On the Influence of Various Metals in Small Quantities On the Nature of Aluminium Alloys. Part 1.

By

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INTRODUCTION.

Binary alloys rich in aluminium have been studied by many authors,* and their literature is abundant, but the ternary or quaternary alloys have been rarely investigated.

As regards the influences brought in by the addition of other metals to aluminium, some were already fully investigated, some others but partially, and the rest not at all, even in the case of the binary alloys. As for those of more than the ternary system only a very limited region has been attacked in order to prove some special points, and those who want to study other problems, have to start from the very beginning.

The aim of the research hereunder communicated was based on the study of the influence of various metals in small quantities upon the physical, chemical and mechanical properties and structure of aluminium, and to obtain some new alloys with improved properties applicable to the present-day aluminium industry.

* A Part of References

Al–Cu	Guillet,	C. R. Vol. 14 (1905) 464;
		Rev. de Metal. (1905) 568.
	Curry;	Jour. Phys. Chem. Vol. 11 (1907) 425.
	Carpenter & Edwards,	Jour. Soc. Chem. Ind. Vol. 83 (1007) 127.
	Gwyer,	Z. anorg. Chem. Vol. 57 (1908) 113.
	Breckenridge,	Met. Chem. Engng. Vol. 8 (1910) 349.

FUNDAMENTAL BINARY ALLOYS.

In the case of binary alloys rich in aluminium, there are some metals which do not alloy with aluminium, e.g. lead, sodium, potassium, tharium, or bismuth; some are very hard to make alloys, offering great difficulty in practice, making them inapplicable for use in modern industry, e.g. calcium, thangsten, molybdenum or vanadium; some are harmful when added to aluminium, e.g. carbon or mercury; some are so rarely produced that they cannot be used technically, e.g. belirium, cerium, thorium, lantanium, etc.; some are very expensive and can hardly be utilized from the economical point of view, e.g. gold, platinum, and silver.

	Campbell & Mathews, &c.	Jour. Am. Chem. Soc. Vol. 24 (1902) 253; Vol. 26 (1904) 1290. &c.
Al–Si	Fraenkel,	Z. anorg. Chem. Vol. 58 (1908) 157.
	Vigouroux,	Bull. Soc. Chem. Vol. 1 (1907) 789.
	Roberts,	Chem. Soc. (London) Trans. Vol. 105 (1914) 1383.
Al–Ni	Gwyer,	Z. anorg. Chem. Vol. 57 (1908) 113.
Al–Mn	Guillet,	C. R. Vol. 134 (1908) 57.
	Gwyer,	Z. anorg. Shem. Vol. 57 (1908) 150.
	Hindricks,	Z. anorg. Chem. Vol. 59 (1908) 44.
Al–Fe	Gwyer,	Z. anorg. Chem. Vol. 59 (1908) 129.
	Portevin,	Rev. de Metal. Vol. 5 (1908) 274.
Al–Mg	Boudouard,	Jour. Soc. Chem. Ind. (1901) 814; (1902) 888.
	Grube,	Z. anorg. Chem. Vol. 45 (1905) 225.
	Barnett,	Jour. Soc. Chem. Ind. Vol. 24 (1905) 832.
	Schirmeister,	Metal u. Erz. Vol. 11 (1914) 522.
Al–Co	Gwyer,	Z. anorg. Chem. Vol. 57 (1908) 136.
	Schirmeister,	Met. Chem. Engng. Vol. 8 (1908) 650.
	Neuburger,	Electrochem. Zeit. Vol. 20 (1908) 295.
Al–Zn	Shephard,	Jour. Phys. Chem. Vol. 9 (1905) 504.
	Rosenhein & Archbutt,	Jour. Inst. Met. Vol. 9 (1911) 236.
		Jour. Soc. Cnem. Ind. Vol. 31 (1912) 499.
	Portevin,	Rev. de Metal. Vol. 8 (1911) 721.
	Lorenz & Plumbridge,	Z. anorg. Chem. Vol. 83 (1913) 243.
	Bauel & Vogel,	Jour. Inst. Met. Abst. Vol. 17 (1917) 328.
	Heycock & Neville,	Jour. Chem. Soc. Vol. 71 (1897) 383.
	&c.	&c.
Al–Sn	Campbell & Mathews,	Jour. Am. Chem. Soc. Vol. 24 (1902) 258.
	Shephard,	Jour. Phys. Chem. Vol. 9 (1905)
	Gwyer,	Z. anorg. Chem. Vol. 49 (1906 311.
	Lorenz & Plumbridge,	Z. anorg. Chem. Vol. 133 (1913) 243
	Heycock & Neville,	Jour. Chem. Soc. Vol. 57 (1890) 376.

In view of all the above facts, the author chose the following metals to be added fundamentally, i.e. copper, silicon, nickel, manganese, iron, magnesium, cobalt, zinc, and tin. It is most probable that some metals other than those mentioned above will also alloy with aluminium, improving the properties of the aluminium alloy so formed. For convenience, they are classified as special metals, and the author hopes to study them later on.

The author prepared 63 kinds of alloys, each about 1 kilogram in weight, as shown in Table 3. The purities of the used materials are shown in Table 1.

For the preparation of these alloys, "hardeners" (shown in Table 2) were first made in a graphite crucible treated in a gas furnace, and the alloys of desired percentages of added metals were subsequently prepared. These alloys were cast at about 670°C. in an iron chill mould. Greater part of the block was shaped by a lathe to a bar of 20 mm. diameter and 230 mm. length, hot rolled, annealed, and ultimately drawn to wires of

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Al–Pb	Gwyer,	Z. anorg. Chem. Vol. 57 (1908) 149.
Al–K	Smith,	Z. anorg. Chem. Vol. 56 (1908) 113.
Al–Na	Mathewson,	Z. anorg. Chem. Vol. 48 (1906) 193.
Al–Cd	Gwyer,	Z. anorg. Chem. Vol. 57 (1908) 150.
Al–Bi	Gwyer,	Z. anorg. Chem. Vol. 49 (1906) 318.
Al–Be	Oesterheld,	Z. anorg. Chem. Vol. 97 (1916) 6.
Al–Ca	Breckenridge,	Met. Chem. Engng. Vol. 8 (1910) 340.
	Donski,	Z. anorg. Chem. Vol. 59 (1908) 185.
Al–Cr	Hindricks,	Z. anorg. Chem. Vol. 59 (1908) 433.
Al–W	Guillet,	C. R. Vol. 132 (1901) 1112.
Al–Mo	Guillet,	C. R. Vol. 132 (1901) 332; Vol. 133 (1901) 291.
Al–Vd	Gzako,	C. R. Vol. 156 (1913) 140.
Al–C	Moisson,	? (1894) (Giua: Chemical Combination among Metals (1918) p. 254
Al–Hg	Tarugi,	Gozz. Chim. Ital. Vol. 34 (1904) 496.
Al–Tl	Doerinkel,	Z. anorg. Chem. Vol. 48 (1906) 189.
Al–Ce	Vogel,	Z. anorg. Chem. Vol. 75 (1912) 4.
Al–Th	Hoenigschmidt,	C. R. Vol. 142 (1906) 280.
Al–La	Muthmann & Beck,	Am. Chem. Vol. 331 (1904) 51.
Al–Sb	Campbell & Mathews,	Jour. Am. Chem. Soc. Vol. 241 (1902) 29.
	Tamman,	Z. anorg. Chem. Vol. 48 (1906) 53.
Al–Ag	Anonymous	Metal Ind. Vol. 4 (1912) 368.
	Petrenko,	Z. anorg. Chem. Vol. 46 (1912) 49.
Al–Au	Heycock & Neville,	Phil. Trans. Roy. Soc. Vol. 214 (1914) 267.
Al–Pt	Chourguine,	C. R. Vol. 155 (1912, 156.

3 mm. diameter in cold state. The rolling practice was carried out under the temperatures which were predetermined with another part of each ingot by compression tests; 7 samples of 10 mm. diameter and 15 mm. length were made from each alloy, and tested under different temperatures with Olsen's Compression Testing Machine at the Osaka Arsenal Laboratory.

Table 1. Materials Used.

Aluminium	Made in Switzerland (Chippis) . . . . (Fe: 0.31%, Si: 0.07%)	99.6%
Copper	„ Japan (Hidachi) (Electo-refined) . . .	99.9%
Iron	„ „ „ (Electo-refined) . . .	?
Silicon	„ „ (Sugibayashi	98%
Manganese	„ „ („)	98%
Nickel.	„ „ („)	98%
Magnesium	„ „ („)	?
Zinc.	„ Germany (E. Merk)	98–99%
Tin	„ „ („)	98–99%
Cobalt	„ „ („)	98–99%

Table 2. Hardeners and Their Analysis.

No.	Added Elements	Analysis %	No.	Added Elements	Analysis %
1	Si	20.00	14	Ni	22.49
2	Fe	13.60	15	Sn	40.40
3	Cu	21.52	16	Mn	20.40
4	Mn	20.89	17	Mg	16.70
5	Zn	23.46	18	Fe	14.40
6	Ni	—	19	Zn	24.62
7	Mg	16.92	20	Si	20.14
8	Mg	18.00	21	Co	21.03
9	Sn	—	22	Fe	15.88
10	Co	20.00	23	Cu	29.89
11	Cu	15.72	24	Ni	25.02
12	Sn	17.40	25	Mn	30.07
13	Ni	25.00			

Table 3. Compositions of the Fundamental Binary Alloys.

No. of Al-loys	Added Metal (%) (theor.)	Analysis %			No. of Al-loys	Added Metal (%) (theor.)	Analysis %		
1	Cu 0.1	Cu 0.15,	Fe 0.28,	Si 0.07	33	Fe 0.7	Fe 0.70,		Si 0.06
2	Cu 0.3	Cu 0.30,	Fe 0.27,	Si 0.06	34	Fe 1.0	Fe 1.20,		Si 0.07
3	Cu 0.5	Cu 0.50,	Fe 0.30,	Si 0.04	35	Fe 1.5	Fe 1.45,		Si 0.04
4	Cu 0.7	Cu 0.81,	Fe 0.29,	Si 0.07	36	Fe 2.0	Fe 2.11,		Si 0.08
5	Cu 1.0	Cu 1.10,	Fe 0.29,	Si 0.08	37	Mg 0.1	Mg 0.08,	Fe 0.25,	Si 0.02
6	Cu 1.5	Cu 1.50,	Fe 0.29,	Si 0.08	38	Mg 0.3	Mg 0.20,	Fe 0.27,	Si 0.02
7	Cu 2.0	Cu 2.00,	Fe 0.29,	Si 0.08	39	Mg 0.5	Mg 0.45,	Fe 0.28,	Si 0.02
8	Cu 2.5	Cu 2.60,	Fe 0.29,	Si 0.07	40	Mg 0.7	Mg 0.58,	Fe 0.30,	Si 0.02
9	Si 0.1	Si 0.09,	Fe 0.16,		41	Mg 1.0	Mg 0.71,	Fe 0.28,	Si 0.02
10	Si 0.3	Si 0.26,	Fe 0.30,		42	Mg 1.5	Mg 1.42,	Fe 0.29,	Si 0.03
11	Si 0.5	Si 0.40,	Fe 0.32,		43	Mg 2.0	Mg 1.63,	Fe 0.27,	Si 0.03
12	Si 0.7	Si 0.63,	Fe 0.31,		44	Co 0.1	Co 0.09,	Fe 0.28,	Si 0.02
13	Si 1.0	Si 0.87,	Fe 0.32,		45	Co 0.3	Co 0.25,	Fe 0.32,	Si 0.02
14	Si 1.5	Si 1.48,	Fe 0.31,		46	Co 0.5	Co 0.48,	Fe 0.33,	Si 0.03
15	Si 2.0	Si 1.82,	Fe 0.32,		47	Co 0.7	Co 0.71,	Fe 0.32,	Si 0.02
16	Ni 0.1	Ni 0.20,	Fe 0.31,	Si 0.06	48	Co 1.0	Co 0.98,	Fe 0.32,	Si 0.02
17	Ni 0.3	Ni 0.35,	Fe 0.30,	Si 0.08	49	Co 1.5	Co 1.52,	Fe 0.34,	Si 0.01
18	Ni 0.5	Ni 0.60,	Fe 0.28,	Si 0.05	50	Co 2.0	Co 2.03,	Fe 0.35,	Si 0.02
19	Ni 0.7	Ni 0.80,	Fe 0.27,	Si 0.06	51	Zn 0.1	Zn 0.08,	Fe 0.32,	Si 0.04
20	Ni 1.0	Ni 1.11,	Fe 0.28,	Si 0.09	52	Zn 0.3	Zn 0.38,	Fe 0.29,	Si 0.07
21	Ni 1.5	Ni 1.43,	Fe 0.29,	Si 0.05	53	Zn 0.5	Zn 0.49,	Fe 0.30,	Si 0.04
22	Ni 2.0	Ni 2.20,	Fe 0.27,	Si 0.09	54	Zn 0.7	Zn 0.70,	Fe 0.28,	Si 0.01
23	Mn 0.1	Mn 0.09,	Fe 0.20,	Si 0.03	55	Zn 1.0	Zn 1.12,	Fe 0.26,	Si 0.01
24	Mn 0.3	Mn 0.40,	Fe 0.30,	Si 0.02	56	Zn 1.5	Zn 1.86,	Fe 0.31,	Si 0.04
25	Mn 0.5	Mn 0.54,	Fe 0.28,	Si 0.03	57	Zn 2.0	Zn 2.21,	Fe 0.26,	Si 0.06
26	Mn 0.7	Mn 0.78,	Fe 0.20,	Si 0.03	58	Sn 0.1	Sn 0.12,	Fe 0.33,	Si 0.07
27	Mn 1.0	Mn 0.98,	Fe 0.34,	Si 0.02	59	Sn 0.3	Sn 0.27,	Fe 0.40,	Si 0.08
28	Mn 1.5	Mn 1.46,	Fe 0.30,	Si 0.03	60	Sn 0.5	Sn 0.54,	Fe 0.40,	Si 0.04
29	Mn 2.0	Mn 1.91,	Fe 0.30,	Si 0.02	61	Sn 0.7	Sn 0.73,	Fe 0.32,	Si 0.03
					62	Sn 1.0	Sn 0.99,	Fe 0.36,	Si 0.03
31	Fe 0.3	Fe 0.31,		Si 0.07	63	Sn 1.5	Sn 1.43,	Fe 0.44,	Si 0.02
32	Fe 0.5	Fe 0.48,		Si 0.07	64	Sn 2.0	Sn 2.13,	Fe 0.45,	Si 0.07

INFLUENCE ON THE RESISTANCE AGAINST CORROSION, AND THE APPLICATIONS.

Aluminium is one of the highly resistant metals against corrosion. However, the systematic study of this problem has not been carried very far, and it is only in special cases that the study has been made.

Resistive properties of metals against corrosion vary according to the kind of reagents, their concentrations, their temperatures, times of contact, and the degree of forging of the metals or alloys.

The reagents which the author chose were hydrochloric acid, sulphuric acid, nitric acid, sodium hydroxide, ammonium hydroxide, saturated carbonic acid, sodium chloride solution, sodium sulphite solution, and town atmosphere. Besides, acetic acid, sour plum verjuice, soy, citric acid, and malic acid were used to test the adaptability of Cooking Utensils. The concentrations of the reagents are shown in the Tables. The influence of concentration was examined only in a few cases. The experiments were carried out at room temperature from Sept. 1922 to Feb. 1923, during which it rose as high as 22°C. when stoves were used in the daytime, and sunk below 0°C. in the night. The duration of immersion was 50 days, 30 days, while 10 days were allowed for special reagents. The reagents were contained in glass basins of 20-litre capacity. The pieces were in the form of wires and cast blocks, about 20 grams in weight for each piece. As a comparison, in some cases, copper and iron were tested in different vessels, avoiding the effects of their galvanic actions. As the pure aluminium No. 31 in the Table 3 was taken as it was found to be commertially purest.

CORROSION BY SULPHURIC ACID.

Table 4 and Fig. 1 show the loss of weight after 50 days immersion in 0.5% sulphuric acid, and Figs. 2 to 10 show the variation of loss of each alloy during that interval.

Increase of the concentration of the acid does not increase the corroding action; on the contrary, the alloys become stable with the increase of the concentration, and in 30% sulphuric acid the action becomes very slow, while in concentrated sulphuric acid the alloys are hardly attacked.

In sulphuric acid, when dilute, the alloys containing nickel or copper separate out those metals and deposit them on the surface.

It may be noticed in the table that the alloys containing nickel or copper are slightly more resistive against sulphuric acid, while those containing magnesium or tin are weaker.

Table 4. Corrosion by 0.5% H_2SO_4.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	After 10 Days		After 30 Days		After 50 Days	
		Loss %	Loss Gr. × 10^{-5} per Sq. Cm.	Loss %	Loss Gr. × 10^{-5} per Sq. Cm.	Loss %	Loss Gr. × 10^{-5} per Sq. Cm.
1	Cu 0.1	1.475	295	2.858	584	3.788	767
2	Cu 0.3	1.089	221	2.396	508	3.357	733
3	Cu 0.5	1.048	208	2.280	461	3.201	655
4	Cu 0.7	1.034	213	2.268	460	3.192	653
5	Cu 1.0	1.032	212	2.184	452	3.099	630
6	Cu 1.5	1.001	205	2.150	441	3.005	616
7	Cu 2.0	0.979	203	2.122	435	2.992	613
8	Cu 2.5	0.965	201	2.031	433	2.847	603
9	Si 0.1	1.075	220	2.313	468	3.306	665
10	Si 0.3	1.081	219	2.361	469	3.308	665
11	Si 0.5	1.126	229	2.412	498	3.469	705
12	Si 0.7	1.142	232	2.462	511	3.622	722
13	Si 1.0	1.145	232	2.498	514	3.674	736
14	Si 1.5	1.147	233	2.553	524	3.689	750
15	Si 2.0	1.164	234	2.560	530	3.707	752
16	Ni 0.1	1.149	235	2.202	469	3.080	627
17	Ni 0.3	1.082	221	2.189	455	3.072	624
18	Ni 0.5	1.073	221	2.164	454	3.044	622
19	Ni 0.7	1.067	218	2.094	435	2.939	601
20	Ni 1.0	0.989	202	2.083	431	2.936	600
21	Ni 1.5	0.990	202	2.085	433	2.928	598
22	Ni 2.0	1.003	202	2.100	433	2.966	609
23	Mn 0.1	1.065	220	2.249	461	3.156	644
24	Mn 0.3	1.097	220	2.368	480	3.368	686
25	Mn 0.5	1.177	239	2.512	501	3.574	728
26	Mn 0.7	1.210	248	2.573	509	3.672	747
27	Mn 1.0	1.211	248	2.624	516	3.713	759
28	Mn 1.5	1.223	250	2.631	533	3.759	771
29	Mn 2.0	1.237	252	2.634	542	3.792	779
31	Fe 0.3	1.119	222	2.172	455	3.123	629
32	Fe 0.5	1.107	221	2.178	467	3.205	655
33	Fe 0.7	1.092	220	2.194	469	3.269	659
34	Fe 1.0	1.006	220	2.200	472	3.253	665
35	Fe 1.5	1.107	220	2.266	486	3.368	686
36	Fe 2.0	1.166	241	2.312	510	3.435	709

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	After 10 Days		After 30 Days		After 50 Days	
		Loss %	Loss Gr. × 10⁻⁵ per Sq. Cm.	Loss %	Loss Gr. × 10⁻⁵ per Sq. Cm.	Loss %	Loss Gr. × 10⁻⁵ per Sq. Cm.
37	Mg 0.1	1.213	245	2.300	531	3.769	761
38	Mg 0.3	1.315	265	2.424	556	3.895	786
39	Mg 0.5	1.351	271	2.463	598	4.304	863
40	Mg 0.7	1.479	296	2.546	643	4.584	926
41	Mg 1.0	1.624	322	2.699	722	5.320	1053
42	Mg 1.5	1.917	382	2.978	809	5.825	1159
43	Mg 2.0	2.040	410	3.142	866	6.242	1256
44	Co 0.1	1.040	210	2.172	452	3.053	624
45	Co 0.3	1.071	219	2.224	453	3.075	624
46	Co 0.5	1.079	220	2.238	458	3.092	627
47	Co 0.7	1.086	222	2.250	463	3.150	636
48	Co 1.0	1.097	225	2.301	469	3.245	662
49	Co 1.5	1.151	237	2.402	487	3.406	703
50	Co 2.0	1.188	249	2.552	540	3.627	739
51	Zn 0.1	1.012	204	2.214	441	3.000	622
52	Zn 0.3	1.045	213	2.219	446	3.048	623
53	Zn 0.5	1.054	215	2.224	452	3.114	629
54	Zn 0.7	1.057	215	2.226	458	3.135	641
55	Zn 1.0	1.059	216	2.227	463	3.155	645
56	Zn 1.5	1.166	238	2.240	487	3.333	676
57	Zn 2.0	1.341	277	2.266	541	3.609	731
58	Sn 0.1	1.011	205	2.258	458	3.265	662
59	Sn 0.3	1.045	211	2.281	470	3.327	673
60	Sn 0.5	1.062	216	2.360	477	3.408	689
61	Sn 0.7	1.076	217	2.374	489	3.466	709
62	Sn 1.0	1.083	221	2.412	493	3.509	716
63	Sn 1.5	1.132	229	2.572	519	3.758	759
64	Sn 2.0	1.732	359	4.473	937	7.082	1471
	Cu	0.163	103	0.469	322	0.796	537

CORROSION BY NITRIC ACID.

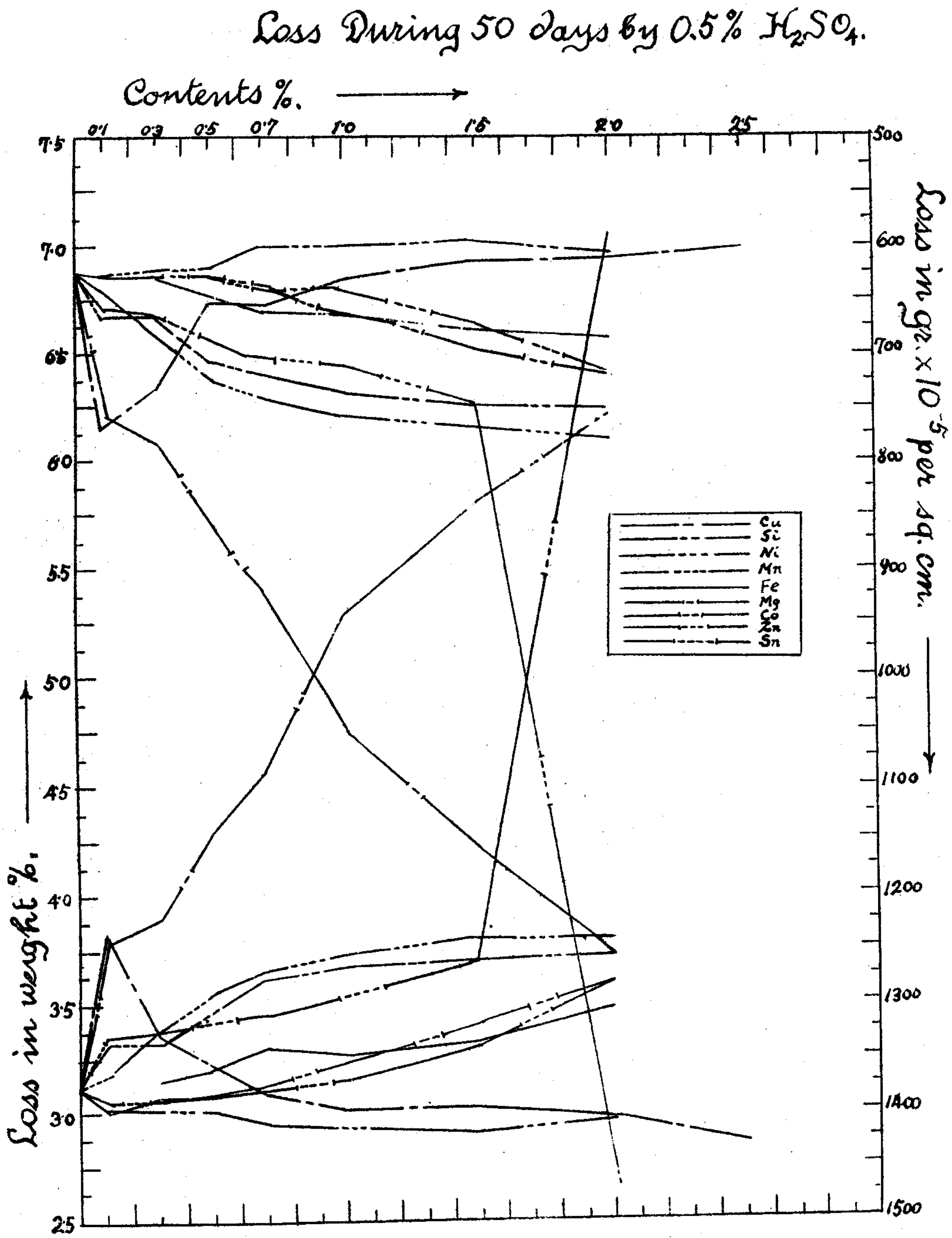
Table 5 and Fig. 11 show the loss of weight after 50 days immersion in 0.5% nitric acid, and Figs. 12 to 20 show the variation of loss of each alloy during that interval.

Increase of the concentrations of the reagent increases its action very slowly by about 8 or 10%.

Alloys that have been dipped in nitric acid for a long time remain bright pearly white, as the metals deposited on the surface are dissolved away by the reagent.

It was observed that the alloys containing copper or manganese were stronger than pure aluminium in the solution, while those containing magnesium or tin were weaker.

Fig. 1



Loss During 50 days by 0.5% H_2SO_4.
Contents %.
0.1
0.3
0.5
0.7
1.0
1.5
2.0
2.5
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
Loss in weight %.
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Loss in gr. × 10⁻⁵ per sq. cm.
Cu
Si
Ni
Mn
Fe
Mg
Co
Zn
Sn

Fig. 2

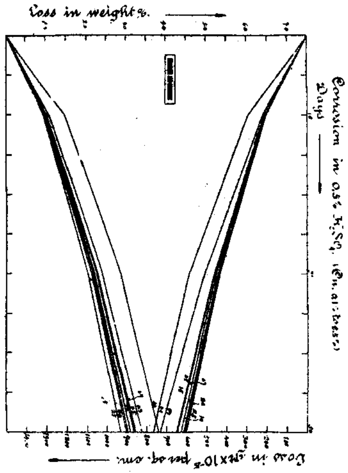


Fig. 3

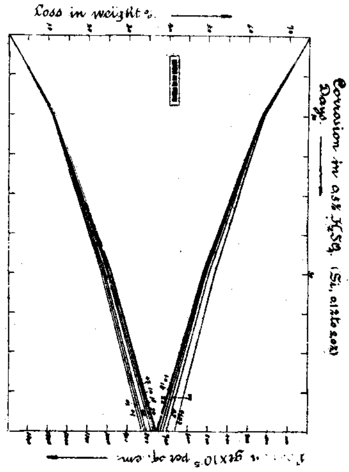


Fig. 4

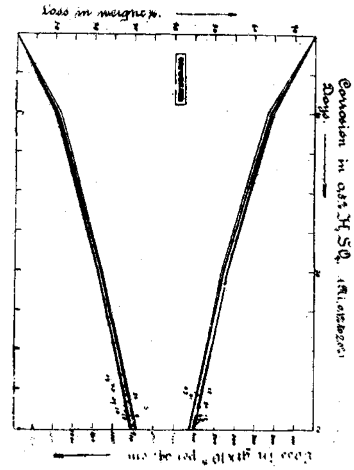


Fig. 5

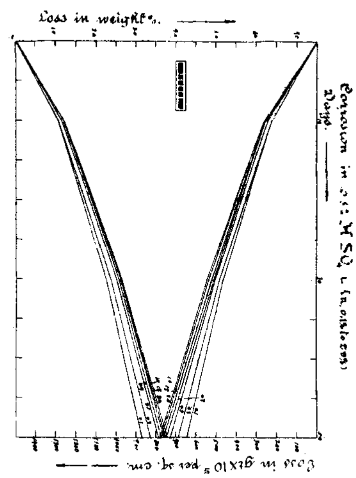


Fig. 6

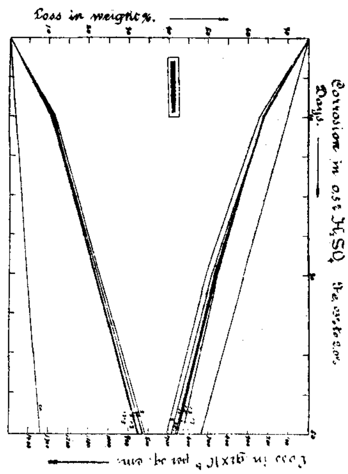


Fig. 7

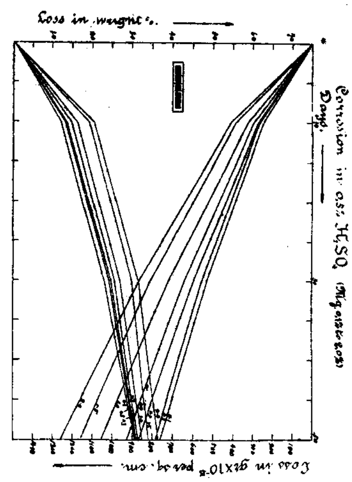


Fig. 8

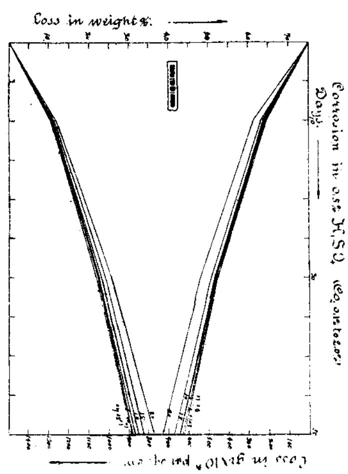


Fig. 9

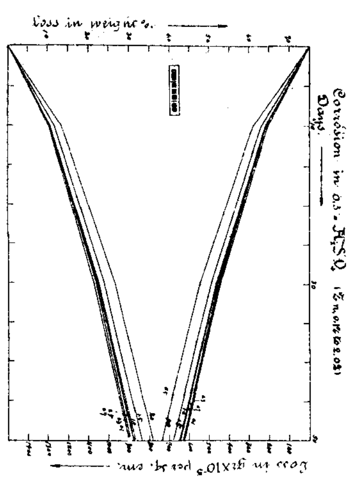


Fig. 10

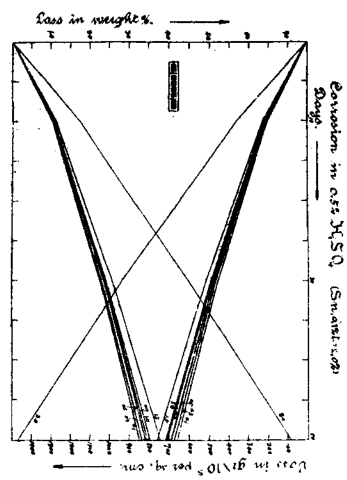


Table 5. Corrosion by 0.5% HNO_3.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	1.141	291	2.895	631	4.419	896
2	Cu 0.3	1.131	288	2.872	621	4.359	885
3	Cu 0.5	1.122	230	2.664	529	3.789	767
4	Cu 0.7	1.122	230	2.361	483	3.306	673
5	Cu 1.0	1.106	227	2.035	430	2.537	519
6	Cu 1.5	1.104	227	1.870	393	2.234	458
7	Cu 2.0	1.104	227	1.868	380	2.142	442
8	Cu 2.5	1.103	227	1.801	364	1.993	409
9	Si 0.1	1.330	270	2.460	582	4.398	889
10	Si 0.3	1.269	257	2.428	577	4.298	879
11	Si 0.5	1.224	239	2.531	591	4.398	889
12	Si 0.7	1.301	235	2.585	599	4.484	905
13	Si 1.0	1.312	238	2.623	628	4.651	935
14	Si 1.5	1.328	269	2.633	640	4.702	953
15	Si 2.0	1.639	332	2.234	712	5.433	1101
16	Ni 0.1	1.459	296	3.298	670	4.839	980
17	Ni 0.3	1.297	264	2.984	608	4.509	916
18	Ni 0.5	1.235	249	2.673	559	3.823	819
19	Ni 0.7	1.258	257	2.909	594	4.299	878
20	Ni 1.0	1.314	260	2.214	623	4.662	947
21	Ni 1.5	1.333	272	2.217	641	4.671	953
22	Ni 2.0	1.376	283	2.297	662	4.778	982
23	Mn 0.1	1.495	307	3.323	680	4.844	991
24	Mn 0.3	1.498	306	3.269	672	4.830	989
25	Mn 0.5	1.488	302	3.231	652	4.644	946
26	Mn 0.7	1.459	299	3.122	639	4.548	929
27	Mn 1.0	1.433	293	3.108	631	4.546	923
28	Mn 1.5	1.399	287	3.039	620	4.413	898
29	Mn 2.0	1.328	271	2.935	570	4.245	803
31	Fe 0.3	1.345	276	3.021	625	4.454	914
32	Fe 0.5	1.279	257	2.990	596	4.383	883
33	Fe 0.7	1.249	252	2.955	585	4.321	868
34	Fe 1.0	1.282	262	2.884	584	4.221	865
35	Fe 1.5	1.268	261	2.942	604	4.353	890
36	Fe 2.0	1.229	253	2.960	608	4.424	913
37	Mg 0.1	1.407	283	3.320	659	4.919	989
38	Mg 0.3	1.464	296	3.371	678	4.992	1009
39	Mg 0.5	1.569	313	3.431	689	4.992	1009
40	Mg 0.7	1.688	339	3.785	708	5.564	1119
41	Mg 1.0	1.805	364	4.089	732	6.057	1223
42	Mg 1.5	1.880	377	4.428	741	6.661	1314
43	Mg 2.0	1.881	377	4.652	754	7.160	1445
44	Co 0.1	1.206	244	2.914	573	4.279	865
45	Co 0.3	1.302	266	2.958	598	4.306	894
46	Co 0.5	1.327	269	3.038	615	4.528	926
47	Co 0.7	1.837	373	4.265	739	6.306	1216
48	Co 1.0	1.428	291	3.258	670	4.833	983
49	Co 1.5	1.309	267	3.158	625	4.632	940
50	Co 2.0	1.271	263	3.069	621	4.621	935

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. × 10⁻⁵ Per Sq. Cm.	%	Gr. × 10⁻⁵ Per Sq. Cm.	%	Gr. × 10⁻⁵ Per Sq. Cm.
51	Zn 0.1	1.262	259	2.945	588	4.313	876
52	Zn 0.3	1.269	260	2.951	594	4.326	879
53	Zn 0.5	1.315	267	3.001	607	4.404	893
54	Zn 0.7	1.334	271	3.028	639	4.707	955
55	Zn 1.0	1.374	278	3.065	666	4.992	1004
56	Zn 1.5	1.585	324	3.482	720	5.059	1049
57	Zn 2.0	1.623	334	3.549	733	5.165	1054
58	Sn 0.1	1.238	249	2.761	570	4.212	855
59	Sn 0.3	1.247	253	2.977	600	4.496	910
60	Sn 0.5	1.251	255	3.000	606	4.503	913
61	Sn 0.7	1.323	266	3.048	624	4.606	938
62	Sn 1.0	1.433	292	3.165	651	4.623	942
63	Sn 1.5	1.561	322	3.467	704	5.060	1027
64	Sn 2.0	1.586	325	3.669	755	5.421	1129
	Cu	0.013	13	0.040	63	0.114	82

CORROSION BY HYDROCHLORIC ACID.

Table 6 and Fig. 21 show the loss of weight after 50 days immersion in 0.5% hydrochloric acid, and Fig. 22 to 30 show the variations of the loss during that interval.

Increase of the concentration of the reagent increases its corroding action very rapidly, the 10% solution of hydrochoric acid acts so strongly that 10 or 12 grams of any of these alloys are dissolved out within a few hours, and no alloys can stand in concentrated hydrochloric acid even for a few minutes. The action of hydrochloric acid is accelarated to a vigorous state on account of products of reaction formed by the dissolution of the alloy. In the case of the very dilute acid copper and nickel are deposited on the surfaces of the alloys which contain them as in the case of dilute sulphuric acid.

It has been found that the alloys containing manganese or copper are stronger than pure aluminium in dilute hydrochloric acid, while those containing zinc or tin are weaker.

Fig. 11

Loss During 50 Days by 0.5% HNO_3.

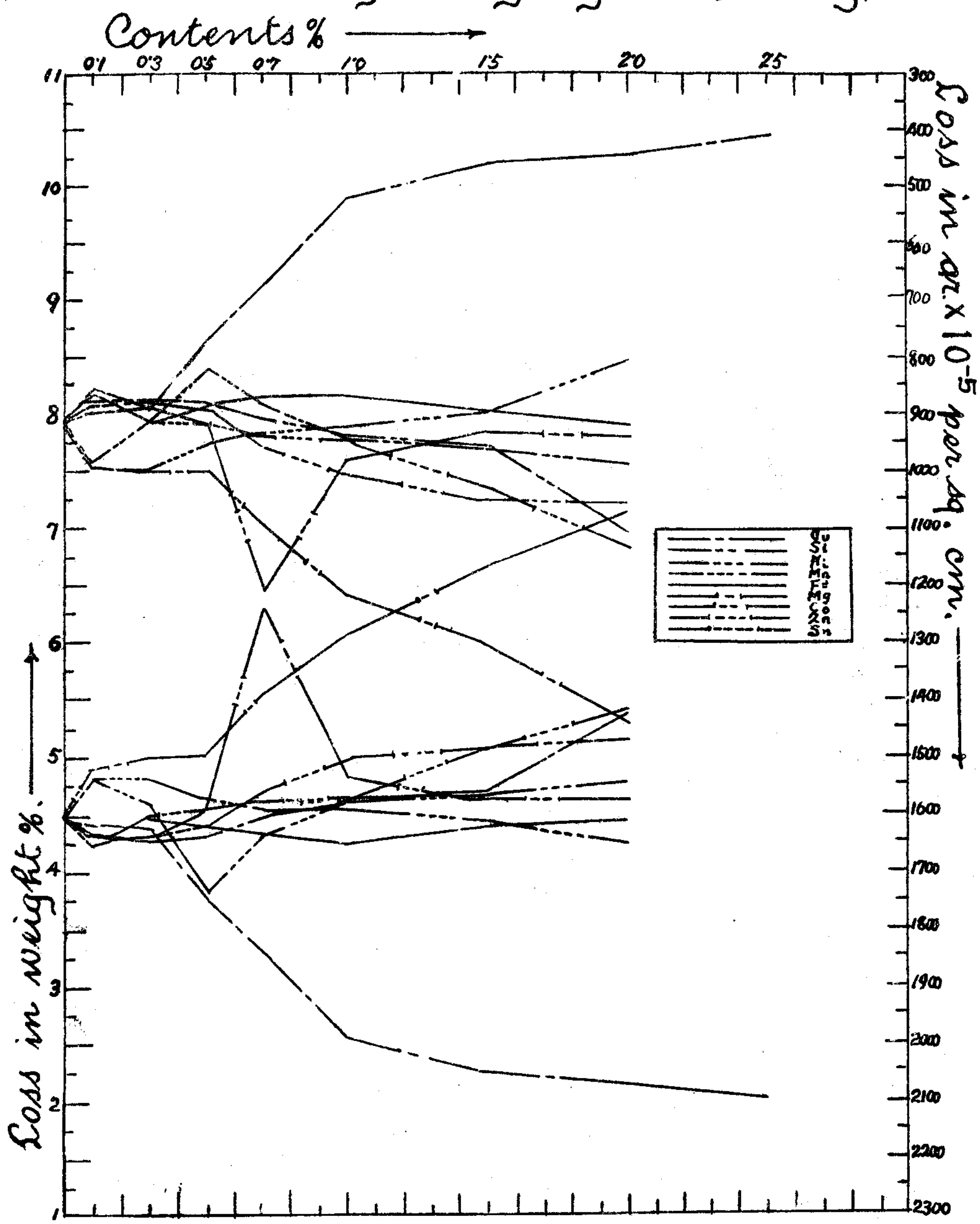


Fig. 12

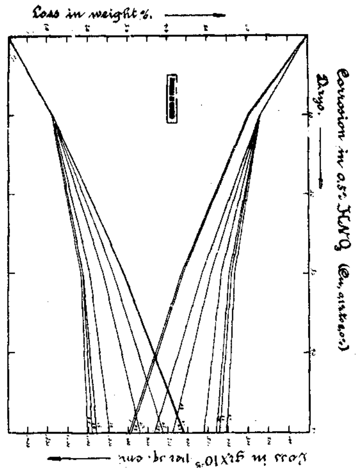


Fig. 13

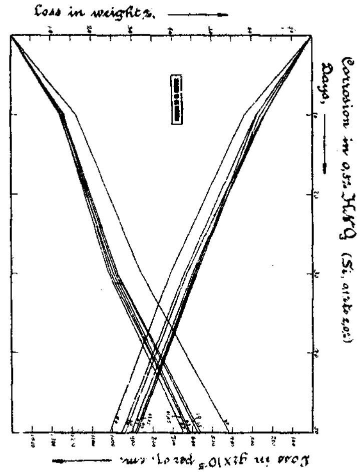


Fig. 14

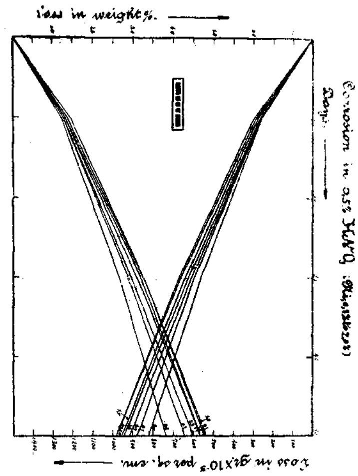


Fig. 15

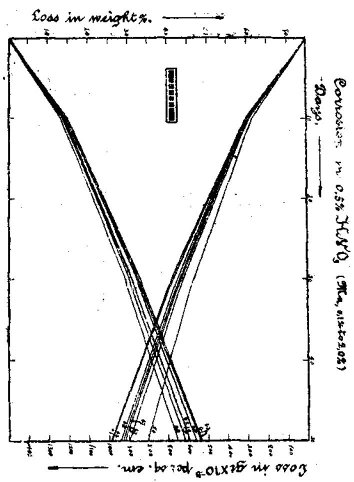


Fig. 16

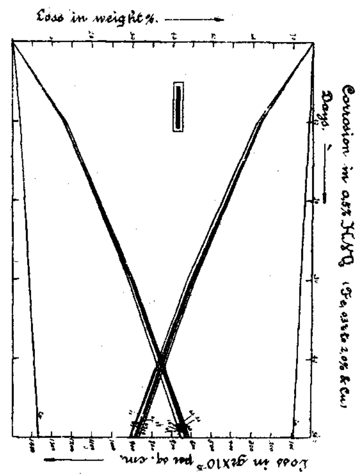


Fig. 17

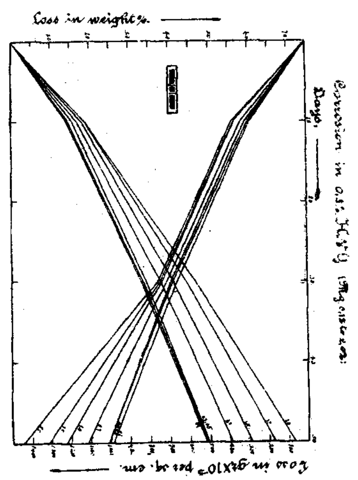


Fig. 18

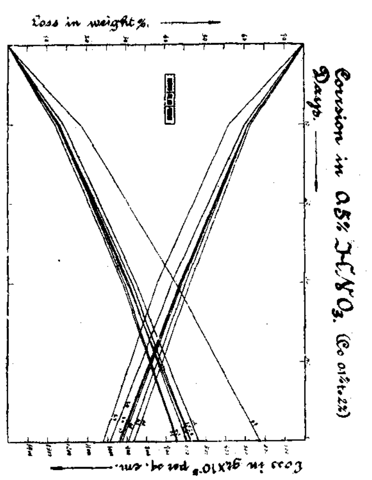


Fig. 19

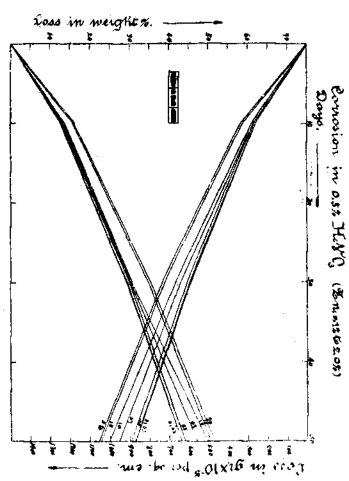


Fig. 20

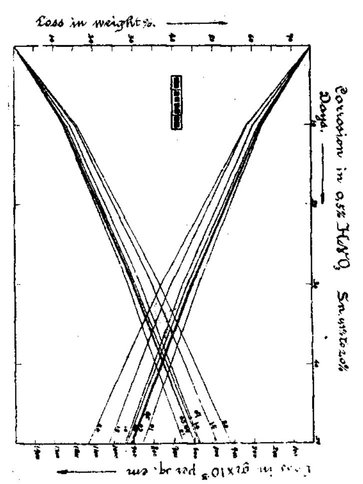


Fig. 2 1

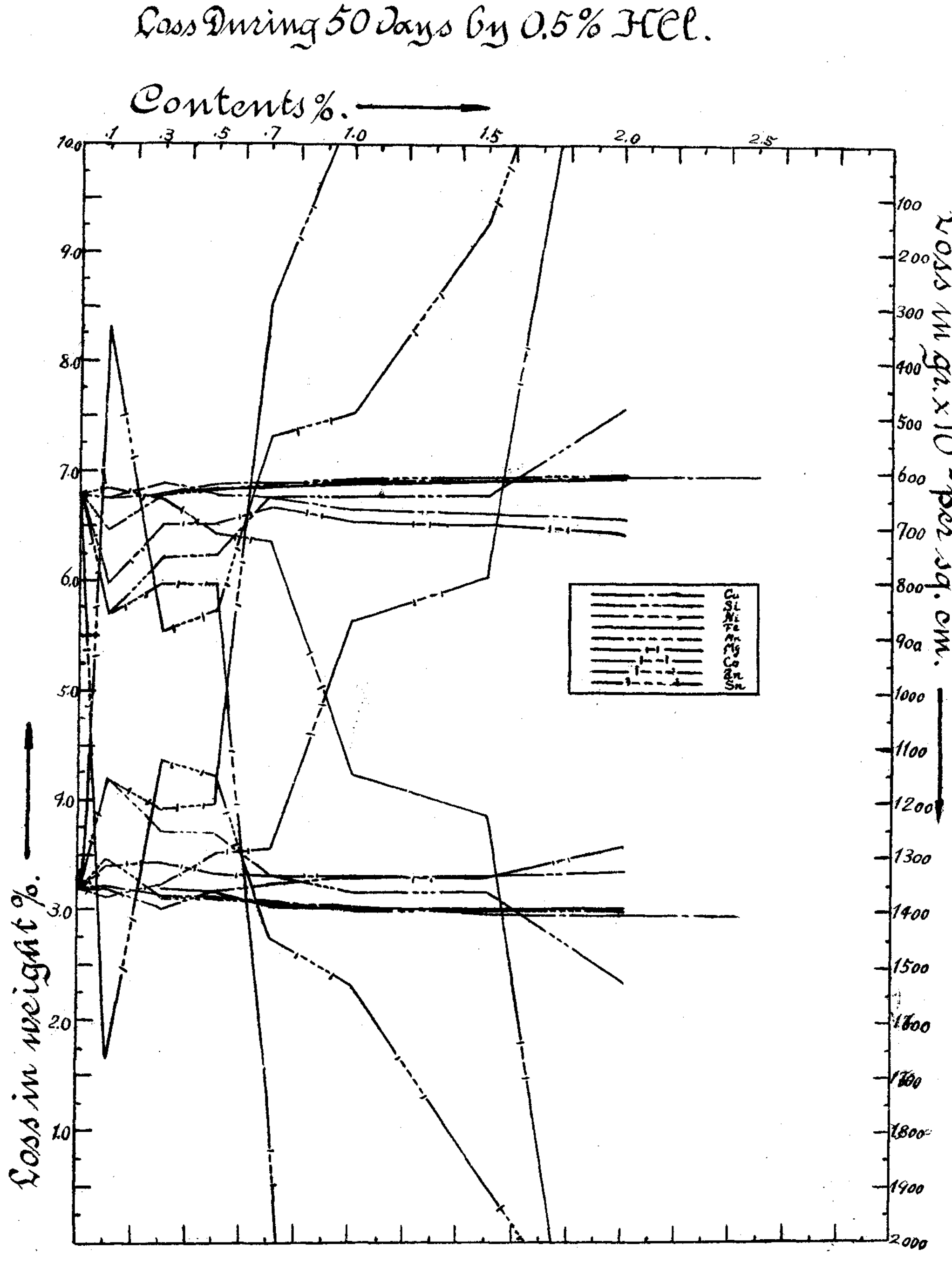

Loss During 50 days by 0.5% HCl.
Contents %.
.1
.3
.5
.7
1.0
1.5
2.0
2.5
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Loss in weight %.
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Loss in gr. x 10^-5 per sq. cm.
Cu
SL
Ni
Fe
Al
Mg
Co
Zn
Sn

Fig. 22

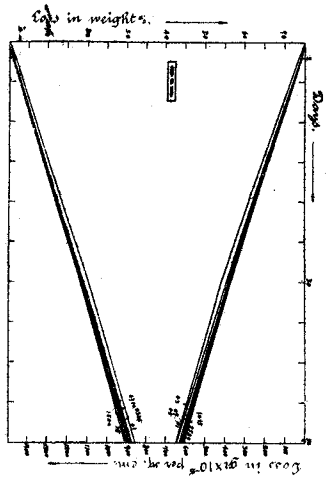


Fig. 23

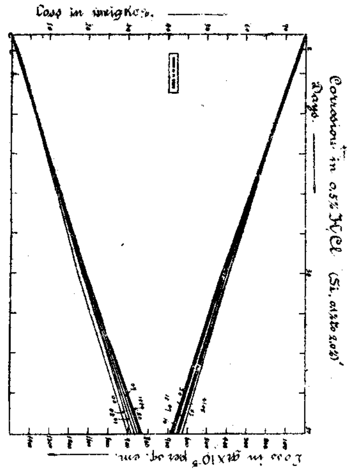


Fig. 24

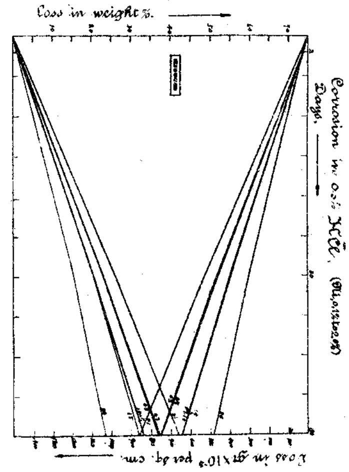


Fig. 25

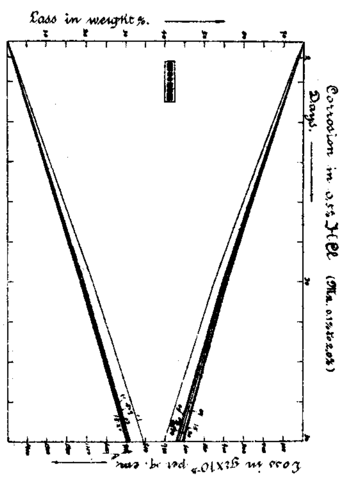


Fig. 26

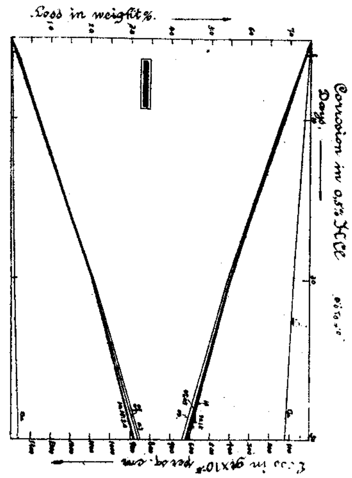


Fig. 27

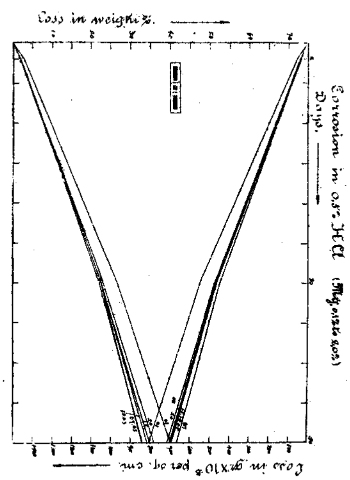


Fig. 28

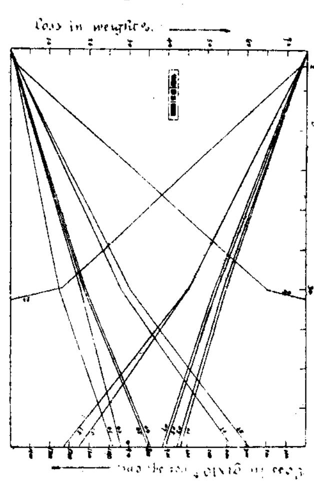


Fig. 29

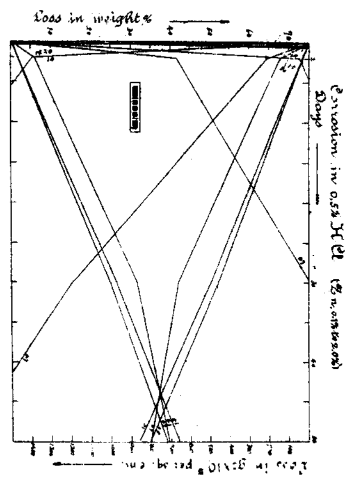


Fig. 30

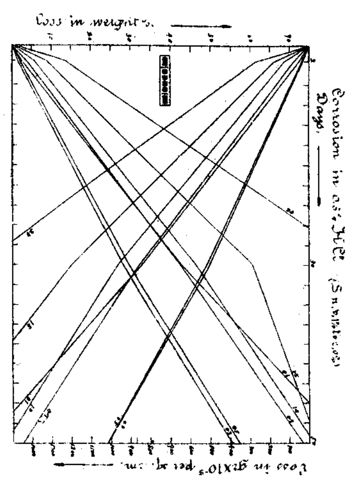


Table 6. Corrosion by 0.5% HCl.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 2 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	0.154	32	2.025	423	3.204	649
2	Cu 0.3	0.096	19	1.918	395	3.123	641
3	Cu 0.5	0.089	18	1.910	383	3.115	622
4	Cu 0.7	0.084	18	1.894	379	3.056	619
5	Cu 1.0	0.080	16	1.894	379	3.039	616
6	Cu 1.5	0.080	16	1.890	377	2.978	615
7	Cu 2.0	0.072	15	1.825	375	2.974	607
8	Cu 2.5	0.070	14	1.821	370	2.951	604
9	Si 0.1	0.099	20	1.825	406	3.187	648
10	Si 0.3	0.152	31	1.713	392	3.001	628
11	Si 0.5	0.142	29	1.802	391	3.176	646
12	Si 0.7	0.132	27	1.827	404	3.240	650
13	Si 1.0	0.132	27	1.830	415	3.297	670
14	Si 1.5	0.130	26	1.837	421	3.325	677
15	Si 2.0	0.125	20	1.926	430	3.367	685
16	Ni 0.1	0.174	35	2.618	529	4.202	859
17	Ni 0.3	0.135	27	2.315	463	3.719	754
18	Ni 0.5	0.124	25	2.320	458	3.698	751
19	Ni 0.7	0.123	25	2.077	400	3.313	647
20	Ni 1.0	0.118	24	2.070	399	3.311	647
21	Ni 1.5	0.116	24	2.056	397	3.171	644
22	Ni 2.0	0.110	23	1.531	301	3.352	683
23	Mn 0.1	0.176	36	2.161	448	3.472	706
24	Mn 0.3	0.139	25	1.948	405	3.105	642
25	Mn 0.5	0.126	23	1.902	400	3.091	634
26	Mn 0.7	0.125	25	1.861	393	3.076	626
27	Mn 1.0	0.125	25	1.860	385	3.019	613
28	Mn 1.5	0.125	25	1.859	381	3.009	609
29	Mn 2.0	0.111	23	1.857	380	3.007	601
31	Fe 0.3	0.149	30	2.041	414	3.189	643
32	Fe 0.5	0.119	24	2.010	407	3.175	631
33	Fe 0.7	0.132	27	2.008	407	3.049	630
34	Fe 1.0	0.141	29	1.995	402	3.046	624
35	Fe 1.5	0.157	32	1.995	401	3.041	613
36	Fe 2.0	0.158	32	1.995	401	3.039	611
37	Mg 0.1	0.289	58	2.678	649	3.999	806
38	Mg 0.3	0.204	38	2.275	470	3.435	699
39	Mg 0.5	0.197	38	2.223	467	3.319	696
40	Mg 0.7	0.181	36	2.220	451	3.312	667
41	Mg 1.0	0.175	35	2.278	468	3.487	692
42	Mg 1.5	0.194	38	2.278	468	3.301	696
43	Mg 2.0	0.197	39	2.332	478	3.595	713
44	Co 0.1	0.148	30	1.248	403	3.118	631
45	Co 0.3	0.131	27	1.780	419	3.299	651
46	Co 0.5	0.129	26	1.863	450	3.503	712
47	Co 0.7	0.149	31	1.922	465	3.559	728
48	Co 1.0	0.159	32	2.801	590	5.638	1148
49	Co 1.5	0.158	32	3.025	594	6.058	1227
50	Co 2.0	0.172	35	6.527	1225	24.514	5070

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 2 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. × 10⁻⁵ Per Sq. Cm.	%	Gr. × 10⁻⁵ Per Sq. Cm.	%	Gr. × 10⁻⁵ Per Sq. Cm.
50	Zn 0.1	0.185	37	2.621	498	4.239	858
51	Zn 0.3	0.153	31	2.469	462	3.929	803
52	Zn 0.5	0.582	144	3.132	661	3.985	804
53	Zn 0.7	4.152	210	7.552	1194	8.504	1736
54	Zn 1.0	7.203	1397	10.018	1988	11.725	2398
55	Zn 1.5	39.247	7692	—	—	—	—
56	Zn 2.0	64.503	13243	—	—	—	—
57	Sn 0.1	0.254	51	4.294	843	8.302	1684
58	Sn 0.3	0.162	32	2.810	507	5.531	1125
59	Sn 0.5	0.211	39	2.909	521	5.734	1157
60	Sn 0.7	0.386	78	4.251	858	7.318	1444
61	Sn 1.0	0.596	123	4.643	961	7.531	1533
62	Sn 1.5	0.883	179	6.063	1195	9.286	1897
63	Sn 2.0	1.259	270	10.227	1642	17.918	3725
	Cu	0.017	8	0.092	83	0.196	124

CORROSION BY SODIUM HYDROXIDE.

Table 7 and Fig. 31 show the loss of weight after 15 days immersion in 0.5%sodium hydroxide solution, and Figs. 32 to 40 show the variations of loss during that interval.

The dilute solution of sodium hydroxide attacks aluminium and its alloys more than dilute acids. A solution, dilute even 0.5%, dissolves the metals with violent action, but after some hours action, the surface of the metals are covered with scales of the hydroxide which grows thicker and denser until it insulates the metal from further action of the reagent, and this insulation occurs usually in a few days. The fact is plainly shown in the curves of Fig. 32 to 40, that they tend to become parallel to the axes of time as the time lapses. The irregularity of the curves occur when the scales are accidentally bared and fresh corrosion proceeds. In Fig. 41, (5) shows the scale produced on the surface and (6) the remains of the metal.

No aluminium alloy can stand in the solution of sodium hydroxide. Only a trace of this reagent, even unrecognisable by means of an ordinary indicator, acts on aluminium and tarnishes its surface. This problem is discussed more fully in the later section (See "Degradation of Aluminium Ingots or Wares by Their Manufacturing Treatment.")

Fig. 41

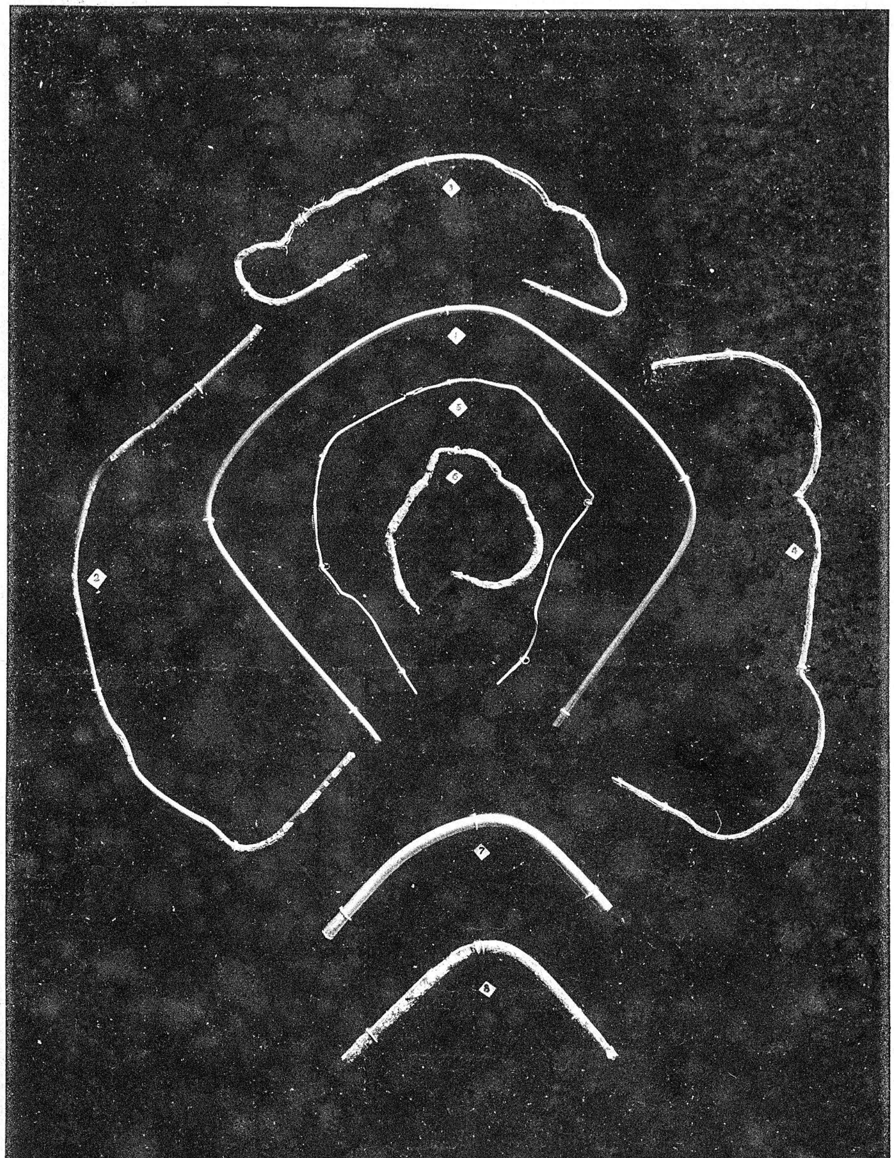


Table 7. Corrosion by 0.5% NaOH.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 45 Hours		Loss after 15 Days	
		%	Gr. × 10⁻⁵ per Sq. Cm.	%	Gr. × 10⁻⁵ per Sq. Cm.
1	Cu 0.1	5.014	604	10.388	2108
2	Cu 0.3	5.603	668	11.568	2347
3	Cu 0.5	6.318	1138	11.981	2502
4	Cu 0.7	6.715	1406	12.295	2545
5	Cu 1.0	6.823	1561	12.602	2561
6	Cu 1.5	7.768	1622	12.690	2562
7	Cu 2.0	8.048	1640	14.256	2934
8	Cu 2.5	8.284	1717	15.656	3233
9	Si 0.1	5.071	1037	Marks out, but corrosions are not greater than others.	
10	Si 0.3	4.029	951		
11	Si 0.5	3.257	917		
12	Si 0.7	3.506	932		
13	Si 1.0	5.106	1101		
14	Si 1.5	5.857	1254		
15	Si 2.0	6.516	1289		
16	Ni 0.1	6.321	1278	14.580	2876
17	Ni 0.3	7.145	1503	15.304	2972
18	Ni 0.5	8.645	2144	16.910	3142
19	Ni 0.7	8.836	1991	16.738	3381
20	Ni 1.0	7.923	1882	15.937	2996
21	Ni 1.5	7.832	1784	16.855	3142
22	Ni 2.0	7.644	1709	15.731	3026
23	Mn 0.1	5.432	1101	23.521	5102
24	Mn 0.3	4.862	988	13.236	2211
25	Mn 0.5	4.821	984	12.723	2426
26	Mn 0.7	5.624	1149	16.581	2604
27	Mn 1.0	5.747	1207	17.322	2823
28	Mn 1.5	6.032	1236	17.774	3433
29	Mn 2.0	6.545	1343	11.798	2185
31	Fe 0.3	5.210	1015	13.682	2935
32	Fe 0.5	4.827	975	18.530	3734
33	Fe 0.7	4.542	932	19.738	3924
34	Fe 1.0	5.497	1125	20.333	4201
35	Fe 1.5	5.908	1209	28.211	4432
36	Fe 2.0	6.327	1343	32.561	4680
37	Mg 0.1	5.486	1105	14.801	2641
38	Mg 0.3	7.419	1492	10.892	2216
39	Mg 0.5	6.124	1313	9.098	1799
40	Mg 0.7	5.513	1022	7.503	1297
41	Mg 1.0	6.181	1235	9.608	1919
42	Mg 1.5	6.330	1223	18.179	3661
43	Mg 2.0	6.608	1234	18.897	3813
44	Co 0.1	5.225	1057	14.507	2802
45	Co 0.3	5.815	1142	29.821	5938
46	Co 0.5	6.324	1287	22.750	3981
47	Co 0.7	6.915	1411	14.490	2914
48	Co 1.0	7.027	1433	24.793	4011
49	Co 1.5	8.391	1704	18.709	3844
50	Co 2.0	9.099	1881	16.084	3326

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 45 Hours		Loss after 15 Days	
		%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.
51	Zn 0.1	5.412	1095	34.553	6922
52	Zn 0.3	5.424	1096	43.648	8844
53	Zn 0.5	7.359	1502	51.978	10638
54	Zn 0.7	3.552	721	28.332	5033
55	Zn 1.0	3.052	623	29.104	4921
56	Zn 1.5	2.816	575	25.218	5119
57	Zn 2.0	2.566	527	23.553	4748
58	Sn 0.1	5.623	1118	25.222	4938
59	Sn 0.3	5.601	1031	24.413	4851
60	Sn 0.5	5.642	1139	23.765	4738
61	Sn 0.7	5.918	1167	23.083	4589
62	Sn 1.0	5.950	1216	22.622	4502
63	Sn 1.5	4.426	902	21.954	4358
64	Sn 2.0	6.479	1347	16.147	3532

CORROSION BY AMMONIUM HYDROXIDE.

Table 8 and Fig. 42 show the loss of weight after 50 days immersion in 0.5% ammonium hydroxide solution, and Figs. 43 to 51 show the variations of loss during that interval.

Ammonium hydroxide also produces the scales of the hydroxide on the surface, the action being less violent than that of sodium hydroxide, and the scales produced are very compact and do not easily come off.

It has been observed that the alloys containing manganese or copper are stronger than alnminium in the solution of ammonium hydroxide, while those containing zinc or tin are weaker.

Table 8. Corrosion by 0.5% NH_4OH.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.
1	Cu 0.1	1.819	372	5.058	1063	5.659	1152
2	Cu 0.3	1.800	368	4.901	1027	5.485	1120
3	Cu 0.5	1.462	297	4.121	845	4.587	923
4	Cu 0.7	1.429	294	3.878	812	4.215	856
5	Cu 1.0	1.418	290	3.518	809	4.199	854
6	Cu 1.5	1.368	282	3.426	778	3.988	828
7	Cu 2.0	1.356	279	3.408	750	3.844	787
8	Cu 2.5	1.351	276	3.412	762	4.108	841
9	Si 0.1	1.974	404	4.982	951	5.214	1067
10	Si 0.3	1.423	283	3.892	825	4.714	959

Fig. 3 1

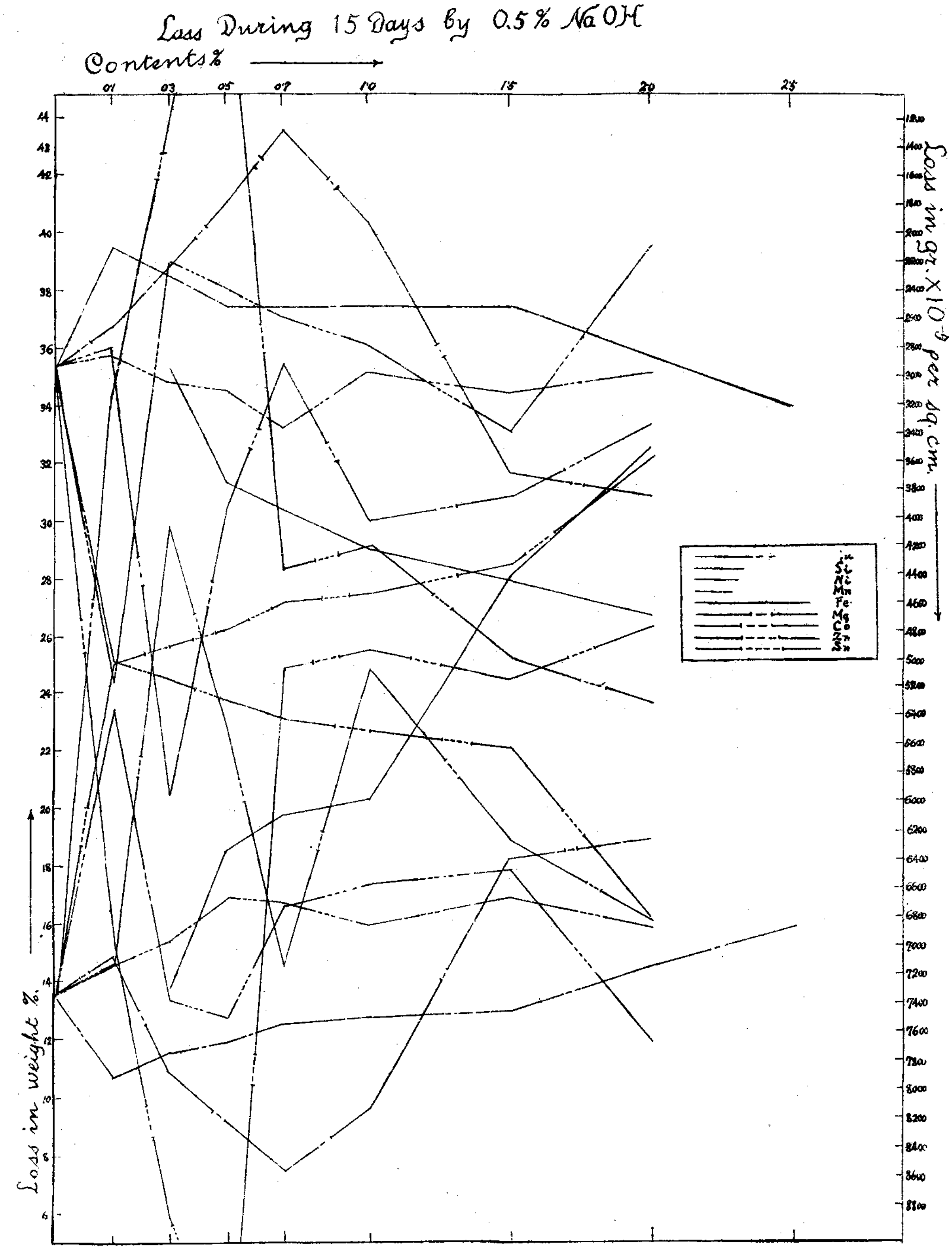

Loss During 15 Days by 0.5% NaOH
Contents%
Loss in weight %
Loss in gr. X10⁻⁴ per sq. cm.
Si
Ni
Mn
Fe
Mg
Co
Zn
Sn

Fig. 32

Corrosion in 0.5% NaOH (Cu, 0.1% to 2.0%)

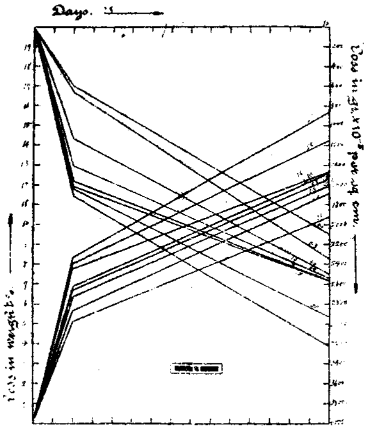


Fig. 33

Corrosion in 0.5% NaOH (Si, 0.1% to 2.0%)

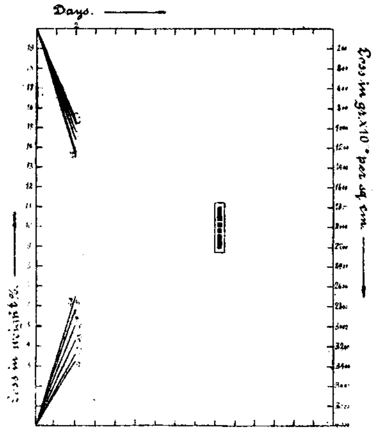


Fig. 34

Corrosion in 0.5% NaOH (Ni, 0.1% to 2.0%)

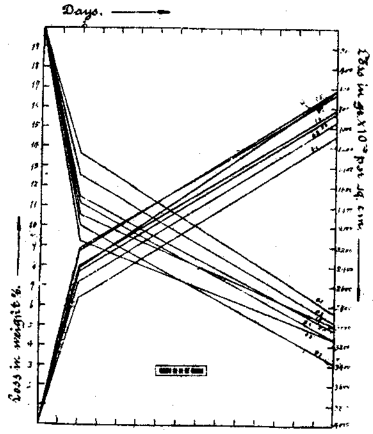


Fig. 35

Corrosion in 0.5% NaOH (Mn, 0.1% to 2.0%)

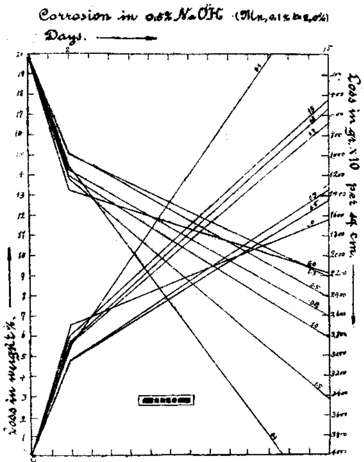


Fig. 36

Corrosion in 0.5% NaOH (Fe, 0.1% to 2.0%, Cu)

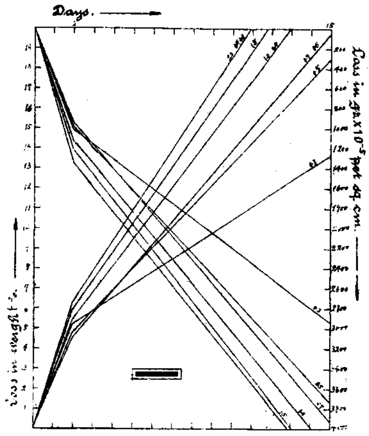


Fig. 37

Corrosion in 0.5% NaOH (Mg, 0.1% to 2.0%)

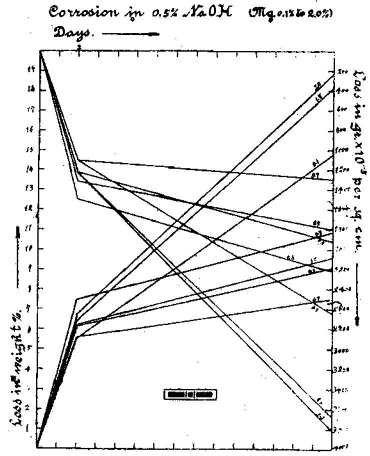


Fig. 38

Corrosion in 0.5% NaOH (Co, 0.1% to 2.0%)

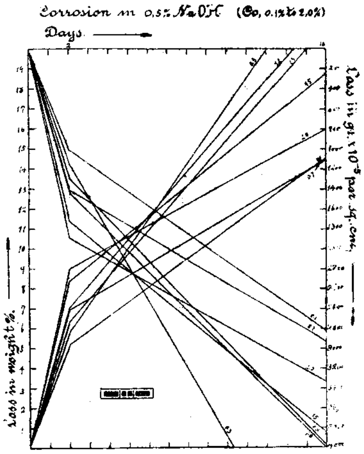


Fig. 39

Corrosion in 0.5% NaOH (Zn, 0.1% to 2.0%)

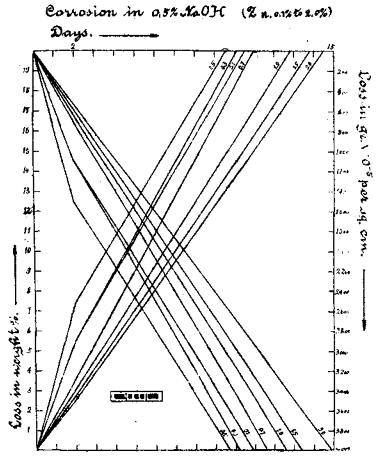
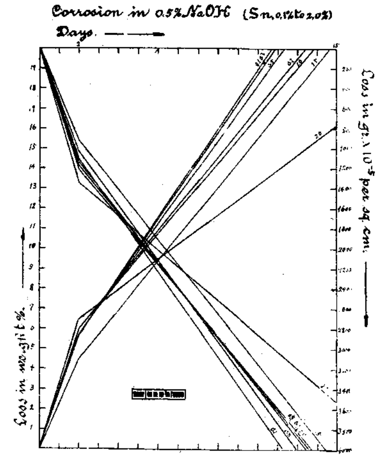


Fig. 40

Corrosion in 0.5% NaOH (Sn, 0.1% to 2.0%)



No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.
11	Si 0.5	1.411	287	3.851	791	4.525	914
12	Si 0.7	1.235	250	3.518	739	4.264	863
13	Si 1.0	1.705	348	4.593	890	4.633	945
14	Si 1.5	2.195	447	5.400	968	5.224	1063
15	Si 2.0	3.595	746	6.004	1118	6.074	1259
16	Ni 0.1	1.559	315	4.598	902	4.709	954
17	Ni 0.3	1.957	391	5.642	1113	5.669	1157
18	Ni 0.5	1.811	369	5.599	1062	5.629	1148
19	Ni 0.7	1.802	364	5.017	1060	5.476	1121
20	Ni 1.0	1.556	315	5.000	913	5.163	1047
21	Ni 1.5	1.889	398	5.288	1025	5.328	1089
22	Ni 2.0	1.969	393	5.004	993	5.119	1047
23	Mn 0.1	1.989	406	4.500	910	4.505	918
24	Mn 0.3	1.771	363	5.304	1067	5.321	1082
25	Mn 0.5	1.673	344	4.931	1013	5.169	1054
26	Mn 0.7	1.622	338	4.928	1010	5.167	1054
27	Mn 1.0	1.620	338	4.911	1013	5.072	1037
28	Mn 1.5	1.573	321	4.706	958	5.068	1075
29	Mn 2.0	1.565	317	3.748	776	3.796	782
31	Fe 0.3	1.391	277	3.929	752	4.570	917
32	Fe 0.5	1.619	324	4.481	863	5.065	1021
33	Fe 0.7	1.562	319	4.154	859	4.828	989
34	Fe 1.0	1.615	332	4.138	834	4.513	926
35	Fe 1.5	1.672	340	4.138	701	4.488	718
36	Fe 2.0	1.743	359	4.200	878	4.739	978
37	Mg 0.1	1.598	320	4.395	908	5.796	1169
38	Mg 0.3	1.587	315	4.637	979	7.138	1441
39	Mg 0.5	1.142	279	3.521	847	6.566	1352
40	Mg 0.7	1.022	204	2.378	567	3.374	675
41	Mg 1.0	0.775	154	2.493	558	4.444	883
42	Mg 1.5	0.770	153	2.198	481	3.982	821
43	Mg 2.0	0.561	111	1.802	368	3.293	654
44	Co 0.1	1.592	322	4.112	813	4.827	977
45	Co 0.3	1.852	378	5.001	959	5.883	1202
46	Co 0.5	2.071	421	5.418	1091	6.353	1291
47	Co 0.7	2.074	422	5.625	1109	6.632	1351
48	Co 1.0	2.137	435	5.830	1324	7.113	1605
49	Co 1.5	2.198	450	5.993	1188	7.899	1442
50	Co 2.0	2.207	452	6.383	1263	8.421	1746
51	Zn 0.1	1.609	326	4.220	841	4.785	970
52	Zn 0.3	1.676	344	3.611	778	3.961	809
53	Zn 0.5	2.001	454	4.842	969	5.054	1025
54	Zn 0.7	2.238	457	7.000	1321	12.899	2597
55	Zn 1.0	2.962	621	8.882	1418	13.664	2778
56	Zn 1.5	3.012	628	9.286	1441	16.429	3369
57	Zn 2.0	3.041	675	9.739	1483	18.509	3779
58	Sn 0.1	1.938	392	5.032	862	5.642	1143
59	Sn 0.3	1.536	314	4.421	763	5.044	1033
60	Sn 0.5	1.796	397	5.522	970	6.038	1227
61	Sn 0.7	2.157	438	5.601	982	6.217	1255
62	Sn 1.0	2.568	526	13.389	1571	28.508	6041
63	Sn 1.5	2.405	491	12.367	1543	29.368	5787
64	Sn 2.0	2.283	477	12.124	1489	35.788	7421
	Cu	1.946	1242	2.000	1272	2.006	1279

CORROSION BY SATURATED CARBONIC ACID SOLUTION.

Table 9 and Fig. 52 show the change of weight after 50 days immersion in the saturated solution of carbonic acid, and Figs. 53 to 61 show the variations of weight change during that interval.

The metals which have been in contact with the carbonic acid solution for a long time increase their weights, probably because of the production of carbonate which adheres to their surface, among which the alloys containing tin show a remarkable increase of weight. On the whole, the alloys, except those containing tin, are so slightly affected by carbonic acid that we may almost neglect its action. The solution of the carbonates of alkali metals, however, causes loss of weight when the metals are brought into contact with the reagent, the action of their alkaline nature being more predominant than that of the carbonic radical.

Table 9. Corrosion by Saturated CO_2 Water.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	After 30 Days Weight Change		After 50 Days Weight Change	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	.011	2	.060	12
2	Cu 0.3	.010	2	.059	12
3	Cu 0.5	.009	2	.059	12
4	Cu 0.7	.010	2	.059	12
5	Cu 1.0	.013	2	.079	16
6	Cu 1.5	.012	2	.064	13
7	Cu 2.0	.011	2	.060	12
8	Cu 2.5	.011	2	.060	12
9	Si 0.1	.008	1	.054	11
10	Si 0.3	.010	1	.055	12
11	Si 0.5	.012	1	.060	12
12	Si 0.7	.010	1	.058	12
13	Si 1.0	.010	1	.058	12
14	Si 1.5	.009	1	.057	12
15	Si 2.0	.009	1	.057	12
16	Ni 0.1	.011	2	.073	15
17	Ni 0.3	.011	2	.073	15
18	Ni 0.5	.010	1	.068	13
19	Ni 0.7	.011	1	.065	13
20	Ni 1.0	.008	1	.053	11
21	Ni 1.5	.010	1	.068	13
22	Ni 2.0	.014	2	.080	16

Fig. 4 2

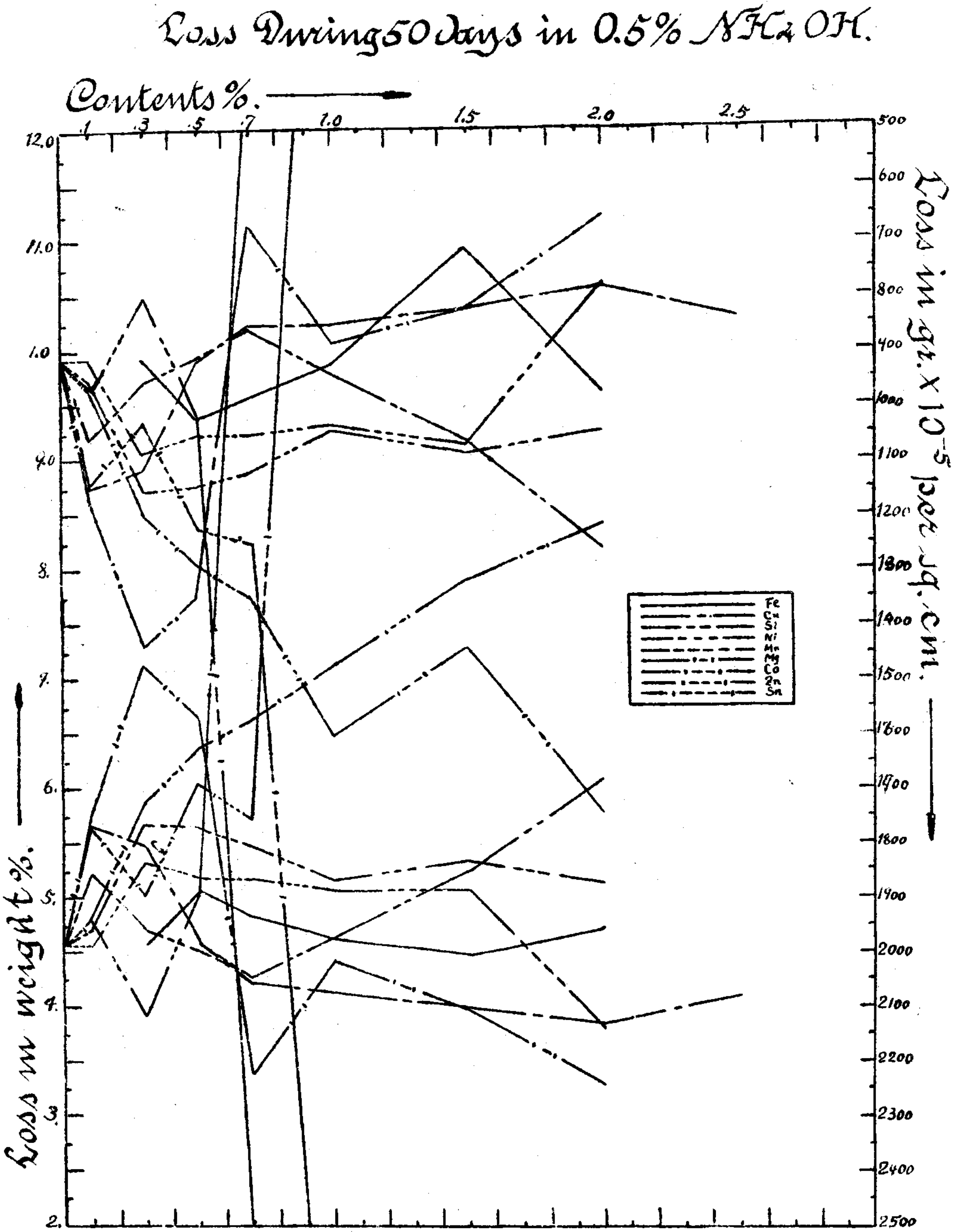

Loss During 50 days in 0.5% NH4 OH.
Contents %.
.1
.3
.5
.7
1.0
1.5
2.0
2.5
12.0
11.0
1.0
9.0
8.
7.
6.
5.
4.
3.
2.
Loss in weight %.
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
Loss in gr. x 10-5 per sq. cm.
Fe
Cu
Si
Ni
Mn
Mg
Co
Zn
Sn

Fig. 43

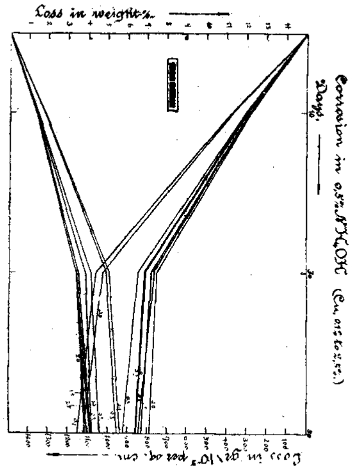


Fig. 44

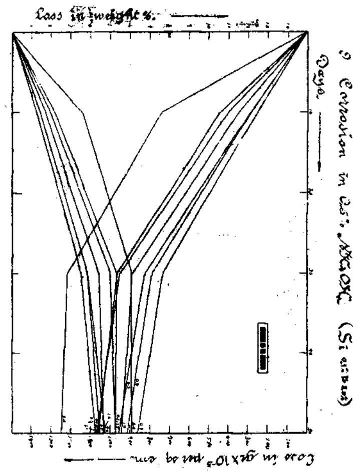


Fig. 45

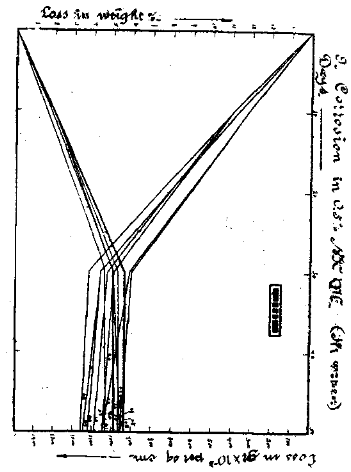


Fig. 46

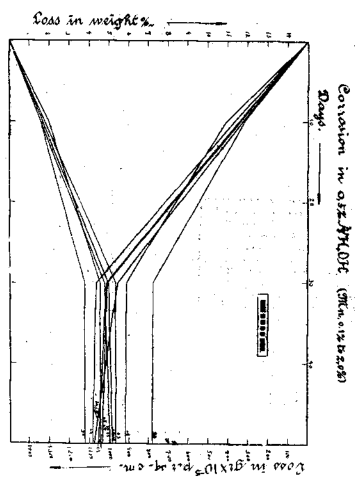


Fig. 47

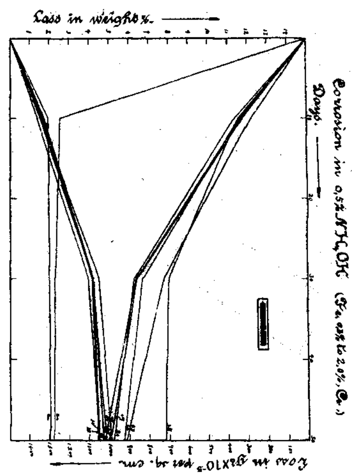


Fig. 48

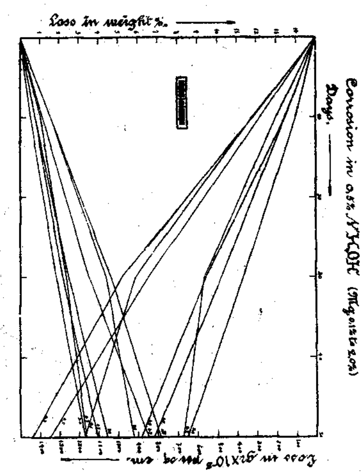


Fig. 49

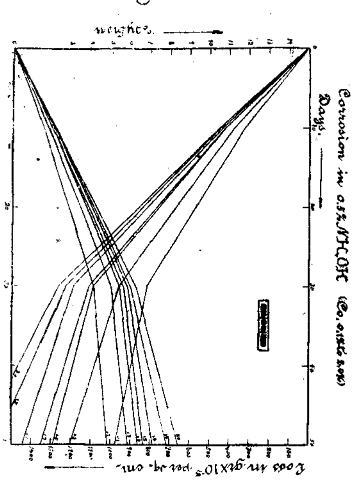


Fig. 50

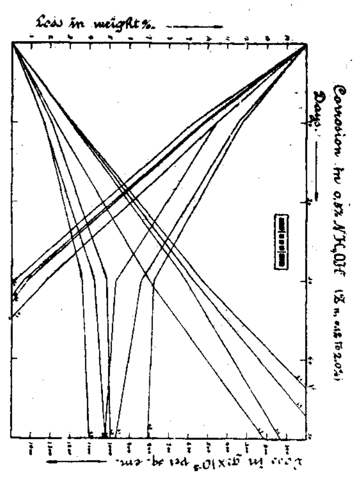


Fig. 51

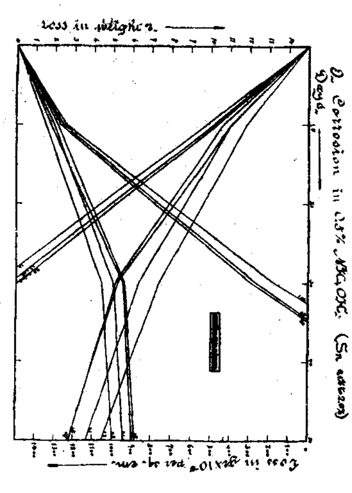
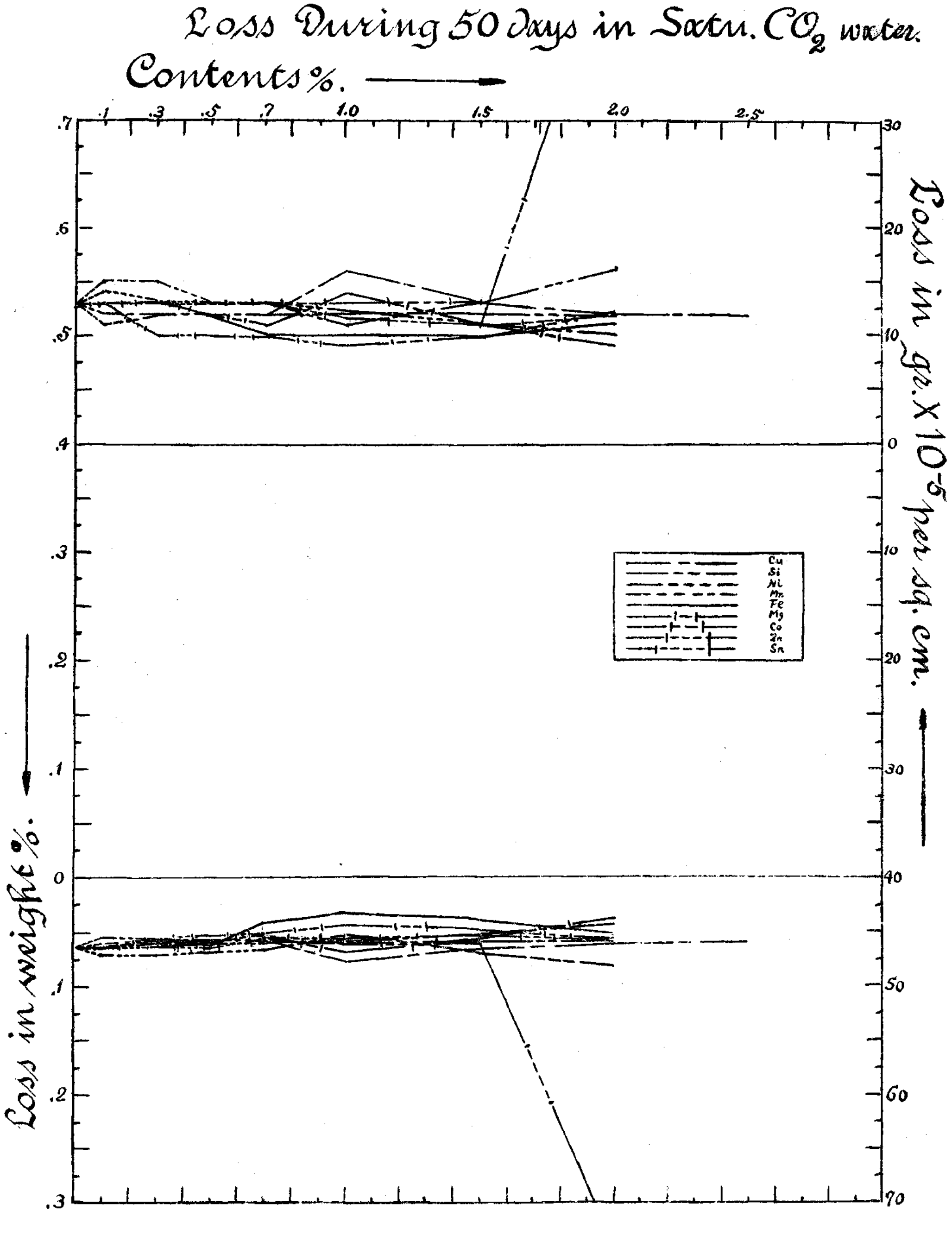


Fig. 5 2



Loss During 50 days in Satu. CO_2 water.
Contents %.
.1
.3
.5
.7
1.0
1.5
2.0
2.5
.7
.6
.5
.4
.3
.2
.1
0
.1
.2
.3
30
20
10
0
10
20
30
40
50
60
70
Loss in gr. X 10^{-5} per sq. cm.
Loss in weight %.
Cu
Si
Ni
Mn
Fe
Mg
Co
Zn
Sn

Fig. 53

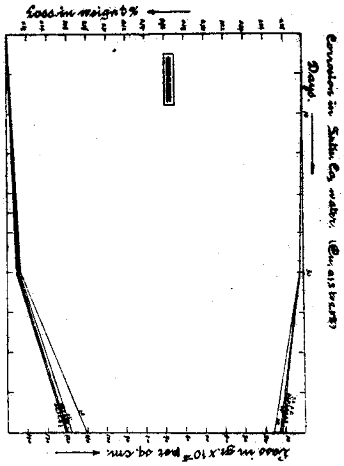


Fig. 54

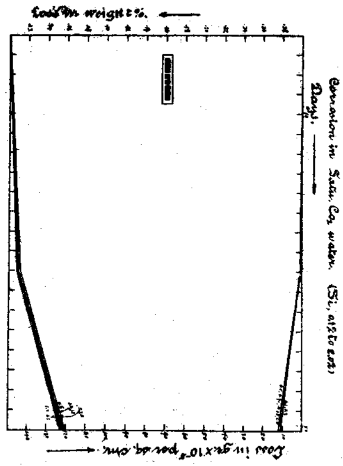


Fig. 55

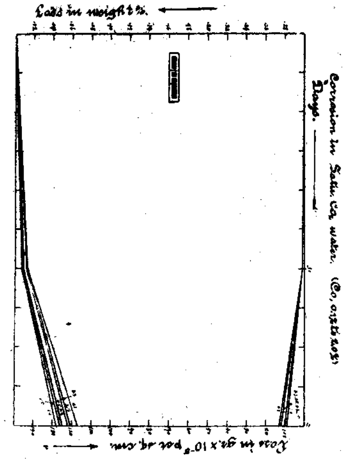


Fig. 56

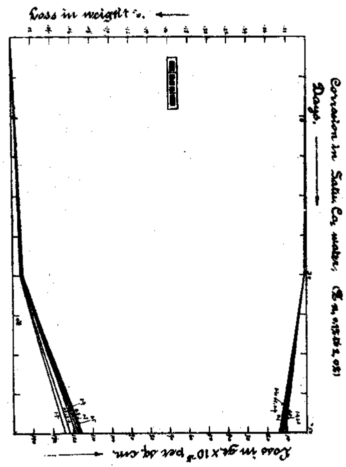


Fig. 57

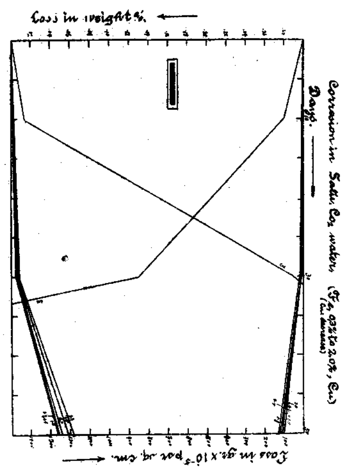


Fig. 58

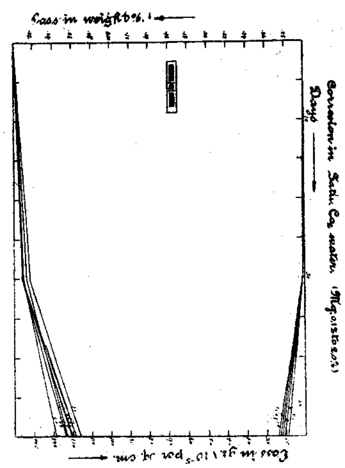


Fig. 59

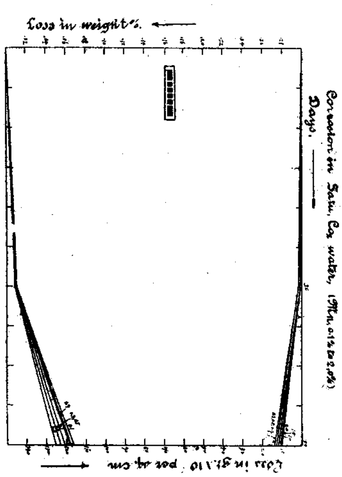


Fig. 60

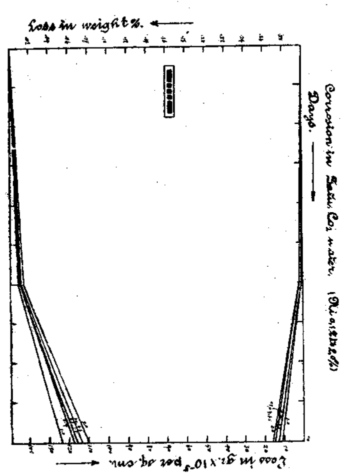
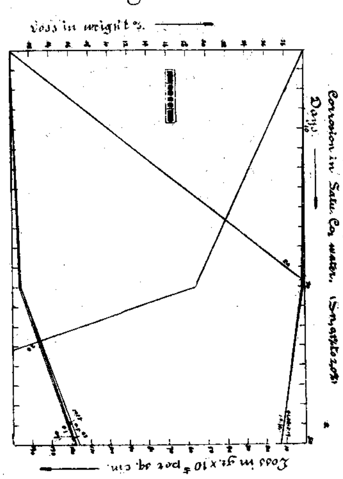


Fig. 61



No. of Alloys	Added Elements and their Per Cent. (Theoretical)	After 30 Days Weight Change		After 50 Days Weight Change	
		%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.
23	Mn 0.1	.010	2	.067	14
24	Mn 0.3	.010	2	.064	13
25	Mn 0.5	.009	2	.064	13
26	Mn 0.7	.009	2	.063	13
27	Mn 1.0	.009	1	.058	12
28	Mn 1.5	.008	1	.054	11
29	Mn 2.0	.008	1	.049	10
31	Fe 0.3	.008	2	.064	13
32	Fe 0.5	.007	1	.058	12
33	Fe 0.7	.007	1	.049	10
34	Fe 1.0	.005	1	.048	10
35	Fe 1.5	.006	1	.049	10
36	Fe 2.0	.007	1	.052	11
37	Mg 0.1	.008	1	.063	13
38	Mg 0.3	.009	1	.060	13
39	Mg 0.5	.009	1	.059	12
40	Mg 0.7	.008	1	.053	11
41	Mg 1.0	.016	2	.068	14
42	Mg 1.5	.013	1	.054	11
43	Mg 2.0	.010	1	.043	9
44	Co 0.1	.013	1	.066	13
45	Co 0.3	.012	1	.056	10
46	Co 0.5	.009	1	.051	10
47	Co 0.7	.008	1	.051	10
48	Co 1.0	.007	1	.044	9
49	Co 1.5	.007	1	.048	10
50	Co 2.0	.013	1	.059	12
51	Zn 0.1	.011	1	.067	14
52	Zn 0.3	.011	1	.069	13
53	Zn 0.5	.010	1	.065	13
54	Zn 0.7	.010	1	.062	13
55	Zn 1.0	.008	1	.057	12
56	Zn 1.5	.008	1	.052	11
57	Zn 2.0	.008	1	.057	12
58	Sn 0.1	.007	1	.063	13
59	Sn 0.3	.008	1	.066	13
60	Sn 0.5	.009	2	.068	13
61	Sn 0.7	.009	2	.064	13
62	Sn 1.0	.009	2	.065	13
63	Sn 1.5	.008	1	.065	13
64	Sn 2.0	.309	56	1.627	333
	Cu	−.289	−85	−.823	−517

CORROSION BY SODIUM CHLORIDE SOLUTION.

Table 10 and Fig. 62 show the loss of weight after 50 days immersion in 3% sodium chloride solntion, and Figs. 63 to 71 show the variations of loss during that interval.

The sea water contain several other substances and their amounts as well as sodium chloride vary considerably.

Even with 3% sodium chloride solution only, the alloys were all tarnished on their surfaces with the formation of dull brownish coloured matter after a long immersion, it may probably have been caused by the action of a trace of sodium hydroxide formed by the hydrolytic decomposition of sodium chloride on account of galvanic action of the metal.

It has been found that the alloys containing manganese are stronger than aluminium in the salt solution, while those containing zinc are very weak, cobalt and tin also gave bad results.

Table 10 Corrosion by 3% Nacl.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	.020	4	.091	16	.176	36
2	Cu 0.3	.018	3	.086	15	.172	35
3	Cu 0.5	.016	3	.083	15	.174	35
4	Cu 0.7	.016	3	.082	15	.171	34
5	Cu 1.0	.013	2	.077	14	.158	32
6	Cu 1.5	.010	2	.070	13	.156	32
7	Cu 2.0	.007	1	.062	11	.129	28
8	Cu 2.5	.006	1	.053	9	.117	24
9	Si 0.1	.023	4	.063	9	.089	19
10	Si 0.3	.024	5	.079	12	.117	24
11	Si 0.5	.027	5	.091	12	.121	24
12	Si 0.7	.028	5	.092	14	.139	29
13	Si 1.0	.030	6	.094	15	.145	29
14	Si 1.5	.028	5	.092	13	.135	27
15	Si 2.0	.022	4	.066	9	.092	19
16	Ni 0.1	.018	4	.138	28	.286	58
17	Ni 0.3	.018	4	.098	20	.196	40
18	Ni 0.5	.018	4	.098	20	.196	41
19	Ni 0.7	.020	5	.092	20	.175	36
20	Ni 1.0	.020	5	.088	19	.158	32
21	Ni 1.5	.029	6	.083	19	.146	30
22	Ni 2.0	.032	6	.078	17	.113	23
23	Mn 0.1	.015	3	.047	9	.080	17
24	Mn 0.3	.015	3	.048	14	.077	16
25	Mn 0.5	.020	5	.056	13	.071	15
26	Mn 0.7	.024	5	.062	14	.078	17
27	Mn 1.0	.032	6	.077	17	.089	18
28	Mn 1.5	.032	6	.087	18	.118	24
29	Mn 2.0	.033	6	.076	17	.090	18

Fig. 6 2

Loss During 50 Days in 3% NaCl.

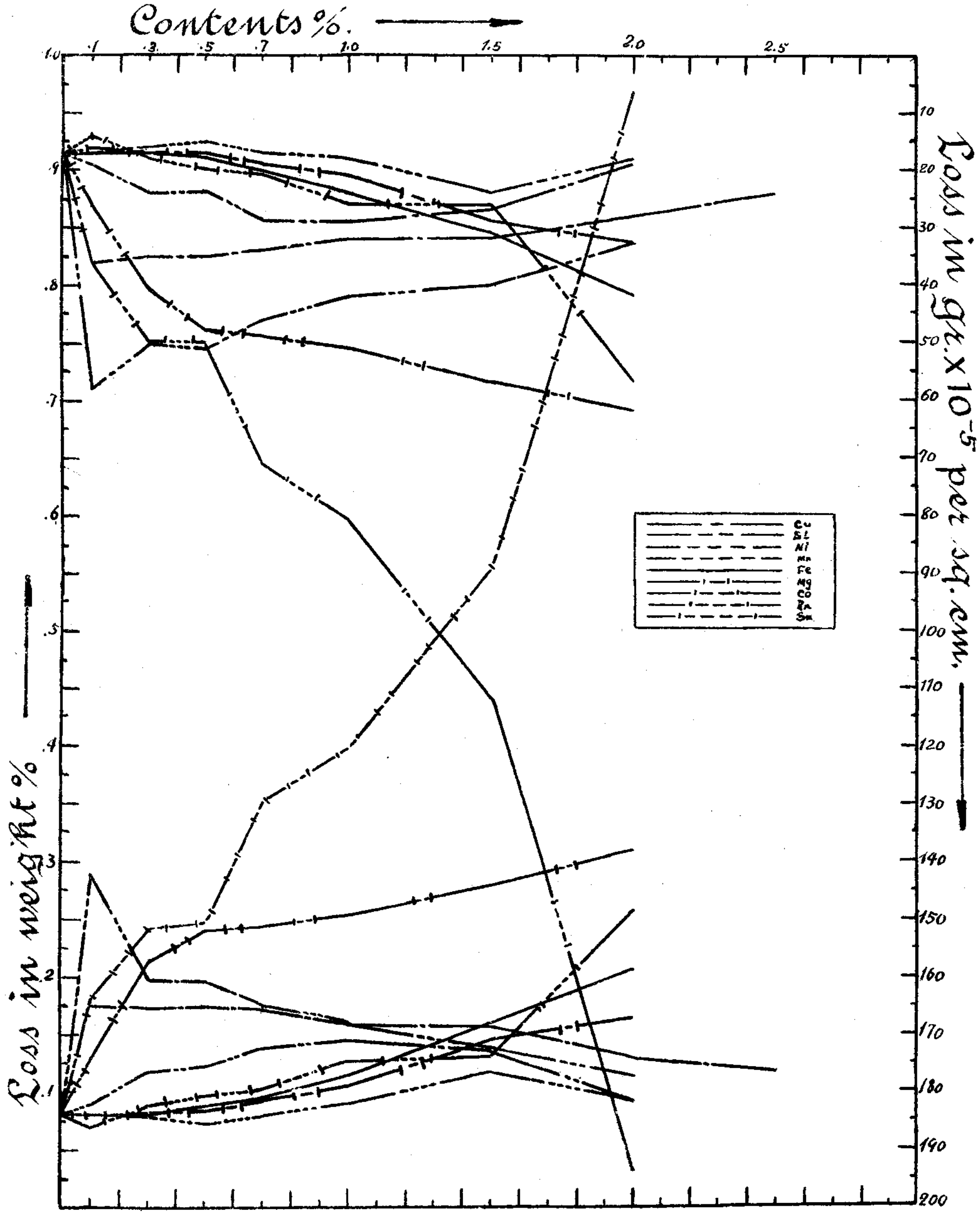


Fig. 63

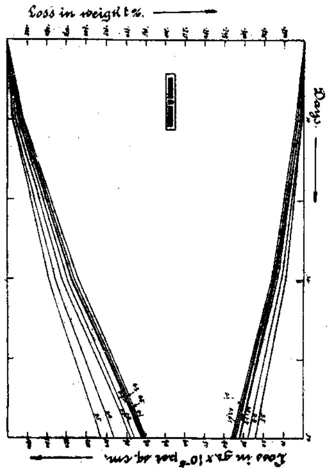


Fig. 64

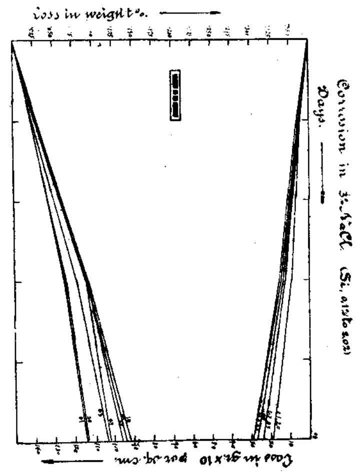


Fig. 65

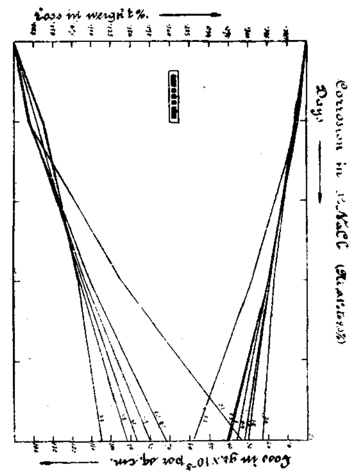


Fig. 66

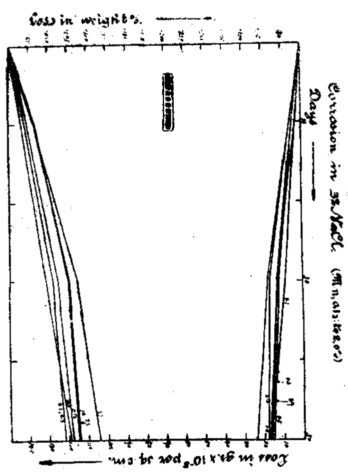


Fig. 67

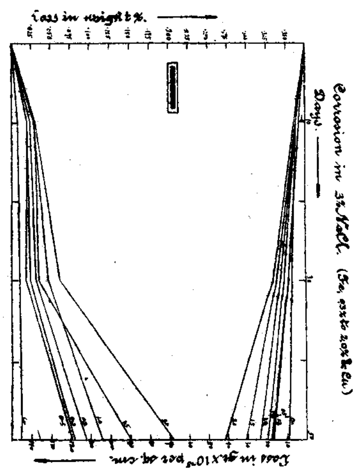


Fig. 68

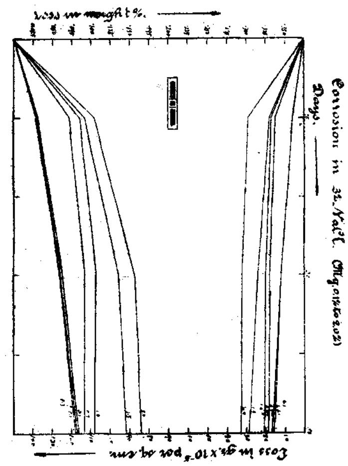


Fig. 69

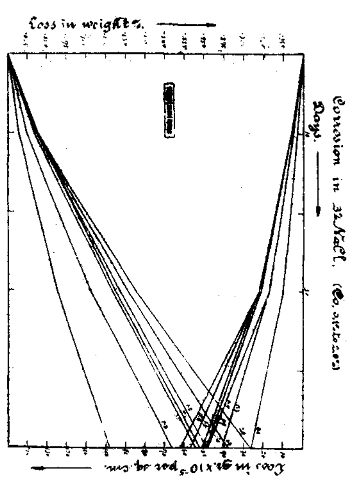


Fig. 70

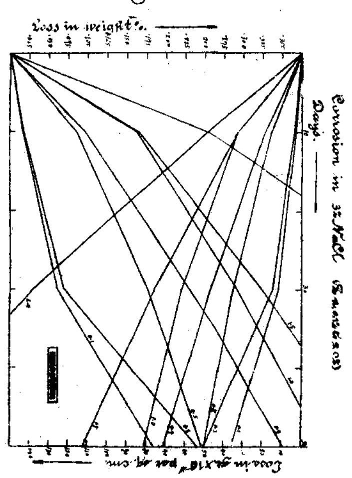
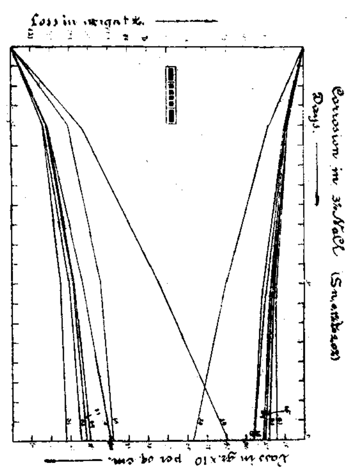


Fig. 71



No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. × 10⁻⁵ Per Sq. Cm.	%	Gr. × 10⁻⁵ Per Sq. Cm.	%	Gr. × 10⁻⁵ Per Sq. Cm.
31	Fe 0.3	.019	3	.018	9	.080	17
32	Fe 0.5	.019	3	.024	9	.087	18
33	Fe 0.7	.023	5	.031	11	.095	20
34	Fe 1.0	.027	5	.047	13	.115	24
35	Fe 1.5	.029	5	.035	15	.151	31
36	Fe 2.0	.030	6	.062	17	.206	42
37	Mg 0.1	0.028	6	0.059	12	0.080	16
38	Mg 0.3	0.030	6	0.060	12	0.082	17
39	Mg 0.5	0.031	6	0.063	12	0.084	17
40	Mg 0.7	0.072	15	0.080	18	0.092	19
41	Mg 1.0	0.085	17	0.108	20	0.105	21
42	Mg 1.5	0.092	18	0.137	24	0.146	29
43	Mg 2.0	0.105	29	0.157	32	0.165	33
44	Co 0.1	0.013	3	0.064	10	0.129	26
45	Co 0.3	0.023	5	0.106	17	0.213	41
46	Co 0.5	0.033	5	0.133	17	0.240	48
47	Co 0.7	0.038	6	0.137	21	0.244	49
48	Co 1.0	0.036	6	0.143	22	0.253	51
49	Co 1.5	0.035	6	0.153	22	0.279	57
50	Co 2.0	0.036	6	0.164	22	0.309	62
51	Zn 0.1	0.016	3	0.062	12	0.179	36
52	Zn 0.3	0.018	4	0.069	15	0.241	50
53	Zn 0.5	0.086	16	0.177	35	0.247	50
54	Zn 0.7	0.097	19	0.233	47	0.351	71
55	Zn 1.0	0.163	33	0.292	62	0.396	81
56	Zn 1.5	0.165	33	0.325	76	0.551	112
57	Zn 2.0	0.256	49	0.587	138	0.969	194
58	Sn 0.1	0.040	8	0.063	14	0.069	14
59	Sn 0.3	0.041	8	0.074	15	0.089	18
60	Sn 0.5	0.044	8	0.079	16	0.096	20
61	Sn 0.7	0.046	9	0.081	17	0.101	21
62	Sn 1.0	0.046	9	0.092	19	0.127	26
63	Sn 1.5	0.073	10	0.115	21	0.130	26
64	Sn 2.0	0.089	18	0.190	40	0.276	57
	Cu	0.007	5	0.010	7	0.014	9

CORROSION BY SODIM SULPHITE SOLUTION.

Table 11 and Fig. 72 show the loss of weight after 50 days immersion in 3% sodium sulphite solution, and Figs. 73 to 81 show the variations of loss during that interval.

The surface of all of these alloys turn blackish when kept in contact with this reagent for a long time, by the formation of sulphides of the metals.

The corrosion is not generally evident in sodium sulphite solution, except with those alloys containing silicon, which suffered a fair decrease of weight as shown in the figure.

Table 11 Corrosion by 3% Na_2SO_3.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.	%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	0.054	10	0.054	11	0.054	11
2	Cu 0.3	0.041	9	0.053	11	0.053	11
3	Cu 0.5	0.040	7	0.034	7	0.034	7
4	Cu 0.7	0.035	7	0.039	8	0.039	8
5	Cu 1.0	0.031	6	0.047	9	0.048	9
6	Cu 1.5	0.035	7	0.044	9	0.044	9
7	Cu 2.0	0.041	9	0.057	12	0.058	12
8	Cu 2.5	0.051	10	0.067	14	0.067	14
9	Si 0.1	0.087	17	0.087	20	0.087	20
10	Si 0.3	0.094	19	0.098	21	0.105	21
11	Si 0.5	0.140	29	0.140	29	0.140	29
12	Si 0.7	0.232	46	0.232	46	0.232	46
13	Si 1.0	0.289	57	0.288	58	0.290	58
14	Si 1.5	0.240	49	0.242	50	0.248	50
15	Si 2.0	0.236	48	0.289	55	0.291	57
16	Ni 0.1	0.037	8	0.055	12	0.057	12
17	Ni 0.3	0.046	9	0.062	13	0.062	13
18	Ni 0.5	0.046	9	0.072	15	0.078	16
19	Ni 0.7	0.045	9	0.074	16	0.084	18
20	Ni 1.0	0.068	14	0.111	22	0.115	23
21	Ni 1.5	0.084	17	0.129	25	0.129	26
22	Ni 2.0	0.086	17	0.189	27	0.191	29
23	Mn 0.1	0.187	39	0.188	40	0.189	40
24	Mn 0.3	0.181	38	0.237	51	0.247	51
25	Mn 0.5	0.150	31	0.202	43	0.221	43
26	Mn 0.7	0.137	28	0.183	41	0.199	41
27	Mn 1.0	0.130	27	0.145	28	0.145	29
28	Mn 1.5	0.046	10	0.046	10	0.046	10
29	Mn 2.0	0.028	7	0.040	7	0.040	8
31	Fe 0.3	0.089	18	0.113	23	0.113	23
32	Fe 0.5	0.099	22	0.126	25	0.127	25
33	Fe 0.7	0.040	8	0.052	11	0.052	11
34	Fe 1.0	0.040	8	0.051	10	0.051	10
35	Fe 1.5	0.036	7	0.042	9	0.042	9
36	Fe 2.0	0.034	7	0.037	8	0.037	8
37	Mg 0.1	0.119	24	0.119	24	0.119	24
38	Mg 0.3	0.044	9	0.058	12	0.058	12
39	Mg 0.5	0.041	8	0.057	12	0.057	12
40	Mg 0.7	0.041	8	0.055	12	0.055	12
41	Mg 1.0	0.033	7	0.049	11	0.049	11
42	Mg 1.5	0.045	9	0.058	12	0.058	12
43	Mg 2.0	0.062	12	0.067	13	0.067	13

Fig. 7 2

Loss During 50 days in 3% Na_2SO_3.

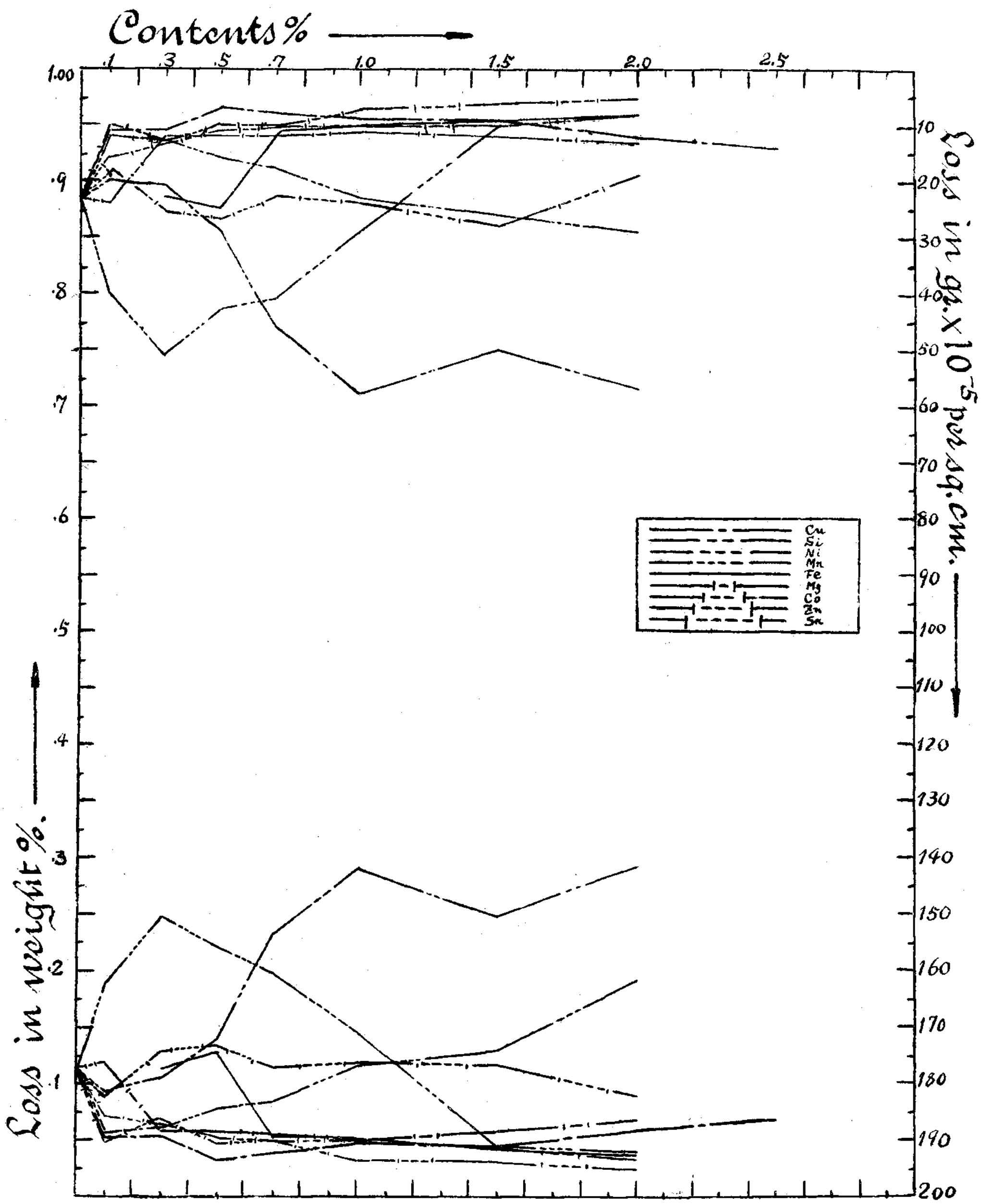


Fig. 73

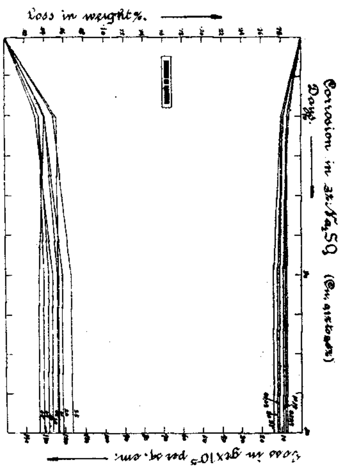


Fig. 74

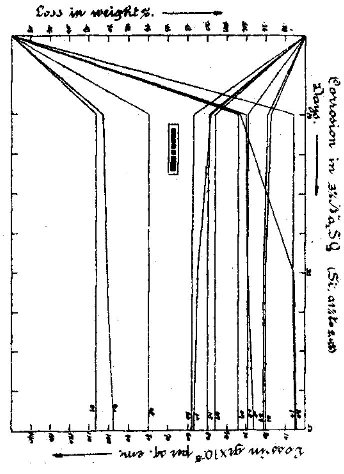


Fig. 75

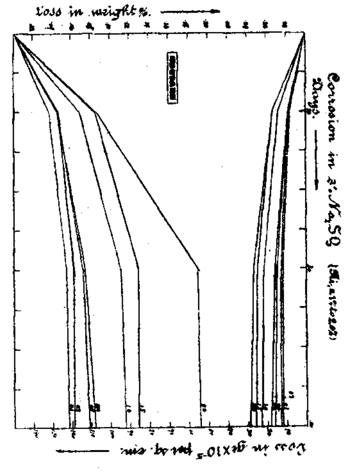


Fig. 76

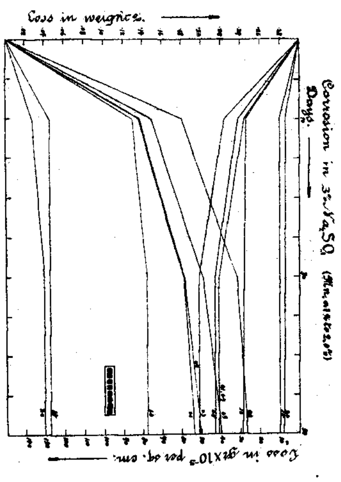


Fig. 77

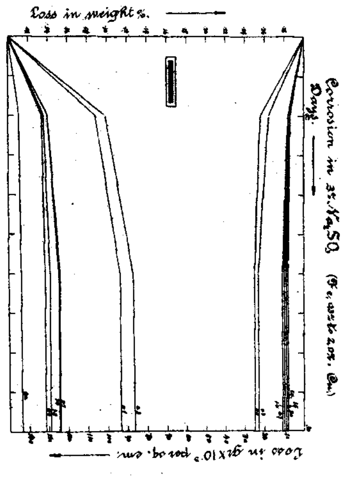


Fig. 78

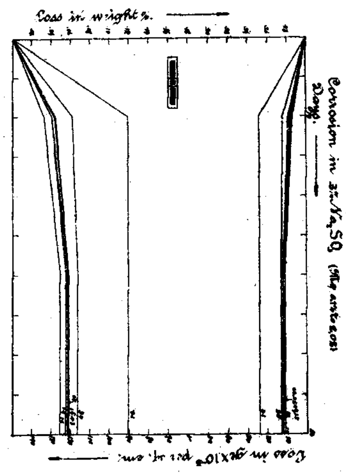


Fig. 79

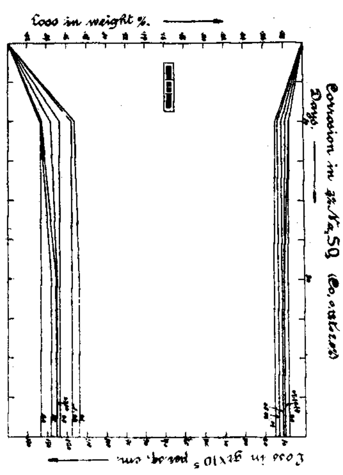


Fig. 80

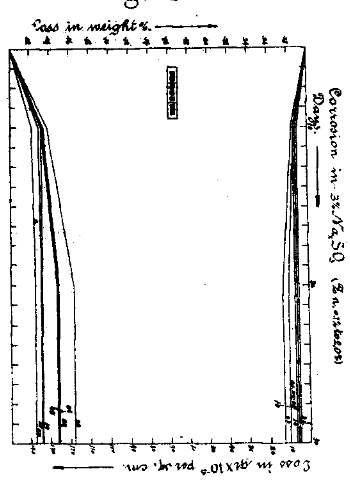
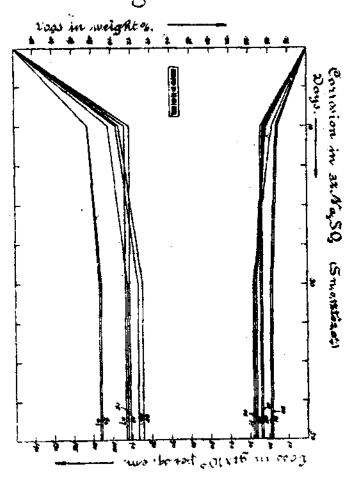


Fig. 81



No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		Loss after 30 Days		Loss after 50 Days	
		%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.	%	Gr. × 10^{-5} Per Sq. Cm.
44	Co 0.1	0.068	14	0.072	15	0.072	15
45	Co 0.3	0.065	13	0.065	13	0.065	13
46	Co 0.5	0.053	11	0.053	11	0.053	11
47	Co 0.7	0.044	9	0.050	10	0.050	10
48	Co 1.0	0.035	7	0.049	10	0.050	10
49	Co 1.5	0.034	7	0.044	10	0.044	10
50	Co 2.0	0.034	7	0.034	8	0.034	8
51	Zn 0.1	0.033	7	0.048	10	0.048	10
52	Zn 0.3	0.038	8	0.064	13	0.064	13
53	Zn 0.5	0.032	7	0.047	10	0.047	10
54	Zn 0.7	0.034	7	0.049	10	0.049	10
55	Zn 1.0	0.033	7	0.032	7	0.032	7
56	Zn 1.5	0.029	6	0.031	6	0.031	6
57	Zn 2.0	0.022	5	0.025	5	0.025	5
58	Sn 0.1	0.076	15	0.087	18	0.087	18
59	Sn 0.3	0.105	21	0.127	26	0.127	26
60	Sn 0.5	0.108	22	0.132	27	0.132	27
61	Sn 0.7	0.114	23	0.114	23	0.114	23
62	Sn 1.0	0.119	24	0.118	24	0.119	24
63	Sn 1.5	0.097	18	0.116	28	0.116	28
64	Sn 2.0	0.076	16	0.089	19	0.089	19
	Cu	0.011	8	0.013	9	0.013	9

CORROSION BY ATMOSPHERE.

Aluminium and its alloys are very stable in the ordinary atmosphere. The author obtained some sheets of aluminium which had been exposed to the town atmosphere of Osaka as roofing for 15 years, and found that they had suffered no noticeable corrosion. The sheet contains as impurities, 0.8% Fe and 0.5% Si.

The change of weight of aluminium and its alloys is negligible even when exposed to the atmosphere for year or two.

The use of aluminium is wide and varied in our days, and its use in the manufacture of cooking utensils is the most prominent. But, on account of its susceptibility to acids, its use is naturally limited.

For the purpose of removing the grave defect from the aluminium metals, the author examined the corrosive action of those liquids usnally used in our kitchens.

CORROSION BY ACETIC ACID.

The main component of the Vinegar used domestically is acetic acid, and its content usually varies from 5 to 10%.

Table 12 and 13 and Figs. 82 and 83 show the loss of weight after 10 days immersion in 5% and 30% acetic acid solutions respectively.

We can see from the Tables and Figures that the corrosive action of acetic acid is generally the stronger the more dilute the solution, and very active for the concentrations as used in our kitchens.

The addition of copper or manganese augments the strength against, acetic acid, while the addition of zinc shows the contrary effect.

Table 12.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days by 5% Acetic Acid		No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days by 5% Acetic Acid	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.			%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	0.117	24	35	Fe 1.5	0.082	17
2	Cu 0.3	0.087	18	36	Fe 2.0	0.085	18
3	Cu 0.5	0.075	15	37	Mg 0.1	0.108	21
4	Cu 0.7	0.067	14	38	Mg 0.3	0.135	28
5	Cu 1.0	0.067	14	39	Mg 0.5	0.136	29
6	Cu 1.5	0.068	13	40	Mg 0.7	0.134	28
7	Cu 2.0	0.098	15	41	Mg 1.0	0.132	28
8	Cu 2.5	0.087	18	42	Mg 1.5	0.134	28
9	Si 0.1	0.121	24	43	Mg 2.0	0.134	28
10	Si 0.3	0.106	21	44	Co 0.1	0.097	20
11	Si 0.5	0.105	21	45	Co 0.3	0.096	20
12	Si 0.7	0.102	20	46	Co 0.5	0.098	21
13	Si 1.0	0.101	19	47	Co 0.7	0.097	19
14	Si 1.5	0.090	18	48	Co 1.0	0.098	20
15	Si 2.0	0.090	19	49	Co 1.5	0.105	21
16	Ni 0.1	0.107	21	50	Co 2.0	0.098	20
17	Ni 0.3	0.107	21	51	Zn 0.1	0.097	19
18	Ni 0.5	0.095	19	52	Zn 0.3	0.090	19
19	Ni 0.7	0.095	19	53	Zn 0.5	0.093	19
20	Ni 1.0	0.092	18	54	Zn 0.7	0.096	20
21	Ni 1.5	0.093	19	55	Zn 1.0	0.199	40
22	Ni 2.0	0.093	19	56	Zn 1.5	0.231	55
23	Mn 0.1	0.109	18	57	Zn 2.0	0.869	179
24	Mn 0.3	0.109	20	58	Sn 0.1	0.095	19
25	Mn 0.5	0.094	19	59	Sn 0.3	0.102	22
26	Mn 0.7	0.086	18	60	Sn 0.5	0.104	25
27	Mn 1.0	0.099	17	61	Sn 0.7	0.110	26
28	Mn 1.5	0.086	18	62	Sn 1.0	0.116	26
29	Mn 2.0	0.080	16	63	Sn 1.5	0.125	27
31	Fe 0.3	0.107	21	64	Sn 2.0	0.127	29
32	Fe 0.5	0.097	20				
33	Fe 0.7	0.095	19				
34	Fe 1.0	0.089	17		Cu	0.018	17

Fig. 8 2

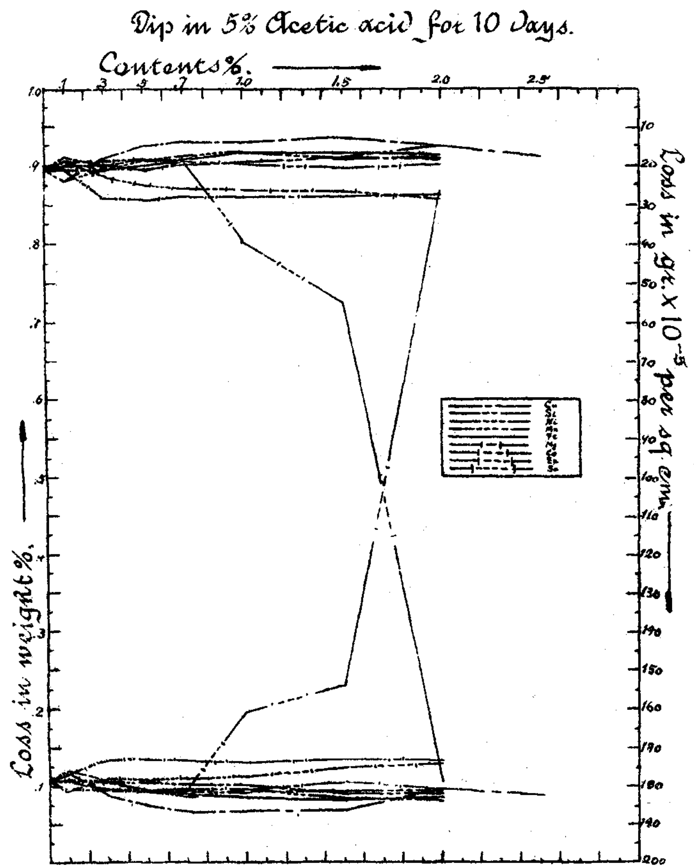

Dip in 5% Acetic acid for 10 Days.
Contents%.
Loss in weight%.
Loss in gr. x 10⁻⁵ per sq. cm.

Fig. 8 3

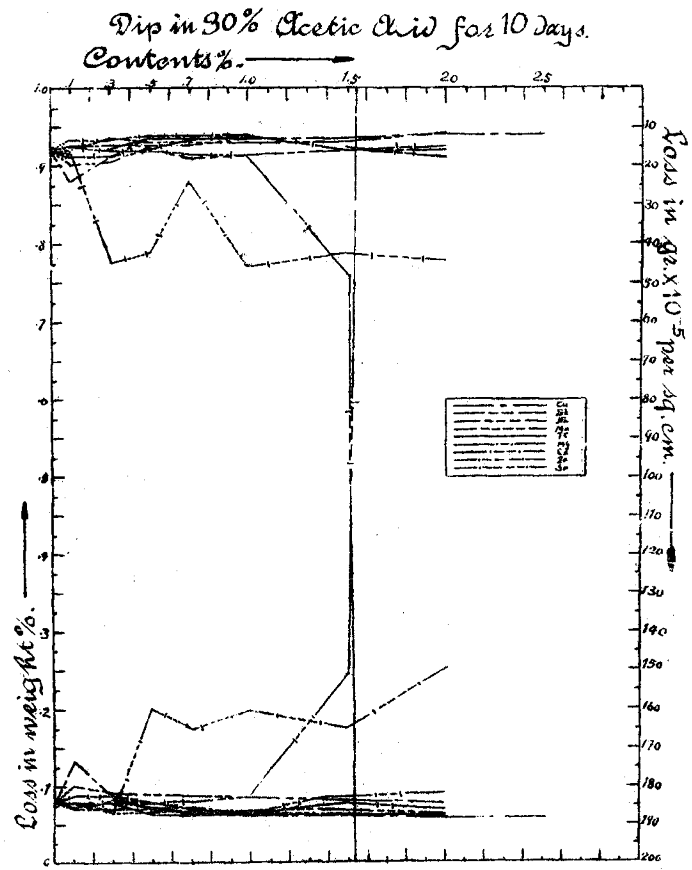
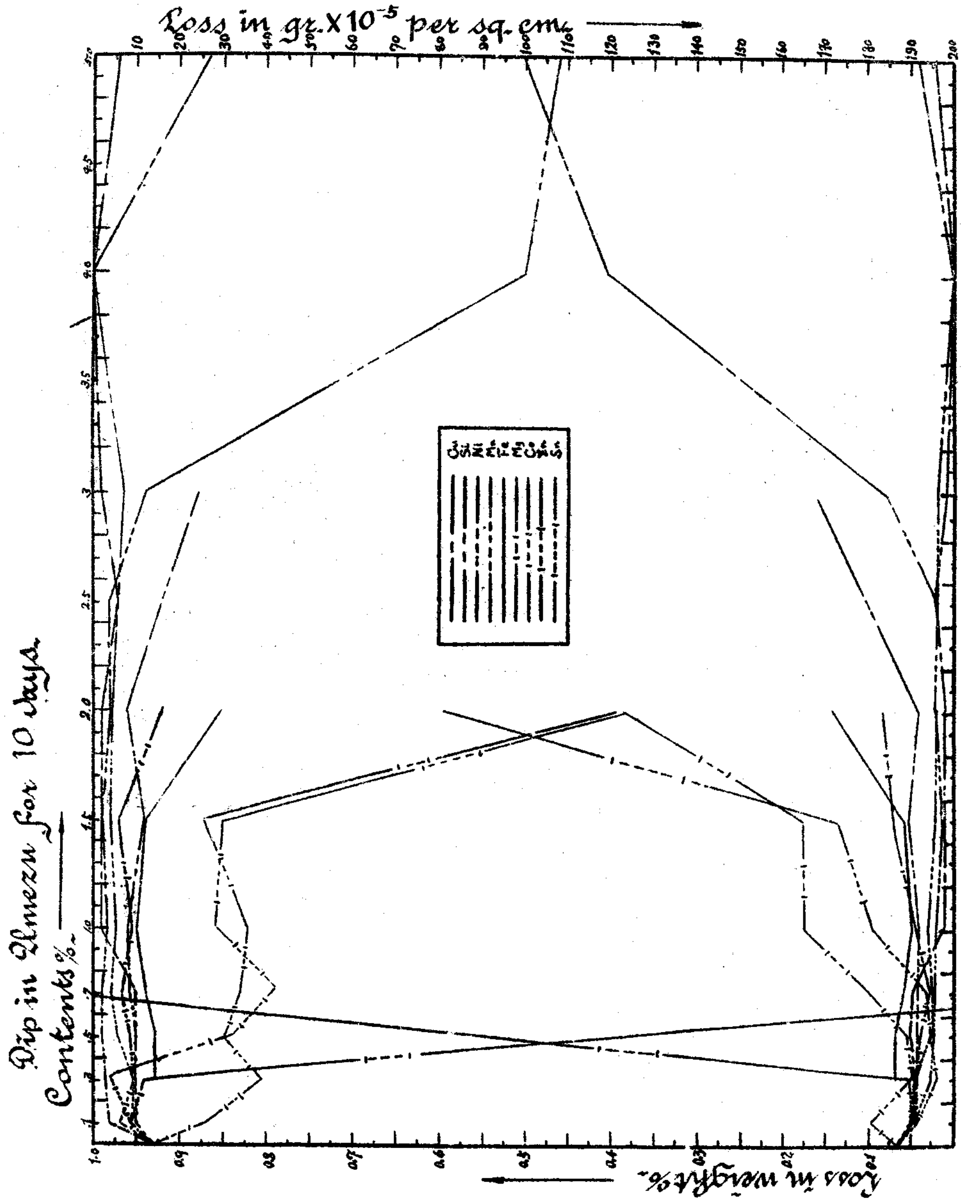

Dip in 30% Acetic Acid for 10 Days.
Contents%.
Loss in weight%.
Loss in gr. x 10⁻⁵ per sq. cm.

Fig. 8 4



Loss in gr. X 10^-5 per sq. cm.
Dip in Umezu for 10 days
Contents %
Loss in weight %

Table 13.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days by 30% Acetic Acid	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.
1	Cu 0.1	0.134	24
2	Cu 0.3	0.085	18
3	Cu 0.5	0.070	13
4	Cu 0.7	0.062	13
5	Cu 1.9	0.061	13
6	Cu 1.5	0.061	13
7	Cu 2.0	0.058	12
8	Cu 2.5	0.058	12
9	Si 0.1	0.101	20
10	Si 0.3	0.091	19
11	Si 0.5	0.073	15
12	Si 0.7	0.087	18
13	Si 1.0	0.086	17
14	Si 1.5	0.081	16
15	Si 2.0	0.077	16
16	Ni 0.1	0.072	15
17	Ni 0.3	0.071	15
18	Ni 0.5	0.071	15
19	Ni 0.7	0.074	15
20	Ni 1.0	0.065	13
21	Ni 1.5	0.063	13
22	Ni 2.0	0.059	12
23	Mn 0.1	0.078	16
24	Mn 0.3	0.065	13
25	Mn 0.5	0.067	14
26	Mn 0.7	0.068	14
27	Mn 1.0	0.068	14
28	Mn 1.5	0.068	14
29	Mn 2.0	0.063	12
31	Fe 0.3	0.078	16
32	Fe 0.5	0.066	13
33	Fe 0.7	0.063	13
34	Fe 1.0	0.061	13

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days by 30% Acetic Acid	
		%	Gr. $\times 10^{-5}$ Per Sq. Cm.
35	Fe 1.5	0.063	13
36	Fe 2.0	0.058	12
37	Mg 0.1	0.087	18
38	Mg 0.3	0.088	18
39	Mg 0.5	0.078	16
40	Mg 0.7	0.070	14
41	Mg 1.0	0.066	13
42	Mg 1.5	0.075	16
43	Mg 2.0	0.073	15
44	Co 0.1	0.075	15
45	Co 0.3	0.079	16
46	Co 0.5	0.073	14
47	Co 0.7	0.068	13
48	Co 1.0	0.067	13
49	Co 1.5	0.082	16
50	Co 2.0	0.089	18
51	Zn 0.1	0.072	15
52	Zn 0.3	0.077	17
53	Zn 0.5	0.076	17
54	Zn 0.7	0.079	18
55	Zn 1.0	0.083	18
56	Zn 1.5	0.246	48
57	Zn 2.0	17.742	3125
58	Sn 0.1	0.078	15
59	Sn 0.3	0.070	45
60	Sn 0.5	0.200	42
61	Sn 0.7	0.172	24
62	Sn 1.0	0.199	46
63	Sn 1.5	0.177	43
64	Sn 2.0	0.201	44
	Cu	0.052	23
	Fe	0.334	261

CORROSION BY "UMEZU".

Umezu is made from sour plums, common salt, and some vegetables, and is widely used in Japanese kitchens, especially those of school, domitories, factories and military barracks. "Umezu" is one of the most corrosive reagents for aluminium utensils, those containing "Umezu" are easily attacked, giving rise to leakage of the juicy content after a few days and darkening any food in it with the formation of a disagreeable black substance.

Table 14 and Fig. 84 show the loss of weight after 10 days immersion in "Umezu".

It has been found that the alloys containing copper, nickel or manganese suffer practically no change, while those containing zinc, tin, or cobalt are attacked to a great extent, among which zinc is most harmful, causing a total dissolution in a few days if the metal contains more than 1.5% zinc.

(2), (3), and (4) in Fig. 41 show the conditions of the alloys containing 0.5, 1.0, and 0.7% of zinc after being corroded by "Umezu". The remaining parts have the appearance of bundled rope showing macrographic stracture of the wire.

Table 14 Corrosion by Umezu, Loss after 10 Days.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	(Wire) %	(Wire) Gr. × 10^{-5} Per Sq. Cm.	Added Elements and their Per Cent (Theoretical)	(In Cast States) %	(In Cast States) Gr. × 10^{-5} Per Sq. Cm.
1	Cu 0.1	0.052	10			
2	Cu 0.3	0.049	10			
3	Cu 0.5	0.051	10	Cu 3	0.006	2
4	Cu 0.7	0.049	10	Cu 4	0.000	0
5	Cu 1.0	0.012	2	Cu 5	0.021	6
6	Cu 1.5	0.012	2			
7	Cu 2.0	0.010	2			
8	Cu 2.5	0.021	6			
9	Si 0.1	0.044	9			
10	Si 0.3	0.047	10			
11	Si 0.5	0.046	10			
12	Si 0.7	0.045	9			
13	Si 1.0	0.043	8			
14	Si 1.5	0.052	12			
15	Si 2.0	0.042	8	Si 3	0.16	25
16	Ni 0.1	0.045	4			
17	Ni 0.3	0.028	3	Ni 2.5	0.020	4
18	Ni 0.5	0.023	2	Ni 3	0.080	12
19	Ni 0.7	0.021	2	Ni 4	0.403	100
20	Ni 1.0	0.021	3	Ni 5	0.502	108
21	Ni 1.5	0.013	2			
22	Ni 2.0	0.021	4			
23	Mn 0.1	0.048	9			
24	Mn 0.3	0.049	9	Mn 3	0.019	7
25	Mn 0.5	0.023	5	Mn 4	0.000	0
26	Mn 0.7	0.022	4	Mn 5	0.041	27
27	Mn 1.0	0.028	5			
28	Mn 1.5	0.022	4			
29	Mn 2.0	0.021	4			
31	Fe 0.3	0.067	14			
32	Fe 0.5	0.067	14	Fe 3	—	—
33	Fe 0.7	0.056	12	Fe 4	—	—

Fig. 8 5

Dip in Shoyu for 10 Days.

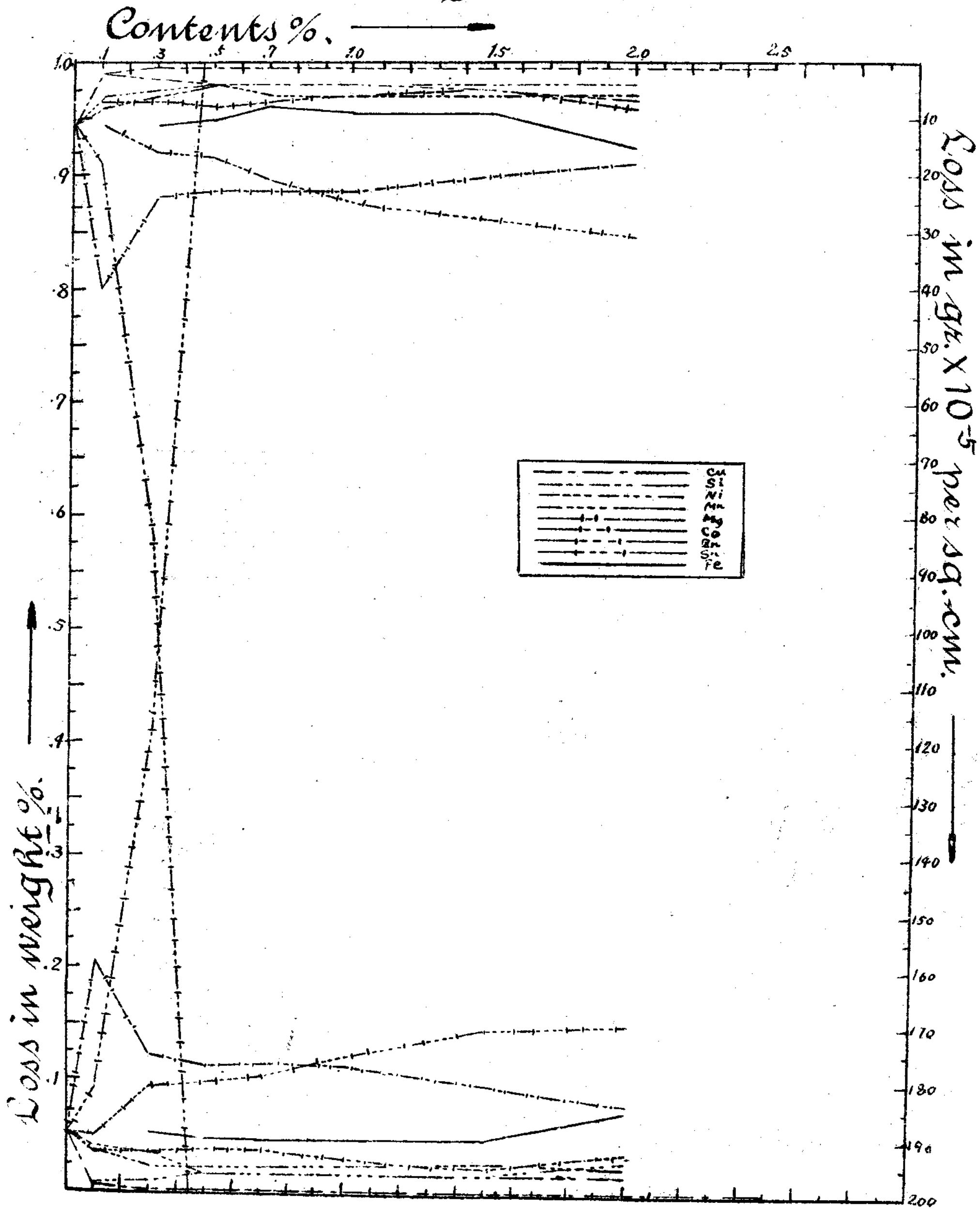
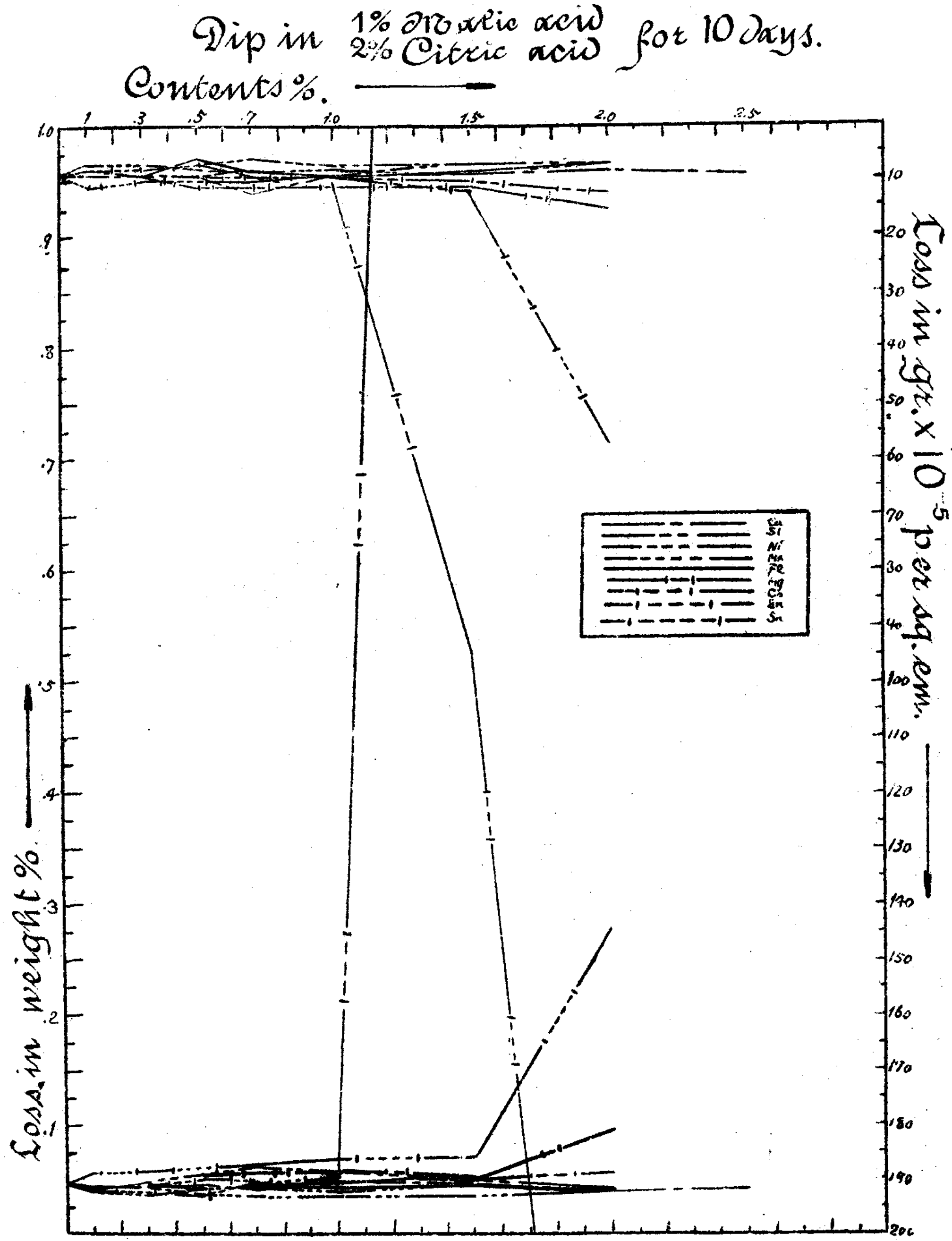


Fig. 8 6


Dip in 1% Oxalic acid 2% Citric acid for 10 days.
Contents %.
.1 .3 .5 .7 1.0 1.5 2.0 2.5
1.0 .9 .8 .7 .6 .5 .4 .3 .2 .1
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Loss in weight %
Loss in gr. × 10⁻⁵ per sq. cm.
Si
Ni
Fe
Mg
Sn

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	(Wire)		Added Elements and their Per Cent. (Theoretical)	(In Cast States)	
		%	Gr. × 10⁻⁵ Per Sq. Cm.		%	Gr. × 10⁻⁵ Per Sq. Cm.
34	Fe 1.0	0.049	10	Fe 5	—	—
35	Fe 1.5	0.056	12			
36	Fe 2.0	0.146	30			
37	Mg 0.1	0.049	7			
38	Mg 0.3	0.050	10			
39	Mg 0.5	0.047	9			
40	Mg 0.7	0.035	7			
41	Mg 1.0	0.046	9			
42	Mg 1.5	0.071	6			
43	Mg 2.0	0.083	16			
44	Co 0.1	0.096	26			
45	Co 0.3	0.048	39			
46	Co 0.5	0.054	30			
47	Co 0.7	0.099	34			
48	Co 1.0	0.175	35			
49	Co 1.5	0.177	25			
50	Co 2.0	0.388	121			
51	Zn 0.1	0.045	9			
52	Zn 0.3	0.055	12			
53	Zn 0.5	3.800	757			
54	Zn 0.7	—	—			
55	Zn 1.0	—	—			
56	Zn 1.5	—	—			
57	Zn 2.0	—	—			
58	Sn 0.1	0.046	8			
59	Sn 0.3	0.022	4			
60	Sn 0.5	0.025	31			
61	Sn 0.7	0.029	42			
62	Sn 1.0	0.093	28			
63	Sn 1.5	0.135	30			
64	Sn 2.0	0.595	123			
	Cu	8.553	4420			
	Fe	0.072	6			

The alloys containing more than 2% of iron separate a dirty blackish mud, and the corrosion penetrates to the inmost core. (8) in Fig. 41 shows an alloy containing 3% of iron immersed in "Umezu" for 10 days; (7) an alloy containing 3% of iron and 3% of copper, and treated in the same way.

Sometimes, utensils made of aluminium tarnish to a brown colour during use, and it has hitherto been attributed to the presence of iron as an impurity, but the author proved that it comes from other sources in many cases, and found a partial remedy for this condition, which will be discussed under the caption, "Degradation of Aluminium Ingots or Wares by Their Manufacturing Treatment.")

CORROSION BY "SHÔYU".

"Shôyu" is a kind of sauce, made from the soya bean, common salt and yiest, and is indispensable in Japanese cooking.

Table 15 and Fig. 85 show the loss of weight after 10 days immersion in "Shôyu".

It has been found that the alloys containing copper, nickel, or man ga nese are stronger than pure aluminium, while those containing zinc, tin, or magnesium are weaker, among which zinc gives a remarkably bad effect.

Table 15 Corrosion by Shôyu.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days	
		%	Gr. × 10^{-5} Per Sq. Cm.			%	Gr. × 10^{-5} Per Sq. Cm.
1	Cu 0.1	0.006	2	35	Fe 1.5	0.049	9
2	Cu 0.3	0.003	1	36	Fe 2.0	0.073	15
3	Cu 0.5	0.002	1	37	Mg 0.1	0.206	40
4	Cu 0.7	0.001	1	38	Mg 0.3	0.123	24
5	Cu 1.0	0.001	1	39	Mg 0.5	0.113	23
6	Cu 1.5	0.001	1	40	Mg 0.7	0.115	23
7	Cu 2.0	0.001	1	41	Mg 1.0	0.114	23
8	Cu 2.5	0.004	1	42	Mg 1.5	0.096	20
9	Si 0.1	0.008	2	43	Mg 2.0	0.082	18
10	Si 0.3	0.012	3	44	Co 0.1	0.037	7
11	Si 0.5	0.018	4	45	Co 0.3	0.036	7
12	Si 0.7	0.018	4	46	Co 0.5	0.040	8
13	Si 1.0	0.019	4	47	Co 0.7	0.038	7
14	Si 1.5	0.018	5	48	Co 1.0	9.031	6
15	Si 2.0	0.030	7	49	Co 1.5	0.024	5
16	Ni 0.1	0.042	8	50	Co 2.0	0.038	8
17	Ni 0.3	0.037	6	51	Zn 0.1	0.089	18
18	Ni 0.5	0.018	4	52	Zn 0.3	0.412	84
19	Ni 0.7	0.017	4	53	Zn 0.5	1.194	308
20	Ni 1.0	0.017	4	54	Zn 0.7	2.013	483
21	Ni 1.5	0.018	4	55	Zn 1.0	2.845	692
22	Ni 2.0	0.017	4	56	Zn 1.5	3.735	761
23	Mn 0.1	0.038	6	57	Zn 2.0	4.545	926
24	Mn 0.3	0.025	5	58	Sn 0.1	0.050	11
25	Mn 0.5	0.021	4	59	Sn 0.3	0.095	16
26	Mn 0.7	0.024	6	60	Sn 0.5	0.099	17
27	Mn 1.0	0.026	6	61	Sn 0.7	0.104	21
28	Mn 1.5	0.028	6	62	Sn 1.0	0.121	25
29	Mn 2.0	0.024	6	63	Sn 1.5	0.146	28
31	Fe 0.3	0.053	11	64	Sn 2.0	0.152	31
32	Fe 0.5	0.050	10		Cu	0.013	2
33	Fe 0.7	0.048	8		Fe	0.036	7
34	Fe 1.0	0.050	9				

CORROSION BY CITRIC AND MALIC ACIDS.

Table 16 and Fig. 86 show the loss of weight after 10 days immersion in 2% of citric and 1% of malic acids.

It has been found that the addition of zinc or tin has a deleterious effect, while that of other metals is practically indifferent.

Table 16 Corrosion by 3% Malic and Citric Acids.

No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days		No. of Alloys	Added Elements and their Per Cent. (Theoretical)	Loss after 10 Days	
		%	Gr. × 10^{-5} Per Sq. Cm.			%	Gr. × 10^{-5} Per Sq. Cm.
1	Cu 0.1	0.044	9	37	Mg 0.1	0.041	8
2	Cu 0.3	0.045	9	38	Mg 0.3	0.047	9
3	Cu 0.5	0.046	9	39	Mg 0.5	0.053	11
4	Cu 0.7	0.042	8	40	Mg 0.7	0.056	11
5	Cu 1.0	0.048	9	41	Mg 1.0	0.054	11
6	Cu 1.5	0.046	9	42	Mg 1.5	0.052	11
7	Cu 2.0	0.038	8	43	Mg 2.0	0.093	15
8	Cu 2.5	0.042	9				
				44	Co 0.1	0.041	7
9	Si 0.1	0.040	8	45	Co 0.3	0.045	9
10	Si 0.3	0.048	9	46	Co 0.5	0.050	9
11	Si 0.5	0.055	9	47	Co 0.7	0.045	9
12	Si 0.7	0.062	12	48	Co 1.0	0.047	9
13	Si 1.0	0.056	9	49	Co 1.5	0.050	10
14	Si 1.5	0.048	7	50	Co 2.0	0.054	12
15	Si 2.0	0.040	8				
				51	Zn 0.1	0.043	8
16	Ni 0.1	0.044	8	52	Zn 0.3	0.042	8
17	Ni 0.3	0.042	8	53	Zn 0.5	0.040	7
18	Ni 0.5	0.036	7	54	Zn 0.7	0.048	9
19	Ni 0.7	0.033	6	55	Zn 1.0	0.052	10
20	Ni 1.0	0.033	7	56	Zn 1.5	4.230	95
21	Ni 1.5	0.034	7	57	Zn 2.0	14.168	292
22	Ni 2.0	0.037	7				
				58	Sn 0.1	0.056	11
23	Mn 0.1	0.037	7	59	Sn 0.3	0.059	10
24	Mn 0.3	0.035	7	60	Sn 0.5	0.060	10
25	Mn 0.5	0.041	8	61	Sn 0.7	0.065	10
26	Mn 0.7	0.042	8	62	Sn 1.0	0.068	9
27	Mn 1.0	0.044	8	63	Sn 1.5	0.069	12
28	Mn 1.5	0.046	9	64	Sn 2.0	0.275	57
29	Mn 2.0	0.040	8				
					Cu	0.022	23
31	Fe 0.3	0.046	9				
32	Fe 0.5	0.035	6				
33	Fe 0.7	0.045	8				
34	Fe 1.0	0.043	9				
35	Fe 1.5	0.043	8				
36	Fe 2.0	0.038	7				

SUMMERY ON THE INFLUENCE OF METALS AGAINST CORROSION IN THE BINARY ALUMINIUM ALLOYS.

Summerizing the foregoing experiments we can arrange the metals as in Table 17, classified according to their effects on corrosion.

It may be seen that, on the whole, the addition of copper, nickel, and manganese is desirable in order to strengthen the property against corrosion; while other metals (with certain exceptions in special cases) among which zinc is the most deleterious element from the point of view of corrosiveness, give bad results.

Table 17.

Reagents and Their Concentrations	Elements Which give Good Effects	Elements Which give Bad Effects
0.5% Sulphuric Acid	Ni Cu	Sn Mg
0.5% Nitric Acid	Cu Mn	Sn Mg
0.5% Hydrochloric Acid	Ni Cu Mn	Sn Zn
0.5% Sodium Hydroxide	—	—
0.5% Ammonium Hydroxide	Mg Mn Cu	Co Sn Zn
Saturated Carbonic Acid	Ni Cn Si	Sn
3% Sodium Chloride Soln.	Mn	Sn Zn
3% Sodium Sulphite Soln.	Zn Fe Co	Si
5% & 30% Acetic Acid	Ni Cu Mn Fe	Co Zn
"Umezu" or Verjuice	Mn Cu Ni	Fe Sn Zn
"Shôyu" or Soy	Cu Ni Mn	Mg Sn Zn
3% Citric and Malic Acids	Ni	Mg Sn Zn
For Most Reagents	Cu Ni Mn	Fe Co Si Mg Sn Zn

STUDY ON THE ACID-RESISTING MATERIALS FOR ALUMINIUM UTENSILS.

It is almost impossible to obtain an alloy resisting the corrosive action of inorganic acids or caustic alkalis. The author therefore aimed to make an alloy resisting the corrosive action of organic acids or weak alkalis in order to minimize the defects of aluminium metals as used in the manufacture of cooking utensils.

With a view to removing that disagreeable muddy matter produced by "Umezu," a number of alloys containing several metals together with iron which is the chief cause of this bad effect, were made and their properties were examined, the results of which are shown in Table 18.

Table 18.

No. of Alloys	Added Metal %		By Umezu			By Acetic Acid (30%)			By Malic & Citric Acids (3%)			By Shôyu		
			Colour	% in Wt. Loss for 30 Days	Loss of Wt. per Sq. Cm. for 30 Days	Colour	% in Wt. Loss for 30 Days	Loss of Wt. per Sq. Cm. for 30 Days	Colour	% in Wt. Loss for 30 Days	Loss of Wt. per Sq. Cm. for 30 Days	Colour	% in Wt. Loss for 30 Days	Loss of Wt. per Sq. Cm. for 30 Days
15	Fe 2	Cu 1	◎	0.018	0.00010	◎	0.058	0.00036	◎	0.014	0.00009	◎	0.017	0.00010
16	Fe 2	Cu 2	◎	0.012	0.00008	◎	0.032	0.00021	◎	0.038	0.00024	◎	0.012	0.00008
17	Fe 3	Cu 3	◎	0.014	0.00008	◎	0.056	0.00036	◎	0.026	0.00017	◎	0.016	0.00011
18	Fe 3	Cu 2	◎	0.030	0.00020	◎	0.049	0.00033	◎	0.007	0.00005	◎	0.001	0.00001
19	Fe 3	Cu 1	◎	0.040	0.00029	◎	0.040	0.00029	◎	0.032	0.00019	◎	0.017	0.00011
20	Fe 2	Ni 1	◈	≀≀	≀≀	◎	0.737	0.00472	◎	0.016	0.00010	●	0.039	0.00024
21	Fe 2	Ni 2	◈	≀≀	≀≀	◎	0.350	0.00226	◎	0.003	0.00002	●	0.049	0.00034
22	Fe 2	Ni 3	◈	≀≀	≀≀	○	0.451	0.00301	◎	0.030	0.00018	○	0.013	0.00008
23	Fe 3	Ni 1	◈	≀≀	≀≀	○	1.308	0.00699	◎	0.008	0.00005	□	0.020	0.00004
24	Fe 3	Ni 2	◈	≀≀	≀≀	○	1.308	0.00903	◎	0.000	0.00000	●	0.015	0.00010
25	Fe 3	Ni 3	◈	≀≀	≀≀	○	1.780	0.01151	◎	0.009	0.00006	●	0.065	0.00044
26	Fe 3	Mn 3	▲	≀≀	≀≀	◎	0.054	0.00036	◎	0.005	0.00003	□	0.012	0.00008
27	Fe 3	Mn 2	▲	≀≀	≀≀	◎	0.086	0.00056	◎	0.015	0.00010	○	0.014	0.00010
28	Fe 3	Mn 1	▲	≀≀	≀≀	□	0.130	0.00087	◎	0.015	0.00010	□	0.019	0.00012
29	Fe 3	Sn 2	▲	≀≀	≀≀	◎	0.349	0.00228	◎	0.019	0.00013	○	?	?
30	Fe 3	Sn 3	▲	≀≀	≀≀	◎	0.310	0.00207	◎	0.030	0.00019	□	?	?

N.B. ≀≀ . . . Indicates that the corrosion is so great that the alloys can not be weighed.
? . . . Indicates the data are confused and exact values could not be found.
◎ . . . No change in colour and lustre, remains bright.
○ . . . No change in colour, but crystals can be seen.
□ . . . Lustre out, crystals can be seen, but no stain.
● . . . Surface stairs a little.
▲ . . . Surface becomes blackish; but original forms retained.
◈ . . . Black dirty jelly-like compound adheres all over the surface of the samples, and they can not be used in any way.

It has been found that copper in the alloy removes the bad effect of iron perfectly, the reason of this fact may probably be traced to the composition of the special structure in the Al-Fe-Cu ternary alloy with the modification properties of Al-Fe alloy.

The addition of copper alone, however, does not bring about a marked difference. Nickel and manganese are also desirable for the augumentation of the resistive property. Especially in the case of more than 1.5% Mn, it makes a compound of formula Al_3Mn with aluminium, increasing the resisting property to a marked degree, the α—constituent of the Al-Ni alloy containing less than 2% of nickel is also very resistant.

Standing on these facts, the author tries to find the most suitable proportions of metals to be added to aluminium in order to obtain the most resisting alloy against corrosion.

Table 19.

No.	Composition (%)				Loss in Weight % During 30 Days by			
	Cu	Ni	Mn	Other	NaCl (3%)	Umezu	Acetic Acid (5%)	H_2SO_4 (0.5%)
1	1	1	1	—	0.024	0.013	0.098	4.96
2	1	1	2	—	0.016	0.012	0.082	3.91
3	1	1	3	—	0.006	0.004	0.085	3.20
4	1	1	4	—	0.003	0.004	0.085	3.00
5	1	2	2	—	0.008	0.010	0.058	2.31
6	1	2	3	—	0.000	0.000	0.030	2.00
7	1	2	4	—	0.000	0.000	0.032	1.05
8	1	3	2	—	0.013	0.002	0.041	2.04
9	1	4	2	—	0.021	0.002	0.045	3.12
10	1	2	1	—	0.025	0.085	0.050	4.05
11	2	2	1	—	0.034	0.000	0.042	5.55
12	2	2	3	—	0.0c0	0.000	0.020	1.28
13	2	3	2	—	0.001	0.000	0.038	2.88
14	2	2	4	—	0.000	0.000	0.020	0.68
15	2	1	1	—	0.032	0.008	0.060	7.94
16	3	1	2	—	0.014	0.000	0.045	3.46
17	3	2	1	—	0.031	0.000	0.061	5.46
18	3	2	2	—	0.030	0.000	0.038	4.00
19	3	3	3	—	0.004	0.000	0.033	3.82
20	1.5	2	3	—	0.000	0.000	0.012	1.37
21	1.5	2	2	—	0.000	0.000	0.010	1.07
22	4	3	3	—	0.004	0.000	0.021	4.00
23	3	3	4	—	0.004	0.000	0.018	3.04
24	3	4	3	—	0.002	0.000	0.021	6.38
25	4	2	2	—	0.008	0.000	0.025	7.90
Extra:								
1	2	3	—	—	0.123	0.044	0.067	4.42
2	2	—	3	—	0.084	0.010	0.050	4.26
3	1.5	2	2	Co 1.5	0.014	0.008	0.031	3.35
4	1.5	2	2	Sn 1.5	0.077	0.012	0.029	2.88
5	1.5	2	2	Mg 1	0.008	0.003	0.018	2.36

As shown in Table 19 it has been found that the best result is obtained by adding 1.5—2% Cu, 2-4% Mn, and 1-2% Ni to aluminium.

Table 20 shows the comparison of the resisting powers of the alloys with the above composition, of pure commercial aluminlum, and of some of the alloys known as acid resisting.

Table 20.

			Halumin (Cast State)			Extra 5	Yamamoto's Patent Alloy	Rosenhain's "Y" Alloy	Duralumin	Pure Al. (Wire)
			(12)	(20)	(21)					
	Analysis		Cu 1.52 Ni 1.99 Mn 3.46 Fe 0.34 Si 0.06	Cu 1.20 Ni 1.91 Mn 2.61 Fe 0.41 Si 0.06	Cu 1.60 Ni 1.80 Mn 2.24 Fe 0.38 Si 0.07	Cu 1.20 Ni 1.93 Mn 2.51 Fe 0.41 Si 0.08 Mg 1.03	Sn 1.48 Ni 1.98 Mg 1.51 Fe 0.40 Si 0.07	Cu 4.05 Ni 2.00 Mg 1.47 Fe 0.58 Si 0.07	Cu 4.60 Mn 0.82 Mg 0.57 Fe 0.38 Si 0.08	Fe 0.31 Si 0.04 Al Bal.
After 30 Days	0.5% NH_4OH	Loss %	0.0000	0.0014	0.0021	0.0021	0.0741	0.0031	0.1013	3.7292
		Gr./Sq. Cm.	0.00000	0.00001	0.00001	0.00001	0.00044	0.00001	0.00062	0.0752
	3% NaCl	Loss %	0.0000	0.0000	0.0000	0.0075	0.1206	0.0159	0.0126	0.0184
		Gr./Sq. Cm.	0.00000	0.00000	0.00000	0.00006	0.00051	0.00008	0.00006	0.00009
	3% Malic & Citric Acid	Loss %	0.0000	0.0029	0.0032	0.0208	0.1284	0.0000	0.0135	0.0076
		Gr./Sq. Cm.	0.00000	0.00003	0.00002	0.00010	0.00075	0.00000	0.00009	0.00006
	3% Na_2CO_3	Loss %	0.0060	0.0063	0.0034	0.0123	0.0248	0.0209	15.6495	0.0081
		Gr./Sq. Cm.	0.00003	0.00004	0.00001	0.00008	0.00010	0.00010	0.07935	0.00003
	3% Na_2SO_3	Loss %	0.0000	0.0071	0.0013	0.0016	0.0065	0.0091	0.0072	0.0113
		Gr./Sq. Cm.	0.00000	0.00003	0.00001	0.00001	0.00003	0.00005	0.00003	0.00023
	Umezu	Loss %	0.0000	0.0000	0.0000	0.0278	1.6572	0.4603	0.0342	0.1533
		Gr./Sq. Cm	0.00000	0.00000	0.00000	0.00016	0.00762	0.00229	0.00018	0.00101
	Shôyu	Loss %	0.0000	0.0000	0.0000	0.0026	0.0746	0.0000	0.0268	0.1520
		Gr./Sq. Cm.	0.00000	0.00000	0.00000	0.00001	0.00045	0.00000	0.00019	0.00242
	5% Acet. Acid	Loss %	0.0514	0.0119	0.0418	0.0287	0.1921	0.0463	0.0229	0.2015
		Gr./Sq. Cm.	0.00029	0.00012	0.00013	0.00013	0.00110	0.00013	0.00014	0.00041
	30% Acet. Acid	Loss %	0.0202	0.0117	0.0101	0.0176	0.1946	0.0135	0.0293	0.1520
		Gr./Sq. Cm.	0.00010	0.00006	0.00004	0.00009	0.00084	0.00008	0.00016	0.00034
	0.5% HCl	Loss %	1.3852	1.3733	1.0736	0.7824	§ § §	3.4319	2.4888	2.0412
		Gr./Sq. Cm	0.00758	0.01599	0.00435	0.00453	§ §	0.01520	0.01222	0.00484
	0.5% H_2SO_4	Loss %	1.2845	1.3743	1.0014	2.3569	6.2540	§ § §	1.6498	2.1724
		Gr./Sq. Cm.	0.00758	0.01599	0.00449	0.01329	0.02873	§ §	0.00847	0.00455
	0.5% HNO_3	Loss %	2.0961	1.1064	1.0852	0.4716	2.4122	0.4231	0.2358	3.0227
		Gr./Sq. Cm.	0.00981	0.00678	0.00713	0.00348	0.01528	0.00208	0.00143	0.01625
	N.B. § § § § §	Indicates the losses are so great that they cannot be weighed exactly.								
After 10 Days	10% H_2SO_4	Loss %	0.417	0.183	0.475	1.077	2.549	15.112	0.947	2.187
	Saturatd. NaCl	Loss %	0.002	0.000	0.003	0.107	0.039	0.000	0.208	0.025
	3% H NO_3	Loss %	0.087	0.209	0.147	0.809	1.707	4.841	0.747	0.974

In a ward, the most resistant aluminium alloy should have the compositions given above, and no other metal than copper, nickel, and manganese should be added, nor should any of the three be omitted.

In case an alloy which is more resistant against corrosion should be dicovered in the future, the author would think that it will probably contain metals other than those which have not been investigated by the present author, or else some metallic compounds that may have specially resisting power.

The alloy of the composition mentioned above has been designated "HALUMIN" by the author, and its mechanical properties are shown in Table 21.

Table 21.

Mechanical Properties of "Halumin" with an example.

Analysis of the Sample used for the following tests	Cu : 1.48%
	Ni : 2.00%
	Mn: 2.30%
	Fe : 0.47%
	Si : 0.09%
	Al and Other Impurities: Balance.
Specific Gravity	2.78

Ultimate Tensile Strength: (Thin Plate 0 3–0 5 mm. thick)

Cold Worked	Annealed
25–38 Kg./Sq. mm.	19.5–25 Kg./Sq. mm.
or 15.8–24.2 Ton/Sq. In.	or 12.1–15.8 Ton/Sq. In.

Ultimate Elongation: (Thin Plate 0.3–0.5 mm. thick)

Cold Worken	Annealed
1–3%	13–17%
	(Thick Plate 5–7 mm. thick)
4–7%	20–26%

Hardness (Cold Worked Plate)

Brinnel No. (With 10 mm. Ball, 500 Kg. Press.)	65–70
Shore's No. (With Soft)	36–42

Cupping Tests: (With Erichsen's Machine)

	Thickness of Plate (mm.)	Depth of Cup (mm.)
Cold Worked	0.3	2.92
	0.4	3.45
	0.5	3.83

	Thickness of Plate (mm.)	Depth of Cup. (mm.)
Annealed	0.3	4.71
	0.4	5.72
	0.5	6.93

Cooking utensils made of "Halumin" have the following characteristics:

(1) Resistant against corrosion.

(2) Hard and strong, so that breakage or deformation is less than with ordinary aluminium wares.

(3) The thermal conductivity is slightly less than pure aluminium.

(4) Welding can be applied much more easily than pure aluminium.

(5) The usual bad effect of iron (even in the case of more than 1.0% content) is entirely eliminated.

DEGRADATION OF ALUMINIUM INGOTS OR WARES BY THE MANUFACTURING TREATMENT.

Aluminium wares sometimes aquire a brownish or black colour on their surface when used for boiling water, or in contact with water for a long time. This problem has hitherto been attributed to the presence of iron in the metal. But the mode of colouring is different according to the method of treatment, if they contain the same amount of iron. It is noticed that water boiled in well-washed aluminium ware for hours show distinctly alkaline reaction to the indicator, proving the production of sodium hydroxide; W. Smith[1] also observed the same phenomenon.

The most of the aluminium factories in our country use sodium hydroxide in order to get uniform and pearly white luster on aluminium at the time of manufacturing into utensils, and the hydroxide is neutralised by washing with sulphuric acid, or with a mixture of nitric and sulphuric acids, and then, carefully, with water. The author found that the sodium hydroxide thus applied cannot be removed perfectly by such methods, but more than a trace of the sodium salts is left behind on the surface of the metal. The salts, when in contact with hot water or steam, are electroly-

(1) Jour. Soc. Chem. Ind. Vol. 23 (1904) 475.

sed into NaOH by the aluminium, and the produced hydroxide begins to attack the wares. Repeated polishing of the wares diminishes the colour production, and the question is, will the sodium salts on the surface be thus dissipated.

But every specimen of aluminium, in a virgin state, does contain some sodium salts, as has been proved by D. Fairlite and G. Brook[1] and the present author has also ascertained that it is true of all the samples of the metal made by 5 companies of different countries.

The iron, the impurity of aluminium, therefore is not always the cause of the production of colour; for this is mainly due to the presence of sodium salts produced by the way which is mentioned above.

The sodium salts, which are thus left behined and which can not be removed by mere washing, can most satisfactorily be removed by the use of a dilute solution of the so-called "Chromic-Mixture," i.e. a mixture of sulphuric acid and potassium bichromate. But, the sodium salts originally contained in the metal which came from the manipuration of metallurgy, though in a minute quantity, cannot be removed by the above method unless the process to obtain the pure aluminium from its ores be improved, and some other processes take the place of the present methods in which the use of sodium salts is indispensable.

The new facts which the author found in the course of this investigation are as follows:—

(1) The production of a new excellent aluminium alloy which is most suitable for the manufacture of cooking utensils.

(2) Aluminium suffers marked corrosion when it contains even small quantities of zinc and tin, the former being much more deleterious.

(3) Special points in the constitutional diagrams of the metallography of aluminium and other metals could be found by corrosion tests, which the author hopes to discuss in another paper.

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(1) Met. Ind. (London) Vol. 25 (1924) 281.

(4) Blackish dirty substances produced in aluminium utensils by "Umezu" is due to the iron contained in the metal.

(5) The bad effects of iron in the aluminium can be removed by the addition of copper.

(6) The dirty brownish colour produced on the surface of utensils of aluminium or its alloys during usage is mainly due to the action of sodium hydroxide coming either from procedure of metallurgy or the finishing treatment with alkali.

(7) The sodium hydroxide thus found near the surface of the metal can best be removed by the "Chromic-Mixture," though perpaps not entirely.

In bringing this Part I to a conclusion, the author wishes to express his hearty thanks to Prof. D. Saitô for his kind advices during the carrying out of this investigation, and to the Osaka Arsenal for preparing the samples.