

## I. Detergents and Cleansers

Mildly alkaline solutions of ordinary laundry soaps develop a protective coating on zinc and its alloys. They are satisfactory for both warm and cold applications. Detergent solutions are more corrosive; however, the better grades include inhibitors, which reduce corrosion to allow reasonably satisfactory service for zinc alloys. Strong alkalies (e.g., hypochlorite bleach solutions) or acid solutions (e.g., Harpic, which contains trisodium hydrogen disulfate) are to be avoided.

Table 5.1 gives results for five series of immersion trials designed to show the short-term and long-term effects of both simple chemicals and commercial solutions. Although the corrosion rates are calculated per year (for consistency with other tables), it must be remembered that often the contact time will be in hours or even minutes per year; hence, quite high corrosion rates may be acceptable. Some tests were made on zinc sheet and some on hot dip galvanized material. The results should be of the same order, so this detail is normally omitted from the tables in this chapter. When the original source shows significant differences in the two materials, it is anticipated that the dissimilarities are due to surface films (e.g., chromating) being left in place unwittingly. Trials in the United Kingdom were made by BNF and by Imperial Smelting (unpublished) at room temperature, at 70°C, and at 100°C on commercial detergents in use in Britain in 1959. Corrosion was significant at the higher temperatures, suggesting that for long life of die-cast components in washing machines, a protective coating is desirable.

## J. Trichlorethylene

Normal trichlorethylene degreasing has no effect on zinc or zinc-aluminum alloys, provided immersion in solution that has become degraded or contaminated is avoided.

## III. INORGANIC CHEMICALS

In the presence of moisture such as rain or condensation, or in solution, many chemicals react with zinc. Corrosion is serious if the reaction of the chemical with zinc forms acidic products. Mixtures of chemicals can sometimes be more corrosive than the sum of their effects taken separately but, when such mixtures come from natural sources, there are often unsuspected inhibitors present, which give a net beneficial effect.

A short immersion trial is desirable for water-based solutions. Linear extrapolation of the results will usually indicate the worst possibility, since the attack often reduces with time.

**Table 5.1** Corrosion Data for Zinc and Zinc Coatings with Detergents, Cleaners, Soaps, Synthetic Detergents (Syndets), etc.

Letter code for references cited in the table:						
I	=	International Nickel Co. (direct information)				
K	=	Stupel and Koch (1959)				
L	=	Bukowiecki (1958)				
M	=	Bablik and Belohlavy (1957)				
P	=	Bacon and Nutting (1952)				
Materials	Time (days unless otherwise indicated)	Temperature (°C)	Corrosion rates		Remarks	Refs.
			mg/m <sup>2</sup> /year	μm/year		
Detergents and Cleaners						
Calcium chloride						
20% solution	10	33	125	17	Dairy cleaning	I
20% solution	10	33	82	11	Dairy cleaning	I
20% solution + silicate	10	35	92	13	Dairy cleaning	I
20% solution + 0.05% Ca(OH) <sub>2</sub>	10	35	95	13	Dairy cleaning	I
20% solution + 0.17% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	10	35	80	11	Dairy cleaning	I
Lime mix						
200 g/L of 66.5% Ca(OH) <sub>2</sub> + 32.5% MgO	5	21	270	38	Dairy cleaning	I
Sodium carbonate						
sodium carbonate–zinc sheet	5 h	66	1,425	200	Dairy cleaning	I
sodium carbonate–HDG sheet	5 h	66	1,350	190	Dairy cleaning	I
Sodium hydroxide						
0.5% solution	5 h	66	3,250	450	Dairy cleaning	I
0.5% solution	5	21	171	24	Dairy cleaning	I
0.5% solution–HDG sheet	5 h	66	7,450	1,040	Dairy cleaning	I
0.5% solution–HDG sheet	5	21	440	61	Dairy cleaning	I

Table 5.1 Continued

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L	=	Bukowiecki (1958)				
M	=	Bablik and Belohlavy (1957)				
P	=	Bacon and Nutting (1952)				
Materials	Time (days unless otherwise indicated)	Temperature (°C)	Corrosion rates		Remarks	Refs.
			mg/m <sup>2</sup> /year	μm/year		
Sodium hypochlorite						
6 g/L, 236 ppm available Cl <sup>-</sup>	5	21	190	110	Dairy cleaning	I
6 g/L, 236 ppm available Cl <sup>-</sup>	5	21	752	105	Dairy cleaning	I
Diversol						
7 g/L, 236 ppm available Cl <sup>-</sup>	5	21	175	25	Dairy cleaning	I
7 g/L, 236 ppm available Cl <sup>-</sup>	5	21	Gained weight		Dairy cleaning	I
4 g/L, 137 ppm available Cl <sup>-</sup>	5	21	215	30	Dairy cleaning	I
4 g/L, 137 ppm available Cl <sup>-</sup>	5	21	266	37	Dairy cleaning	I
Chloramine T, 0.6 g/L, 222 ppm available Cl <sup>-</sup>	5	21	617	86	Dairy cleaning	I
Chloramine T, 0.6 g/L, 222 ppm available Cl <sup>-</sup>	5	21	0	0	Dairy cleaning	I
Trisodium phosphate						
0.16% solution	5 h	66	1,059	150	Dairy cleaning	I
0.16% solution	5 h	66	47	7	Dairy cleaning	I
0.50% solution	5 h	66	876	120	Dairy cleaning	I
0.50% solution	5 h	66	Gained weight		Dairy cleaning	I
Carbon tetrachloride-benzol						
90%-10% mixture	40	RT	1,522	210	Dry cleaning	I
90%-10% mixture	38	140	Very high		Dry cleaning	I

Perchlorethylene						
vapor	64	127	4,300	600	Dry cleaning	I
liquid	64	151	14,874	2,080	Dry cleaning	I
Syndet components						
sodium tripolyphosphate 0.08%	7 h	95	6,883	965	Individual component of syndet at concentration present in detergent	M
tetrasodium pyrophosphate 0.085%	7 h	95	4,856	680		M
sodium perborate 0.064%	7 h	95	976	137		M
sodium carbonate 0.18%	7 h	95	625	87		M
sodium sulfate 0.12%	7 h	95	250	35		M
sodium chloride 0.004%	7 h	95	488	68		M
sodium metasilicate 0.045%	7 h	95	650	91		M
lauryl alcohol sulfonate 0.18%	7 h	95	538	75		M
lauric acid ethanalamide 0.015%	7 h	90	187	26	Solution also contained 0.1% sodium perborate; solution renewed every hour	M
sodium tripolyphosphate 0.15%	12 h	90	36,534	5,090		L
sodium tripolyphosphate 0.50%	12 h	90	49,640	6,950		L
tetrasodium pyrophosphate 0.15%	12 h	90	32,193	4,510		L
sodium metaphosphate 0.15%	12 h	90	35,551	4,980		L
ordinary soap 0.3%	12 h	90	4,672	655		L
lauryl sulfate 0.05%	12 h	90	Gain	Gain		L
sodium carbonate, tech calcined 0.1%	12 h	90	2,409	340		L
sodium metasilicate · 5H <sub>2</sub> O 0.03%	12 h	90	438	61	Perborate-free solutions	L
sodium sulfate cryst 0.05%	12 h	90	4,818	675		L
sodium trisulfate 0.15%	12 h	90	8,249	1,155		L
sodium carbonate 0.1%	12 h	90	1,022	143		L
sodium metasilicate · 5H <sub>2</sub> O 0.03%	12 h	90	Gain	Gain		L
ordinary soap, 0.03%	12 h	90	4,745	665		L
Tetrasodium pyrophosphate						
0.1%	20 min	95	3,940	560	Effect of solution concentration and duration of immersion	M
0.1%	20 min	95	27,070	3,760		M
0.1%	80 min	95	10,840	1,525		M
0.1%	7 h	95	4,850	685		M

Table 5.1 Continued

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P	=	Bacon and Nutting (1952)				

  

Materials	Time (days unless otherwise indicated)	Temperature (°C)	Corrosion rates		Remarks	Refs.
			g/m <sup>2</sup> /5 cycles	μm/year		
Tetrasodium pyrophosphate						
0.5 g/L in 0 g water		bp	6.0	(1,965)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle g/m <sup>2</sup> /5 cycles × 328 = μm/year Aeration and agitation from boiling	K
0.5 g/L in 21 g water		bp	1.2	(391)		K
0.5 g/L in 21 g water + 1 g/L perborate		bp	1.5	(493)		K
1.0 g/L in 0 g water		bp	11.2	(3,665)		K
1.0 g/L in 21 g water		bp	4.7	(1,540)		K
1.0 g/L in 21 g water + 1 g/L perborate		bp	5.1	(1,670)		K
2.0 g/L in 0 g water		bp	25.8	(8,460)		K
2.0 g/L in 21 g water		bp	19.0	(6,450)		K
2.0 g/L in 21 g water + 1 g/L perborate		bp	21.2	(6,935)		K
3.0 g/L in 0 g water		bp	34.5	(11,300)		K
3.0 g/L in 21 g water		bp	27.2	(8,915)		K
3.0 g/L in 21 g water + 1 g/L perborate		bp	32.8	(10,745)		K

## Sodium tripolyphosphate

0.01%	20 min	95	2,630	380	Effect of solution concentration and duration of immersion	M
0.05-1%	20 min	95	31,270	4,400		M
0.08%	7 h	95	6,880	965		M
0.5 g/L in 0 g water		bp	5.4	(1,770)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle $\text{g/m}^2/5 \text{ cycles} \times 328 = \mu\text{m/year}$ Aeration and agitation from boiling	K
0.5 g/L in 21 g water		bp	2.8	(920)		K
0.5 g/L in 21 g water + 1 g/L perborate		bp	3.7	(1,210)		K
1.0 g/L in 0 g water		bp	14.8	(4,850)		K
1.0 g/L in 21 g water		bp	8.5	(2,800)		K
1.0 g/L in 21 g water + 1 g/L perborate		bp	11.4	(3,730)		K
2.0 g/L in 0 g water		bp	36.9	(12,100)		K
2.0 g/L in 21 g water		bp	24.9	(8,150)		K
2.0 g/L in 21 g water + 1 g/L perborate		bp	29.7	(9,730)		K
3.0 g/L in 0 g water		bp	46.2	(15,140)		K
3.0 g/L in 21 g water		bp	32.6	(10,700)		K
3.0 g/L in 21 g water + 1 g/L perborate		bp	39.8	(13,030)		K

## Sodium metaphosphate

0.5 g/L in 0 g water		bp	5.9	(1,930)	5 cycles, each 30 min at boiling + 15 min cooling; solution renewed after each cycle	K
0.5 g/L in 21 g water		bp	3.7	(1,210)		K
0.5 g/L in 21 g water + 1 g/L perborate		bp	4.8	(1,570)		K
1.0 g/L in 0 g water		bp	17.1	(5,610)	Aeration and agitation from boiling	K
1.0 g/L in 21 g water		bp	9.9	(3,250)		K
1.0 g/L in 21 g water + 1 g/L perborate		bp	15.9	(5,210)		K
2.0 g/L in 0 g water		bp	32.9	(10,770)		K
2.0 g/L in 21 g water		bp	28.1	(9,200)		K
2.0 g/L in 21 g water + 1 g/L perborate		bp	33.1	(10,850)		K

Table 5.1 Continued

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M	=	Bablik and Belohlavy (1957)				
P	=	Bacon and Nutting (1952)				
Materials	Time (days unless otherwise indicated)	Temperature (°C)	Corrosion rates		Remarks	Refs.
			g/m <sup>2</sup> /5 cycles	μm/year		
3.0 g/L in 0 g water		bp	49.0	(16,050)	5 cycles, each 30 min at boiling + 15 min cooling; solution renewed after each cycle Aeration and agitation from boiling	K
3.0 g/L in 21 g water		bp	37.4	(12,250)		K
3.0 g/L in 21 g water + 1 g/L perborate		bp	47.4	(15,550)		K
Tetrasodium pyrophosphate			mg/m <sup>2</sup> /year			
0.06% solution	6 h	80	8,570	1,200		P
0.15% solution of mixture: 40% tetrasodium pyrophosphate + 30% trisodium phosphate · 12H <sub>2</sub> O + 30% sodium metasilicate · 5H <sub>2</sub> O	6 h	80	65,300	9,150		P
0.15% solution of mixture: 31.2% sodium hexametaphosphate + 24.7% trisodium phosphate · 12H <sub>2</sub> O + 39.2% sodium metasilicate · 5H <sub>2</sub> O + 4.5% sodium carbonate	6 h	80	20,000	2,800		P

# Commercial Soaps and Syndets

## Syndet 1

0.2% solution (Fab)	1 week	RT	235	33		I
0.2% solution (Fab)	7 h	60	18	<2		I

## Syndet 2

0.2% solution (Mytron)	1 week	RT	890	125		I
0.2% solution (Mytron)	7 h	60	57	8		I
0.2% solution + sodium silicate	1 week	RT	1,215	170		I

## Syndet 3

0.2% solution (OS)	1 week	RT	870	122		I
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## Syndet 4

0.2% solution (Tide)	1 week	RT	400	56		I
0.2% solution (Tide)	7 h	60	71	10		I

## Syndet 5 containing phosphates

0.5% solution	20 min	95	51,500	7,215	pH 10.20	M
0.5% solution	80 min	95	16,850	2,360		M
0.5% solution	4 h	95	9,250	1,295		M
1.0% solution	20 min	95	89,350	12,520		M
0.5% solution		95	3,000	415	5 consecutive 20 min cycles on same piece	M
0.5% solution		95	3,050	430		M
0.5% solution		95	4,535	655		M
0.5% solution		95	4,600	650		M
0.5% solution		95	5,060	710		M

## Syndet 6

0.4% solution	80 min	95	13,600	1,905	pH 9.89	M
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## Soap 1

0.8% solution, pH 10.65	80 min	95	4,355	610	5 consecutive 20 min cycles on same piece	M
0.8% solution, pH 10.65		95	1,050			M
0.8% solution, pH 10.65		95	685			M
0.8% solution, pH 10.65		95	370			M
0.8% solution, pH 10.65		95	210			M
0.8% solution, pH 10.65		95	105			M



Table 5.1 Continued

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L	=	Bukowiecki (1958)				
M	=	Bablik and Belohlavy (1957)				
P	=	Bacon and Nutting (1952)				
Materials	Time (days unless otherwise indicated)	Temperature (°C)	Corrosion rates		Remarks	Refs.
			mg/m <sup>2</sup> /year	μm/year		
Soap 2						
0.8% solution, pH 10.73	80 min	95	1,450	203		M
0.8% solution, pH 10.73	4 h	95	490	69		M
0.5% solution	20 min	95	4,470	635		M
2.0% solution	20 min	95	6,310	890		M
Syndet 7 (U.S.)			g/m <sup>2</sup> /5 cycles			
in 0 g water		bp	49.0	(16,050)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle.	K
in 12.5 g water		bp	24.8	(8,130)		K
Syndet 8 (German)					Aeration and agitation from boiling	
in 0 g water		bp	7.9	(2,590)		K
in 12.5 g water		bp	13.8	(4,520)	K	
Syndet 9 (Swiss)						
in 0 g water		bp	7.8	(2,540)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle.	K
in 12.5 g water		bp	14.1	(4,620)		K
Syndet 10					Aeration and agitation from boiling	
in soft water		bp	58.9	(19,250)		K
+ 1% acid orthophosphate		bp	54.2	(17,730)		K
+ 5% acid orthophosphate		bp	47.8	(15,650)		K
+ 10% acid orthophosphate		bp	31.0	(10,160)	K	

# Syndet 11

in soft water (silicates; no orthophosphate)	bp	34.5	(11,330)	K
+ 1% acid orthophosphate	bp	28.2	(9,250)	K
+ 5% acid orthophosphate	bp	17.9	(5,870)	K
+ 10% acid orthophosphate	bp	8.7	(2,845)	K

# Syndet 12

in soft water	bp	22.4	(7,340)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle.	K
+ 1% acid orthophosphate	bp	20.4	(6,680)		K
+ 5% acid orthophosphate	bp	19.6	(6,430)		K
+ 10% acid orthophosphate	bp	17.3	(5,660)		K
Hard water soap 3 (U.S.)				g/m <sup>2</sup> /5 cycles × 328 = μm/year Aeration and agitation from boiling	
in 0 g water	bp	7.9	(2,590)		K
in 12.5 g water	bp	13.2	(4,320)		K
Hard water soap 4 (Swiss)					
in 0 g water	bp	2.2	(720)		K
in 12.5 g water	bp	6.6	(2,160)		K

# Laboratory-Prepared Soap Mixtures and Syndets\*

## Syndet I

6 g/L in 0 g water	bp	40.2	(13,160)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle. Aeration and agitation from boiling	K
6 g/L in 21 g water	bp	28.5	(9,350)		K
6 g/L in 42 g water	bp	12.1	(3,960)		K
6 g/L + 0.3 g/L sodium metasilicate 0 g H <sub>2</sub> O	bp	36.4	(1,200)		K
0.3 g/L sodium disilicate 0 g H <sub>2</sub> O	bp	32.9	(1,080)		K
0.3 g/L sodium trisilicate 0 g H <sub>2</sub> O	bp	27.6	(9,040)		K
1.8 g/L sodium trisilicate 0 g H <sub>2</sub> O	bp	18.3	(6,000)		K
0.3 g/L monoammonium phosphate 0 g H <sub>2</sub> O	bp	22.2	(7,260)		K
0.3 g/L monoammonium phosphate 21 g H <sub>2</sub> O	bp	14.6	(4,780)		K

Table 5.1 Continued

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L	=	Bukowiecki (1958)				
M	=	Bablik and Belohlavy (1957)				
P	=	Bacon and Nutting (1952)				
Materials	Time (days unless otherwise indicated)	Temperature (°C)	Corrosion rates		Remarks	Refs.
			g/m <sup>2</sup> /5 cycles	µm/year		
0.18 g/L sodium nitrate 0 g H <sub>2</sub> O		bp	24.1	(7,900)	5 cycles, each 30 min at boiling + 15 min cooling: solution renewed after each cycle. Aeration and agitation from boiling	K
0.3 g/L magnesium lactate 0 g H <sub>2</sub> O		bp	19.3	(6,325)		K
0.3 g/L magnesium lactate 21 g H <sub>2</sub> O		bp	21.0	(6,880)		K
0.3 g/L calcium chloride 0 g H <sub>2</sub> O		bp	16.0	(5,230)		K
0.36 g/L sodium thiosulfate		bp	16.8	(5,510)		K
0.3 g/L sodium aluminate 0 g H <sub>2</sub> O		bp	21.7	(7,110)		K
0.3 g/L sodium perborate 0 g H <sub>2</sub> O		bp	56.2	(18,400)		K
0.3 g/L sodium perborate 21 g H <sub>2</sub> O		bp	34.7	(11,380)		K
Syndet 1, 6 g/L + magnesium silicate 0.18 g/L +						
0 g/L perborate - 0 g H <sub>2</sub> O		bp	51.9	(17,000)		K
2 g/L perborate - 0 g H <sub>2</sub> O		bp	55.8	(18,300)		K
4 g/L perborate - 0 g H <sub>2</sub> O		bp	64.8	(21,200)		K
6 g/L perborate - 0 g H <sub>2</sub> O		bp	75.1	(24,600)		K
8 g/L perborate - 0 g H <sub>2</sub> O		bp	79.0	(26,000)		K
10 g/L perborate - 0 g H <sub>2</sub> O		bp	81.2	(26,700)		K
12 g/L perborate - 0 g H <sub>2</sub> O		bp	82.0	(26,900)		K
13 g/L perborate - 0 g H <sub>2</sub> O		bp	81.9	(26,900)		K
15 g/L perborate - 0 g H <sub>2</sub> O		bp	80.4	(26,400)		K
20 g/L perborate - 0 g H <sub>2</sub> O		bp	63.7	(20,850)		K

Syndet II <sup>a</sup>						
6 g/L solution	12 h	20	5,800	810	} Solution renewed every hour—HDG  + Vigorous aeration and agitation here	L
6 g/L solution	12 h	40	13,200	1,850		L
6 g/L solution	12 h	65	27,800	3,890		L
6 g/L solution	12 h	90	57,300	8,030		L
6 g/L solution	12 h	90	59,500	8,330		L
6 g/L solution	12 h	90	49,100	6,880	} Solutions renewed every hour—zinc Solutions renewed every hour—HDG Vigorous aeration and agitation	L
without perborate, 5 g/L	12 h	90	5,250	735		L
without perborate, 5 g/L	12 h	90	13,200	1,850		L
Soap detergent I						
9 g/L	12 h	90	3,785	530	HDG—solutions renewed every hour	L
9 g/L	12 h	90	1,165	163	Zinc—solutions renewed every hour	L
8 g/L	12 h	90	1,380	193	HDG—solutions renewed every hour	L
Soap detergent II						
9 g/L	12 h	90	12,350	1,730	HDG—solutions renewed every hour	L
9 g/L	12 h	90	4,530	635	Zinc—solutions renewed every hour	L
8 g/L	12 h	90	6,000	840	HDG—solutions renewed every hour	L

<sup>a</sup>Compositions of laboratory syndets and soaps:

Syndet I: sodium tripolyphosphate, 50%; sodium sulfate, 19%; dodecylbenzylsulfonate, 10%; sodium perborate · (4H<sub>2</sub>O), 8%; lauryl sulfate, 5%; sodium metasilicate, 5%; sodium chloride, 1%; sodium salt of EDTA, 0.5%; carboxymethyl cellulose, 0.5%; water, 1%.

Syndet II: lauryl sulfate, 10%; dodecylbenzylsulfonate, 17%; sodium tripolyphosphate, 30%; tetrasodium pyrophosphate, 5%; waterglass (powder), 6%; magnesium silicate, 2%; carboxymethylcellulose, 1%; sodium sulfate, 13%; sodium perborate, 16%.

Soap detergent I: ordinary soap, 40%; soda, 25%; trisodium phosphate, 11%; tetrasodium pyrophosphate, 5%; waterglass (powder), 6%; magnesium silicate, 2%; sodium perborate, 11%.

Soap detergent II: ordinary soap, 35%; soda, 21%; trisodium phosphate, 5%; sodium tripolyphosphate, 20%; waterglass (powder), 6%; magnesium silicate, 2%; sodium perborate, 11%.