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PREPARATION AND PROPERTIES OF SOME GOLD ALLOYS

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ABSTRACT

Samples of gold and five gold alloys were prepared and tested for hardness, yield strength in compression, and density. The alloys contained approximately 5 per cent and 10 per cent Ni, and 10 per cent each of Mn, Fe, and U. Nickel was by far the most potent addition for hardening and strengthening; a yield strength (0.2 per cent offset) of about 69,000 psi was found for the alloy with 10 per cent, compared with 5,800 psi for pure gold. All alloys were less dense than gold, 10 percent Ni having a density of 17.06, 10 per cent U, 18.6. The gold-manganese and the gold-iron alloys showed some age hardening effects.

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PREPARATION AND PROPERTIES OF SOME GOLD ALLOYS

Preparation of the Alloys

Alloys were made in 75 g amounts by melting the gold under hydrogen in alundum thimbles surrounded by a graphite sleeve in an induction furnace, adding the other component and then casting into graphite moulds. The use of hydrogen during melting prevented excessive oxidation of the alloying metals and obviated the use of a flux. A previous attempt had been made to alloy gold with uranium in a relatively poor vacuum. No alloying occured owing to the formation of an oxide film on the uranium. This did not form when an hydrogen atmosphere was used. No allowance of loss was made except with uranium where 1.4 per cent additio al was added. This allowance was too high as recovery was actually 90 per cent of the 11.4 per cent used.

The small heats were poured into a graphite mould to produce a plate of dimensions 4" x 3/4" x 1½". Possibly because of the use of hydrogen the heats were somewhat unsound, and gave some trouble with the subsequent hardness readings.

The nominal and actual compositions of the heats are shown in Table I. After hardness tests the samples were remelted and used for compression tests. The analyses after remelting are given in Table II.

Experimental Results

Hardness Tests

To investigate the response of the alloys to heat treatment, and in particular to find out if any of the alloys were susceptible to age hardening, the Rockwell B hardness of each sample was measured after it had been subjected to a series of successive heat treatments. The results are shown in Table I. [redacted]

It will be observed that both the iron and manganese alloys show some tendency toward age hardening.

Microstructure

The microstructure of the four alloys was determined after this series of heat treatments, which terminated in an anneal at 600°C. for two hours followed by air coolihg. Figures 1, 2, 3, and 4 show the structures after etching with aqua regia. The gold-iron alloy (Fig. 1) shows a fine precipitated phase covering the entire field. It was probably a uniform solution when quenched. The gold-uranium alloy (Fig. 2) exhibits a eutectic structure in which the dark-etching phase is obviously rich in uranium; there is excess uranium phase over the eutectic composition which has crystallized in large platelets or thick needles. Both the gold-nickel and gold-manganese alloys show more complex structures (Figs. 3 and 4). In the case of the latter, the structure appears to be closely similar to copper-silicon alloys in the neighborhood of 5 per cent Si, where a homogeneous solid solution stable only at elevated temperatures precipitates on cooling a second phase closely akin to it in structure and which forms in thin twin-like plates.

The presence of cracks suggests that a brittle phase had existed at the grain boundary after one of the low temperature anneals, but had disappeared by solution at 600°. Internal oxidation has taken place along the cracks and there is a layer adjacent to them which is richer in gold as a result of oxidation of the element.

The gold-nickel sample (Fig. 3) appears to contain two phases, one of which is somewhat segregated in the grain boundaries, or which has spheroidized into larger particles, leaving the gold matrix in a condition which etches more lightly. [redacted]

Density measurements

The four gold alloys were re-melted in a graphite crucible-mould yielding ingots about 7/16 in. in diameter by about 1 in. long. In addition, two new heats were made, one containing 5 per cent Ni and the other pure gold. After casting, they were quenched from 850°C. and the ends turned square leaving the length about 1 in. These samples were intended for compression tests, but before such tests were made the densities were measured. The results are given in Table II.

Compression Tests

The tests were carried out in a specially designed compression jig fitted with a 0.001 in. dial gauge. Stress-strain curves for each sample are reproduced in Fig. 5. From these curves were read the approximate proportional limits and the yield strengths (0.2 per cent offset) given in Table II.

The Rockwell B hardness values were measured after the compression tests, during which about 1.5 per cent reduction in length occured. See Table II. The discrepancy between the hardness values given for the previous as-quenched samples and for the same alloys remelted, quenched and compression-tested is probably due both to changes in analysis occuring on remelting and to cold work resulting from the compression tests.

No compression tests were made on Au-Mn and Au-Fe alloys after heat treatment for maximum hardness.

The specimens were tested to failure in compression after the hardness readings were made. Only two specimens fractured during these tests, the Au-Mn at 83,300 psi and the Au-U at 73,000 psi. The two nickel alloys failed by slipping along a 45° plane, the 5 Ni at 114,000 psi and 10 Ni at 191,000 psi. Both the Au-Fe and the pure gold samples merely flattened out into discs without fracture.

Table I Rockwell B Hardness of Gold Alloys after Heat Treatments

Sample No.	Composition Intended, Per cent	Composition by Analysis, Per cent	Rockwell B Hardness								
			As Cast	Quenched after 1 hr.@850°C	Quenched and reheated 2 hr. successively at 300°C	350°C	400°C	450°C*	500°C	500°C+	600°C
15	10.0 Manganese	90.96 gold	94	79	78	80	83	83	86	90	89
16	10.0 Nickel	90.50 "	89	91	86	91	89	95	95	91	93
17	10.0 Uranium	88.86 "	76	45	53	53	43	43	50	41	36
18	10.0 Iron	90.18 "	47	48	47	51	50	70	75	77	48

* 3 hours at temperature

\+ 18 hours total time at temperature

Above figures are averages of four or more readings after each treatment.

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Table II Density, Compression and Hardness Tests

Alloy No.	Composition Intended, Per Cent	Composition by Analysis Per Cent	Density g/cc	Proportional Limit, lbs./sq. in.	Yield Strength (0.2% offset) lbs./sq. in.	Rockwell B Hardness As Cast	Quenched 850°C	Maximum Observed Hardness	After Compressive Testing
20	pure gold		19.30	3,300	5,800	--	--	--	30
19	5.0 Nickel	94.87 gold	18.07	27,000	38,000	--	--	--	64
16A	10.0 Nickel	89.74 "	17.06	54,000	69,000	89	91	95 (2 hr. 500°C)	92
17A	10.0 Uranium	90.68 "	18.60	12,000	26,000	76	45	76 (as cast)	71
15A	10.0 Manganese	91.41 "	15.86	33,000	51,000	94	79	94 (as cast)	83
13A	10.0 Iron	90.14 "	16.29	15,000	25,000	47	48	77 (18 hr. 500°C)	38

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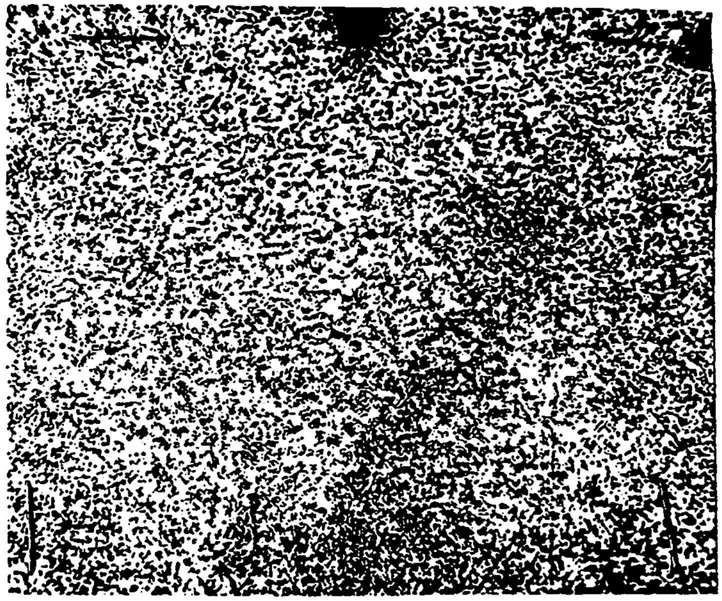

Fig. 1 Alloy 18, 9.82 Fe,
Etched with Aqua Regia X 500
Photo No. 2017-0

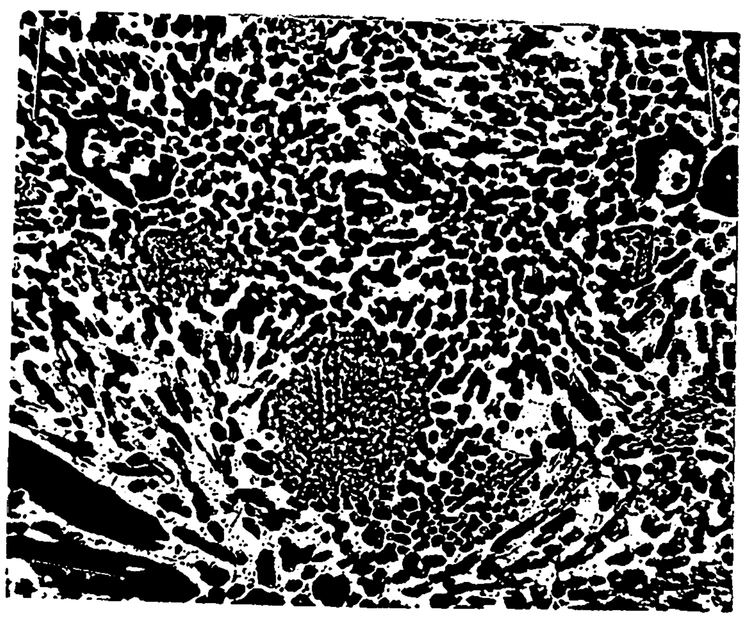

Fig. 2 Alloy 17, 11.14 U,
Etched with Aqua Regia X 500
Photo No. 2018-0

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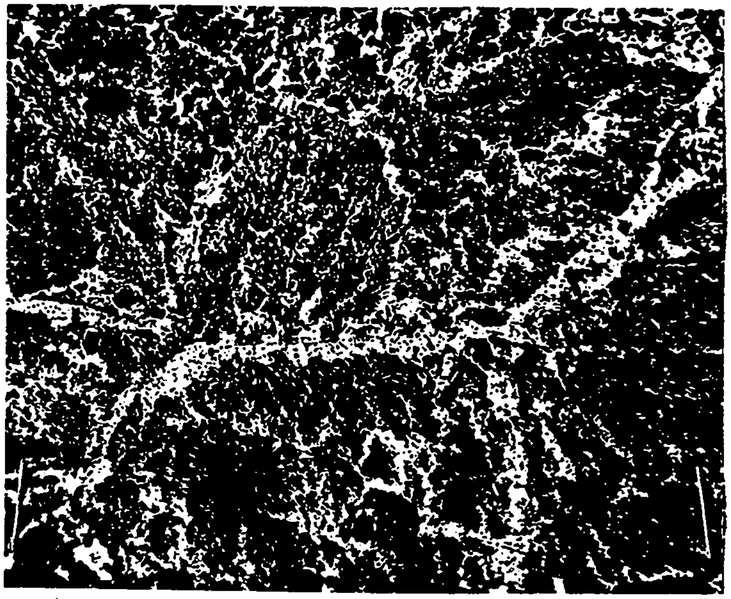

Fig. 3 Alloy 16, 9.50 Ni.
Etched with Aqua Regia X 500
Photo No. 2020-0

Fig. 4 Alloy 15, 9.04 Ni
Etched with Aqua Regia X 100
Photo No. 2019-0

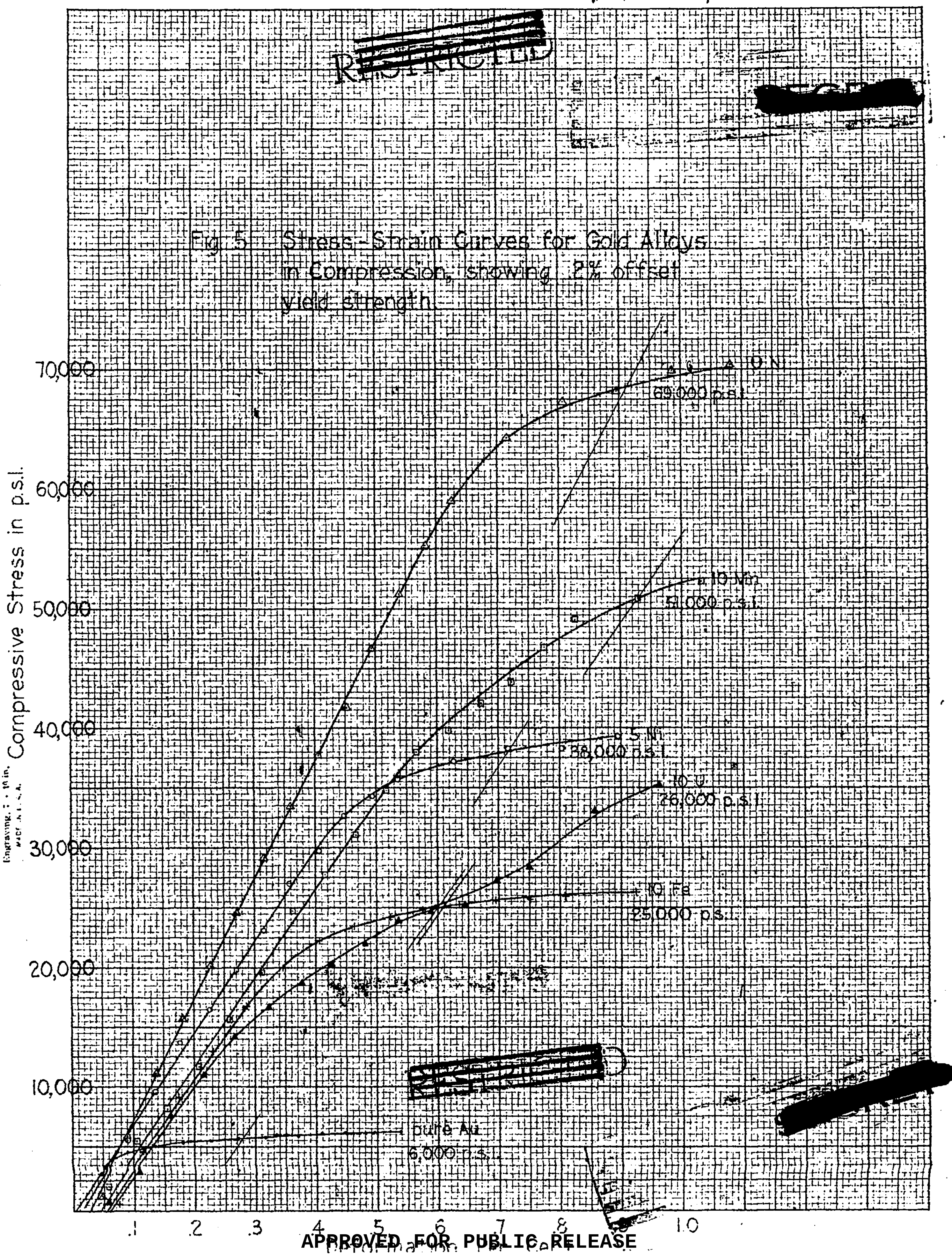
Fig. 5 Stress-Strain Curves for Gold Alloys in Compression, showing .2% offset yield strength.
Compressive Stress in p.s.i.
70,000
60,000
50,000
40,000
30,000
20,000
10,000
10 Ni
69,000 p.s.i.
10 Mn
51,000 p.s.i.
5 Mn
38,000 p.s.i.
10 U
26,000 p.s.i.
10 Fe
25,000 p.s.
pure Au
6,000 p.s.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

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