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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)

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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 (CO₂+H₂S). 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 (CO₂+H₂S). 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.**

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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 (CO₂+H₂S) 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 °F),
- Brine contaminants oxygen and CO₂
- Presence of H₂S, either directly or via thiocyanate decomposition
- C-ring stress levels

Test concentration of the acid gases, H₂S and CO₂, were intentionally varied depending on alloy content. Most testing with martensitic stainless steels had CO₂ levels of 100 psi. Duplex stainless steels and higher alloys had levels of 500 psi CO₂. H₂S levels was typically 0.15 psi, but when H₂S was generated in tests due to decomposition of thiocyanate (SCN), H₂S 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.

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C.2 Instructions for Use of the Tables

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

- a) Individual CRAs are shown on each table.
- b) Numerical values in the cells denote a temperature limit where passing or failing results were obtained.
- c) The legend for the tables is shown below. Footnotes are provided for further explanation where available.
- d) 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

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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

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Table C.2 - Standard 13Cr 80 & 85

Alloy 13Cr-80 & 85 No testing was done with this alloy with CO ₂ or H ₂ S added.	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)	(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 _A ₃
18.0 ppg ZnBr ₂ /CaBr ₂	265 ₁₃	225 ₁		265 _A ₉
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).				

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

Alloy 13Cr(2Mo)-95 (modified chemistry)	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	350 ₃₇	225 ₄₆ / 265 ^A	(L) ^A	
12.4 ppg NaBr	(L) ^B	265 ₃₀	265 ^C ₄₅	225 ₈₇
14.2 ppg CaBr ₂	350 _{33a}	265 ^D _A		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 programm				
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.				

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

Alloy 13Cr(0.6Mo)-110	SCC observed at noted temperature with acid gas contamination			
	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 ₃₇ ^A	225 ₄₆ / 265 ₂₀ ^B		
12.4 ppg NaBr	265 _{65, 71}	265 _{30,48} ^C	350 ₇₂	
14.2 ppg CaBr ₂	350 _{33a}	350 ₆₃	265 ₇₀ ^D	
14.1 CaCl ₂ /CaBr ₂ (medium Cl ⁻)	350 ₂₂		265 _{23, 83}	
14.2 ppg CaCl ₂ /CaBr ₂ (high Cl ⁻)	350 ₂₅			
15.5 ppg ZnBr ₂ /CaBr ₂			265 _{35,43}	
15.5 ppg 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>				

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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		

A Test #31 failures at 265 °F. Pass at 350 °F, Test #37 with new deaeration procedure.
 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.
 C Based on Piccollo data ^[13] & Henke data ^[14].
 D Failed in Tests #30 and #28 before deaeration procedure modified.
 E Test #56 failed at 265 °F and 0.3 psi H₂S. Test #87 pass at 225 °F and 0.15 psi H₂S.
 F Conflicting results in Tests #50a, #51, & #52. Test #62 confirms SCC at 350 °F.
 G 1Mo-110 pass but 2Mo-110 failed in Tests #1 & #4.

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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			
	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>				

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

Alloy 13Cr(2Mo)-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	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 ^{B7} 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 ^K 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.

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

Alloy 13Cr(3Mo)-125	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	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	

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Table C.9 – Duplex SS–22Cr-125

Alloy 22Cr - 125	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	CO ₂ and H ₂ S
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).				

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Table C.10 – Duplex SS–25Cr(W)-125

Alloy 25Cr(W)-125	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	CO ₂ and H ₂ S
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

A Erskine field failure of lower 25Cr grade (130ksi) with O₂ contamination, SPE paper 67779^[3].

B Based on Piccolo tests limited to 0.3psi H₂S, SPE paper 97593 ^[13]

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.

D Conflicts with literature. Tests #5 & #6 with air had no cracking at 350 °F.

E Based on literature (SPE paper 84515) and Silverman ^[11], replicated in Tests #58 & #64, H₂S is limited to 0.3 psi

F Tested with SCN⁻ which can potentially decompose and yield H₂S at high temperatures. No acid gases were added. (Test labelled 14).

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Table C.11 – High Ni–Alloy 925

Alloy 925	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	H ₂ S (and CO ₂)
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.

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

Alloy 945	SCC observed at noted temperature with gas contamination			
Brine Composition	None	O ₂	CO ₂	CO ₂ and H ₂ S
14.2 ppg CaBr ₂				350 ^A ₈₂
A Test #82: Alloys passed loaded at YS both room temperature and 350 °F.				

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Table C.13 - High Ni—Alloy 718

Alloy 718	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	CO ₂ and H ₂ S
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.				

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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.				

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Table 15 – High Ni—Alloy 725

Alloy 725 Bar Stock	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	CO ₂ and H ₂ S
Brine Composition				
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.				

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Table C.16 – High Ni–Alloy 2550

Alloy 2550	SCC observed at noted temperature with gas contamination			
	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)			
14.2 ppg CaBr ₂				350 ₅₈
15.5 ppg trisalt ZnBr ₂ /CaBr ₂ /CaCl ₂	425 ₁₈			

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Table C.17 – High Ni–Alloy G50

Alloy G50	SCC observed at noted temperature with gas contamination			
	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)			
15.5 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.				

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Table C.18 – High Ni–Alloy 2535

Alloy 2535-125	SCC observed at noted temperature with gas contamination			
	None	O ₂	CO ₂	CO ₂ and H ₂ S
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

A Based on unpublished company test failures of 28Cr at 260 °F with 2.4 psi H₂S following API protocol. No known field failures.

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.

C No SCC in Test #18. Cracking occurred in Test #26 at 425 °F with SCN⁻. No SCN⁻ should be used.

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.

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Table C.19 – High Ni–Alloy C-276

Alloy C276	SCC observed at noted temperature with gas contamination			
	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			
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.