Corrosion Resistance of 20Cb-3 Stainless

The corrosion resistance of 20Cb-3 stainless in pure sulfuric acid at 176°F (80°C) and at the boiling point are shown in Figures 1 and 2. The corrosion resistance is expressed as a corrosion rate in inches penetration per year (ipy). The corrosion rates in pure sulfuric acid should be used only as a guide since many contaminants in commercial sulfuric acid decrease the corrosive attack. Corrosion rates in sulfuric acid are actually much lower in the presence of iron, copper, and chromium ions, usually present in pickling and plating solutions. Higher rates may occur in the presence of chloride ions.

At 176°F (80°C) 20Cb-3 stainless exhibits a slight improvement over the former lower nickel grade, Carpenter 20 stainless. In the region of the "hump," which exists in the range of 60 to 75% sulfuric acid, 20Cb-3 stainless generally exhibits about half the corrosion rate experienced in the lower nickel grade. Although 20Cb-3 stainless would not usually be recommended for service in 60 to 75% sulfuric acid, the alloy offers an advantage in the case of accidental dilution of acid into this range.

The corrosion rates in boiling sulfuric acid for 20Cb-3 stainless are significantly lower than the lower nickel grade -- particularly above 10% acid.

Figure 1

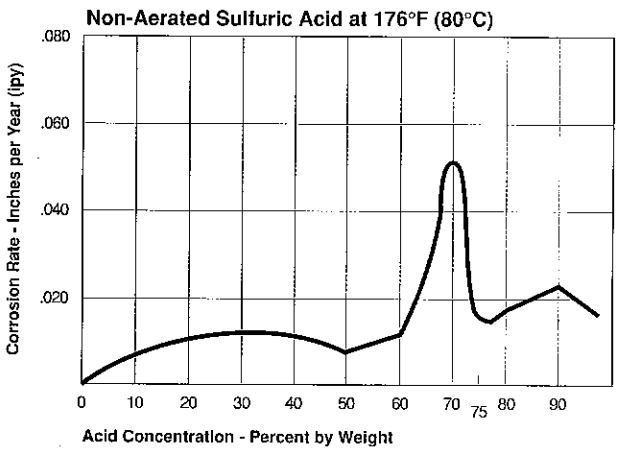


Figure 2

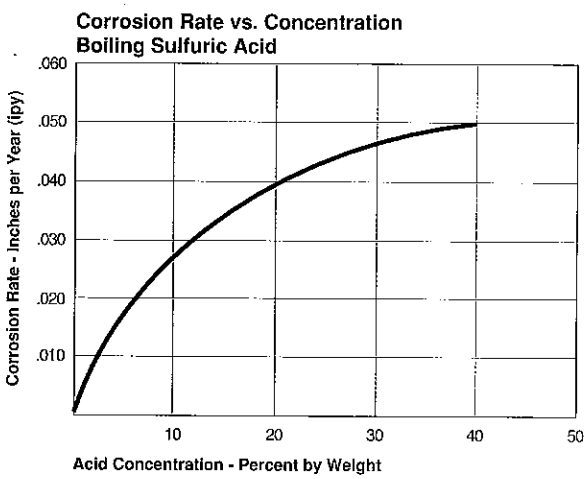


Figure 3 shows an iso-corrosion chart for 20Cb-3 stainless. The chart is divided into zones according to the corrosion resistance of 20Cb-3 stainless exposed to the range of temperatures and concentrations represented by each zone. These data are based on laboratory tests in reagent grade H_2SO_4 with no intentional aeration or deaeration. The chart provides resistance to only general corrosion and is intended for general guidance as the corrosion resistance can vary with impurities, aeration, etc. See page 13 for other factors that influence corrosion resistance.

Heat Transfer Conditions

The corrosion rates presented in Figure 4 were obtained under conditions that are frequently encountered in the chemical process industries. Many times the application of a material involves a situation where the metal is maintained at a temperature above that of the corrosion environment. Thus, heat is transferred from the metal to the solution, with the metal acting as a heat transfer surface. Corrosion rates under these conditions can be markedly higher than those experienced where the metal and solution are at the same temperature and atmospheric pressure. These heat transfer tests were conducted by sealing a circular specimen to the bottom of a custom designed glass vessel.

Figure 3

Iso-Corrosion Chart for Carpenter 20Cb-3 Stainless in Sulfuric Acid

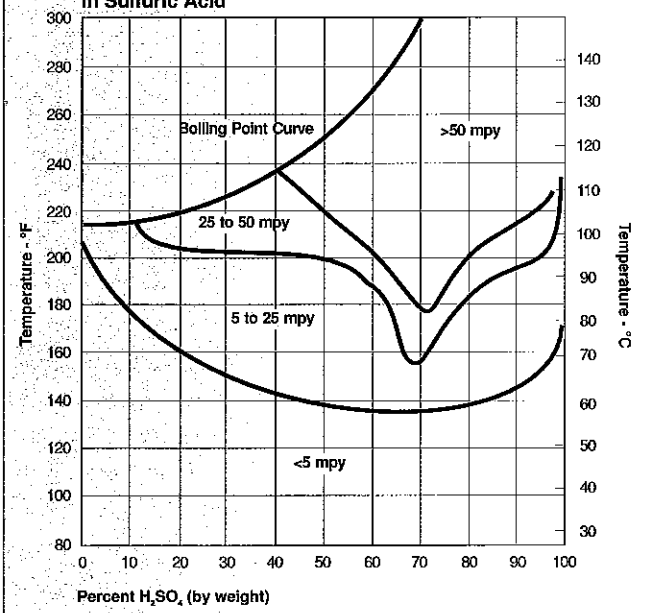
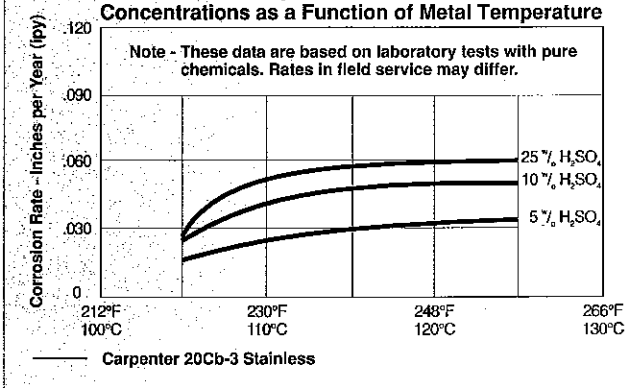


Figure 4

The Corrosion of Annealed Carpenter 20Cb-3 Stainless to Boiling Sulfuric Acid at Various Concentrations as a Function of Metal Temperature



One side of the specimen was exposed to the corrodent while the other side was heated by an external source. This enabled testing to be conducted where the metal specimen temperature was higher than the temperature of the corrodent, simulating heat exchanger conditions.

The curves shown in Figure 4 indicate the corrosion rate of 20Cb-3 stainless to various sulfuric acid concentrations as a function of the metal temperature. While the sulfuric acid solutions were maintained at their normal atmospheric boiling points of 214/223°F (101/106°C), corrosion rates were obtained at metal temperatures of 221°F (105°C) to 257°F (125°C). These data are particularly useful where sulfuric acid solutions are being heated, such as in pickling tanks.

Stress-Corrosion Resistance

The nickel content of 20Cb-3 stainless has provided resistance to stress-corrosion cracking in sulfuric acid at a variety of temperatures and concentrations. 20Cb-3 stainless also has better resistance than lower-nickel austenitic stainless to chloride stress-corrosion cracking in magnesium chloride ($MgCl_2$) boiling at 311°F (155°C), a standard test for susceptibility to this cracking mechanism. While the alloy has been made to crack in this unusually severe test, it has provided excellent resistance in most service environments. For example, 20Cb-3 stainless did not crack in boiling acidified 25% sodium chloride (NaCl, pH 1.5), an environment which cracked Type 304 and Type 316 stainless steels. This sodium chloride test is believed to provide a better indication of service performance than boiling magnesium chloride solutions.

Intergranular Corrosion Resistance

In the annealed and annealed plus sensitized [1250°F (677°C), one hour] conditions, 20Cb-3 stainless will pass the nitric acid test (240 hours in boiling 65% nitric acid) and the ferric sulfate-sulfuric acid test (120 hours in a 50% sulfuric acid solution containing ferric sulfate) with a rate of 0.002 ipm or less.

The nitric acid test is described in ASTM A-262, Practice C. The ferric sulfate-sulfuric acid test is described in ASTM A-262, Practice B, and ASTM G-28, Method A.

The 24-hour copper accelerated acidified copper sulfate test in A-262, Practice E, is also applicable to 20Cb-3 stainless in the annealed and annealed plus sensitized [1250°F (677°C), one hour] condition.

See page 30 for the heat treatment to properly stablize 20Cb-3 stainless.

Sour Service

The excellent resistance of 20Cb-3 stainless to sulfide stress cracking has enabled inclusion of this alloy in NACE MR0175, "Sulfide Stress Cracking Resistant Metallic Materials for Oil Field Equipment." The alloy (UNS N08020) is acceptable in the annealed or cold worked condition at a hardness level of Rockwell C 32 maximum.

Scaling

20Cb-3 stainless has a safe scaling temperature in continuous service of 1800°F (982°C). Figures 5 and 6 compare the oxidation resistance of 20Cb-3 stainless with that of Types 304 and 316 stainless steels. The data shown in these figures were developed in Carpenter's Research Laboratory using an electric furnace with a still air atmosphere. Oxidation rates in field service may vary depending on the atmosphere, temperature, etc.

Figure 5

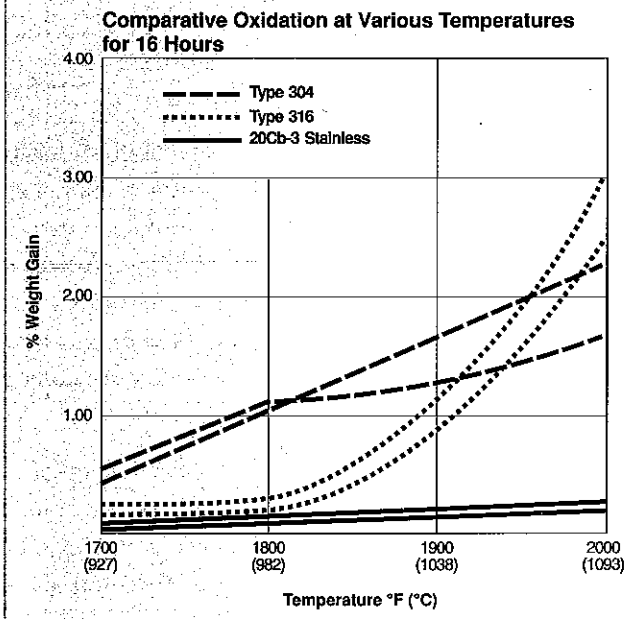
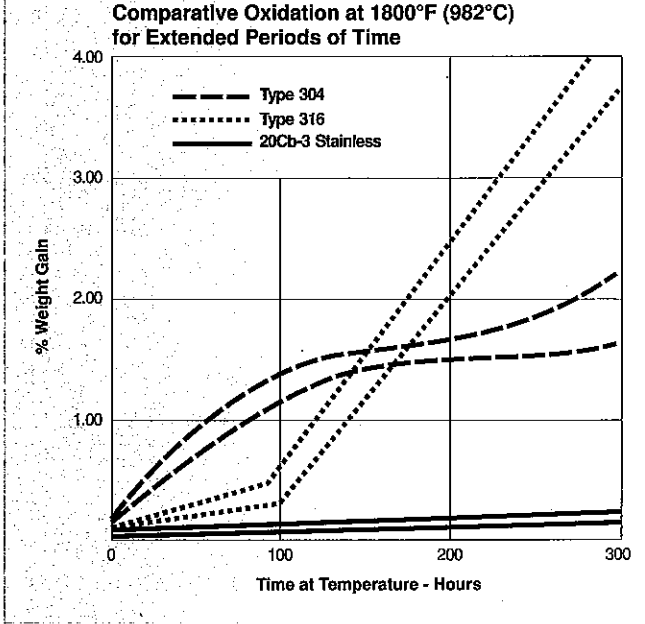


Figure 6



20Cb-3 Stainless

Corrosion Resistance Table

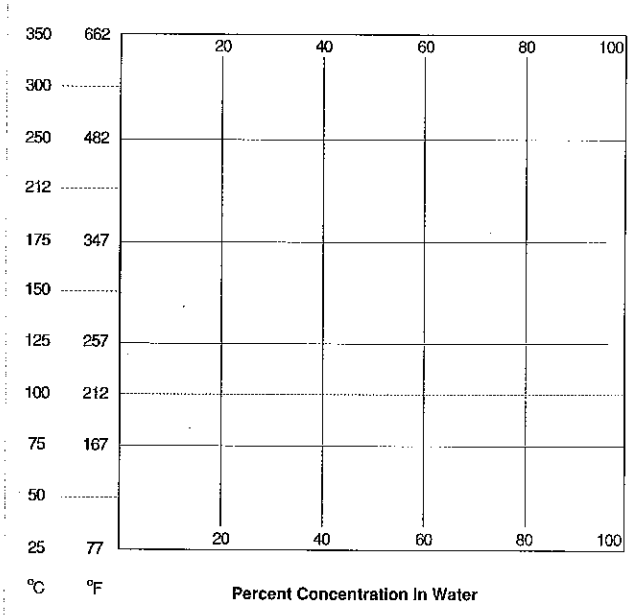
This table shows the resistance of a number of materials to the more common chemicals. Many factors influence the resistance of materials to various solutions. Factors which must be given consideration for service in corrosive environments are: temperature, concentration, aeration, influence of inhibiting or accelerating contaminants, influence of recirculation, solids in suspension, velocity, frequency of use, and equipment design. See page 13 for details.

The influence of contaminants is probably the most important from a commercial standpoint. Few corrosive solutions will be free of all contaminants. The majority of these contaminants have no influence on corrosion, but those that do generally affect the conditions greatly.

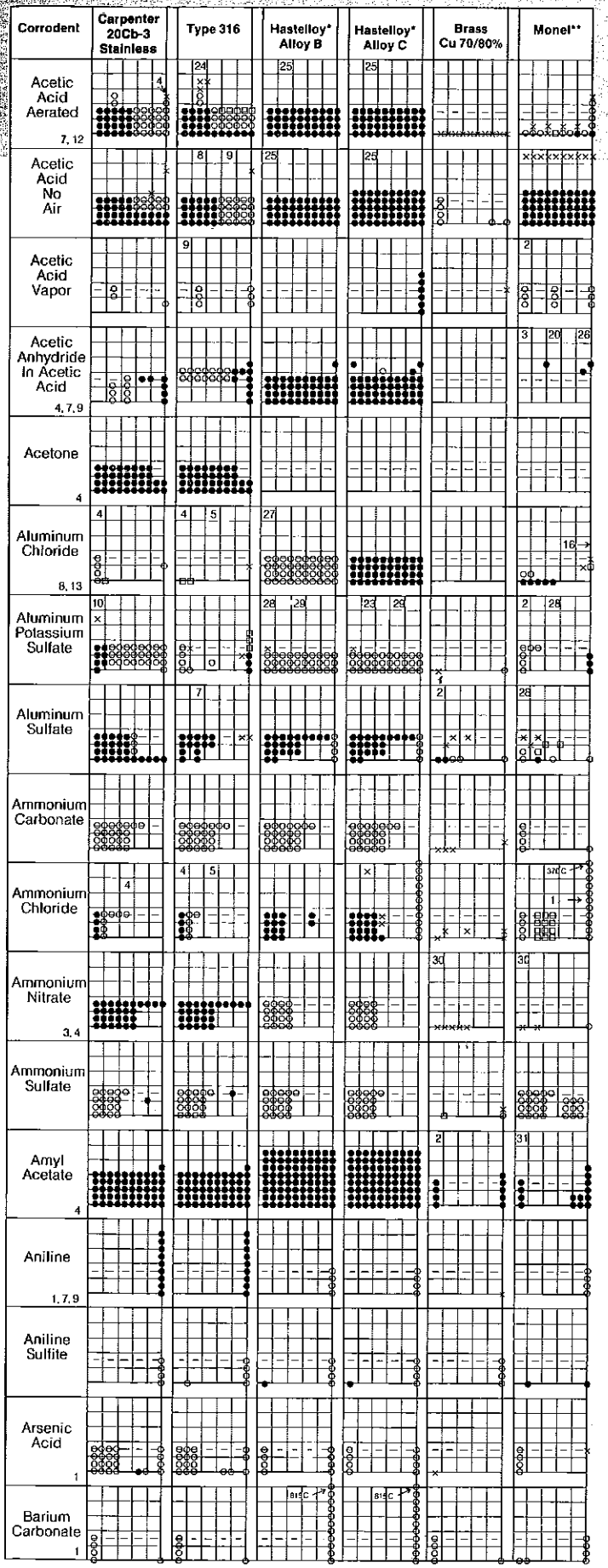
The corrosion data for all grades except 20Cb-3 stainless is reprinted from Corrosion Data Survey, 1974 Edition, published by the National Association of Corrosive Engineers. The corrosion rates for 20Cb-3 stainless represent a composite of the NACE Corrosion Data Survey and more current data developed in Carpenter's Corrosion laboratory.

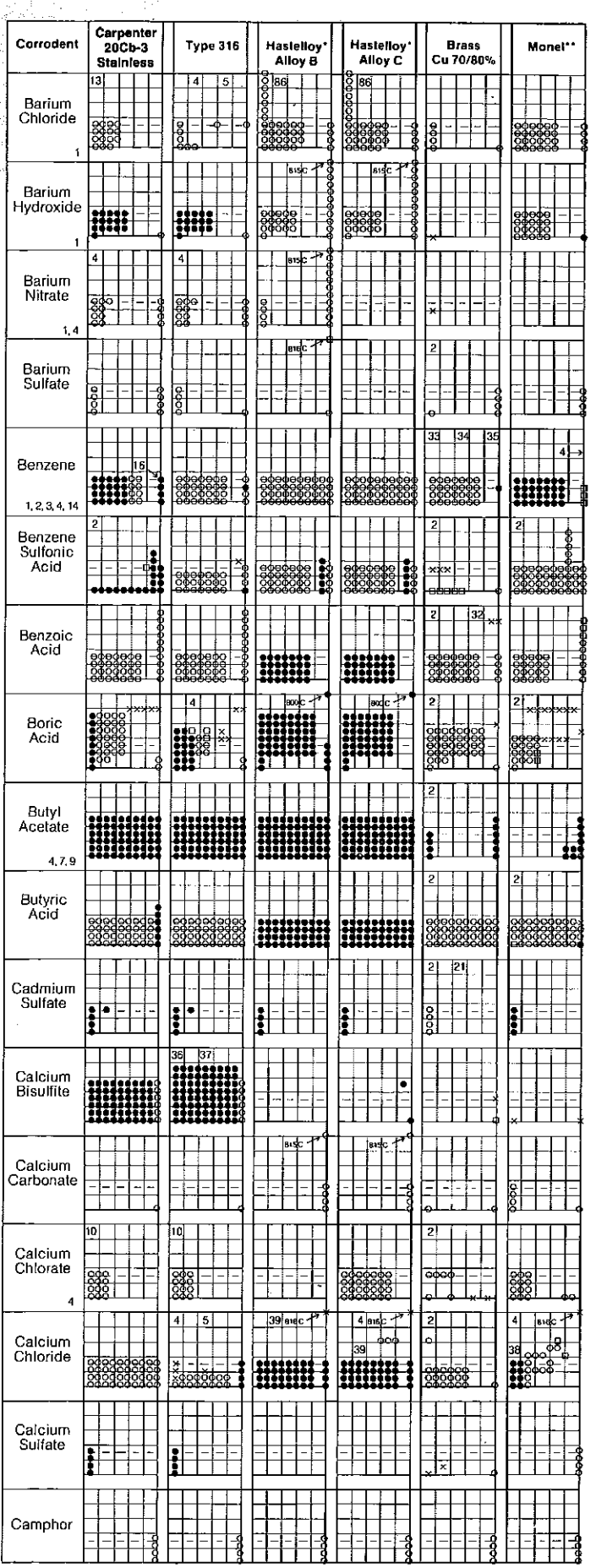
Code:

- ● Corrosion Rate less than 0.002" per year
- ○ Corrosion Rate less than 0.020" per year
- □ Corrosion Rate from 0.020" to 0.050" per year
- X Corrosion Rate greater than 0.050" per year



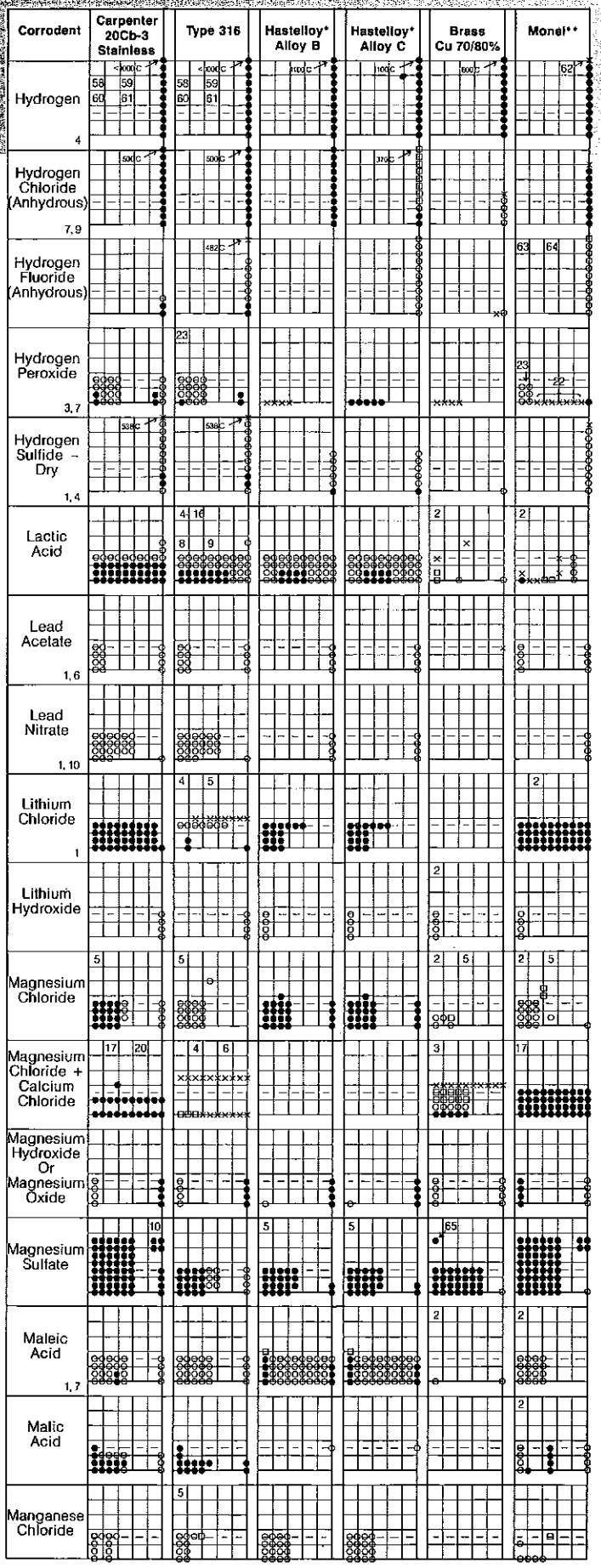
Because the in-service performance of stainless steels may be significantly affected by minor variations in environment and application, Carpenter Specialty Alloys makes no warranty, either express or implied, and accepts no liability, compensatory or consequential, for the performance of stainless steels in specific applications for which this publication may be the basis for information. See disclaimer on inside front cover.

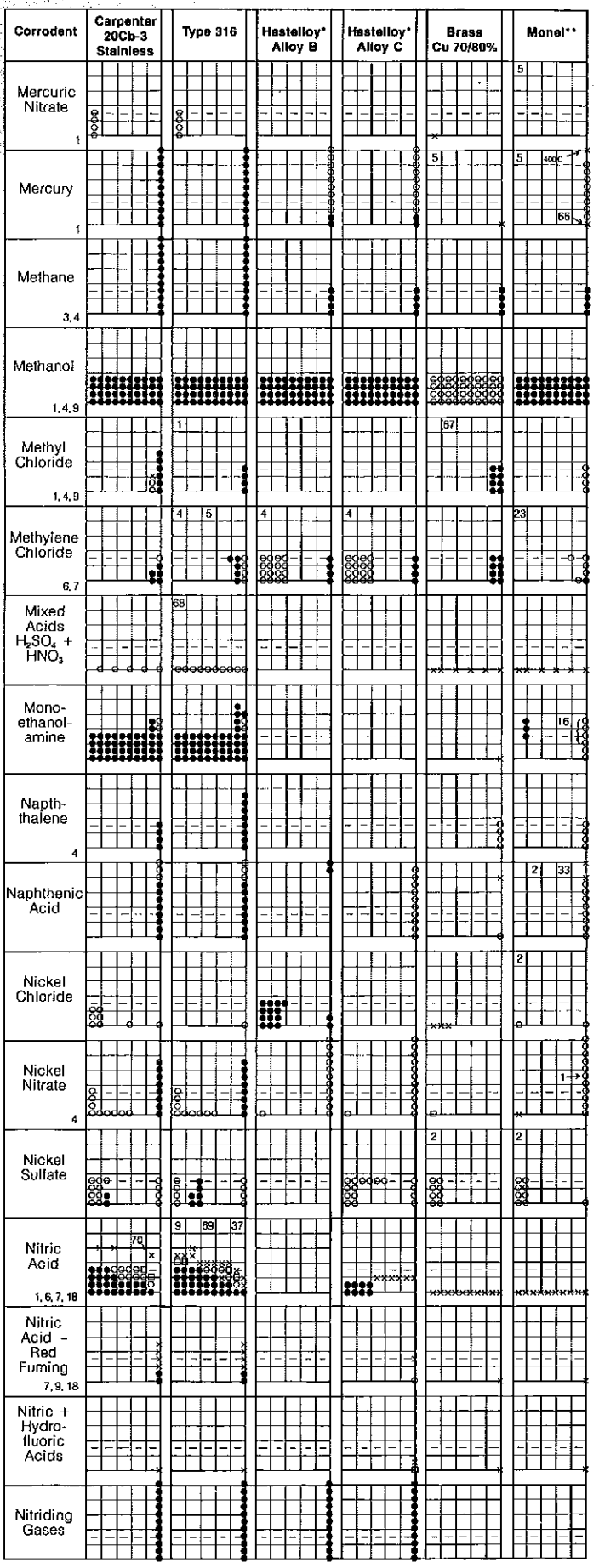

Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Acetic Acid Aerated
7, 12
Acetic Acid No Air
Acetic Acid Vapor
Acetic Anhydride In Acetic Acid
4, 7, 9
Acetone
4
Aluminum Chloride
8, 13
Aluminum Potassium Sulfate
Aluminum Sulfate
Ammonium Carbonate
Ammonium Chloride
Ammonium Nitrate
3, 4
Ammonium Sulfate
Amyl Acetate
4
Aniline
1, 7, 9
Aniline Sulfite
Arsenic Acid
1
Barium Carbonate
1


Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Barium Chloride
1
Barium Hydroxide
1
Barium Nitrate
1, 4
Barium Sulfate
Benzene
1, 2, 3, 4, 14
Benzene Sulfonic Acid
Benzoic Acid
Boric Acid
Butyl Acetate
4, 7, 9
Butyric Acid
Cadmium Sulfate
Calcium Bisulfite
Calcium Carbonate
Calcium Chlorate
4
Calcium Chloride
Calcium Sulfate
Camphor

Corrodent	Carpenter 20Cb-3 Stainless	Type 316	Hastelloy* Alloy B	Hastelloy* Alloy C	Brass Cu 70/80%	Monel**
Carbonic Acid 6, 9						
Carbon Disulfide 1, 4, 9, 15						
Carbon Monoxide 1, 4						
Carbon Tetra-chloride 1, 9						
Chlorine 1, 16						
Chloroform 1, 9						
Chloro-sulfonic Acid 1, 7, 11						
Chromic Acid 7, 10						
Chromic Sulfates						
Citric Acid						
Copper Nitrate 1, 10						
Copper Sulfate 1						
Cupric Cyanide 1						
Ethanol						
Ethyl Acetate 4						
Ethyl-Chloride 4						
Ethylene Dibro-mide 1, 8, 9						

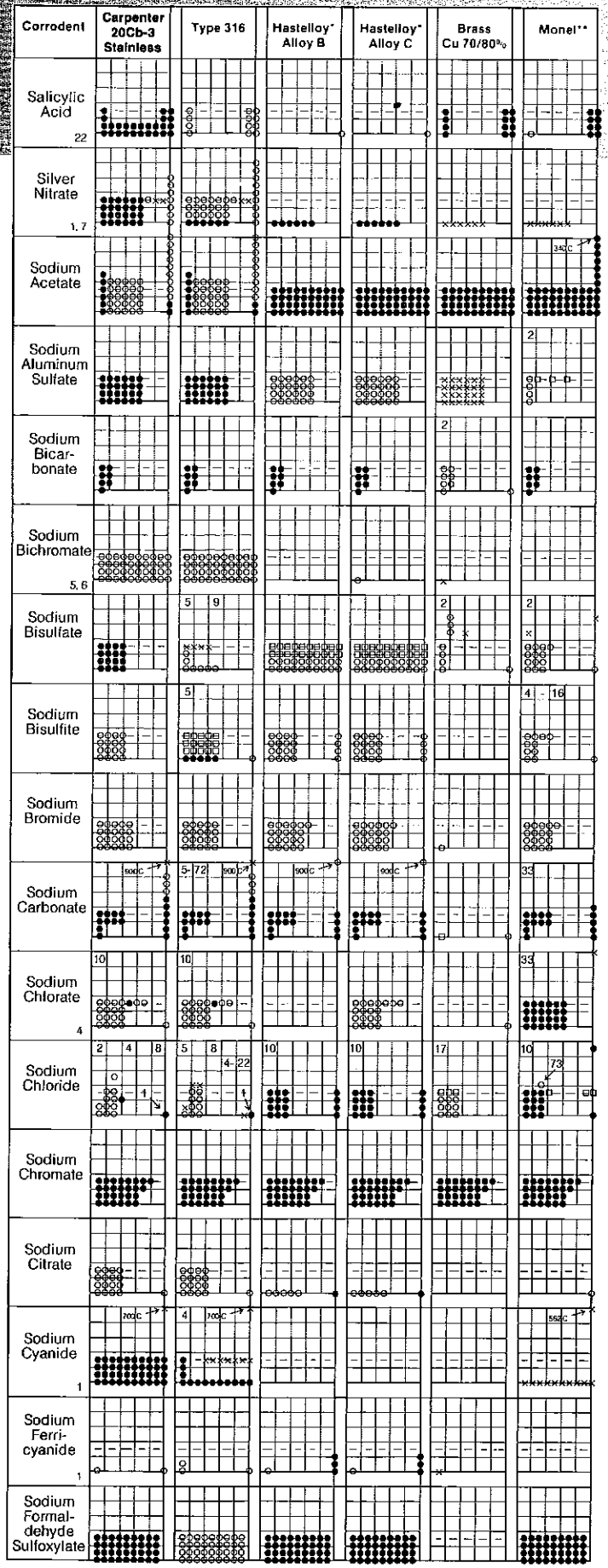
Corrodent	Carpenter 20Cb-3 Stainless	Type 316	Hastelloy* Alloy B	Hastelloy* Alloy C	Brass Cu 70/80%	Monel**
Ethylene Dichloride 4, 9						
Ferric Nitrate 4						
Ferric Sulfate						
Ferrous Sulfate						
Fluorine Gas 1, 4, 17						
Fluosilicic Acid 1						
Formal-dehyde 2, 4, 6, 8						
Formic Acid 3, 7, 9						
Furfural 4						
Gallic Acid						
Glutamic Acid						
Glycerol						
Hexa-methylene Tetramine 4, 7						
Hydro-chloric (Aerated) 1, 6, 7, 9						
Hydro-chloric Acid (No Air)						
Hydrocy-anic Acid + Hydrogen Cyanide 3, 4, 7, 9						
Hydrofluoric Acid (Aerated) 1, 7, 9						

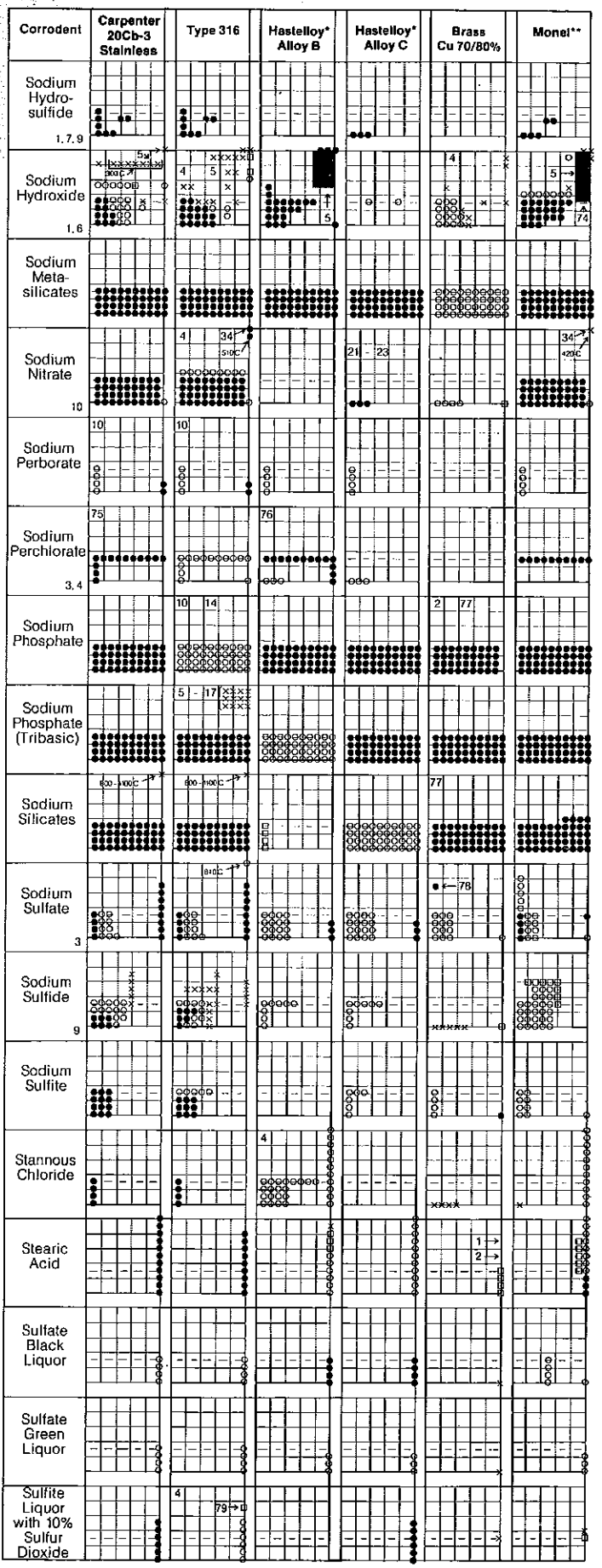

Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Hydrogen
4
Hydrogen Chloride (Anhydrous)
7, 9
Hydrogen Fluoride (Anhydrous)
Hydrogen Peroxide
3, 7
Hydrogen Sulfide – Dry
1, 4
Lactic Acid
Lead Acetate
1, 6
Lead Nitrate
1, 10
Lithium Chloride
1
Lithium Hydroxide
Magnesium Chloride
Magnesium Chloride + Calcium Chloride
Magnesium Hydroxide Or Magnesium Oxide
Magnesium Sulfate
Maleic Acid
1, 7
Malic Acid
Manganese Chloride

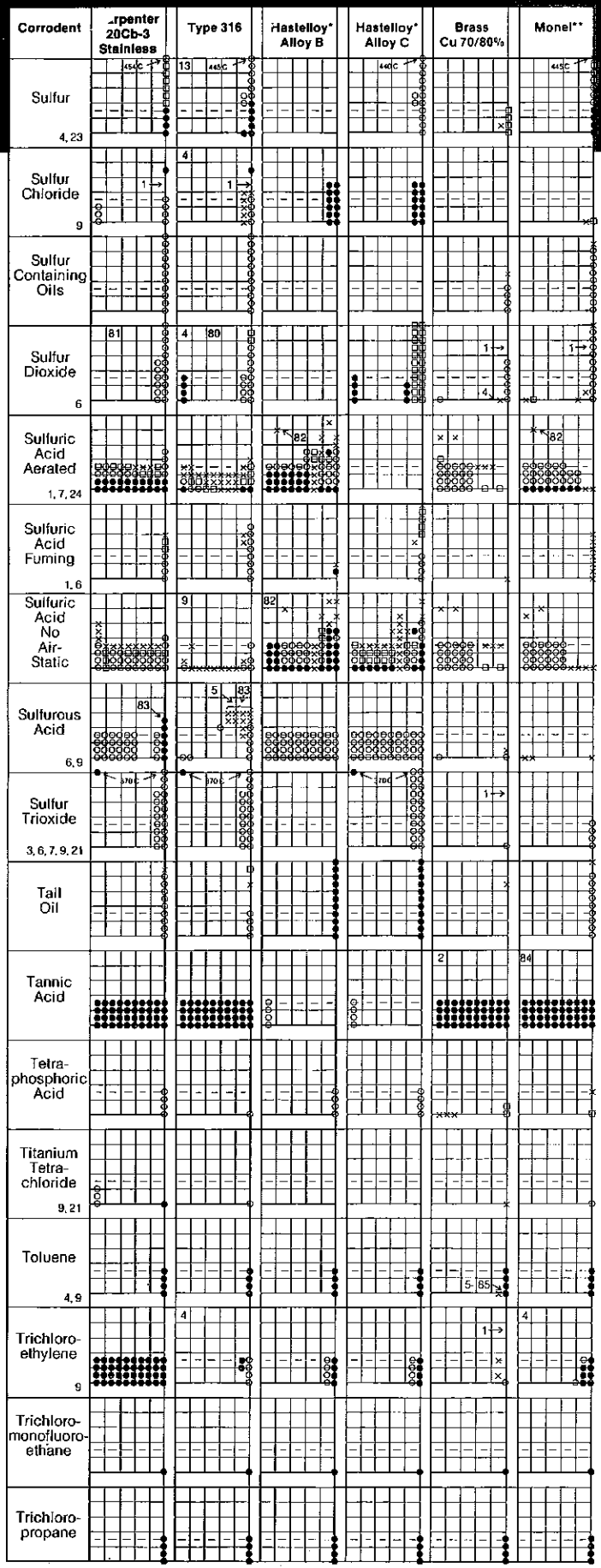

Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Mercuric Nitrate
1
Mercury
1
Methane
3, 4
Methanol
1, 4, 9
Methyl Chloride
1, 4, 9
Methylene Chloride
6, 7
Mixed Acids H_2SO_4 + HNO_3
Mono-ethanol-amine
Naph-thalene
4
Naphthenic Acid
Nickel Chloride
Nickel Nitrate
4
Nickel Sulfate
Nitric Acid
1, 6, 7, 18
Nitric Acid – Red Fuming
7, 9, 18
Nitric + Hydro-fluoric Acids
Nitriding Gases

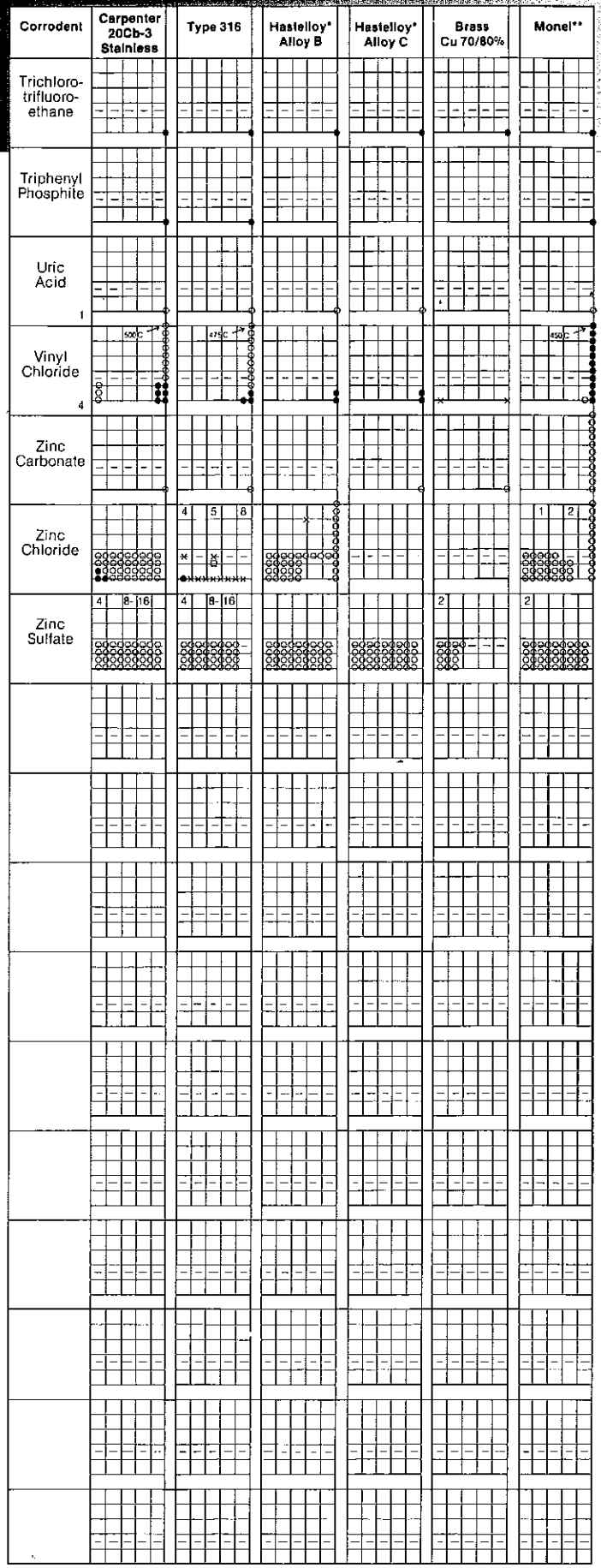
Corrodent	Carpenter 20Cb-3 Stainless	Type 316	Hastelloy* Alloy B	Hastelloy* Alloy C	Brass Cu 70/80%	Monel**
Nitro-Benzene 1, 7, 9						
Nitro-glycerin 3						
Nitrous Acids						
Nitrous Oxide						
Oleic Acid						
Oxalic Acid 1, 7						
Per-chloric Acid 7, 18, 19						
Per-chloro-ethylene 9						
Phenol 1, 7						
Phosphoric Acid (Aerated) 7						
Phosphorus 1, 4, 7, 20						
Phthalic Anhydride 7						
Phthalic Anhydride (Pure) + Maleic Anhydride						
Picric Acid 1, 3, 4						
Potassium Bromide						
Potassium Carbonate						
Potassium Chlorate 1, 10						

Corrodent	Carpenter 20Cb-3 Stainless	Type 316	Hastelloy* Alloy B	Hastelloy* Alloy C	Brass Cu 70/80%	Monel**
Potassium Chloride						
Potassium Chromate						
Potassium Cyanide 1, 6, 7						
Potassium Dichromate 1, 7						
Potassium Ferri-cyanide 1						
Potassium Ferro-cyanide 1						
Potassium Hydroxide 1, 5, 7, 8, 21						
Potassium Nitrate 4, 10						
Potassium Oxalate						
Potassium Perman-ganate 4, 10						
Potassium Peroxide 3, 4, 10						
Potassium Sulfate						
Propionic Acid						
Pyridine 4, 9						
Pyrogallic Acid						
Pyro-ligneous Acid						
Rosin 4						


Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Salicylic Acid 22
Silver Nitrate 1, 7
Sodium Acetate
Sodium Aluminum Sulfate
Sodium Bicarbonate
Sodium Bichromate 5, 6
Sodium Bisulfate
Sodium Bisulfite
Sodium Bromide
Sodium Carbonate
Sodium Chlorate 4
Sodium Chloride
Sodium Chromate
Sodium Citrate
Sodium Cyanide 1
Sodium Ferricyanide 1
Sodium Formaldehyde Sulfoxylate


Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Sodium Hydrosulfide 1, 7, 9
Sodium Hydroxide 1, 6
Sodium Metasilicates
Sodium Nitrate 10
Sodium Perborate
Sodium Perchlorate 3, 4
Sodium Phosphate
Sodium Phosphate (Tribasic)
Sodium Silicates
Sodium Sulfate 3
Sodium Sulfide 9
Sodium Sulfite
Stannous Chloride
Stearic Acid
Sulfate Black Liquor
Sulfate Green Liquor
Sulfite Liquor with 10% Sulfur Dioxide


Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Sulfur
4, 23
Sulfur Chloride
9
Sulfur Containing Oils
Sulfur Dioxide
6
Sulfuric Acid Aerated
1, 7, 24
Sulfuric Acid Fuming
1, 6
Sulfuric Acid No Air-Static
Sulfurous Acid
6, 9
Sulfur Trioxide
3, 6, 7, 9, 21
Tall Oil
Tannic Acid
Tetra-phosphoric Acid
Titanium Tetra-chloride
9, 21
Toluene
4, 9
Trichloro-ethylene
9
Trichloro-monofluoro-ethane
Trichloro-propane


Corrodent
Carpenter 20Cb-3 Stainless
Type 316
Hastelloy* Alloy B
Hastelloy* Alloy C
Brass Cu 70/80%
Monel**
Trichloro-trifluoro-ethane
Triphenyl Phosphite
Uric Acid
1
Vinyl Chloride
4
Zinc Carbonate
Zinc Chloride
Zinc Sulfate

Footnotes

Footnotes for Corrosives:

1 Poison
2 Toxic
3 Explosive
4 Flammable
5 Ingestion poison
6 Inhalant poison
7 Attacks skin
8 Irritant
9 Vapor harmful
10 Ignites organics
11 Fuming liquid
12 Hygroscopic
13 Liberates HC1 in water
14 Narcotic
15 Volatile
16 Hazardous under pressure
17 Ignites combustibles
18 Fire hazard
19 Explosive over 70%
20 Ignites in moist air at 30°C
21 Exothermic in water
22 Dust explodes
23 Explosive dust
24 Exothermic with water

* Registered Trademark of Haynes International, Inc.

** Registered Trademark of INCO

Footnotes for Data Squares:

1 No water
2 No air, oxygen
3 Low air, oxygen
4 Pits
5 Stress cracks
6 Stress corrosion
7 Discolors
8 Crevice attack
9 Intergranular attack
10 No chlorides
11 May discolor
12 May catalyze
13 May pit
14 May stress crack
15 Transgranular attack
16 Vapor
17 Aerated
18 Catalyzes
19 Static
20 Agitated
21 ~7 pH
22 <7 pH
23 >7 pH
24 No HCl, H_2SO_4, NaCl
25 No ferric chloride
26 ~0.1% acetic acid
27 Also sludge
28 No iron salts
29 No sulfuric acid
30 Explosive
31 With H_2SO_4
32 With steam
33 No sulfur
34 No stress
35 No ammonia
36 300 psi
37 Stress relieved
38 No HCl, Cu, Ni ions
39 No Cu, Fe ions
40 Over 70% air
41 20-70% air, 530 psi
42 With sulfur, <340°C =x
43 <10 mg/1
44 No H_2SO_4
45 <60 psi
46 No sulfides
47 <20% zinc
48 Trace HCl
49 pH 2 to 3.5
50 Annealed, immersed
51 >2.25% Mo
52 Erratic
53 With NaCl
54 With NaCl, HCl, H_2O_2
55 No Fe, Cl
56 With + ~0.05-1% H_3PO_4 or H_2SO_4
57 +SO_2 or HCOOH
58 >RC 22, 60,000
59 Annealed
60 No cold work
61 No H_2S
62 Permeable to H_2
63 Unsulfated
64 With or without steam
65 240 psi
66 Cold worked
67 >80% copper
68 >20% sulfuric, bal. nitric acid
69 No Mo; low C
70 Red fuming
71 Pits in chlorides
72 Over 400°C
73 Steam and air
74 75-100% concentration
75 Low NaCl
76 With HCl
77 <17% zinc
78 <0.23%, 200 psi
79 300 psi
80 No SO_3
81 No SO_3
82 High pressure
83 75-120 psi
84 No sodium sulfite
85 + ammonia
86 Avoid hydroxides
87 Saturated