



Rate of Corrosion Data for WP Industrial Cleaning Products

Project Description: Evaluate Corrosion Rate Data of Various West Penetone Industrial Cleaning Solutions

Objective: To determine the relative rate of corrosion of West Penetone chemical cleaning solutions under conditions of different application temperatures and metallurgy types. The corrosion rate testing is performed by exposing clean, corrosion free metallic test specimens to the cleaning solution under controlled conditions. The test specimens are weighed before and after the test, and the corrosion rate is calculated from the mass loss. Localized corrosion such as pitting may also be evaluated.

The actual corrosion rate can be determined for each test specimen by applying the following formula:

$$CR = \frac{87.6w}{dat}$$

CR = corrosion rate (mm/year)

w = mass loss in mg

d = density in g/cm³

a = exposed area in cm²

t = time in hours

For more details of the recommended corrosion testing procedure, refer to NACE Standard Test Method TM0193-2000.

Notes: **For performing corrosion rate calculation, the following density may be assumed for the coupon materials suggested in the testing parameters:**

| | |
|-------------------------|----------------------------------|
| For carbon steel | density = 7.85 g/cm ³ |
| For stainless steel 304 | density = 7.94 g/cm ³ |
| For stainless steel 316 | density = 7.97 g/cm ³ |
| For copper nickel 90/10 | density = 8.94 g/cm ³ |

Preparation: **To prepare for determining the relative rate of corrosion of the cleaning products, test solutions should be prepared by diluting the cleaning products with distilled water, to achieve an active ingredient concentration of approximately 10% w/w concentration and a second solution of 5% w/w concentration.**



GROUP 1 – Hydrochloric Acid-Based Products

Corrosion Testing on Carbon Steel 1018 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AG 150 | --- | 100 | 38.2863 | 38.1231 | 0.1632 | 35.08 | 85.222 | 2.163 |
| Penscrub AG150 | 0.2 | 100 | 38.3097 | 38.1764 | 0.1333 | 35.08 | 69.620 | 1.767 |
| Penscrub AG 150 | --- | 50 | 38.2697 | 38.1580 | 0.1177 | 35.08 | 61.464 | 1.560 |
| Penscrub AG150 | 0.2 | 50 | 38.2667 | 38.2076 | 0.0591 | 35.08 | 30.850 | 0.783 |
| Tetragard | --- | 50 | 38.2623 | 37.8729 | 0.3894 | 35.08 | 203.343 | 5.161 |
| Tetragard | 0.2 | 50 | 38.2508 | 38.0663 | 0.1845 | 35.08 | 96.333 | 2.445 |
| Tetragard | --- | 25 | 38.2776 | 38.1040 | 0.1736 | 35.08 | 90.659 | 2.301 |
| Tetragard | 0.2 | 25 | 38.2156 | 38.1334 | 0.0822 | 35.08 | 42.907 | 1.089 |

Conditions: 24 hours at 70°C (160°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AG 150 | --- | 100 | 38.2931 | 37.5660 | 0.7271 | 35.08 | 379.698 | 9.637 |
| Penscrub AG150 | 0.2 | 100 | 38.2440 | 37.9594 | 0.2846 | 35.08 | 148.617 | 3.772 |
| Penscrub AG 150 | --- | 50 | 38.3088 | 37.7145 | 0.5943 | 35.08 | 310.354 | 7.877 |
| Penscrub AG150 | 0.2 | 50 | 38.2365 | 38.1486 | 0.0879 | 35.08 | 45.901 | 1.165 |
| Tetragard | --- | 50 | 38.2646 | 36.6860 | 1.5786 | 35.08 | 824.389 | 20.924 |
| Tetragard | 0.2 | 50 | 38.2960 | 38.0507 | 0.2453 | 35.08 | 128.102 | 3.251 |
| Tetragard | --- | 25 | 38.3006 | 37.6566 | 0.6440 | 35.08 | 336.315 | 8.536 |
| Tetragard | 0.2 | 25 | 38.2392 | 38.0870 | 0.1522 | 35.08 | 79.483 | 2.017 |

Corrosion Testing on Copper Nickel 90-10 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AG 150 | --- | 100 | 12.4380 | 12.4002 | 0.0378 | 22.06 | 27.580 | 0.700 |
| Penscrub AG150 | 0.2 | 100 | 12.4130 | 12.3624 | 0.0506 | 22.06 | 36.878 | 0.936 |
| Penscrub AG 150 | --- | 50 | 12.3545 | 12.2958 | 0.0587 | 22.06 | 42.789 | 1.086 |
| Penscrub AG150 | 0.2 | 50 | 12.2636 | 12.2299 | 0.0337 | 22.06 | 24.586 | 0.624 |
| Tetragard | --- | 50 | 12.2829 | 12.2351 | 0.0478 | 22.06 | 34.869 | 0.885 |
| Tetragard | 0.2 | 50 | 12.3527 | 12.3121 | 0.0406 | 22.06 | 29.589 | 0.751 |
| Tetragard | --- | 25 | 12.3694 | 12.3412 | 0.0282 | 22.06 | 20.567 | 0.522 |
| Tetragard | 0.2 | 25 | 12.3817 | 12.3381 | 0.0436 | 22.06 | 31.796 | 0.807 |

Conditions: 24 hours at 70°C (160°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AG 150 | --- | 100 | 12.3911 | 12.3165 | 0.0746 | 22.06 | 54.411 | 1.381 |
| Penscrub AG150 | 0.2 | 100 | 12.2662 | 12.2074 | 0.0588 | 22.06 | 42.867 | 1.088 |
| Penscrub AG 150 | --- | 50 | 12.3023 | 12.2741 | 0.0282 | 22.06 | 20.567 | 0.522 |
| Penscrub AG150 | 0.2 | 50 | 12.4127 | 12.3975 | 0.0152 | 22.06 | 11.071 | 0.281 |
| Tetragard | --- | 50 | 12.2569 | 12.2006 | 0.0563 | 22.06 | 41.055 | 1.042 |
| Tetragard | 0.2 | 50 | 12.3633 | 12.3120 | 0.0513 | 22.06 | 37.408 | 0.949 |
| Tetragard | --- | 25 | 12.4087 | 12.3808 | 0.0279 | 22.06 | 20.345 | 0.516 |
| Tetragard | 0.2 | 25 | 12.0807 | 12.0258 | 0.0549 | 22.06 | 40.033 | 1.016 |

Corrosion Testing on Stainless Steel 304 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AG 150 | 100 | 10.8279 | 10.5307 | 0.2972 | 22.06 | 244.004 | 6.193 |
| Penscrub AG 150 | 50 | 10.8444 | 10.4696 | 0.3748 | 22.06 | 307.714 | 7.810 |
| Tetragard | 50 | 10.7774 | 10.6902 | 0.0872 | 22.06 | 71.590 | 1.817 |
| Tetragard | 25 | 10.7927 | 10.7351 | 0.0576 | 22.06 | 47.280 | 1.200 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AG 150 | 100 | 10.8286 | 9.1432 | 1.6854 | 22.06 | 1383.767 | 35.121 |
| Penscrub AG 150 | 50 | 10.8561 | 9.6946 | 1.1615 | 22.06 | 953.638 | 24.204 |
| Tetragard | 50 | 10.8226 | 10.5349 | 0.2877 | 22.06 | 236.203 | 5.995 |
| Tetragard | 25 | 10.8780 | 10.7370 | 0.1410 | 22.06 | 115.766 | 2.938 |

GROUP 1 – Hydrochloric Acid-Based Products cont'd

Corrosion Testing on Stainless Steel 316 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-----------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Penscrub AG 150 | 100 | 11.0703 | 10.5800 | 0.4903 | 22.06 | 401.053 | 10.179 |
| Penscrub AG 150 | 50 | 11.0446 | 10.6873 | 0.3573 | 22.06 | 292.269 | 7.418 |
| Tetragard | 50 | 11.0805 | 11.0340 | 0.0465 | 22.06 | 38.021 | 0.965 |
| Tetragard | 25 | 11.0057 | 10.9020 | 0.1037 | 22.06 | 84.828 | 2.153 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-----------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Penscrub AG 150 | 100 | 10.9990 | 9.5938 | 1.4052 | 22.06 | 1149.377 | 29.172 |
| Penscrub AG 150 | 50 | 11.0693 | 10.3046 | 0.7647 | 22.06 | 625.475 | 15.875 |
| Tetragard | 50 | 11.0436 | 10.9074 | 0.1362 | 22.06 | 111.404 | 2.828 |
| Tetragard | 25 | 11.0785 | 10.8831 | 0.1954 | 22.06 | 159.827 | 4.057 |

GROUP 2 – Sulfuric Acid-Based Products

Corrosion Testing on Carbon Steel 1018 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AS 150 | --- | 33 | 38.2295 | 37.2388 | 0.9907 | 35.08 | 517.371 | 13.131 |
| Penscrub AS150 | 0.2 | 33 | 38.2392 | 37.4806 | 0.7586 | 35.08 | 396.162 | 10.055 |
| Penscrub AS150 | 0.3 | 33 | 38.3444 | 37.7026 | 0.6418 | 35.08 | 335.166 | 8.507 |
| Penscrub AS 150 | --- | 17 | 38.2817 | 37.4697 | 0.8120 | 35.08 | 424.049 | 10.763 |
| Penscrub AS150 | 0.2 | 17 | 38.2551 | 37.7616 | 0.4935 | 35.08 | 257.719 | 6.541 |
| Penscrub AS150 | 0.3 | 17 | 38.2725 | 37.8235 | 0.4490 | 35.08 | 234.480 | 5.951 |
| Acid Wash 200 | --- | 70 | 38.2707 | 33.0949 | 5.1758 | 35.08 | 2702.946 | 68.603 |
| Acid Wash 200 | 0.2 | 70 | 38.2655 | 37.8905 | 0.3750 | 35.08 | 195.835 | 4.970 |
| Acid Wash 200 | --- | 35 | 38.2852 | 35.4073 | 2.8779 | 35.08 | 1502.919 | 38.145 |
| Acid Wash 200 | 0.2 | 35 | 38.2451 | 38.0365 | 0.2086 | 35.08 | 108.937 | 2.765 |

Conditions: 24 hours at 70°C (160°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AS 150 | --- | 33 | 38.2820 | 36.5132 | 1.7688 | 35.08 | 923.716 | 23.445 |
| Penscrub AS150 | 0.2 | 33 | 38.2810 | 36.4921 | 1.7889 | 35.08 | 934.213 | 23.711 |
| Penscrub AS150 | 0.3 | 33 | 38.2711 | 36.6223 | 1.6488 | 35.08 | 861.049 | 21.854 |
| Penscrub AS 150 | --- | 17 | 38.2423 | 36.8888 | 1.3535 | 35.08 | 706.835 | 17.940 |
| Penscrub AS150 | 0.2 | 17 | 38.2394 | 38.2644 | 0.9750 | 35.08 | 509.172 | 12.923 |
| Penscrub AS150 | 0.3 | 17 | 38.2270 | 37.4961 | 0.7309 | 35.08 | 381.696 | 9.688 |
| Acid Wash 200 | --- | 70 | 38.2817 | 33.3263 | 4.9554 | 35.08 | 2587.846 | 65.681 |
| Acid Wash 200 | 0.2 | 70 | 38.2697 | 37.8141 | 0.4556 | 35.08 | 237.927 | 6.039 |
| Acid Wash 200 | --- | 35 | 38.2535 | 35.5924 | 2.6611 | 35.08 | 1389.700 | 35.272 |
| Acid Wash 200 | 0.2 | 35 | 38.2366 | 38.0068 | 0.2298 | 35.08 | 120.008 | 3.046 |

Corrosion Testing on Copper Nickel 90-10 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AS 150 | --- | 33 | 12.1994 | 12.1785 | 0.0209 | 22.06 | 15.240 | 0.387 |
| Penscrub AS150 | 0.2 | 33 | 12.3704 | 12.3475 | 0.0229 | 22.06 | 16.699 | 0.424 |
| Penscrub AS 150 | --- | 17 | 12.4021 | 12.3844 | 0.0177 | 22.06 | 12.907 | 0.328 |
| Penscrub AS150 | 0.2 | 17 | 12.2445 | 12.2269 | 0.0176 | 22.06 | 12.834 | 0.326 |
| Acid Wash 200 | --- | 70 | 12.2325 | 12.2181 | 0.0144 | 22.06 | 10.500 | 0.267 |
| Acid Wash 200 | 0.2 | 70 | 12.3659 | 12.3496 | 0.0163 | 22.06 | 11.886 | 0.302 |
| Acid Wash 200 | --- | 35 | 12.0721 | 12.0578 | 0.0143 | 22.06 | 10.428 | 0.265 |
| Acid Wash 200 | 0.2 | 35 | 12.3514 | 12.3354 | 0.0160 | 22.06 | 11.667 | 0.296 |

Conditions: 24 hours at 70°C (160°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AS 150 | --- | 33 | 12.2076 | 12.1792 | 0.0284 | 22.06 | 20.709 | 0.526 |
| Penscrub AS150 | 0.2 | 33 | 12.1573 | 12.1307 | 0.0266 | 22.06 | 19.397 | 0.492 |
| Penscrub AS 150 | --- | 17 | 12.3519 | 12.3239 | 0.0280 | 22.06 | 20.418 | 0.518 |
| Penscrub AS150 | 0.2 | 17 | 12.2733 | 12.2513 | 0.0220 | 22.06 | 16.042 | 0.407 |
| Acid Wash 200 | --- | 70 | 12.2018 | 12.1882 | 0.0136 | 22.06 | 9.917 | 0.252 |
| Acid Wash 200 | 0.2 | 70 | 12.2276 | 12.2169 | 0.0107 | 22.06 | 7.802 | 0.198 |
| Acid Wash 200 | --- | 35 | 12.2443 | 12.2319 | 0.0124 | 22.06 | 9.042 | 0.229 |
| Acid Wash 200 | 0.2 | 35 | 12.3424 | 12.3304 | 0.0120 | 22.06 | 8.750 | 0.222 |

Corrosion Testing on Stainless Steel 304 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penscrub AS 150 | 33 | 10.8004 | 10.7064 | 0.0940 | 22.06 | 77.178 | 1.959 |
| Penscrub AS 150 | 17 | 10.8429 | 10.7049 | 0.1380 | 22.06 | 113.303 | 2.876 |
| Acid Wash 200 | 70 | 10.8408 | 10.0100 | 0.8308 | 22.06 | 682.118 | 17.313 |
| Acid Wash 200 | 35 | 10.6980 | 10.3479 | 0.3501 | 22.06 | 287.445 | 7.296 |

GROUP 2 – Sulfuric Acid-Based Products cont'd

Corrosion Testing on Stainless Steel 304 Coupons

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-----------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Penscrub AS 150 | 33 | 10.8557 | 10.6665 | 0.1892 | 22.06 | 155.340 | 3.943 |
| Penscrub AS 150 | 17 | 10.7626 | 10.5319 | 0.2307 | 22.06 | 189.413 | 4.807 |
| Acid Wash 200 | 70 | 10.7261 | 9.5370 | 1.1891 | 22.06 | 976.296 | 24.779 |
| Acid Wash 200 | 35 | 10.7909 | 10.2538 | 0.5371 | 22.06 | 440.979 | 11.192 |

Corrosion Testing on Stainless Steel 316 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-----------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Penscrub AS 150 | 33 | 11.0811 | 10.9774 | 0.1037 | 22.06 | 84.821 | 2.153 |
| Penscrub AS 150 | 17 | 11.0481 | 10.8862 | 0.1619 | 22.06 | 132.426 | 3.361 |
| Acid Wash 200 | 70 | 11.0834 | 10.8608 | 0.2226 | 22.06 | 182.075 | 4.621 |
| Acid Wash 200 | 35 | 10.9338 | 10.8488 | 0.0850 | 22.06 | 69.526 | 1.765 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-----------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Penscrub AS 150 | 33 | 11.0768 | 10.8779 | 0.1989 | 22.06 | 162.690 | 4.129 |
| Penscrub AS 150 | 17 | 10.9996 | 10.7509 | 0.2487 | 22.06 | 203.423 | 5.163 |
| Acid Wash 200 | 70 | 11.0376 | 10.5961 | 0.4415 | 22.06 | 361.124 | 9.166 |
| Acid Wash 200 | 35 | 11.0762 | 10.9010 | 0.1752 | 22.06 | 143.304 | 3.637 |

GROUP 3 – Sodium Hydroxide-Based Products

Corrosion Testing on Carbon Steel 1018 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 38.2730 | 38.2697 | 0.0033 | 35.08 | 1.723 | 0.044 |
| Penblitz 688L | 5 | 38.2762 | 38.2734 | 0.0028 | 35.08 | 1.462 | 0.037 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 38.3294 | 38.3255 | 0.0039 | 35.08 | 2.037 | 0.052 |
| Penblitz 688L | 5 | 38.2647 | 38.2536 | 0.0111 | 35.08 | 5.797 | 0.147 |

Corrosion Testing on Copper Nickel 90-10 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 12.2121 | 12.2064 | 0.0057 | 22.06 | 4.156 | 0.105 |
| Penblitz 688L | 5 | 12.3626 | 12.3581 | 0.0045 | 22.06 | 3.281 | 0.083 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 12.1676 | 12.1639 | 0.0037 | 22.06 | 2.698 | 0.068 |
| Penblitz 688L | 5 | 12.3975 | 12.3932 | 0.0043 | 22.06 | 3.136 | 0.080 |

Corrosion Testing on Stainless Steel 304 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 10.7891 | 10.7880 | 0.0011 | 22.06 | 0.903 | 0.023 |
| Penblitz 688L | 5 | 10.7405 | 10.7394 | 0.0011 | 22.06 | 0.903 | 0.023 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 10.8522 | 10.8504 | 0.0018 | 22.06 | 1.478 | 0.038 |
| Penblitz 688L | 5 | 10.8520 | 10.8505 | 0.0015 | 22.06 | 1.232 | 0.031 |

Corrosion Testing on Stainless Steel 316 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 10.9732 | 10.9724 | 0.0008 | 22.06 | 0.654 | 0.017 |
| Penblitz 688L | 5 | 11.0534 | 11.0528 | 0.0006 | 22.06 | 0.491 | 0.012 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|---------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Penblitz 688L | 10 | 11.0342 | 11.0333 | 0.0009 | 22.06 | 0.736 | 0.019 |
| Penblitz 688L | 5 | 11.0148 | 11.0139 | 0.0009 | 22.06 | 0.736 | 0.019 |

GROUP 4 – EDTA-Based Products

Corrosion Testing on Carbon Steel 1018 Coupons

Conditions: 24 hours at 75°C (167°F)

| Product | Corr. Inhib. Addition | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|-----------------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | --- | 25 | 38.3493 | 38.3477 | 0.0016 | 35.08 | 0.836 | 0.021 |
| Clean Add 2 | 0.2 | 25 | 38.2700 | 38.2693 | 0.0007 | 35.08 | 0.366 | 0.009 |
| Clean Add 2 | --- | 12.5 | 38.2957 | 38.2945 | 0.0012 | 35.08 | 0.627 | 0.016 |
| Clean Add 2 | 0.2 | 12.5 | 38.2740 | 38.2732 | 0.0008 | 35.08 | 0.418 | 0.011 |

Conditions: 24 hours at 85°C (185°F)

| Product | Corr. Inhib. Addition | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|-----------------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | --- | 25 | 38.1681 | 38.1543 | 0.0138 | 35.08 | 7.207 | 0.183 |
| Clean Add 2 | 0.2 | 25 | 38.3254 | 38.3250 | 0.004 | 35.08 | 2.089 | 0.053 |
| Clean Add 2 | --- | 12.5 | 38.1847 | 38.1732 | 0.0115 | 35.08 | 6.006 | 0.152 |
| Clean Add 2 | 0.2 | 12.5 | 38.2533 | 38.2529 | 0.004 | 35.08 | 2.089 | 0.053 |

Corrosion Testing on Copper Nickel 90-10 Coupons

Conditions: 24 hours at 75°C (167°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | 25 | 12.2891 | 12.2785 | 0.0106 | 22.06 | 7.730 | 0.196 |
| Clean Add 2 | 12.5 | 12.2449 | 12.2350 | 0.0099 | 22.06 | 7.219 | 0.183 |

Conditions: 24 hours at 85°C (185°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | 25 | 12.3666 | 12.3580 | 0.0086 | 22.06 | 6.271 | 0.159 |
| Clean Add 2 | 12.5 | 12.3318 | 12.3217 | 0.0101 | 22.06 | 7.365 | 0.187 |

Corrosion Testing on Stainless Steel 304 Coupons

Conditions: 24 hours at 75°C (167°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | 25 | 10.8147 | 10.8138 | 0.0009 | 22.06 | 0.739 | 0.019 |
| Clean Add 2 | 12.5 | 10.7392 | 10.7391 | 0.0001 | 22.06 | 0.082 | 0.002 |

Conditions: 24 hours at 85°C (185°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | 25 | 10.7870 | 10.7864 | 0.0006 | 22.06 | 0.493 | 0.013 |
| Clean Add 2 | 12.5 | 10.8504 | 10.8494 | 0.0010 | 22.06 | 0.821 | 0.021 |

Corrosion Testing on Stainless Steel 316 Coupons

Conditions: 24 hours at 75°C (167°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | 25 | 11.0591 | 11.0586 | 0.0005 | 22.06 | 0.409 | 0.010 |
| Clean Add 2 | 12.5 | 11.0529 | 11.0527 | 0.0002 | 22.06 | 0.164 | 0.004 |

Conditions: 24 hours at 85°C (185°F)

| Product | Concentration | Initial Weight | Final Weight | Weight Loss | Surface Area | Corrosion Rate | Corrosion Rate |
|-------------|---------------|----------------|--------------|-------------|--------------------|-----------------|----------------|
| | (%v/v) | (grams) | (grams) | (grams) | (cm ²) | (mils per year) | (mm per year) |
| Clean Add 2 | 25 | 10.9722 | 10.9721 | 0.0001 | 22.06 | 0.082 | 0.002 |
| Clean Add 2 | 12.5 | 11.0139 | 11.0131 | 0.0008 | 22.06 | 0.654 | 0.017 |

GROUP 5– Methanesulfonic Acid-Based Products

Corrosion Testing on Carbon Steel 1018 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | --- | 33 | 38.2849 | 37.4141 | 0.8708 | 35.08 | 454.756 | 11.542 |
| Tetragard Ultra | 0.2 | 33 | 38.3178 | 38.1677 | 0.1501 | 35.08 | 78.386 | 1.990 |
| Tetragard Ultra | --- | 17 | 38.2768 | 37.5650 | 0.7118 | 35.08 | 371.722 | 9.435 |
| Tetragard Ultra | 0.2 | 17 | 38.2387 | 38.1855 | 0.0837 | 35.08 | 43.710 | 1.109 |

Conditions: 24 hours at 70°C (160°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | --- | 33 | 38.3193 | 33.9264 | 4.3929 | 35.08 | 2294.094 | 58.226 |
| Tetragard Ultra | 0.2 | 33 | 38.2397 | 37.8996 | 0.3401 | 35.08 | 177.610 | 4.508 |
| Tetragard Ultra | --- | 17 | 38.2213 | 37.1891 | 1.0322 | 35.08 | 539.043 | 13.681 |
| Tetragard Ultra | 0.2 | 17 | 38.2620 | 38.1677 | 0.0943 | 35.08 | 49.246 | 1.250 |

Corrosion Testing on Copper Nickel 90-10 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | --- | 33 | 12.2160 | 12.1961 | 0.0199 | 22.06 | 14.511 | 0.368 |
| Tetragard Ultra | 0.2 | 33 | 12.3075 | 12.3004 | 0.0071 | 22.06 | 5.177 | 0.131 |
| Tetragard Ultra | --- | 17 | 12.3647 | 12.3417 | 0.0230 | 22.06 | 16.772 | 0.426 |
| Tetragard Ultra | 0.2 | 17 | 12.3833 | 12.3753 | 0.0080 | 22.06 | 5.834 | 0.148 |

Conditions: 24 hours at 70°C (160°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | --- | 33 | 12.4361 | 12.4164 | 0.0197 | 22.06 | 14.218 | 0.361 |
| Tetragard Ultra | 0.2 | 33 | 12.3985 | 12.3891 | 0.0094 | 22.06 | 6.854 | 0.174 |
| Tetragard Ultra | --- | 17 | 12.3392 | 12.3215 | 0.0177 | 22.06 | 12.774 | 0.324 |
| Tetragard Ultra | 0.2 | 17 | 12.4532 | 12.4451 | 0.0081 | 22.06 | 5.907 | 0.150 |

Corrosion Testing on Stainless Steel 304 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | 33 | 10.7889 | 10.7882 | 0.0007 | 22.06 | 0.575 | 0.015 |
| Tetragard Ultra | 17 | 10.7867 | 10.7861 | 0.0006 | 22.06 | 0.493 | 0.013 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | 33 | 10.7305 | 10.7295 | 0.0010 | 22.06 | 0.821 | 0.021 |
| Tetragard Ultra | 17 | 10.6919 | 10.6908 | 0.0011 | 22.06 | 0.903 | 0.023 |

Corrosion Testing on Stainless Steel 316 Coupons

Conditions: 24 hours at 60°C (140°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | 33 | 11.0669 | 11.0663 | 0.0006 | 22.06 | 0.491 | 0.012 |
| Tetragard Ultra | 17 | 11.0574 | 11.0566 | 0.0008 | 22.06 | 0.654 | 0.017 |

Conditions: 24 hours at 70°C (160°F)

| Product | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|-----------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Tetragard Ultra | 33 | 11.0569 | 11.0533 | 0.0036 | 22.06 | 2.945 | 0.075 |
| Tetragard Ultra | 17 | 11.0537 | 11.0525 | 0.0012 | 22.06 | 0.982 | 0.025 |



GROUP 6– THPS-Based Products

Corrosion Testing on Carbon Steel 1018 Coupons

Conditions: 6 hours at 80°C (176°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|------------------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Iron Sulfide Dissolver | 0.5* | 100 | 38.1743 | 37.7329 | 0.4414 | 35.08 | 897.125 | 22.770 |
| Iron Sulfide Dissolver | 0.5* | 100 | 38.1554 | 37.6876 | 0.4678 | 35.08 | 950.782 | 24.132 |

* - novel corrosion inhibitor A

Conditions: 56°C (133°F)

| Product | Corr. Inhib. Addition (%v/v) | Concentration (%v/v) | Initial Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Surface Area (cm ²) | Corrosion Rate (mils per year) | Corrosion Rate (mm per year) |
|------------------------------|---------------------------------|-------------------------|---------------------------|-------------------------|------------------------|------------------------------------|-----------------------------------|---------------------------------|
| Iron Sulfide Dissolver | --- | 50 | 37.6586 | 37.6478 | 0.0108 | 35.08 | 22.560 | 0.573 |
| Iron Sulfide Dissolver | --- | 25 | 36.6871 | 36.6596 | 0.0275 | 35.08 | 57.445 | 1.458 |
| Iron Sulfide Dissolver | 0.5 ^t | 50 | 37.4644 | 37.4539 | 0.0105 | 35.08 | 43.867 | 1.113 |
| Iron Sulfide Dissolver | 0.5 ^t | 25 | 37.4174 | 37.3742 | 0.0432 | 35.08 | 180.482 | 4.581 |
| Iron Sulfide Dissolver | 0.5** | 50 | 38.2008 | 38.186 | 0.0148 | 35.08 | 37.099 | 0.942 |
| Iron Sulfide Dissolver | 0.5** | 25 | 38.1193 | 38.1093 | 0.0100 | 35.08 | 25.067 | 0.636 |
| Iron Sulfide Dissolver OPP | --- | 50 | 38.0528 | 37.5484 | 0.5044 | 35.08 | 1053.646 | 26.742 |
| Iron Sulfide Dissolver OPP | --- | 25 | 38.0528 | 37.5863 | 0.4665 | 35.08 | 974.477 | 24.733 |
| Iron Sulfide Dissolver OPP | 0.5 ^t | 50 | 38.2530 | 38.1490 | 0.1040 | 35.08 | 434.493 | 11.028 |
| Iron Sulfide Dissolver OPP | 0.5 ^t | 25 | 38.3261 | 38.0621 | 0.2640 | 35.08 | 1102.945 | 27.994 |
| Iron Sulfide Dissolver OPP | 0.5** | 50 | 38.2128 | 38.1838 | 0.0290 | 35.08 | 72.694 | 1.845 |
| Iron Sulfide Dissolver OPP | 0.5** | 25 | 38.1860 | 38.1710 | 0.0150 | 35.08 | 37.600 | 0.954 |
| Iron Sulfide Dissolver OSP-1 | --- | 50 | 38.1141 | 37.3735 | 0.7406 | 35.08 | 1547.047 | 39.265 |
| Iron Sulfide Dissolver OSP-1 | --- | 25 | 37.5611 | 37.0872 | 0.4739 | 35.08 | 989.935 | 25.125 |
| Iron Sulfide Dissolver OSP-1 | 0.5 ^t | 50 | 38.1487 | 37.8613 | 0.2874 | 35.08 | 1200.706 | 30.475 |
| Iron Sulfide Dissolver OSP-1 | 0.5 ^t | 25 | 38.9589 | 37.8101 | 1.1488 | 35.08 | 4799.481 | 121.814 |
| Iron Sulfide Dissolver OSP-1 | 0.5** | 50 | 38.1052 | 38.0497 | 0.0555 | 35.08 | 139.121 | 3.531 |
| Iron Sulfide Dissolver OSP-1 | 0.5** | 25 | 38.8748 | 38.8231 | 0.0517 | 35.08 | 129.596 | 3.289 |

^t - formula corrosion inhibitor

** - novel corrosion inhibitor B