United States Patent [19]

Richardson et al.

[11] **3,769,005**

[45] **Oct. 30, 1973**

[54] **COPPER NICKEL ALLOYS**

[75] Inventors: **William Henry Richardson,** Datchet; **Douglas Brown,** Slough; **Prodyot Guha,** High Wycombe, all of England

[73] Assignee: **Langley Alloys Limited,** Slough, Buckinghamshire, England

[22] Filed: **July 7, 1971**

[21] Appl. No.: **160,531**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 784,024, Dec. 12, 1968, abandoned.

[52] **U.S. Cl.** **75/159,** 148/32, 148/32.5

[51] **Int. Cl.** **C22c 9/06**

[58] **Field of Search** 75/153, 159, 161, 75/162; 148/32, 32.5

[56] **References Cited**

UNITED STATES PATENTS

3,399,057	8/1968	Richardson	75/159

FOREIGN PATENTS OR APPLICATIONS

578,223	6/1946	Great Britain	75/159
655,931	1/1938	Germany	75/159
1,194,632	6/1970	Great Britain	75/159
1,090,734	11/1967	Great Britain	75/159
999,438	7/1965	Great Britain	75/159

Primary Examiner—Charles N. Lovell

Attorney—Luke A. Mattare et al.

[57] **ABSTRACT**

A high quality, high strength, highly ductile, castable, weldable and corrosion resistant Copper alloy consisting of the following elements in the following proportions by weight :

Nickel 9% – 18%
Aluminium 1% – 3.5%
Manganese 8.5% – 13%
Iron 2.5% – 6.5%
Chromium 0% – 1%
Copper the balance

with the Aluminium, Manganese and Nickel contents being so controlled that they satisfy the following formulae :

a. $4 \times Al\% + Mn\% = 14\% - 20\%$
b. $4 \times Al\% + Ni\% = 17\% - 25\%$
c. $Ni\%/5Al\% =$ Greater than 1

1 Claim, No Drawings

COPPER NICKEL ALLOYS

This Application is a Continuation-in-Part of application Ser. No. 784,024 filed Dec. 12th, 1968, now abandoned.

This invention relates to the production of high quality, high strength, castable, weldable and corrosion resistant Copper Nickel alloys containing additions of Aluminium, Manganese, Iron and optionally Chromium.

The invention has for its object to produce alloys which satisfy the following exacting criteria :

1. In the as cast condition the alloy fulfils the requirements of the weld test set out in ASTM B369-61T.
2. The alloy possesses a 0.5 percent Proof Stress of at least 17.5 tons per square inch in the as cast condition, and should respond to heat treatment to give even higher strength.
3. The alloy possesses an Ultimate Tensile Strength of at least 30 tons per square inch in the as cast condition.
4. The alloy possesses a high degree of ductility as represented by an Izod Impact value of at least 26 ft.lbs. in the as cast condition, and at least 23 ft.lbs. even after heat treatment for four hours at 550°C.
5. The alloy has a low magnetic permeability not exceeding 1.05.
6. The alloy is strongly resistant to corrosion in sea water.

In modern marine engineering and shipbuilding practice, there is a growing demand for high quality castings used in the production of valves, pumps, heat exchangers and other components of sea water circulating systems.

High quality castings of this kind are often of intricate form and have considerable variation in sectional thickness. They require to be highly resistant to corrosion by sea water, of low magnetic permeability, preferably of below 1.05, and to possess high yield and tensile strength combined with excellent ductility and notch impact strength as measured by Izod or Charpy Impact value. The alloy used should be readily castable into intricate form and as the finished product may involve a plurality of castings welded together, or the finished product may be required to be welded to another component, the alloy should be capable of being welded with the weld being of excellent quality and so that the casting and the weld are radiographically sound.

Aluminium is a well-known strengthening agent for Copper Nickel alloys. However, cupro Nickels strengthened by Aluminium additions are subject to variable weldability. This can be alleviated by incorporating additions of Manganese. However, castings produced from such an alloy are only weldable if the Nickel, Aluminium and Manganese constituents are controlled within very close limits. This invention has for a principal object to define these limits and also to ensure that the resultant casting has the high criteria of strength and ductility as set out at the beginning of this Specification.

Iron is also a known strengthening agent. However, sufficient Iron must be added for its strengthening effect to be apparent, while too high an Iron content may impair the corrosion resistance of the alloy. A further object of this invention is to define a beneficial range for the Iron constituent of the alloy.

Wrought alloys having as constituents Copper, Nickel, Aluminium, Manganese and Iron are well-known in the art.

For example, British Patent Specification No. 578,223 dating from 1942 discloses such an alloy having constituents as follows :

Nickel 9% – 30%
Aluminium 0.1% – 2.0%
Manganese 5.0% – 30%
Iron Up to 5%
Copper substantially the remainder

Also in German Patent Specification No. 655,931 dating from 1933 an alloy is disclosed having constituents as follows :

Nickel 10% – 40%
Aluminium 0.1% – 6%
Manganese 0.5% – 10%
Iron 3.0% – 20%
Copper Substantially the remainder

However, these prior references contain no teaching as to how the exacting criteria set out at the beginning of this Specification can be ensured.

On the contrary we have found that these criteria can be achieved with surety with an alloy consisting essentially of Copper, Nickel, Aluminium, Manganese, Iron and optionally Chromium, if the various constituents are controlled within very close limits.

Specifically the invention provides a Copper Nickel alloy consisting of the following elements in the following proportion by weight :

Nickel 9% – 18%
Aluminium 1% – 3.5%
Manganese 8.5% – 13%
Iron 2.5% – 6.5%
Chromium 0% – 1%
Copper the balance

with the Aluminium, Manganese and Nickel contents being so controlled that they satisfy the following formulae:

a. $4 \times Al\% + Mn\% = 14\% - 20\%$
b. $4 \times Al\% + Ni\% = 17\% - 25\%$
c. $Ni\%/5Al\% =$ Greater than 1

The Chromium content is optional and confers beneficial results when the alloy is heat treated; specifically it provides more uniform dispersion of the precipitation hardening phase.

In the accompanying Tables, various examples of alloys are shown, all of which are highly resistant to corrosion in sea water. In the Tables the values for the computation $4 \times Al\% + Mn\%$ are given under heading (a), the values for the computation $4 \times Al\% + Ni\%$ are given under heading (b) and the values for the computation $Ni \div 5 \times Al\%$ are given under heading (c).

The alloys of Table I are examples according to this invention which all satisfy the criteria set out at the beginning of this Specification.

Table II gives examples of various alloys of a generally similar composition to those in Table I, and all of which satisfy the weld test. However, for various reasons the alloys of Table II fail to satisfy one or more of the criteria set out at the beginning of this specification.

Specifically the alloys of Table II have lower strength coupled with high ductility than the alloy examples of Table I.

Table III gives some examples of alloys of a broadly similar composition to those of Table I. However all the alloys of Table III suffered a significant loss of ductility when subjected to heat treatment.

Table IV sets out various alloys also of broadly similar composition to those set out in Table I. However all

the alloys in Table IV failed to satisfy the weld test according to ASTM B369-61T.

All the alloys of Table I achieve the requirements of the weld test set out in ASTM B369-61T.

All the alloys of Table I possess an 0.5 percent Proof Stress of at least 17.5 tons per square inch in the as cast condition, the results of this test ranging from 17.6 tons per square inch, in examples 2, 10, 11 and 14, to 22.4 tons per square inch in example 17, with even higher strengths being achieved after heat treatment.

All the alloys of Table I achieved an Ultimate Tensile Strength in excess of 30 tons per square inch, in the as cast condition, and all achieved higher strengths after heat treatment.

All the alloys of Table I achieved a satisfactory degree of ductility as measured by elongation and Izod Impact tests, in the as cast condition, and ductility was not significantly reduced after heat treatment for four hours at 550°C., the examples all recording after such heat treatment, an— Izod Impact value in excess of 23 ft.lbs.

The Nickel constituent of the alloys of Table I ranges from 10.7 percent in Example 14 to 18.0 percent in Example 17. The Aluminium content ranges from 1.1 percent in Example 16 to 2.35 percent in Example 1. The Manganese content ranges from 8.8 percent in Example 1 to 12 percent in Example 10. The Iron content ranges from 2.81 percent in Example 6 to 5.24 percent in Example 12. The Chromium content of the alloys of Table I ranges from nil in Example 15 to 0.86 percent in Example 7.

More importantly the Manganese and Aluminium constituents when computed by formula (a) — 4Al + Mn — range from 14.25 percent in the case of Example 17 to 19.9 percent in Example 6; the Nickel and Aluminium contents when computed by formula (b) — 4Al + Ni — range from 17.5 in Example 10 to 24.2 percent in Example 17; and in all the Examples in Table I, the Nickel content is more than five times greater than the Aluminium content.

The effect of Iron on the strength of alloys according to the invention is demonstrated by the following table where alloy examples are shown with Iron contents ranging from 0.42 percent to 3.77 percent.

Iron (percent)	Aluminium (percent)	Nickel (percent)	Manganese (percent)	Formula (a)	Formula (b)	Formula (c)	0.5 percent proof stress tons/sq. in
0.42.....	2.09	11.9	10.0	18.4	20.3	1.18	11.8
2.2.....	2.16	11.8	10.7	19.3	20.4	1.09	15.6
2.43.....	1.92	12.5	11.1	18.8	19.2	1.30	16.5
3.0.....	2.08	11.4	9.0	17.3	19.7	1.13	17.6
3.77.....	2.09	12.0	10.1	18.5	20.4	1.19	18.6

It will be seen that where the Aluminium and Nickel contents computed by formula (b) are in the range of about 19 – 21, an Iron content of at least about 3 percent is required if a 0.5 percent Proof Stress of at least 17.5 tons per square inch is achieved. Where, however, the value computed by formula (b) is higher the Iron content may be reduced slightly as evidenced by Example 6 in Table I. However, with Nickel and Aluminium contents according to the teachings of this Specification, an Iron content of at least 2.5 percent is required, while if the Iron content exceeds 6.5 percent there is a risk that the corrosion resistance of the alloy may be reduced.

Certain of the alloys of the Tables were tested for magnetic permeability and the results shown on the Tables indicate that these alloys are substantially non-magnetic. However, tests on an alloy consisting of 10.1 percent Manganese, 13 percent Nickel, 5.16 percent Iron but only 0.04 percent Aluminium, the balance being Copper, indicated for this alloy a magnetic permeability of 1.4.

Moreover the alloys according to the invention, examples of which are shown in Table I, do not exhibit any significant variation in properties in the as cast condition in dependence upon the sectional size of the casting. As an example, an alloy consisting of Nickel 12.3 percent, Aluminium 2.03 percent, Manganese 10.6 percent, Iron 4.61 percent and Copper the balance, was produced in cast form as a 2 inch square cast bar, a 3 inch square cast bar and a 4 inch square cast bar, and was found to have properties as follows:

Size of Cast Bar	0.1% Proof Stress tons/in²	0.5% Proof Stress tons/in²	Ultimate Tensile Strength tons/in²	Elong. %	Izod Impact Value ft./lb.
2 inch square	16.8	20.2	30.8	26	29,30,29
3 inch square	16.0	20.3	30.0	21	34,30,28
4 inch square	17.4	20.0	29.2	28	27,28,32

The alloys of Table II while satisfactory so far as their ductility is concerned have significantly lower strength in the as cast condition as compared with the examples listed in Table I.

The best example in Table II is Example 5 which achieves a 0.5 percent Proof Stress of 16.6 tons per square inch in the as cast condition. This figure would undoubtedly be improved with small additions of Nickel and/or Aluminium to bring the value of these when computed by formula (b) — 4Al + Ni — up to at least 17 as taught by this Specification.

Example 21 has a 0.5 percent Proof Stress of only 9.6 tons per square inch in the as cast condition and it is significant that this alloy is substantially identical in composition to some of the alloys specifically listed by way of example in the aforementioned prior British Patent Specification No. 578,223. The alloy, Example 21 also failed to respond to heat treatment. Example 21 of Table II may be compared with Example 7 of Table I and it will be noted that the Aluminium and Iron contents of Example 7 are significantly higher while the Nickel content is maintained at least five times greater than the Aluminium content. Thus if the Aluminium content of Example 21 were increased to above 2 percent and the Iron content were increased above 3 percent then this alloy would satisfy the criteria set out at the beginning of this Specification. Comparison may be made with Example 5 of Table I.

Examples 22 and 23 are also virtually identical with certain alloys specifically listed by way of example in the aforementioned British Patent Specification No. 578,223. However, these examples had 0.5 percent Proof Stress strengths of only 10.5 and 10.8 tons per square inch respectively and were in comparison with the alloy examples of Table I, relatively low strength ductile alloys.

The alloys of Table III may be compared with Examples 16 and 17 of Table I. It will be noted that the first five Examples of Table III have relatively high Manganese and Aluminium contents when computed by for-

mula (a) — 4Al + Mn — and it will be seen that these alloys, while being otherwise generally satisfactory suffered a significant loss in ductility as measured by Izod or Charpy test after heat treatment.

Example 32 is just outside formula (a) at 20.4 percent. If the Manganese and Aluminium contents were lowered slightly, the ductility after heat treatment would be increased to a more satisfactory level.

The last alloy 36 in Table III has relatively high Nickel content so as to give a high value according to formula (b) — 4Al + Ni — at 25.5 percent and this alloy had low ductility even in the as cast condition. It is a relatively strong brittle alloy. With slightly less Nickel this alloy would have more ductility in the as cast condition.

Table IV when compared with the Examples given in the other Tables demonstrates the effect of the Manganese content, taken in conjunction with the Aluminium and Nickel contents, on the weldability of the alloy.

The first Example 41 of Table IV is of an alloy where the Manganese and Nickel contents are lower than specified according to this invention. Examples 42 and 43 also have low Manganese contents.

Examples 44, 45 and 46 exhibit relatively high Nickel and Aluminium contents when computed by formula (b) — 4Al + Ni.

The last Example 47 in Table IV has a relatively high Manganese content.

All the alloys in Table IV failed the weld test.

A careful study of the various examples will, therefore, show that if the exacting criteria, set out at the outset of this specification, are to be not only achieved, but satisfied with surety, then the various constituent elements must be controlled as to their relative proportions by weight to one another, within very close limits.

The alloys according to the invention, examples of which are given in Table I possess an excellent combination of properties which hitherto it has not been possible to ensure in Copper Nickel alloys.

TABLE I

Example	Mn (per-cent)	Al (per-cent)	Fe (per-cent)	Ni (per-cent)	Cr (per-cent)	Formula (a)	Formula (b)	Formula (c)	Condition	0.1 percent proof stress T/sq. in	0.5 percent proof stress T/sq. in	Tensile strength T/sq. in	Elong. per-cent	Izod impact value ft. lbs	Weld test	Magnetic permeability
1	8.8	2.25	3.7	11.4	0.79	17.8	20.4	1.01	As cast	17.2	21.2	32.4	35	44, 45, 48	Satisfactory	1.002
									4 hrs @ 550°C	22.2	25.7	38.0	25	25, 25, 26		
2	9.0	2.08	3.0	11.4	0.69	17.3	19.8	1.09	As cast	16.0	17.6	30.8	56	56, 58, 56	do	1.003
									4 hrs @ 550°C	18.1	19.0	34.7	28	29, 29, 30		
3	10.1	2.09	3.77	12.0	0.63	18.4	20.3	1.15	As cast	16.9	18.6	32.9	39	43, 45, 47	do	1.004
									4 hrs @ 550°C	21.4	25.9	41.6	23	26, 27, 27		
4	10.6	2.01	5.03	12.1	0.62	18.6	20.1	1.19	As cast	16.9	18.6	32.9	39	43, 45, 47	do	1.003
									4 hrs @ 550°C	19.6	23.6	35.0	24	37, 38, 40		
5	10.9	2.08	4.01	10.8	0.72	19.2	19.1	1.04	As cast	16.0	18.4	31.6	54	56, 56, 57	do	
									4 hrs @ 550°C	21.1	25.9	41.5	20	28, 28, 29		
6	11.5	2.1	2.81	14.2	0.65	19.9	22.6	1.35	As cast	16.0	18.0	32.2	48	45, 47	do	1.004
									4 hrs @ 550°C	18.4	21.5	36.1	36	34, 35		
7	10.1	2.15	4.46	11.6	0.86	18.7	20.2	1.08	As cast	16.2	18.6	32.0	51	54, 54, 56	do	
									4 hrs @ 550°C	21.0	25.6	39.2	29	30, 32, 30		
8	10.6	2.25	4.8	12.3	0.62	19.6	21.3	1.09	As cast	16.8	20.5	33.1	40	44, 45, 46	do	
									4 hrs @ 550°C	20.0	23.7	35.2	31	30, 33, 35		
9	10.2	2.13	4.8	12.6	0.61	18.7	21.1	1.18	As cast	16.0	19.0	33.0	45	43, 40, 42	do	
									4 hrs @ 550°C	19.4	23.2	38.0	31	28, 29, 30		
10	12.0	1.48	4.46	11.6	0.51	17.94	17.5	1.57	As cast	15.4	17.6	30.8	42	48, 52, 50	do	
									4 hrs @ 550°C	16.8	19.5	33.4	37	44, 46, 46		
11	9.67	2.15	4.8	12.0	Nil	18.27	20.6	1.11	As cast	15.6	17.6	31.0	47	49, 51, 49	do	
									4 hrs @ 550°C	18.6	23.2	39.4	35	38, 38, 37		
12	10.5	2.05	5.24	12.0	0.52	18.7	20.2	1.14	As cast	15.7	17.8	33.2	45	58, 67, 69	do	
									4 hrs @ 550°C	18.6	23.2	39.4	35	49, 51, 49		
13	8.9	2.1	4.89	12.6	0.56	17.3	21.0	1.20	As cast	15.8	18.0	32.0	35	35, 36, 37	do	
									4 hrs @ 550°C	17.6	21.0	35.0	32	30, 32, 30		
14	9.7	1.97	4.10	10.7	0.56	17.57	18.57	1.09	As cast	14.5	17.6	30.0	58	54, 57, 59	do	
									4 hrs @ 550°C	17.5	21.5	35.5	32	31, 32, 31		
15	10.7	1.75	4.46	13.25	Nil	17.7	20.25	1.51	As cast	18.0	20.5	34.5	45	58, 63, 60	do	1.004
16	9.85	1.1	5.0	17.7	0.54	14.25	22.1	3.22	As cast	16.5	18.2	30.6	22	30, 28, 29	do	
									4 hrs @ 550°C	20.5	24.0	33.6	17	25, 24, 25		
17	9.9	1.56	5.0	18.0	.54	16.1	24.2	2.30	As cast	20.0	22.4	33.0	24	30, 27, 28	do	1.012
									4 hrs @ 550°C	23.5	28.0	38.0	19	24, 24, 26		
18	9.10	1.89	4.70	13.8	Nil	16.66	21.36	1.46	As cast	17.2	19.6	32.7	40	50, 48, 52	do	1.004
									4 hrs @ 550°C	22.3	25.2	37.7	34	35, 37, 38		

TABLE II

Example	Mn (per-cent)	Al (per-cent)	Fe (per-cent)	Ni (per-cent)	Cr (per-cent)	Formula (a)	Formula (b)	Formula (c)	Condition	0.1 percent proof stress T/sq. in	0.5 percent proof stress T/sq. in	Tensile strength T/sq. in	Elong. per-cent	Izod impact value ft. lbs	Weld test	Magnetic permeability
21	10.18	1.37	0.42	9.70	Nil	15.66	15.18	1.43	As cast	8.8	9.6	24.4	60	70, 66, 63	Satisfactory	
									4 hrs @ 550°C	9.3	10.5	24.3	44	60, 63, 66		
22	14.4	1.18	.23	16.0	Nil	19.12	20.72	2.54	As cast	8.9	10.5	23.0	58	67, 68	do	
									4 hrs @ 550°C	10.3	10.8	23.8	57	73, 74		
23	14.25	1.63	.17	16.0	Nil	20.77	22.52	1.96	As cast	9.5	10.8	23.2	56	65, 66	do	
									4 hrs @ 550°C	10.8	11.3	23.9	53	68, 67		
24	9.85	2.04	4.61	7.3	0.58	18.04	15.46	0.71	As cast	13.0	14.5	27.6	63	60, 58, 63	do	1.003
									4 hrs @ 550°C	14.2	18.2	32.5	39	45, 46, 45		
25	9.5	1.2	4.7	11.2	.61	14.5	16.0	1.87	As cast	14.8	16.6	27.8	52	55, 60, 58	do	
									4 hrs @ 550°C	15.6	17.5	31.0	38	34, 35, 34		
26	8.7	1.00	4.89	7.1	.04	12.7	11.1	1.42	As cast	12.6	14.2	27.0	45	66, 68, 62	do	1.003
									4 hrs @ 550°C	13.4	14.9	27.3	42	64, 62, 65		
27	8.7	1.01	4.70	8.7	.04	12.74	12.74	1.72	As cast	13.6	15.4	27.8	47	62, 56, 58	do	1.004
									4 hrs @ 550°C	14.4	16.0	28.4	42	56, 58, 52		
28	9.1	1.9	4.01	9.0	.60	16.7	16.6	0.95	As cast	13.0	14.6	27.0	48	60, 65, 63	do	1.003
									4 hrs @ 550°C	16.0	18.5	32.5	38	61, 62, 58		
29	9.6	3.5	4.46	7.0	.58	23.6	21.0	.40	As cast	13.25	15.0	28.25	45	48, 45, 47	do	1.004
									4 hrs @ 550°C	22.0	26.5	41.6	23	22, 24, 25		
30	9.85	2.98	4.53	7.0	.58	21.77	18.9	.47	As cast	12.75	14.8	27.75	46	48, 50, 53	do	1.004
									4 hrs @ 550°C	17.4	22.2	37.6	30	31, 31, 36		

TABLE III

Example	Mn (percent)	Al (percent)	Fe (percent)	Ni (percent)	Cr (percent)	Formula (a)	Formula (b)	Formula (c)	Condition	0.1 percent proof stress T/sq. in	0.5 percent proof stress T/sq. in	Tensile strength T/sq. in	Elong. percent	Izod impact value ft. lbs	Weld test	Magnetic permeability
1	9.7	2.81	4.16	10.7	0.53	20.9	21.9	0.76	As cast	14.6	17.5	30.2	50	25, 28, 27	Satisfactory	
									4 hrs @ 550°C	20.8	28.5	43.2	15	14, 15, 15		
2	11.75	2.16	4.61	11.6	.61	20.4	20.24	1.07	As cast	15.7	18.5	31.8	48	30, 28, 31	do	
									4 hrs @ 550°C	23.2	32.1	47.6	14	17, 18, 19		
3	11.6	2.59	4.51	11.6	.59	21.97	21.97	0.90	As cast	16.2	19.2	32.6	46	28, 32, 33	do	
									4 hrs @ 550°C	24.0	33.3	47.2	10	14, 15, 14		
4	10.5	2.63	2.28	11.8	.66	21.0	22.3	.90	As cast	17.0	20.2	32.5	50	35, 32, 30	do	
									4 hrs @ 550°C	23.4	27.6	42.5	12	14, 15, 16		
5	12.8	2.3	4.46	12.8	.68	22.0	22.0	1.11	As cast	16.6	20.0	33.0	44	43, 44	do	
									4 hrs @ 550°C	20.4	28.1	43.6	17	17, 17		
6	9.7	1.92	4.9	17.8	.51	17.4	25.5	1.85	As cast	23.0	26.5	35.0	20	25, 24, 23	do	1.004
									4 hrs @ 550°C	25.6	28.2	38.5	19	21, 21, 23		

TABLE IV

Example	Mn (percent)	Al (percent)	Fe (percent)	Ni (percent)	Cr (percent)	Formula (a)	Formula (b)	Formula (c)	Condition	0.1 percent proof stress T/sq. in	0.5 percent proof stress T/sq. in	Tensile strength T/sq. in	Elong. percent	Izod impact value ft. lbs	Weld test	Magnetic permeability
1	7.05	1.88	4.7	8.8	0.68	13.58	16.32	0.94	As cast	13.7	15.5	29.6	45	48, 50, 54	Cracked	
									4 hrs @ 550°C	16.0	18.6	33.0	37	34, 37, 38		
2	7.3	1.92	4.46	12.3	.61	14.97	19.98	1.28	As cast	16.7	20.1	31.6	18	37, 38, 39	do	
									4 hrs @ 550°C	22.7	26.4	39.5	18	32, 35, 33		
3	8.2	2.14	3.0	11.1	.67	16.74	19.64	1.04	As cast	16.0	18.4	30.6	35	37, 37, 40	do	
									4 hrs @ 550°C	19.2	21.9	34.8	19	22, 29, 30		
4	9.15	4.8	4.7	10.9	.56	28.35	30.1	0.45	As cast	20.6	26.8	40.6	18	17, 19, 18	do	
									4 hrs @ 550°C	38.6	.....	52.0	1	2, 3, 3		
5	11.2	2.47	4.37	19.9	.52	21.08	29.78	1.62	As cast	25.0	28.7	35.3	13	17, 20, 18	do	1.005
									4 hrs @ 550°C	.....	28.5	34.5	12	10, 12, 11		
6	13.0	3.3	4.1	13.5	.61	26.2	26.7	0.82	As cast	15.2	18.5	32.0	26	24, 22, 25	do	1.004
									4 hrs @ 550°C	21.4	24.6	38.4	9	12, 14, 18		
7	17.3	2.1	4.3	11.5	.50	25.7	19.9	1.09	As cast	16.4	18.5	31.4	36	31, 36, 39	do	
									4 hrs @ 550°C	22.2	31.6	43.4	6	9, 9, 9		

We claim :

1. A high quality, high strength, highly ductile, cast, weldable and corrosion resistant copper alloy consisting of the following elements in the following proportions by weight:

Nickel 9% – 18%
Aluminium 1% – 3.5%
Manganese 8.5% – 13%
Iron 2.5% – 6.5%
Chromium 0% – 1%
Copper the balance

with the Aluminium, Manganese and Nickel contents being so controlled that they satisfy the following formulae:

a. $4 \times Al\% + Mn\% = 14\% - 20\%$

b. $4 \times Al\% + Ni\% = 17\% - 25\%$

c. $Ni\%/5Al\% =$ Greater than 1

said alloy characterized by the following properties in as cast condition:

1. fulfills the requirements of the weld test set out in ASTM B369-61T
2. possesses a 0.5 percent Proof Stress of at least 17.5 tons per square inch
3. possesses an Ultimate Tensile Strength of at least 30 tons per square inch
4. has an Izod Impact value of at least 26 ft. lbs.
5. has a low magnetic permeability not exceeding 1.05.

* * * * *