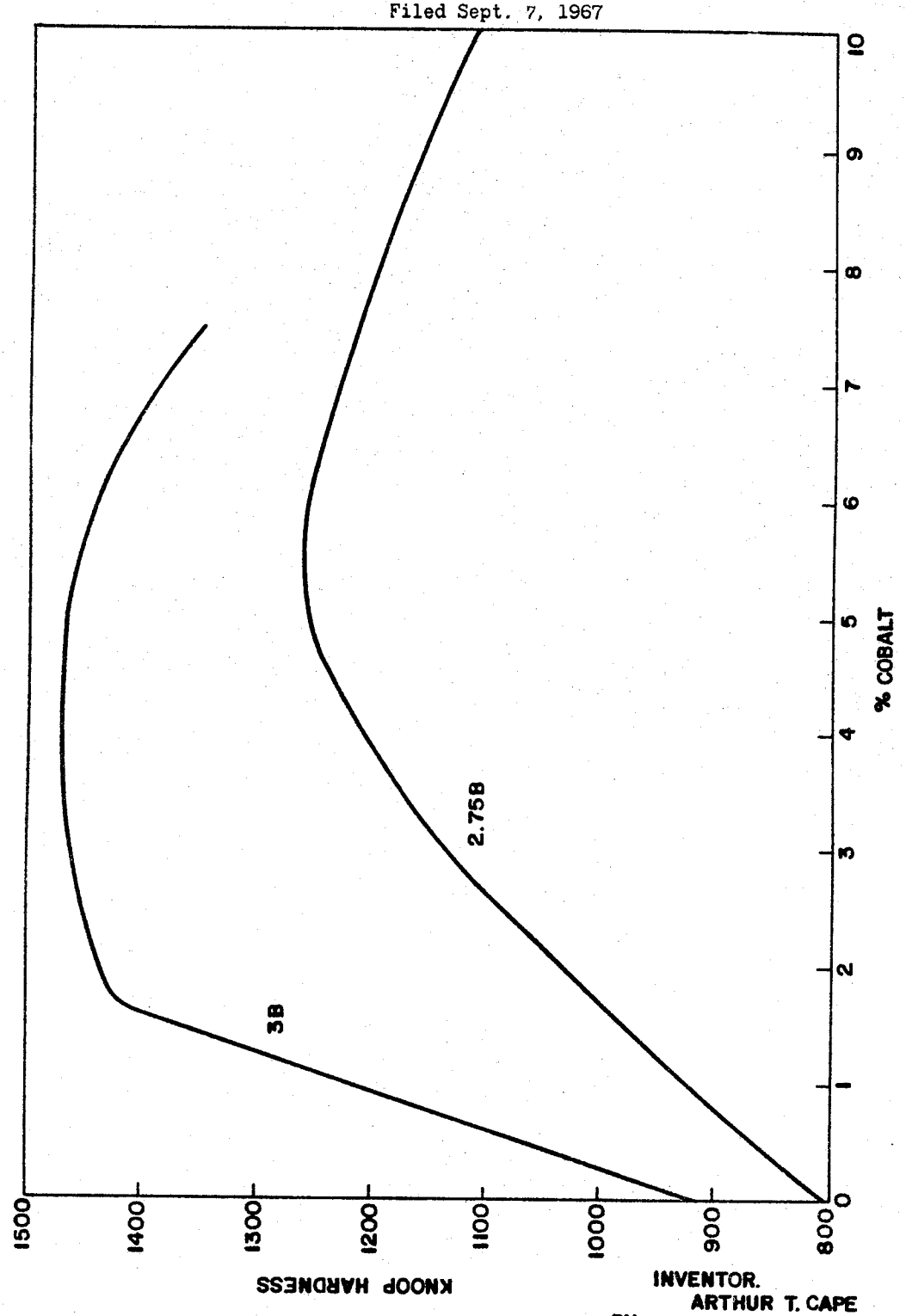
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NICKEL-BASE ALLOYS

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NICKEL-BASE ALLOYS

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ABSTRACT OF THE DISCLOSURE

Effect of additions of cobalt to nickel-base alloys containing chromium, tungsten, iron and boron, and particularly the increase in Knoop hardness caused by such additions.

This invention relates generally to nickel-base alloys of the type used for hard surfacing.

A coating alloy known as "Pratt & Whitney Aircraft Specification—PWA 693," has the following composition:

Carbon	0.4–0.7
Silicon	2.5–4.0
Chromium	10.0–13.0
Tungsten	15.0–17.0
Iron	2.5–4.3
Boron	1.75–3.25
Nickel	Remainder

I have found, as the result of extensive tests that the Knoop hardnesses of the foregoing alloy can be greatly improved by incorporating in the aforesaid alloy cobalt, in a controlled amount such that the cobalt constitutes from .5 to 7.5% by weight of the alloy. At the same time, the ranges of several of the other ingredients of the aforesaid alloy may be broadened without detracting from the increased Knoop hardnesses or other desirable properties of the alloy.

This increase in Knoop hardness is illustrated in the accompanying graph which forms a part of this application, and in which varying amounts of cobalt were incorporated in nickel-base alloys of slightly different compositions, as follows:

In the lower graph, the composition of the basic alloy was as follows:

	Percent
Carbon	0.6
Chromium	12
Silicon	3.5
Iron	3.5
Tungsten	16
Boron	2.75
Nickel	Balance

Without the addition of cobalt, the average Knoop hardness, as indicated in the graph, was 802.

With the addition to such alloy of cobalt in various amounts, the average Knoop hardness were as follows.

Cobalt added (percent):	Knoop hardness
2.5	1092
5.0	1258
10.0	1168

It is apparent from the lower graph that the maximum hardness of the alloy was established as somewhere between 5 and 7.5% cobalt, or, more strictly, between 4 and 7.5%, and that beyond 7.5% cobalt, the hardness falls off.

In the upper graph, the composition of the basic alloy was as follows:

	Percent
Carbon	0.5
Chromium	13
Silicon	4
Iron	4
Tungsten	15.5
Boron	3
Nickel	Balance

Reference to this graph shows that the Knoop hardness of thes alloy, without cobalt, was 915, and that with the addition to the alloy of cobalt in various amounts, the average Knoop hardnesses were as follows.

Cobalt added (percent):	Knoop hardness
0.5	1060
0.75	1162
1.00	1192
1.5	1419
5.0	1450
7.5	1351

It is apparent from the upper graph that the Knoop hardness increased very rapidly, even with as little as 0.5% cobalt, and on up to 1.5% cobalt with a maximum hardness established at somewhere between 1.5 and 7% cobalt, and the hardness decreasing slightly beyond about 5% cobalt.

It further appears from a comparison of the two graphs that since the respective compositions were of substantially similar analysis from the viewpoint of those ingredients which do not enhance the hardness, that the difference in rate of hardness increase was due primarily to the difference in the boron content of the alloys.

Stated in another way, the variation in hardness in such alloys, due to cobalt additions thereto, is apparently related, in some way to the boron content of the alloy. This relationship has not, as yet, been fully determined, but it is clear that the addition of cobalt to such alloys, in amounts of from 0.5 to 7.5%, does cause a marked increase in the Knoop hardnes.

The alloys, in accordance with the invention, are encompassed within the following ranges:

	Broad Range	Preferred Range	Preferred Analysis
Carbon	.005–1.00	0.1–0.7	0.5
Silicon	2.5–4.75	2.5–4.00	3.75
Chromium	6–16	10–13	12
Tungsten	7–17	15–17	16
Iron	2–5	2.5–4.3	3.75
Boron	1.00–5.00	1.75–3.25	3.00
Cobalt	0.5–7.5	2–5	2–2.5
Nickel	Remainder	Remainder	Remainder

Having thus described my invention, I claim:

1. A nickel-base alloy consisting of from 0.005 to 1.0% carbon, 2.5 to 4.75% silicon, 6 to 16% chromium, 7 to 17% tungsten, 2 to 5% iron, 1 to 5% boron, 0.5 to 7.5% cobalt, and the remainder essentially all nickel.

2. A nickel-base alloy consisting of from 0.005 to 1.0% carbon, 2.5 to 4.00% silicon, 10 to 13% chromium, 15 to 17% tungsten, 2.5 to 4.3% iron, 1.75 to 3.25% boron, 2 to 5% cobalt, and the remainder essentially all nickel.

3. A nickel-base alloy consisting of about 0.5% carbon, about 3.75% silicon, about 12% chromium, about 16%

tungsten, about 3.75% iron, about 3% boron, 2 to 2.5% cobalt, and the remainder essentially all nickel.

4. The method of increasing the Knoop hardness of nickel-base alloys consisting of from 0.005 to 1.00% carbon, 2.5 to 4.75% silicon, 6 to 16% chromium, 7 to 17% tungsten, 2 to 5% iron, 1 to 5% boron, and balance nickel, which consists in adding to said alloys cobalt in amounts of from 0.5 to 7.5%.

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