Cast Iron

There are many types of cast iron. The below information is only meant as a general reference.

Types of Cast Irons

1 **Grey Cast Irons;**

Grey cast iron nominally contains 2.5-4.0% carbon and high silicon. It is used for many applications, including those under conditions of static compressive load, lightly stressed process equipment and where severe thermal and mechanical shock would not normally be expected. Due to the presence of graphite in its structure, grey cast iron is easily machined. The graphite also provides lubrication when surfaces are subject to sliding and is therefore good for bearings and for damping mechanical vibration. Grey cast iron is however quite brittle and has low tensile strength.

Applications include, but are not limited to brake drums, clutch plates and cam shafts in the automotive industry. Furnace parts, ingot and glass molds and melting pots that operate at elevated temperatures are also made of grey cast iron, as are various types of pipes, valves, flanges and fittings for both pressure and non-pressure applications.

2 **Spheroidal Graphite (SG) Cast Irons (Nodular Cast Iron, Ductile Cast Iron);**

SG cast irons have mechanical properties similar to those of mild steel and far greater than grey cast iron. SG can replace steel castings and forgings as well as grey cast iron in many applications. SG cast irons also contain graphite thus making them machinable.

Applications include culverts, sewers, pressure pipes as well as fittings, valves and pumps. The advantages of these products are their relatively good toughness and weldability when compared to grey cast iron

3 **Austenitic Cast Irons;**

Austenitic cast irons are nickel alloys of grey, SG and white cast irons. Due to the nickel addition, austenitic cast irons exhibit corrosion resistance, erosion resistance, cavitation resistance and exhibit resistance to high temperature service. Austenitic cast irons are stronger and tougher than grey cast iron, producing good wear and galling resistance as well as good machinability. Austenitic SG cast iron is approximately twice as strong as austenitic grey cast iron. Austenitic white cast irons containing nickel, chromium and molybdenum make up the range of Ni-Hard, Ni-Resist and Nicrosilal grades. Ni-Hard is used for abrasion resistance, Ni-Resist for corrosion resistance, and Nicrosilal for heat resistance.

4 **White Cast Irons ("Chilled" Iron)**

Unlike the grey and SG cast irons, white cast irons are virtually free of graphite. They are considered un-machinable and are very brittle with high hardness and low tensile strength. They are often used in the manufacture of crushing rolls. "Meehanite"* is a high tensile white cast iron made by adding calcium silicide to white cast iron. The silicide addition gives uniform hardness as well as physical properties superior to that of grey cast iron.

5 **Malleable Cast Irons;**

Malleable cast irons, which include the white heart and black heart irons, are formed by heating white iron for a set period of time. Malleable cast irons have a higher tensile strength and better ductility than grey cast iron and will bend or deform before breaking and will withstand shock better than grey cast iron.

Applications include flanges, pipe fittings and valve parts. Automotive parts include steering components, compressor crank shafts and hubs, transmission and differential parts, connecting rods and universal joints.

*(registered trademark of International Meehanite Metal Co. Ltd.)

Identify Cast Iron Type

There are a number of ways of identifying the type of cast iron that is to be welded.

1 **Visual observation;**

Grey and SG cast iron have a dirty, dark grey appearance due to the presence of graphite in the structure. White cast irons will have a whitish colour in a fracture in the casting. Malleable and austenitic cast irons have a cleaner appearance than grey or nodular.

2 **Source of supply;**

If possible, check with the supplier of the cast iron if at all possible.

3 **Mechanical tests;**

These are the best tests for identification.

a) Spark test

Touch the metal against a high speed grinding wheel and observe the sparks against a black background. SG cast irons look the same as malleable cast irons. Meehanite cast irons look the same as grey cast irons.

White Cast Irons

Produce a very small volume of thin red coloured spark close to the part being ground, tapering off to a small thin straw yellow coloured spark that is about 1’-6” long. The sparks are finer then grey cast iron.

Grey Cast Irons

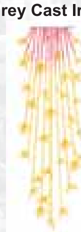
Produce a small volume of thin red coloured spark close to the part being ground, tapering off to a small thin straw yellow coloured spark that is about 2’-0” long. The sparks are courser then white cast iron.

Malleable Cast Irons

Produce a medium volume of larger straw yellow coloured sparks that are about 2’-6” long. The sparks have longer shafts then grey cast iron.

White Cast Irons

Grey Cast Irons



Malleable Cast Irons

b) Chisel Test

This test can be used to separate grey cast iron and malleable iron. Grey cast iron chips break easily, whereas malleable cast iron chips will curl.

c) Spectrographic analysis

Spectrographic analysis is the most accurate if an analyzer is available.

Welding Various Cast Irons

Although cast irons are considered weldable, they are much harder to weld then mild steel and the degree of brittleness and likelihood of cracking of the welded material will depend on the type of casting, the heat treatment, and the welding procedure that is followed. As an example, an SG cast iron is more likely to absorb welding stresses than grey cast iron.

In general most cast irons can be welded using all standard welding processes such as SMAW, FCAW, GMAW, Braze Welding. Below is a chart of the cast irons that can be welded using various consumables.

Cast Iron Type	Process				
	SMAW	FCAW	GTAW	GMAW	Brazing
Grey	1,2	3	4,5	4,5	6
SG	1	3	4	4	6
Austenitic [a]	1	3	4	4	
Malleable	1,2	3	5	5	6
Meehanite	1,2				
Ni-Resist	1,2				
Nicrosilal	Considered unweldable				
White	Considered unweldable				
Ni-Hard	Considered unweldable				

1 - Nickel 55 electrode - Harder to machine then Ni99 electrode
2 - Nickel 99 electrode - Easier to machine then Ni55 electrode
3 - Nickel 55 FC wire
4 - Nickel 55 wire - Harder to machine then Ni99 wire
5 - Nickel 99 wire - Easier to machine then Ni55 wire
6 - Nickel Silver Brazing Rod
a - Nickel 55 may be unsuitable for applications where corrosion-heat resistance values are required.

Welding Consumables;

-Fusion welding of cast irons is normally done with SMAW electrodes such as the Nickel 99 (AWS A5.15 ENi-CI), and Nickel 55 (AWS A5.15 ENiFe-CI) or their bare wire equivalents.

-Braze welding of cast irons is normally done with brazing rods such as the bare of flux coated Low Fuming Bronze (RBCuZn-C) or the Nickel Silver (RBCuZn-D). Additional brazing flux during welding aids in the flow characteristics of the molten puddle.

General Cast Iron Welding Procedure – *New and Used Castings*

The most important aspect in the welding of all cast irons, is to have the surface clean and free of defects prior to welding.

On new castings;
- All sand, slag and scale must be removed from the area of the casting to be welded by mechanical means such as grinding, machining, chipping or rotary burrs.
- Physical defects such as blowholes, sand inclusions, soft spots, shrinkage cracks and pin holes need to be removed. Quite often a pinhole will open up to expose a large cavity hidden underneath.
- Cracks should be ground out to their full length and depth, with no part of the crack remaining. If not done correctly, the crack could propagate after welding causing failure in the casting.

On used castings;
- All contaminates that have impregnated the casting while in service must be removed to prevent porosity during the welding process. This can again be done by mechanical means such as grinding, machining, chipping or rotary burrs.
- Cracks should be ground out to their full length and depth, with no part of the crack remaining. If not done correctly, the crack could propagate after welding causing failure in the casting.

Cleaning

During cleaning, grinding wheels can become coated with carbon or other contaminates which can then be smeared on the finished surface, re-contaminating the part to be repaired. For this reason, the final 1/16” should be cleaned using a new grinding wheel or by chipping, rotary burrs or a coarse file. Also an oxidizing flame from an oxy-acetylene torch can be used to burn off any surface graphite or other oily contaminates. Do so by press the cutting trigger on the torch and run the torch up and down the area to be welded, making sure that you do not over heat the casting. The added pressure caused by pressing the cutting trigger will help to clean out any contaminates that are trapped in the porous surface of the casting. This also provides a light preheat which is advantageous.

When a casting has become so impregnated with contaminates (eg. gear boxes), that standard practices do not clean off the casting adequately enough to make a sound weld, the elimination of the residual can be achieved by heating the casting to 400-600°F for 2-3 hours followed by wire brushing and/or polish grinding. This will help overcome porosity and poor welds. Cast irons that are “out-gassing” during welding should be heated to a dull red for a short period of time before welding. This will help “degasify” the cast iron prior to welding. Wire brush and/or a polish grind the part before welding to remove remaining surface contaminates.

On heavier or large castings where heating is unattainable, weld a “butter pass” or a thin weld bead on the surface area of the casting to be welded. A butter pass separates the contaminates that are in the casting from the area to be welded. If porosity, comes through the butter pass, grind the butter pass down by 50% of its thickness and do another butter pass. Repeat until a clean surface is obtained, and then complete the weld that is required using proper cast iron welding techniques.

Arc-air gouging is not usually recommended. However, it can be used to remove the bulk of metal providing the last 1-2mm is removed by grinding.

High Phosphorus Castings;

Castings high in phosphorous are difficult to weld and can be identified by a glassy and shiny appearance. Often brazing is the best way to repair these castings.

Cracked Castings;

To repair cracked castings, drill a hole at each end of the crack to prevent it spreading further and grind out to the bottom. Begin welding at the drilled end of the crack, where restraint is greatest and move towards the less restrained are

Welding Factors to Consider;

1. Cast irons have low ductility and are in danger of cracking due to stresses setup by welding. (This is not so important when welding SC iron due to its good ductility)
2. Welding can cause formation of a hard brittle zone in the weld area. This is caused by rapid cooling of molten metal to form a white cast iron structure in the weld area and makes the weld unsuitable for service where fairly high stresses are required.
3. The formation of a hard, brittle weld bead due to pick-up of carbon from the base metal. This does not occur with weld electrodes or wires which do not form hard carbides such as Monel and high nickel alloys. These are also used where machinable welds are desired.

Preheating of Cast Irons;

-Arc Welding

Although preheating is not always necessary when welding cast irons, due to the lack of ductility in cast irons, cracking can be minimized by the use of a preheat.

-Brazing

In general all cast irons need to be preheated when oxy-acetylene braze welding to reduce the heat input requirements.

1. Local preheating occurs where parts not held in restraint may be preheated to about 1000°F in the area of the weld, with slow cooling after welding is completed. Cracking from unequal expansion can take place during the preheating of complex castings or when the preheating is confined to a small area of a large casting which is why local preheating should always be gradual.

2. Indirect preheating involves a preheat of 400°F on others areas of the part, in addition to local preheating. This is done so that the overall part will contract with the weld and minimize contraction stresses. Such a technique is suitable for open frames, spokes etc.

3. Complete preheating is used for intricate castings, especially those varying in section thicknesses such as cylinder blocks. It involves complete preheating to 1000°C in a furnace, followed by slow cooling after

welding. The preheating temperature should be maintained during welding. A simple preheating furnace may be made of bricks into which gas jets project.

Post Weld Heating of Cast Irons;

After welding on a cast iron part, especially with welds intended for use in severe service or subject to close machining tolerances, cool the casting as slow as possible by putting the part back into the preheating furnace or encapsulating it in an insulating blanket or an insulating powder/sand. It is sometimes the practice to post-heat welded joints to relieve stresses and soften hard areas. If done, heat the casting to a temperature 1100-1150°F. The casting should be held at this temperature for one hour per 1" of thickness. The cooling rate should not exceed 50°F per hour until the casting has cooled to about 700°F. (For maximum softening and stress relief, heat to 1650°F followed by slow cooling to 1000°F or lower.) To obtain optimum ductility, the above heat treatment should be carried out immediately following welding.

For the best results with SG cast iron, the casting should be placed in a furnace (1100-1200°F) and the temperature brought up to 1650°F. The casting should be held at temperature for 2-4 hours, then cooled to 1300°F, held there for 5 hours, cooled again to 1100°F, and finally cooled to room temperature.

Malleable cast iron may be reheat-treated after welding

Peening of Cast Iron Welds;

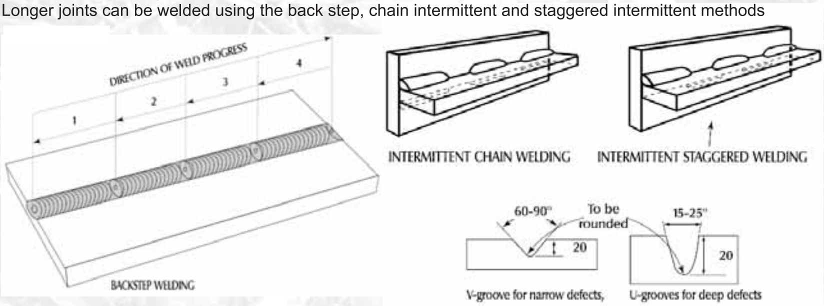
Satisfactory welds may be made on cast iron without preheating, by using proper electrodes that deposit soft metal and peening the weld with a blunt tool (such as a ball hammer) immediately after welding. This spreads the weld metal and counteracts the effect of the contraction of the cooling weld metal.

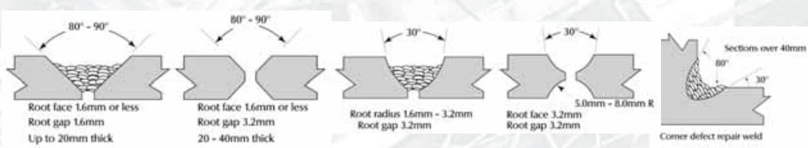
Good welding practice is to deposit short weld runs (~2" at a time) and then peen before too much cooling takes place.

Welding Process / Joint Design;

In general, joint design used for carbon steels are applicable for cast irons. Below are some suggested single "V" and double "V" preparations. Keep in mind that welds should be as narrow as is practical for access, particularly for grey iron, as wide welds build up more stress than narrow ones. A double "V" joint design uses only half the weld metal of a single "V" joint design. For thick materials that are not accessible from both sides, a U-preparation is a good compromise.

Longer joints can be welded using the back step, chain intermittent and staggered intermittent methods





Grey Cast Iron

-The Nickel 99 is more suitable for single layers and for filling small defects, as the deposit remains highly machinable. Single-layered welds using the Nickel 55 are not as machinable as Nickel 99, however they do have increased strength and ductility. Nickel 55 welds are more tolerant towards contaminants such as sulphur and phosphorous and are superior to Nickel 99 electrodes when welding castings that are high in phosphorous.

-Peening is a must for grey cast irons.

-Joining of cast iron to steel can be performed with either Nickel 55 or Nickel 99, but Nickel 55 is preferred.

-Ferrous based electrodes, including hydrogen controlled types (E7018) are generally not recommended for welding cast iron.

-Brackets, lags and even wear plates can be attached to castings using the correct welding parameters and Nickel 55.

SG Cast Iron

-SG cast irons should only really be repaired using Nickel 55 due to its higher tensile strength and better ductility.
-Penetration should be low and wide joints or cavities should be built up from the sides towards the centre.
-Stringer beads or narrow weaves should be used.
-Deposit short beads and allow the weld to cool back to preheat temperature.
-Peening is advisable but not as critical as when welding grey cast iron.

Austenitic Cast Irons
-When attempted, Austenitic cast irons usually welded with Nickel 55.
-The weld may be unsuitable for applications where corrosion/heat resistance qualities do not match the parent metal.

Braze Welding of Cast Iron
-For successful braze welding of cast iron, it is essential that the part be preheated to a dull red heat.
-A neutral or slightly oxidizing flame should be used with a medium or heavy duty welding nozzle.
-The temperature should be maintained during welding. It is necessary to use a furnace to ensure even heating of large castings.
-It is important that the casting be protected from drafts during welding. Sudden chills to the cast iron can cause the formation of white cast iron, which is very hard and brittle. This may cause cracking or make subsequent machining impossible.

Braze welding should only be used to repair old castings because of the poor colour match. Braze welding is suitable for grey, SC and malleable cast irons, however joint strength equivalent to fusion welds are only possible with grey cast iron.