# High-Alloy Mineral Processing White Irons


## Abstract

**High-alloy white cast irons** are a specific group of materials whose production must be considered separately from that of ordinary types of cast irons.

In these cast iron alloys, the alloy content is well above 4%, and consequently, they cannot be produced by ladle additions to irons of otherwise standard compositions. They are usually produced in foundries specially equipped to produce high alloy irons. **intMPE** pours on the average of more than 300 tons of white metal per month with a single cast size ability of 10 tons with a 21 inch thick cross section.

**intMPE** products that are produced with these materials are in conformance to standards set forth in this paper. Our chemical analysis is "state of the art" with capabilities of monitoring more than 35 elements at the same time; from this, we provide our customers with physical and test coupons.


The high-alloy white irons are primarily used for abrasion-resistant applications and are readily cast into parts needed in machinery for crushing, grinding, and handling of abrasive materials.

The chromium content of high-alloy white irons enhances their corrosion-resistant properties. The large volume fraction of primary and/or eutectic carbides in their micro structures provides the hardness needed for crushing and grinding other materials. The metallic matrix supporting the carbide phase in these irons can be adjusted by alloy content and heat treatment to develop the proper balance between the resistance to abrasion and the toughness needed to withstand repeated impact.

While low-alloy white iron castings, which have an alloy content below 4%, develop hardness in the range of 350 to 550 HB, the high alloy irons range in hardness from 450 to 800 HB. Specification ASTM A532 covers the composition and hardness of the abrasion-resistant white iron grades. Many castings are ordered according to these specifications, but a large number of castings are produced with composition modifications for specific applications. The designer, metallurgist, and foundry man must work together to specify the composition, heat treatment, and foundry practice to develop the most suitable alloy and casting design for a specific application.

The high-alloy white cast irons fall into two major groups:

**1) Nickle -Chromium white irons** - Low-Chromium alloys containing 3 - 5% Ni and 1 - 4% Cr, with one alloy modification that contains 7 - 11% Cr.

**2) Chromium-Molybdenum irons** - 11 - 23% Cr, up to 3% Mo and often additionally alloyed with nickel or copper.

A third group comprises the 25% or 28% Cr white irons, which may contain other alloying additions of molybdenum and/or nickel up to 1.5%. The nickel-chromium irons are also commonly identified as Ni-Hard types 1 - 4.

The **nickel-chromium white irons or Ni-Hard irons**, are the oldest group of high-alloy irons of industrial importance, and have been produced for more than 50 years. The Ni-Hard irons have proven to be very cost effective materials that are used for crushing and grinding.

In these martensitic white irons, nickel is the primary alloying element. Nickel, at levels of 3 - 5%, is effective in suppressing the transformation of the austenite matrix to pearlite. This ensures that a hard martensitic structure (usually containing significant amounts of retained austenite) will develop upon cooling in the mold. Chromium is included in these alloys, at levels from 1/4 - 4%, to ensure that the irons solidify carbidic, that is, to counteract the graphitizing effect of nickel.

The optimum composition of a nickel-chromium white iron alloy depends on the properties required for the service conditions and the dimensions and weight of the casting. 4 types of nickel-chromium white iron alloy are listed below:

**a) Class I type A** - Abrasion resistance is the general function of the bulk hardness and the volume of carbide in the microstructure. When this resistance is the principal requirement, and resistance to impact loading is secondary, alloys having high carbon contents, ASTM A532 class I type A (Ni-Hard 1) are recommended.

**b) Class I type B** - In repeated impact, the lower carbon alloys, class I type B (Ni-Hard 2) are recommended because of the existence of less carbide, and therefore, greater toughness.

**c) Class J type C** - This special grade, that has a nickel- chromium alloy composition, is used for chill casting, specialized sand casting processes, and producing grinding balls and slugs.

**d) Class I type D** - Ni-Hard4 alloy is a modified nickel-chromium iron that contains higher levels of chromium, ranging from 7 - 11%, and increased levels of nickel, ranging from 5 - 7%. Carbon is varied according to the properities needed for the intended service.

For example:

1) Carbon content in the range of 3.2% - 3.6% is used when maximum abrasion resistance is desired

2) Carbon content in the range of 2.7% - 3.2% is used when impact loading is expected.

**Nickel** content increases with section size or cooling time of the casting to inhibit pearlitic transformation. It is important to limit nickel content to the level needed for control of pearlite; excess nickel increases the amount of retained austenite and lowers hardness. For castings of 38 - 50 mm thick, 3.4 - 4.2% Ni is sufficient to suppress pearlite formation upon mold cooling. Heavier sections may require nickel levels up to 5.5% to avoid the formation of pearlite.

**Silicon** is needed for several reasons:

1) A minimum amount of silicon is necessary to improve fluidity of the melt and to produce a fluid slag, plus it has an effect on as-cast hardness.

2) Increased levels of silicon, in the range of 1 - 1.5% increases the amount of martensite and the resulting hardness.

3) Late additions of ferrosilicon - 0.2% as 75% Si grade ferrosilicon- increases toughness.

4) Higher silicon contents promotes pearlite and may increase nickel requirements.

**Chromium** is used to offset the graphitizing effects of nickel and silicon in types A, B, C alloys, and in ranges from 1.4 - 3.5%. As the section size increases, the chromium content must increase. In type D alloy, chromium levels range from 7 - 11% (usually 9%) for the purpose of producing eutectic carbides of the $M_7C_3$ chromium carbide type, which are harder and less deleterious to toughness.

**Manganese** is typically held to a maximum of 0.8% even though 1.3% maximum is allowed according to ASTM A532 specifications. While it provides increased harden ability to avoid pearlite formation, it is a more potent austenite stabilizer than nickel, plus it promotes increased amounts of retained austenite and lower as-cast hardness. For this reason, higher manganese levels are undesirable. When considering the nickel content required to avoid pearlite in a given casting, the level of manganese present should be a factor.

**Molybdenum** is a potent harden ability agent in these alloys and is used in heavy section castings to augment harden ability and inhibit pearlite.

## High-Chromium White Irons

The high-chromium white irons have excellent abrasion resistance and they must also be able to withstand heavy impact loading. These alloyed white irons are recognized as providing the best combination of toughness and abrasion resistance attainable among the white cast irons.

The white irons are used in:

1) slurry pumps
2) brick molds
3) coal-grinding mills
4) shot-blasting equipment
5) components for quarrying, hard-rock mining, and milling

There is a trade-off between wear resistance and toughness in the high-chromium white irons, as with most abrasion resistant materials. By varying composition and heat treatment, these properties can be adjusted to meet the needs of most abrasive applications.

Specification ASTM A532 covers the compositions are hardness of 2 general classes of the high-chromium irons.

**Class II of ASTM A532:**

- 11 - 23% Cr and up to 3.5% Mo (chromium-molybdenum irons)
- can be supplied as-cast with an austenitic or austenitic-martensitic matrix
- can be supplied heat-treated with a martensitic matrix micro structure for maximum abrasion resistance and toughness.
- hardest of all grades of white cast irons
- the eutectic carbides are harder and can be heat-treated to achieve castings of higher hardness.
- To prevent pearlite, molybdenum, nickel and copper are added when needed.

**Class III of ASTM A532:**

- oldest grade of high-chromium irons (patent 1917)
- general purpose irons (25% Cr and 28% Cr irons), contain 23 - 28% Cr with up to 1.5% Mo.
- To prevent pearlite, and attain maximum hardness, molybdenum is added.
- can be alloyed with nickel and copper up to 1%
- Class III is used when resistance to corrosion is needed.