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Corrosion studies on GeoBrom® HG520

X GeoBrom® HG520

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Contents

Background information

A 90-day vapor space corrosion rate study was conducted using GeoBrom® HG520 calcium bromide solution and six selected metals at 20° and 50 °C. ASTM Method "Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens" G1–03 (reapproved 2011) was used to prepare, clean, and evaluate tests specimens.

The following six metals were evaluated:

- **C-1018** mild carbon steel coupon
- **304-W** 304SS welded coupon
- **316-LW** 316SS, low carbon, welded coupon
- **2205** Duplex 2205 coupon
- **304-LW** 304SS, low carbon, welded coupon
- **316** 316SS coupon

Objectives of the study

- Suspend coupons at half above and half below surface in individual bottles.
- Establish corrosion rates at 20 °C and 50 °C for each metal with only half of coupon subsurface.
- Visually document coupon condition before and after 90-day exposure.
- Inspect coupons at liquid / vapor interface for any indication of higher corrosion rates.
- Analyze solution for metal content before and after 90-day exposure to evaluate metals in test solution.

There was little to no corrosion observed on these coupons in the vapor space. Visually, all corrosion occurred in the liquid phase where half of the coupons were suspended. There was no increase in corrosion rate observed at vapor / liquid interface on any of the specimens. Based on this 90 day study, all specimens were less than 0.70 mpy corrosion rate with half the coupon below surface. Mild carbon steel (C-1018) gave the highest corrosion rate at 0.14 mpy at 20 °C and 0.65 mpy at 50 °C. All remaining specimens were under 0.10 mpy. ICP analysis of GeoBrom® HG520 samples reflect elevated iron and chromium levels at end of the 90-day period. The maximum allowable corrosion rate for each specimen with GeoBrom® HG520 depends on the application.

Description of test procedure

Metal test coupons with dimensions of ~ 2.0" x 0.75" x 0.125" were supplied by an outside vendor. The vendor prepared the coupons by abrading surfaces and stamping metal type and marking specimens with a unique identification number. Prior to using, coupons were cleaned using reagent grade aqueous HCl and a bristle brush followed by a thorough deionized water rinse, degreased using acetone, dried using hot air, then allowed to cool in desiccators. The clean, dry specimens were weighed and measured. Using forceps, a four place OHAUS Galaxy Model G160D analytical balance was used to attain initial weights for all coupons. Dimensions were established using a Starrett® Micrometer part # 436RL-1, EDP 51568 and a Starrett® Dial Caliper Part # 120Z, EDP 55951. Three measurements were taken on all dimensions and averaged for the length, width, and thickness. Pictures were taken to record coupon condition prior to vapor exposure tests.

Test coupons were split into two groups, containing specimens of each metal type, and placed into individual 4-oz bottles with Teflon® liners. Coupons were suspended 3/8 inches above the liquid surface using Teflon® string. One group was placed in a Yamato Model DVS600 drying oven to hold samples at 50 °C and the second group placed in a controlled environment room held at 20 °C. There was no agitation or aeration of the test specimens while in the glass bottles.

Duration of the test was 90 days and 1 hour or 2,161 hours. Prior to cleaning, pictures were taken to record coupon condition after the 90 day immersion test. After cleaning, pictures were taken again. None of the specimens were heavily corroded, so post immersion cleaning was simple and consisted of the following:

- Immersion in deionized water to remove test solution
- Immersion and brushed in aq. HCl (for mild carbon steel), and nitric acid (for the stainless steels)
- Thoroughly rinsed with deionized water, then immediately dried. The C1018 coupon required light scrubbing using a brush in deionized water. Table A1.1 in ASTM G1-03 was used as a guide to select cleaning procedure for removal of corrosion products. After drying test specimens with hot air and then allowing them to cool in desiccators, all specimens were re-weighed and the final weights recorded

Spreadsheets were developed to capture data and to make calculations per ASTM method. Calculated metal densities and published metal densities were used in corrosion rate calculations for comparison.

The average corrosion rate calculation per ASTM G1-03 is:

Corrosion rate = (K x W) / (A x T x D)

- K = a constant "(K) constant listed in ASTM G1-03, Section 8 for desired units"
- T = time of exposure in hours
- A = area in cm^2
- W = mass loss in grams
- D = density in gm/cm^3

Results and discussion

Tables 1 and 2 provide data on test specimens at 20°C and at 50°C, respectively. Corrosion rates on all specimens were under 0.70 mpy rate. Mild carbon steel C-1018 gave the highest corrosion rate at 0.14 mpy at 20°C and 0.65 mpy at 50°C. Observations were recorded on the number of pits for each coupon specimen within these tables. Visually, there was no increase in corrosion at the liquid / vapor interface on any of the specimens tested. Corrosion rates for each specimen were charted to reflect trends over the two temperatures 20°C and 50°C and data presented within Figure 1. Table 3 presents the chemical composition of each test specimen.

GeoBrom® HG520 test solutions were submitted for inductively coupled plasma (ICP) analysis before and after the 90-day test. Tables 4 to 9 reflect ICP data on metal concentrations in test fluids at start, end, and the difference between start and end.

To visually document condition of test specimens, pictures were taken before immersion tests, after, and after cleaning (see figures 2-15). Pitting occurred on stainless coupons where the rusty colored stains formed, which became noticeable after cleaning.

C-1018 showed signs of a slight surface corrosion in this test and a low corrosion rate. There are a number of different corrosion standards depending on the application. Therefore, whether C-1018 is suitable for use with $CaBr_2$ depends on the application. These data are relevant only to the 52% $CaBr_2$ solution. Dilute solutions or other uses of 52% solution may exhibit different corrosive behaviors.

Conclusion

C-1018 showed signs of corrosion in this test. There are a number of different corrosion standards depending on the application. Therefore, whether C-1018 is suitable for use with $CaBr_2$ depends on the application. These data are relevant only to the 52% $CaBr_2$ solution. Dilute solutions or other uses of 52% solution may exhibit different corrosive behaviors.

Table 1: Coupons at half above and half below subsurface at 20 °C

Corrosion coupon testing with GeoBrom® HG520 calcium bromide solution – half above surface and half below surface at 20 °C
August 14, 2013 to November 12, 2013

Total exposure time: 90 days + 1 hour
Using ASTM Designation: G1–03 (reapproved 2011) standard practice for preparing, cleaning, and evaluating corrosion test specimens

Coupon type	C-1018	304-W	316-LW	Duplex 2205	304-LW	316
Identification mark	A1688	A0026	A8155	Quad dot	A0015	A1166
Weight (grams)	22.3819	23.0081	20.1772	21.9524	22.7938	20.0121
Length (inches)	2.018	2.002	2.001	2.016	2.006	2.000
Width (inches)	0.771	0.759	0.749	0.764	0.757	0.750
Thickness (inches)	0.124	0.131	0.116	0.122	0.130	0.113
Hole dia. (inches)	0.377	0.376	0.376	0.375	0.376	0.375
Calculated density (gm/cc)	7.648	7.592	7.684	7.684	7.580	7.753
Published density (gm/cc) ASTM	7.86	7.94	7.94	7.805	7.94	7.98
Calculated surface area (sq. cm)	24.031	23.850	22.879	23.743	23.806	22.818
Start date (MDY)	8/14/2013	8/14/2013	8/14/2013	8/14/2013	8/14/2013	8/14/2013
Start time (hours)	9:30	9:30	9:30	9:30	9:30	9:30
End date (MDY)	11/12/2013	11/12/2013	11/12/2013	11/12/2013	11/12/2013	11/12/2013
End time (hours)	10:30	10:30	10:30	10:30	10:30	10:30
Temperature (°C)	20	20	20	20	20	20
Exposure time (hours)	2161	2161	2161	2161	2161	2161
Ending weight (grams)	22.3656	23.0027	20.1746	21.9507	22.7897	20.0097
Loss in weight (grams)	0.0163	0.0054	0.0026	0.0017	0.0041	0.0024
Rate of corrosion (mpy) using calculated density	0.1416	0.0476	0.0236	0.0149	0.0363	0.0217
Rate of corrosion (mpy) using published density	0.1378	0.0455	0.0228	0.0146	0.0346	0.0210
Visual observations for pitting observed only on subsurface area	General surface corrosion only	1 very sm. pit	1 med. to large pit	1 med. pit	4 very sm. pits	1 med. pit

Table 2: coupons at half above and half below subsurface at 50 °C

Corrosion coupon testing with GeoBrom® HG520 calcium bromide solution – half above surface and half below surface at 50 °C

August 14, 2013 to November 12, 2013

Total exposure time: 90-days + 1 hour

Using ASTM Designation: G1–03 (reapproved 2011) standard practice for preparing, cleaning, and evaluating corrosion test specimens

Coupon type	C-1018	304-W	316-LW	Duplex 2205	304-LW	316
Identification mark	A1687	A0025	A8154	Triple dot	A0014	A1194
Weight (grams)	22.2425	23.0793	20.0795	21.5165	23.331	19.4456
Length (inches)	2.017	1.999	2.001	2.015	2.012	1.996
Width (inches)	0.772	0.759	0.748	0.767	0.760	0.750
Thickness (inches)	0.123	0.129	0.115	0.120	0.132	0.111
Hole dia. (inches)	0.376	0.375	0.375	0.375	0.375	0.378
Calculated density (gm/cc)	7.633	7.781	7.673	7.621	7.585	7.751
Published density (gm/cc) ASTM	7.86	7.94	7.94	7.805	7.94	7.98
Calculated surface area (sq. cm)	24.017	23.709	22.853	23.746	24.040	22.639
Start date (MDY)	8/14/2013	8/14/2013	8/14/2013	8/14/2013	8/14/2013	8/14/2013
Start time (hours)	9:30	9:30	9:30	9:30	9:30	9:30
End date (MDY)	11/12/2013	11/12/2013	11/12/2013	11/12/2013	11/12/2013	11/12/2013
End time (hours)	10:30	10:30	10:30	10:30	10:30	10:30
Temperature (°C)	50	50	50	50	50	50
Exposure time (hours)	2161	2161	2161	2161	2161	2161
Ending weight (grams)	22.1674	23.0678	20.0698	21.5101	23.3219	19.4408
Loss in weight (grams)	0.0751	0.0115	0.0097	0.0064	0.0091	0.0048
Rate of corrosion (mpy) using calculated density	0.6540	0.0995	0.0883	0.0565	0.0797	0.0437
Rate of corrosion (mpy) using published density	0.6351	0.0975	0.0853	0.0551	0.0761	0.0424
Visual observations for pitting observed only on subsurface area	General surface corrosion with many very sm. pits	5 sm. pits	17 med. size pits	1 med. pit	1 large pit	10 sm. pits

Table 3: Composition of specimens

Chemical composition of specimens tested during 90-day total immersion study

AISI = American Iron and Steel Institute
Data in % by weight

Metal type	AISI 1018	AISI 304	AISI 304-L	AISI 316	AISI 316-L	Duplex 2205
Carbon	0.15 - 0.20	0.08 max	0.03 max	0.08 max	0.03 max	<0.03
Manganese	0.60 - 0.90	2 max	2 max	2 max	3 max	< 2
Phosphorus	0.040 max	0.045 max	0.045 max	0.045 max	0.045 max	< 0.03
Sulfur	0.050 max	0.03 max	0.03 max	0.03 max	0.03 max	< 0.02
Silicon	0.15 to 0.30	0.75 max	0.75 max	1 max	2 max	< 1
Chromium	N/A	18 - 20	18-20	16 - 18	17 - 18	21 - 23
Nickel	N/A	8 to 12	8 to 12	10 to 14	11 to 14	4.5 - 6.5
Molybdenum	N/A	N/A	N/A	2 to 3	2 to 3	2.5 - 3.5
Nitrogen	N/A	0.10 max	0.10 max	N/A	N/A	0.8 - 2.0
Iron	balance	balance	balance	balance	balance	balance

Figure 1: Corrosion rate trend chart with Y axis at 0 to 1.4 mpy scale

Corrosion coupons at 20°C and 50°C subsurface in GeoBrom® HG520 calcium bromide solution

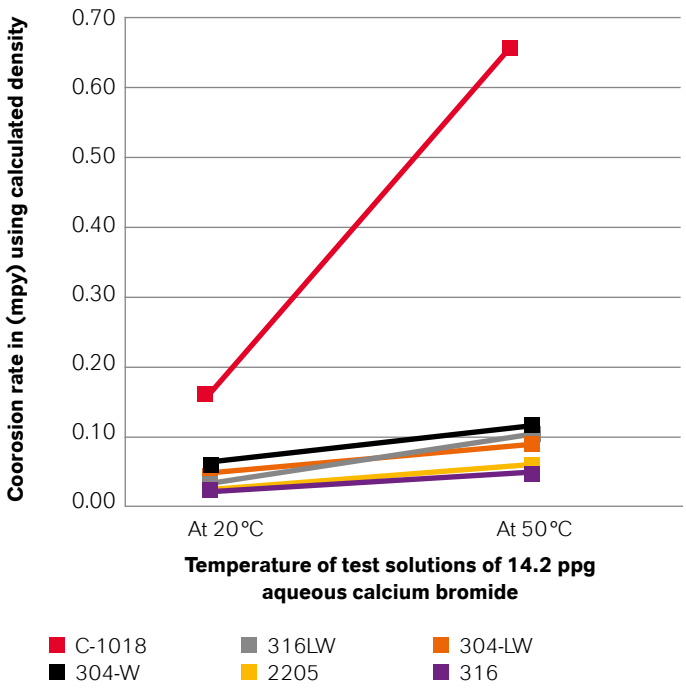

Figure 2: Test coupons before 90-day half above and half below surface exposure

C 1018	304W	316 LW
		
Duplex 2205	**304 LW**	**316**
		

Figure 3: Test coupons before GeoBrom HG520 charged and before 90-day exposure

Figure 4: Test coupons before 90-day exposure at above and half below surface in GeoBrom® HG520

Figure 5: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 20 °C

Figure 6: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 20 °C

C 1018	304W	316LW	Duplex 2205	304LW	316
					

Figure 7: Test coupons before cleaning after 90-day exposure at 20 °C in GeoBrom® HG 520

C 1018	304W	316LW
		

Figure 8: Test coupons before cleaning after 90-day exposure at 20 °C in GeoBrom® HG 520

Duplex 2205	304LW	316
		

Figure 9: C 1018 coupon at half subsurface before cleaning after 90-day exposure at 20 °C

C1018


Figure 10: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 20 °C after cleaning

C 1018	304W	316LW	Duplex 2205	304LW	316
					

Figure 5: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 20 °C

C 1018	304W	316LW	Duplex 2205	304LW	316

Figure 12: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 50 °C before cleaning

C 1018	304W	316LW	Duplex 2205	304LW	316
					

Figure 13: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 50 °C before cleaning

C 1018	304W	316LW
		

Figure 14: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 50 °C before cleaning

Duplex 2205	304LW	316
		

Figure 15: Test coupons half above and half below GeoBrom® HG520 after 90-day exposure at 50 °C after cleaning

C 1018	304W	316LW	Duplex 2205	304LW	316
					

Table 4

ICP analysis of GeoBrom® HG520 before and after 90-day partial immersion corrosion study at 20°C: C1018 and 304W

All results in mg/L

Metal ID		Metals in GeoBrom® HG520 at start	C1018 After	C1018 Difference	304W After	304W Difference
Ag	(Silver)	1.66	5.59	3.93	5.60	3.94
Al	(Aluminum)	10.12	6.80	-3.32	7.01	-3.11
As	(Arsenic)	4.36	4.74	0.38	4.10	-0.26
B	(Boron)	2.11	2.51	0.40	2.42	0.31
Ba	(Barium)	3.40	7.26	3.86	7.38	3.99
Be	(Beryllium)	0.13	1.10	0.97	1.10	1.09
Bi	(Bismuth)	10.41	6.43	-3.98	9.08	-1.33
Cd	(Cadmium)	1.33	2.46	1.13	2.74	1.41
Ce	(Cerium)	4.01	NA	NA	NA	NA
Co	(Cobalt)	2.09	3.23	1.14	3.04	0.95
Cr(II)	(Chromium)	2.36	5.06	2.70	14.46	12.1
Cu	(Copper)	0.54	1.07	0.53	1.50	0.96
Fe(II)	(Iron)	1.66	184.2	182.5	45.04	43.38
K	(Potassium)	NA	NA	NA	NA	NA
La	(Lanthanum)	9.46	NA	NA	NA	NA
Li	(Lithium)	2.73	4.25	1.52	4.27	1.54
Mn	(Manganese)	1.58	5.64	4.03	5.54	7.12
Mo	(Molybdenum)	4.04	8.76	4.72	5.73	1.69
Na	(Sodium)	97.65	80.46	-17.19	80.52	-17.13
Ni	(Nickel)	2.14	2.57	0.43	8.04	5.9
Pb	(Lead)	12.74	10.92	-1.82	1.63	-11.11
Rb	(Rubidium)	0.34	2.93	2.59	2.02	1.68
Sb	(Antimony)	1.28	-1.16	-2.44	2.18	0.90
Se	(Selenium)	6.26	5.33	-0.93	3.26	-3.00
Sn	(Tin)	7.05	4.25	-2.8	7.41	0.36
Sr	(Strontium)	73.41	115.5	42.09	123.4	49.99
Ti	(Titanium)	0.89	4.03	3.14	4.03	3.14
Tl	(Thallium)	17.17	26.35	9.18	22.76	5.59
U	(Uranium)	1.75	5.63	3.88	5.06	3.31
V	(Vanadium)	13.85	19.85	6.00	20.29	6.44
Zn(I)	(Zinc)	16.07	6.18	-9.89	6.44	-9.63

Note: Metals highlighted in the table are major components in the coupons evaluated. Significant increases in the concentration of these metals would be an indication of corrosion of the coupons

Table 5

ICP analysis of GeoBrom® HG520 before and after 90-day partial immersion corrosion study at 20 °C: 316LW and Duplex 2205

All results in mg/L

Metal ID		Metals in GeoBrom® HG520 at start	316LW After	316LW Difference	Duplex 2205 After	Duplex 2205 Difference
Ag	(Silver)	1.66	5.51	3.85	5.50	3.84
Al	(Aluminum)	10.12	6.07	-4.05	5.57	-4.55
As	(Arsenic)	4.36	1.75	-2.61	0.82	-3.54
B	(Boron)	2.11	2.41	0.30	2.57	0.46
Ba	(Barium)	3.40	7.47	4.07	7.33	3.93
Be	(Beryllium)	0.13	1.10	0.97	1.10	0.97
Bi	(Bismuth)	10.41	10.00	-0.41	7.01	-3.40
Cd	(Cadmium)	1.33	3.06	1.73	2.69	1.36
Ce	(Cerium)	4.01	NA	NA	NA	NA
Co	(Cobalt)	2.09	3.00	0.91	3.39	1.30
Cr(II)	(Chromium)	2.36	12.26	9.90	9.07	6.71
Cu	(Copper)	0.54	1.26	0.72	1.14	0.60
Fe(II)	(Iron)	1.66	33.60	31.94	14.76	13.10
K	(Potassium)	NA	NA	NA	NA	NA
La	(Lanthanum)	9.46	NA	NA	NA	NA
Li	(Lithium)	2.73	4.24	1.51	4.80	2.07
Mn	(Manganese)	1.58	5.18	3.60	4.41	2.83
Mo	(Molybdenum)	4.04	4.17	0.13	5.86	1.82
Na	(Sodium)	97.65	83.75	-13.90	98.63	0.98
Ni	(Nickel)	2.14	5.82	3.68	5.05	2.91
Pb	(Lead)	12.74	7.07	-5.67	6.08	-6.66
Rb	(Rubidium)	0.34	2.32	1.98	2.04	1.70
Sb	(Antimony)	1.28	0.79	-0.49	2.22	0.94
Se	(Selenium)	6.26	5.65	-0.61	6.54	0.28
Sn	(Tin)	7.05	6.93	-0.12	3.38	-3.67
Sr	(Strontium)	73.41	119.4	45.99	107.5	34.09
Ti	(Titanium)	0.89	4.01	3.12	4.02	3.13
Tl	(Thallium)	17.17	27.33	10.16	24.91	7.74
U	(Uranium)	1.75	7.30	5.55	5.44	3.69
V	(Vanadium)	13.85	21.73	7.88	20.42	6.57
Zn(I)	(Zinc)	16.07	6.82	-9.25	6.23	-9.84

Note: Metals highlighted in the table are major components in the coupons evaluated. Significant increases in the concentration of these metals would be an indication of corrosion of the coupons

Table 6

ICP analysis of GeoBrom® HG520 before and after 90-day partial immersion corrosion study at 20°C: 304LW and 316

All results in mg/L

Metal ID		Metals in GeoBrom® HG520 at start	304LW After	304LW Difference	316 After	316 Difference
Ag	(Silver)	1.66	5.51	3.85	5.59	3.93
Al	(Aluminum)	10.12	6.07	-4.05	6.92	-3.20
As	(Arsenic)	4.36	1.75	-2.61	0.60	-3.76
B	(Boron)	2.11	2.41	0.30	2.61	0.50
Ba	(Barium)	3.40	7.47	4.07	7.57	4.17
Be	(Beryllium)	0.13	1.10	0.97	1.10	0.97
Bi	(Bismuth)	10.41	10.00	-.41	9.97	-0.44
Cd	(Cadmium)	1.33	3.06	1.73	2.25	0.92
Ce	(Cerium)	4.01	NA	NA	NA	NA
Co	(Cobalt)	2.09	3.00	0.91	2.77	0.68
Cr(II)	(Chromium)	2.36	12.26	9.9	10.21	7.85
Cu	(Copper)	0.54	1.26	0.72	1.18	0.64
Fe(II)	(Iron)	1.66	33.60	31.94	24.23	22.57
K	(Potassium)	NA	NA	NA	NA	NA
La	(Lanthanum)	9.46	NA	NA	NA	NA
Li	(Lithium)	2.73	4.25	1.52	4.21	1.48
Mn	(Manganese)	1.58	5.18	3.6	4.78	3.20
Mo	(Molybdenum)	4.04	4.17	0.13	6.06	2.02
Na	(Sodium)	97.65	83.74	-13.91	92.47	-5.18
Ni	(Nickel)	2.14	5.82	3.68	5.49	3.35
Pb	(Lead)	12.74	7.07	-5.67	8.22	-4.52
Rb	(Rubidium)	0.34	2.32	1.98	2.35	2.01
Sb	(Antimony)	1.28	0.79	-0.49	1.45	0.17
Se	(Selenium)	6.26	5.65	-0.61	6.72	0.46
Sn	(Tin)	7.05	6.93	-0.12	4.38	-2.67
Sr	(Strontium)	73.41	119.4	46.0	122.9	49.5
Ti	(Titanium)	0.89	4.01	3.12	4.00	3.11
Tl	(Thallium)	17.17	27.33	10.16	25.85	8.68
U	(Uranium)	1.75	7.30	5.55	4.20	2.45
V	(Vanadium)	13.85	21.73	7.88	22.34	8.49
Zn(I)	(Zinc)	16.07	6.82	-9.25	6.87	-9.20

Note: Metals highlighted in the table are major components in the coupons evaluated. Significant increases in the concentration of these metals would be an indication of corrosion of the coupons

Table 7

ICP analysis of GeoBrom® HG520 before and after 90-day partial immersion corrosion study at 50 °C: C1018 and 304W

All results in mg/L

Metal ID		Metals in GeoBrom® HG520 at start	C1018 After	C1018 Difference	304W After	304W Difference
Ag	(Silver)	1.66	5.49	3.83	5.53	3.87
Al	(Aluminum)	10.12	7.10	-3.02	6.91	-3.21
As	(Arsenic)	4.36	2.29	-2.07	7.43	3.07
B	(Boron)	2.11	2.26	0.15	2.36	0.25
Ba	(Barium)	3.40	7.32	3.92	7.44	4.04
Be	(Beryllium)	0.13	1.11	0.98	1.10	0.97
Bi	(Bismuth)	10.41	9.51	-0.90	6.12	-4.29
Cd	(Cadmium)	1.33	2.72	1.39	2.50	1.17
Ce	(Cerium)	4.01	NA	NA	NA	NA
Co	(Cobalt)	2.09	3.42	1.33	3.00	0.91
Cr(II)	(Chromium)	2.36	5.45	3.09	11.26	8.90
Cu	(Copper)	0.54	1.24	0.70	1.66	1.12
Fe(II)	(Iron)	1.66	461.8	460.1	53.26	51.6
K	(Potassium)	NA	NA	NA	NA	NA
La	(Lanthanum)	9.46	NA	NA	NA	NA
Li	(Lithium)	2.73	5.95	3.22	4.27	1.54
Mn	(Manganese)	1.58	10.54	8.96	6.81	5.23
Mo	(Molybdenum)	4.04	5.09	1.05	7.68	3.64
Na	(Sodium)	97.65	117.0	19.35	87.44	-10.21
Ni	(Nickel)	2.14	3.21	1.07	8.78	6.64
Pb	(Lead)	12.74	6.60	-6.14	13.05	0.31
Rb	(Rubidium)	0.34	2.17	1.83	1.55	1.21
Sb	(Antimony)	1.28	1.10	-0.18	2.62	1.34
Se	(Selenium)	6.26	2.21	-4.05	2.15	-4.11
Sn	(Tin)	7.05	-1.69	-9.01	8.61	1.56
Sr	(Strontium)	73.41	115.01	41.6	123.0	49.6
Ti	(Titanium)	0.89	4.04	3.15	4.01	3.12
Tl	(Thallium)	17.17	23.26	6.09	22.22	5.05
U	(Uranium)	1.75	3.96	2.21	5.37	3.62
V	(Vanadium)	13.85	20.84	6.99	20.69	6.84
Zn(I)	(Zinc)	16.07	6.61	-9.46	6.47	-9.60

Note: Metals highlighted in the table are major components in the coupons evaluated. Significant increases in the concentration of these metals would be an indication of corrosion of the coupons

Table 8

ICP analysis of GeoBrom® HG520 before and after 90-day partial immersion corrosion study at 50 °C: 316LW and Duplex 2205

All results in mg/L

Metal ID		Metals in GeoBrom® HG520 at start	316LW After	316LW Difference	Duplex 2205 After	Duplex 2205 Difference
Ag	(Silver)	1.66	5.52	3.86	5.41	3.75
Al	(Aluminum)	10.12	6.37	-3.75	5.90	-4.22
As	(Arsenic)	4.36	0.88	-3.48	3.95	-0.41
B	(Boron)	2.11	2.47	0.36	2.39	0.28
Ba	(Barium)	3.40	7.57	4.17	7.32	3.92
Be	(Beryllium)	0.13	1.10	0.97	1.10	0.97
Bi	(Bismuth)	10.41	10.38	-0.03	5.13	-5.28
Cd	(Cadmium)	1.33	2.69	1.36	3.29	1.96
Ce	(Cerium)	4.01	NA	NA	NA	NA
Co	(Cobalt)	2.09	3.14	1.05	3.00	0.91
Cr(II)	(Chromium)	2.36	7.01	4.65	17.47	15.11
Cu	(Copper)	0.54	1.53	0.99	1.24	0.70
Fe(II)	(Iron)	1.66	36.43	34.77	35.26	33.6
K	(Potassium)	NA	NA	NA	NA	NA
La	(Lanthanum)	9.46	NA	NA	NA	NA
Li	(Lithium)	2.73	2.98	0.25	4.25	1.52
Mn	(Manganese)	1.58	6.18	4.60	5.50	3.92
Mo	(Molybdenum)	4.04	5.36	1.32	3.16	-0.88
Na	(Sodium)	97.65	113.3	15.65	76.95	-20.7
Ni	(Nickel)	2.14	6.00	3.86	4.68	2.54
Pb	(Lead)	12.74	12.63	-0.11	13.16	0.42
Rb	(Rubidium)	0.34	2.29	1.95	1.51	1.17
Sb	(Antimony)	1.28	2.36	1.08	2.53	1.25
Se	(Selenium)	6.26	6.81	0.55	4.70	-1.56
Sn	(Tin)	7.05	8.47	1.42	10.20	3.15
Sr	(Strontium)	73.41	128.0	54.59	116.2	42.8
Ti	(Titanium)	0.89	4.03	3.14	4.00	3.11
Tl	(Thallium)	17.17	31.17	14.0	32.78	15.61
U	(Uranium)	1.75	5.11	3.36	5.92	4.17
V	(Vanadium)	13.85	20.97	7.12	19.77	5.92
Zn(I)	(Zinc)	16.07	6.91	-9.16	6.23	-9.84

Note: Metals highlighted in the table are major components in the coupons evaluated. Significant increases in the concentration of these metals would be an indication of corrosion of the coupons

Table 9

ICP analysis of GeoBrom® HG520 before and after 90-day partial immersion corrosion study at 50 °C: 304LW and 316

All results in mg/L

Metal ID		Metals in GeoBrom® HG520 at start	304LW After	304LW Difference	316 After	316 Difference
Ag	(Silver)	1.66	5.65	3.99	5.32	3.66
Al	(Aluminum)	10.12	5.87	-4.25	5.87	-4.25
As	(Arsenic)	4.36	2.24	-2.12	4.46	0.10
B	(Boron)	2.11	2.47	0.36	2.59	0.48
Ba	(Barium)	3.40	7.30	3.90	7.26	3.86
Be	(Beryllium)	0.13	1.10	0.97	1.10	0.97
Bi	(Bismuth)	10.41	11.99	1.58	9.65	-0.76
Cd	(Cadmium)	1.33	3.13	1.80	2.24	0.91
Ce	(Cerium)	4.01	NA	NA	NA	NA
Co	(Cobalt)	2.09	3.00	0.91	3.47	1.38
Cr(II)	(Chromium)	2.36	10.99	8.63	6.04	3.68
Cu	(Copper)	0.54	1.50	0.96	1.37	0.83
Fe(II)	(Iron)	1.66	52.96	51.30	16.33	14.67
K	(Potassium)	NA	NA	NA	NA	NA
La	(Lanthanum)	9.46	NA	NA	NA	NA
Li	(Lithium)	2.73	3.36	0.63	4.27	1.54
Mn	(Manganese)	1.58	6.45	4.87	5.28	3.70
Mo	(Molybdenum)	4.04	8.23	4.19	7.92	3.88
Na	(Sodium)	97.65	88.2	-9.45	99.0	1.35
Ni	(Nickel)	2.14	7.04	4.90	7.44	5.30
Pb	(Lead)	12.74	3.60	-9.14	8.41	-4.33
Rb	(Rubidium)	0.34	2.27	1.93	2.01	1.67
Sb	(Antimony)	1.28	1.35	0.07	2.57	1.29
Se	(Selenium)	6.26	5.29	-0.97	7.72	1.46
Sn	(Tin)	7.05	6.85	-0.20	6.52	-0.53
Sr	(Strontium)	73.41	113.1	39.7	117.4	44.0
Ti	(Titanium)	0.89	3.99	3.10	4.03	3.14
Tl	(Thallium)	17.17	14.29	-2.88	29.23	12.06
U	(Uranium)	1.75	5.69	3.94	7.46	5.71
V	(Vanadium)	13.85	20.77	6.92	19.81	5.96
Zn(I)	(Zinc)	16.07	6.36	-9.71	6.18	-9.89

Note: Metals highlighted in the table are major components in the coupons evaluated. Significant increases in the concentration of these metals would be an indication of corrosion of the coupons

LANXESS
Energizing Chemistry

LANXESS Corporation
Business Unit Polymer Additives
111 RIDC Park West Drive
Pittsburgh, PA 15275-1112, USA
Phone: +1 412-809-1000

polymer.additives@lanxess.com
http://pla.lanxess.com

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