

Alloy Groups

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Nickel Alloy Groups

There are many commercially-available, wrought, corrosion-resistant, nickel-based alloys. To understand their characteristics and metallurgy, it is convenient to group them compositionally. The main groups, as defined by alloying elements present at levels of 10 wt.% or above, are as follows:

- . Commercially-Pure Nickel (Ni)
- . Nickel-Copper (Ni-Cu)
- . Nickel-Chromium (Ni-Cr)
- . Nickel-Molybdenum (Ni-Mo)
- . Nickel-Chromium-Molybdenum (Ni-Cr-Mo)
- . Nickel-Chromium-Iron (Ni-Cr-Fe)
- . Nickel-Iron-Chromium (Ni-Fe-Cr)

The general attributes of each group are listed in the following table, along with the names of some representative alloys:

| Group | Examples | Attributes |
|------------|--|--|
| C-P Nickel | Nickel 200 alloy | Very resistant to caustic alkalis. Useful electrical and magnetic properties. |
| Ni-Cu | MONEL [®] alloy 400 alloy | Very resistant to seawater and hydrofluoric acid. |
| Ni-Cr | HASTELLOY [®] G-35 [®] alloy | Moderately resistant to sulfuric acid. Very resistant to oxidizing acid solutions. |
| Ni-Mo | HASTELLOY [®] B-3 [®] alloy | Very resistant to hydrochloric acid and sulfuric acid. |
| Ni-Cr-Mo | HASTELLOY [®] C-276 alloy | Resistant to both oxidizing and reducing acid solutions. Very resistant to chloride-induced pitting, crevice attack and stress corrosion cracking. |
| Ni-Cr-Fe | HASTELLOY [®] G-30 [®] alloy | Very resistant to oxidizing solutions. Moderately resistant to chloride-induced pitting, crevice attack and stress corrosion cracking. |
| Ni-Fe-Cr | INCOLOY [®] alloy 825 | Resistant to oxidizing solutions. Some resistance to sulfuric acid and chloride-induced localized attack. |

Compositional details of several materials from each group are given in the table below. For completeness, some casting equivalents are included (although their characteristics are generally affected by microstructural inhomogeneity, and elevated residual element contents).

| Group | Alloy | UNS No. | Form | Composition wt.% (values denoted with * are maxima, and ** are minima) | | | | | | | | | | | |
|-------|--------|---------|---------|---|-------|----|----|-----|---|------|-----|------|-----|-----|-------|
| | | | | Ni | Cu | Mo | Cr | Fe | W | Mn | Si | C | Al | Ti | Other |
| Ni | 200 | N02200 | Wrought | 99.5 | 0.1 | - | - | 0.2 | - | 0.2 | 0.2 | 0.08 | - | - | - |
| | 201 | N02201 | Wrought | 99.5 | 0.1 | - | - | 0.2 | - | 0.2 | 0.2 | 0.01 | - | - | - |
| | 301 | N03301 | Wrought | 96.5 | 0.1 | - | - | 0.3 | - | 0.2 | 0.5 | 0.2 | 4.4 | 0.6 | - |
| | CZ-100 | N02100 | Cast | 95** | 1.25* | - | - | 3* | - | 1.5* | 2* | 1* | - | - | - |
| | 400 | N04400 | Wrought | 66.5 | 31.5 | - | - | 1.2 | - | 1 | 0.2 | 0.2 | - | - | - |

| | | | | | | | | | | | | | | | |
|----------|---------------------|--------|---------|------|------|-------|-------|------|------|-------|-------|--------|-------|------------|---------------------------|
| Ni-Cu | K-500 | N05500 | Wrought | 66.5 | 29.5 | - | - | 1 | - | 0.8 | 0.2 | 0.1 | 2.7 | 0.6 | - |
| | M-35-1 | N24135 | Cast | BAL. | 29.5 | - | - | 3.5* | - | 1.5* | 1.25* | 0.35* | - | - | Nb 0.5* |
| Ni-Mo | B-2 | N10665 | Wrought | 69 | 0.5* | 28 | 1* | 2* | 0.5* | 1* | 0.1* | 0.01* | - | - | - |
| | B-3 [®] | N10675 | Wrought | 65** | 0.2* | 28.5 | 1.5 | 1.5 | 3* | 3* | 0.1* | 0.01* | 0.5* | - | - |
| | N-7M | N30007 | Cast | BAL. | - | 31.5 | 1* | 3* | - | 1* | 1* | 0.07* | - | - | - |
| | N-12MV | N30012 | Cast | BAL. | - | 28 | 1* | 5 | - | 1* | 1* | 0.12* | - | - | Co 2.5*, V 0.4 |
| Ni-Cr | 600 | N06600 | Wrought | 76 | 0.2 | - | 15.5 | 8 | - | 0.5 | 0.2 | 0.08 | - | - | - |
| | 625 | N06625 | Wrought | 61 | - | 9 | 21.5 | 2.5 | - | 0.2 | 0.2 | 0.05 | 0.2 | 0.2 | Nb + Ta 3.6 |
| | 690 | N06690 | Wrought | 58** | 0.5* | - | 29 | 9 | - | 0.5* | 0.5* | 0.05* | - | - | - |
| | 725 | N07725 | Wrought | 57 | - | 8 | 21 | 7.5 | - | 0.35* | 0.2* | 0.03* | 0.35* | 1.5 | Nb 3.5 |
| | G-35 [®] | N06035 | Wrought | 58 | 0.3* | 8.1 | 33.2 | 2* | 0.6* | 0.5* | 0.6* | 0.05* | 0.4* | - | - |
| | ALLCORR | N06110 | Wrought | BAL. | - | 10 | 31 | - | 2 | - | - | 0.02 | 0.25 | 0.25 | Nb 0.4 |
| Ni-Cr-Mo | C-4 | N06455 | Wrought | 65 | 0.5* | 16 | 16 | 3* | - | 1* | 0.08* | 0.01* | - | 0.7* | - |
| | C-22 [®] | N06022 | Wrought | 56 | 0.5* | 13 | 22 | 3 | 3 | 0.5* | 0.08* | 0.01* | - | - | V 0.35* |
| | C-22HS [®] | - | Wrought | 61 | 0.5* | 17 | 21 | 2* | 1* | 0.8* | 0.08* | 0.01* | 0.5* | - | - |
| | C-276 | N10276 | Wrought | 57 | 0.5* | 16 | 16 | 5 | 4 | 1* | 0.08* | 0.01* | - | - | V 0.35* |
| | C-2000 [®] | N06200 | Wrought | 59 | 1.6 | 16 | 23 | 3* | - | 0.5* | 0.08* | 0.01* | 0.5* | - | - |
| | 59 | N06059 | Wrought | BAL. | - | 16 | 23 | 1.5* | - | 0.5* | 0.1* | 0.01* | 0.25 | - | - |
| | 686 | N06686 | Wrought | BAL. | - | 16 | 21 | 5* | 3.7 | 0.75* | 0.08* | 0.01* | - | 0.15 | - |
| | CW-2M | N26455 | Cast | BAL. | - | 16.25 | 16.25 | 2* | 1* | 1* | 0.8* | 0.02* | - | - | - |
| | CW-6M | N30107 | Cast | BAL. | - | 18.5 | 18.5 | 3* | - | 1* | 1* | 0.07* | - | - | - |
| | CW-12MW | N30002 | Cast | BAL. | - | 17 | 16.5 | 6 | 4.5 | 1* | 1* | 0.12* | - | - | V 0.3 |
| CX-2MW | N26022 | Cast | BAL. | - | 13.5 | 21.5 | 4 | 3 | 1* | 0.8* | 0.02* | - | - | V 0.35* | |
| Ni-Cr-Fe | G-3 | N06985 | Wrought | 44 | 2 | 7 | 22 | 19.5 | 1.5* | 1* | 1* | 0.015* | - | - | Co 5*, Nb 0.5* |
| | G-30 [®] | N06030 | Wrought | 43 | 2 | 5.5 | 30 | 15 | 2.5 | 1.5* | 0.8* | 0.03* | - | - | Co 5*, Nb 0.8 |
| | G-50 [®] | N06950 | Wrought | 50** | 0.5* | 9 | 20 | 17 | 1* | 1* | 1* | 0.02* | 0.4* | - | Co 2.5*, Nb 0.5* |

| | | | | | | | | | | | | | | | |
|--------|-----|--------|---------|----|-----|---|------|------|---|-----|------|-------|-----|-----|------------|
| Ni-Fe- | 825 | N08825 | Wrought | 42 | 2.2 | 3 | 21.5 | 30 | - | 0.5 | 0.2 | 0.05* | 0.1 | 0.9 | - |
| Cr | 925 | N09925 | Wrought | 44 | 2.2 | 3 | 21 | 22** | - | 1* | 0.5* | 0.03* | 0.3 | 2.2 | Nb 0.5* |

Cobalt Alloy Groups

There are relatively few wrought, corrosion- and wear-resistant, cobalt-based alloys. On the other hand, there are many cast, wear-resistant, cobalt-based alloys (closely associated with the STELLITE® tradename) that, despite their high carbon contents, possess a modicum of resistance to aqueous corrosion. This manual is concerned with the former materials. However, the cast alloys will be referred to often, since they provide a well-known frame of reference.

There are essentially three types of wrought, cobalt alloys used to resist aqueous corrosion. All contain high levels (20 wt.% or more) of chromium, and significant molybdenum and/or tungsten contents.

First are those derived from the cast, tungsten-bearing, high-carbon alloys, exemplified by HAYNES® 6B alloy (also known as STELLITE® 6B alloy). With a 1 wt.% carbon content, this alloy can be hot worked, but cannot be cold worked. Wrought processing enables the breaking down of large carbide particles (within the cast, ingot structure) into a discontinuous dispersion of equiaxed carbide particles; this results in enhanced ductility, increased resistance to corrosion, and excellent resistance to low stress abrasion, relative to compositionally-similar, cast and weld overlay materials.

Second are those tungsten-bearing, low-carbon, wrought materials designed for high temperature service, but whose resistance to aqueous corrosion is so high that they have found use in low temperature applications also. The primary example is HAYNES® 25 alloy, which is approved for biomedical use.

Third are those molybdenum-bearing alloys with carbon contents of about 0.35 wt.% or less, and designed to excel in both corrosive solutions and systems subject to wear. The prime example is ULTIMET® alloy, which exhibits a unique blend of properties, including high resistance to aqueous corrosion and wear, relatively high ductility, and excellent weldability.

The nominal compositions of several wrought, corrosion-resistant, cobalt alloys are given in the following table, along with those of several cast, cobalt alloys, for comparison.

| Group | Alloy | UNS No. | Form | Composition, wt.% (values denoted with * are maxima) | | | | | | | | | | |
|------------------------------|-------|--------------|--------------|--|------|----|------|-----|-----|-----|------|-----|-------|--|
| | | | | Co | Ni | Cr | Mo | W | C | Fe | Si | Mn | Other | |
| Tungsten-Bearing High-Carbon | 6B | R30016 | Wrought | 58 | 2.5 | 30 | 1.5* | 4 | 1 | 3* | 0.7 | 1.4 | - | |
| | 1 | R30001 | Cast | | | | | | | | | | | |
| | | W73001** | Weld Overlay | BAL | 1.5 | 30 | 0.5 | 13 | 2.5 | 3* | 1.3 | 0.5 | - | |
| | 6 | R30006 | Cast | | | | | | | | | | | |
| | | W73006** | Weld Overlay | BAL | 3* | 29 | 1.5* | 4.5 | 1.2 | 3* | 1.5* | 1* | - | |
| | 12 | R30012 | Cast | | | | | | | | | | | |
| W73012** | | Weld Overlay | BAL | 3* | 29.5 | 1* | 8.25 | 1.5 | 3* | 1.2 | 1* | - | | |
| Tungsten-Bearing | 25 | R30605 | Wrought | 51 | 10 | 20 | 1* | 15 | 0.1 | 3* | 0.4* | 1.5 | - | |

| Low-Carbon | | | | | | | | | | | | | |
|-------------------------------|----------|--------|---------|-----|----|------|---|------|-------|-------|-----|-----|--|
| Molybdenum-Bearing Low-Carbon | ULTIMET® | R31233 | Wrought | 54 | 9 | 26 | 5 | 2 | 0.06 | 3 | 0.3 | 0.8 | N 0.08 |
| | F75 | R30075 | Cast | BAL | 1* | 28.5 | 6 | 0.2* | 0.35* | 0.75* | 1* | 1* | Al 0.3* B 0.01* N 0.25* |

**Welding filler metal designations, with slight compositional modifications