #30 & #48 at 265 °F. But other modified 13Cr-110 alloys and 2Mo-95 grade had SCC implying there is a risk. Test #48 is guiding.
 D Tests in more severe environments showed no problem. Similar to results by Nakamura ^[10] at 284 °F.
 E Test #41, #50 and #52.
 F Test #86 failed with CO₂ only at 225 °F.
 G Test #76 passed 350 °F with O₂; one of two cracked in Test #4 at 14 days test at 225 °F.
 H Test #35 at 265 °F and Test #77 at 350 °F; but conflicts with Company F data.
 I Pitting observed in Test #21 at 225 °F.
 J Alloy pitted at 225 °F in Test #15 after 14 days at 0.15 psi O₂ at ambient conditions.
 K Test #24 failed at 265 °F but #77 passed at 350 °F and 17 ppg.
 L Test #75 at 350 °F failed; while Test #77 all pass in trisalt brine. Also Test #4 failed lighter trisalt at 265 °F.

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.8 - Modified 13Cr –13Cr(3Mo)-125

| Alloy 13Cr(3Mo)-125 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------|-----------------------|--------------|
| Brine Composition | None | O₂ | CO₂ | Notes |
| 14.1 ppg CaCl ₂ (medium Cl ⁻) | | | 265 ₈₃ | |
| 15.1 ppg CaBr ₂ /CaCl ₂ | 350 ₇₃ | | | |
| 13.0 ppg CaBr ₂ | | | 350 ₇₄ | |
| 12.9 ppg CaBr ₂ /CaCl ₂ (low Cl ⁻) | | | 350 ₈₁ | |
| 13.7 ppg CaBr ₂ Brine (diluted from the 14.2 ppg CaBr ₂) | | | 265 ₇₈ | |
| 14.7 ppg CaBr ₂ | | | 265 ₇₉ | |
| 15.5 ppg ZnBr ₂ /CaBr ₂ | | 350 ₇₆ | | |
| 17.0 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | | | 350 ₇₅ | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.9 – Duplex SS—22Cr-125

| Alloy 22Cr - 125 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | | | | |
| 11.6 ppg CaCl ₂ | (F) | | 265 ₈₄ | |
| 14.2 ppg CaBr ₂ | | 350 ₅ | | 350 ₆₄ |
| 14.2 ppg CaCl ₂ /CaBr ₂ (medium Cl ⁻) | | | 350 ₃₉ | |
| 14.2 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | | 225 ₈₅ | 350 ₃₈ | |
| 15.6 ppg ZnBr ₂ /CaBr ₂ | | | 350 ₃₄ | 350 ₁₇ |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | | 350 ₄₄ | | 350 ₇ |
| 18.0 ppg ZnBr ₂ /CaBr ₂ | | | | 350 ^A ₁₄ |
| A Tested with SCN ⁻ which can potentially decompose and yield H ₂ S at high temperatures. No acid gases were added. (Test labelled 14). | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.10 – Duplex SS–25Cr(W)-125

| Alloy 25Cr(W)-125 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------------------|--------------------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | | | | |
| 11.6 ppg CaCl ₂ | | (L)/(F) ^A | 265 ₈₄ | 338 (L) ^B |
| 12.4 ppg NaBr | 350 ^C ₁₆ | | | |
| 14.2 ppg CaBr ₂ | | 350 ^D _{5, 6} | 350 ₃₉ | 350 _{58, 64} |
| 14.2 ppg CaCl ₂ /CaBr ₂ (medium Cl ⁻) | | 225 ₈₅ | | |
| 14.1 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻) | | 225 ₈₅ | 350 ₃₈ | |
| 15.6 ppg ZnBr ₂ /CaBr ₂ | | | 350 ^F ₃₄ | 350 ₁₇ |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | | 350 ^G ₄₄ | | 350 ₇ |
| 18.0 ppg ZnBr ₂ /CaBr ₂ | | | | 350 ^F ₁₄ |
| <p>A Erskine field failure of lower 25Cr grade (130ksi) with O₂ contamination, SPE paper 67779^[3].</p> <p>B Based on Piccolo tests limited to 0.3psi H₂S, SPE paper 97593 ^[13]</p> <p>C No SCC with SCN⁻ infers that there is no cracking without it. SCN⁻ can potentially decompose to yield H₂S, but no post-test H₂S detection was conducted for Test #16.</p> <p>D Conflicts with literature. Tests #5 & #6 with air had no cracking at 350 °F.</p> <p>E Based on literature (SPE paper 84515) and Silverman ^[11], replicated in Tests #58 & #64, H₂S is limited to 0.3 psi</p> <p>F Tested with SCN⁻ which can potentially decompose and yield H₂S at high temperatures. No acid gases were added. (Test labelled 14).</p> | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.11 – High Ni—Alloy 925

| Alloy 925 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | H₂S (and CO₂) |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 14.2 ppg CaBr ₂ | (L) ^A | | | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | 425 ₄₇ | | |
| A Not tested, inferred from literature. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.12 – High Ni—Alloys 2535 and 2550

| Alloy 945 | SCC observed at noted temperature with gas contamination | | | |
|--|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 14.2 ppg CaBr ₂ | | | | 350^A₈₂ |
| A Test #82: Alloys passed loaded at YS both room temperature and 350 °F. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.13 - High Ni—Alloy 718

| Alloy 718 | SCC observed at noted temperature with gas contamination | | | |
|--|---|----------------------|--------------------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 14.2 ppg CaBr ₂ | (L) | | | 350 ₈₂ |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | | | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ + SCN ⁻ | | | 425 ^A ₂₆ | |
| A Passed Test #26 with SCN ⁻ at 425 °F; gas analysis had 400 ppm H ₂ S & 3 psi CO ₂ from SCN ⁻ decomposition. Test #36 had same conditions as #26 but no gas analysis. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.14 – High Ni—Alloy 825

| Alloy 825 | SCC observed at noted temperature with gas contamination | | | |
|--|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 12.4 ppg NaBr | (L) ^A | | | |
| 15.5ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | 425 ₄₇ | | |
| 15.5ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ + SCN ⁻ | | | | 425 _{26, 36} |
| B Based on Company B tests. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table 15 – High Ni—Alloy 725

| Alloy 725 Bar Stock | SCC observed at noted temperature with gas contamination | | | |
|---|--|----------------|-----------------|--------------------------------------|
| Brine Composition | None | O ₂ | CO ₂ | CO ₂ and H ₂ S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 12.4 ppg NaBr | (L) ^A | | | |
| 14.2 ppg CaBr ₂ | (L) | | | |
| 15.6 ppg ZnBr ₂ /CaBr ₂ | | | | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | - | | |
| A Company B test results. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.16 – High Ni—Alloy 2550

| Alloy 2550 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 12.4 ppg NaBr | (L) | | | |
| 14.2 ppg CaBr ₂ | | | | 350 ₅₈ |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.17 – High Ni—Alloy G50

| Alloy G50 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 12.4 ppg NaBr | (L) ^A | | | |
| 14.2 ppg CaBr ₂ | (L) | | | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | 425 ₄₇ | | 425 ^B ₂₆ |
| A Company B test results. B Test #26 had SCN ⁻ & N ₂ blanket, but no added H ₂ S. | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.18 – High Ni—Alloy 2535

| Alloy 2535-125 | SCC observed at noted temperature with gas contamination | | | |
|--|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 11.8 ppg CaCl ₂ /CaBr ₂ | | | | 260 ^A |
| 12.4 ppg NaBr | (L) | | | |
| 14.1 ppg CaCl ₂ /CaBr ₂ | | | | 260 ^A |
| 14.2 ppg CaBr ₂ | | | | 350 ^B _{58,64} |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ^C ₁₈ | 425 ₄₇ | | 425 ^D |
| <p>A Based on unpublished company test failures of 28Cr at 260 °F with 2.4 psi H₂S following API protocol. No known field failures.</p> <p>B Replicated in Tests #58 & #64. Similar to result of cracking of this alloy in trisalt brine with SCN⁻, Test #26. Test #82: Failed with loading at YS at room temperature but passed loaded at YS at 350 °F. Failures with H₂S and CO₂ even with derated samples.</p> <p>C No SCC in Test #18. Cracking occurred in Test #26 at 425 °F with SCN⁻. No SCN⁻ should be used.</p> <p>D Based on Test #26 with SCN⁻ added, conflicts with Test #36. In Test #36, testing with SCN⁻ at 425 °F passed without H₂S or CO₂.</p> | | | | |

This document is not an API Standard; it is under consideration within an API technical committee but has not received all approvals required to become an API Standard. It shall not be reproduced or circulated or quoted, in whole or in part, outside of API committee activities except with the approval of the Chairman of the committee having jurisdiction and staff of the API Standards Dept. Copyright API. All rights reserved.

Table C.19 – High Ni—Alloy C-276

| Alloy C276 | SCC observed at noted temperature with gas contamination | | | |
|---|---|----------------------|-----------------------|--|
| Brine Composition | None | O₂ | CO₂ | CO₂ and H₂S |
| 9.7 ppg KCl | (F) | | | |
| 10.0 ppg NaCl | (F) | | | |
| 12.4 ppg NaBr | (L) ^A | | | |
| 15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂ | 425 ₁₈ | 425 ₄₇ | | 425 ^B ₂₆ |
| A Company B test results-internal company data. | | | | |
| B Inferred from Test #26 with SCN ⁻ where 400 ppm H ₂ S are detected post-test. | | | | |

The following shall be added to the Bibliography:

[24] to bibliography: Scoppio, L, Barteri, M, Cheldi, T, Ke, M, and Massi, S. *Corrosion behavior of CRA's in high density packer fluids at high temperature*. United States: N. p., 1999.