Methods for Identifying Metals & Recommendation for Welding

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In order to decide on welding method and welding consumable when doing maintenance welding onboard it is absolutely necessary to first identify what base material you are facing. In this article we give practical advice in how you by simple methods can identify what metal you are up against and then continue to inform you how to go about welding it.

Documentation

A ship contains more or less all types of metals from the simplest cast iron to the sophisticated titanium and nickel alloys. Most vessels will have documentation giving information towards what the individual items onboard are made from. For some parts the documentation even informs towards welding procedures including recommending type of consumable. Therefore, always start checking out the available documentation onboard before anything else. If no documentation available you move to Methods of Identifying Metals.

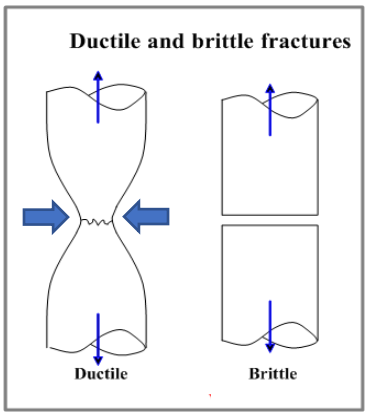
Practical Testing

There are a number of test and observations that can help you pinpoint the type of metal you are facing. Start with the Appearance test followed by the Magnet test. From there you can continue with the Spark test, Oxy-cut test, Flame/Torch test, Chip test, Hacksaw/File test and Chemical test if necessary.

Step by step approach

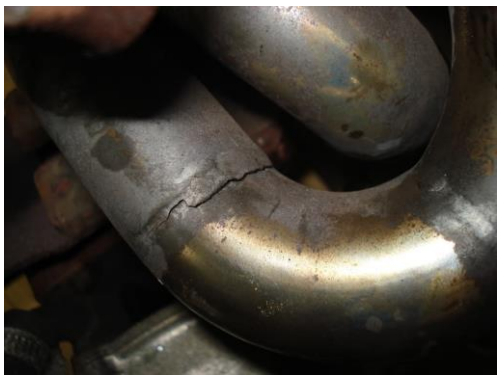
APPEARANCE TEST:

The Appearance test is a number of observations that include Colour, Surface appearance, the metals Practical application and Relative weight. Also look for an imprint on the item that might point toward type of base material. If the part is lighter to lift and handle than expected, when you take its size and shape into consideration, its very likely a metal made from aluminum, magnesium or titanium.



A fractured surface can also provide clues. Is the fracture Brittle or Ductile? In brittle fracture, no apparent plastic deformation takes place before fracture. Brittle fracture occurs most often in metals with low ductility like cast iron. In ductile fracture, extensive plastic deformation (necking) takes place before fracture. This is typical for fractures in metals with high elongation like aluminum and some of its alloys. Steel can also have ductile and brittle fractures or a combination of the two. Low alloyed steel has less tensile strength but high ductility and therefore often ductile fracture. High tensile steel with alloying elements tend to have more brittle fractures. NB. Fracture mechanics are complicated where also ambient temperature plays a part.

Start by having a look at the item to be repaired. If it has a welded joint it tells you that it is weldable. That's a good start. If it is a casted item without a welded joint you will have to be more careful. It can still be weldable but it might require a special procedure in order for the welding job to succeed. Castings will have signs of parting mould lines, no welded joints and for some castings a sandy and/or ruff surface. A strong clue in metal identification is colour. It can differentiate magnesium, aluminum, brass, and copper. If there are signs of oxidation, remove it via scraping to reveal the colour of the unoxidized surface.



Despite the dark colour, the base material is cast aluminum. The rust indicate that the pipe is made from steel.


A Yorcalbro seawater pipe, yellowish brown surface. Freshly filed relives a silvery yellow.

The surface colour of a metal can varies tremendously and depend to a large extent on the surface treatment by manufacturer and the items work environment. The colour indicated in the below table is therefore only a rough guideline.

APPEARANCE TEST:

Metal	**Colour of surface**	**Colour newly fracture**	**Colour freshly filed**	**Relative weight g/m3**
Aluminum and alloys	Bluish white	White; finely crystalline	White	2,72
Brass, Navy*	Ages to light brown/reddish to yellow**	Muted yellow red	Reddish yellow/gold to yellowish white	8,4-8,7
Bronze, alu*. (90%Cu-9%Al) Yorcalbro	Ages to dark brown/dull-gold colour	Reddish brown to yellow	Reddish yellow to yellowish white	7,7
Bronze, phosphor* (90%Cu-10%Sn)	Reddish yellow	Red to yellow	Reddish yellow to yellowish white	8,8
Bronze, silicon* (96%Cu-3%Si)	Reddish yellow	Red to yellow	Reddish yellow to yellowish white	8,6
Copper (deoxidized)	Ages to green/ brown rustic	Bright red	Bright copper colour	8,8-8,95
Copper nickel (70%Cu-30%Ni)	Reddish brown	Silvery	Silvery	8,95
Copper nickel (90%Cu-10%Ni)	Reddish brown	Silvery	Silvery	8,9
Inconel (76%Ni-16%Cr-8%Fe)	Silvery	Silvery	Silvery	8,5

Metal	Colour of surface	Colour newly fracture	Colour freshly filed	Relative weight g/m3
Iron, Grey Cast	Dull grey	Dark grey; crystalline	Light silvery grey	7,03-7,13
Lead	Dark grey	Light grey; crystalline	White shiny crystallin appearance	11,36
Magnesium***	Shiny grey	Silvery white	Silvery white	1,76
Monel (67%Ni-30%Cu)	Dark grey	Light grey	Light grey	8,97
Nickel	Dark grey	Off- white	Bright silvery white	8,8
Steel, Low alloy	Dark grey	Bright grey	Bright silvery grey	7,8
Steel, Cast	Dark grey	Bright grey	Bright silvery grey	7,8
Steel, High tensile	Dark grey	Light grey	Bright silvery grey	7,8
Steel, manganese (14%Mn)	Dark grey	Light grey	Bright silvery grey	7,7
Stainless steel Austenitic (304/316/317) Super Austenitic (254 SMO)	Light grey to shiny silvery	Medium grey	Polished: Silvery with yellow tinge	7,7
Stainless steel Martensitic (420)	Bright silvery grey	Medium grey	Bright silvery grey	7,7
Stainless steel Ferritic (409/430)	Bright silvery grey	Medium grey	Polished: Silvery with blue more metallic tinge	7,7
Stainless steel Duplex (2205/2304)	Light grey to shiny silvery	Medium grey	Bright silvery grey	7,7
Tin	Grey silvery white	Silvery white	Silvery white	7,28
Titanium	Dark silvery grey	Silvery grey	Silvery grey	4,48
Zink***	Dark grey	Silvery	Silvery	7,12
Yorcalbro	Reddish brown	Silvery yellow	Silvery yellow	8,7

*You can also tell the difference between bronze and brass because bronze will have faint rings on its surface.

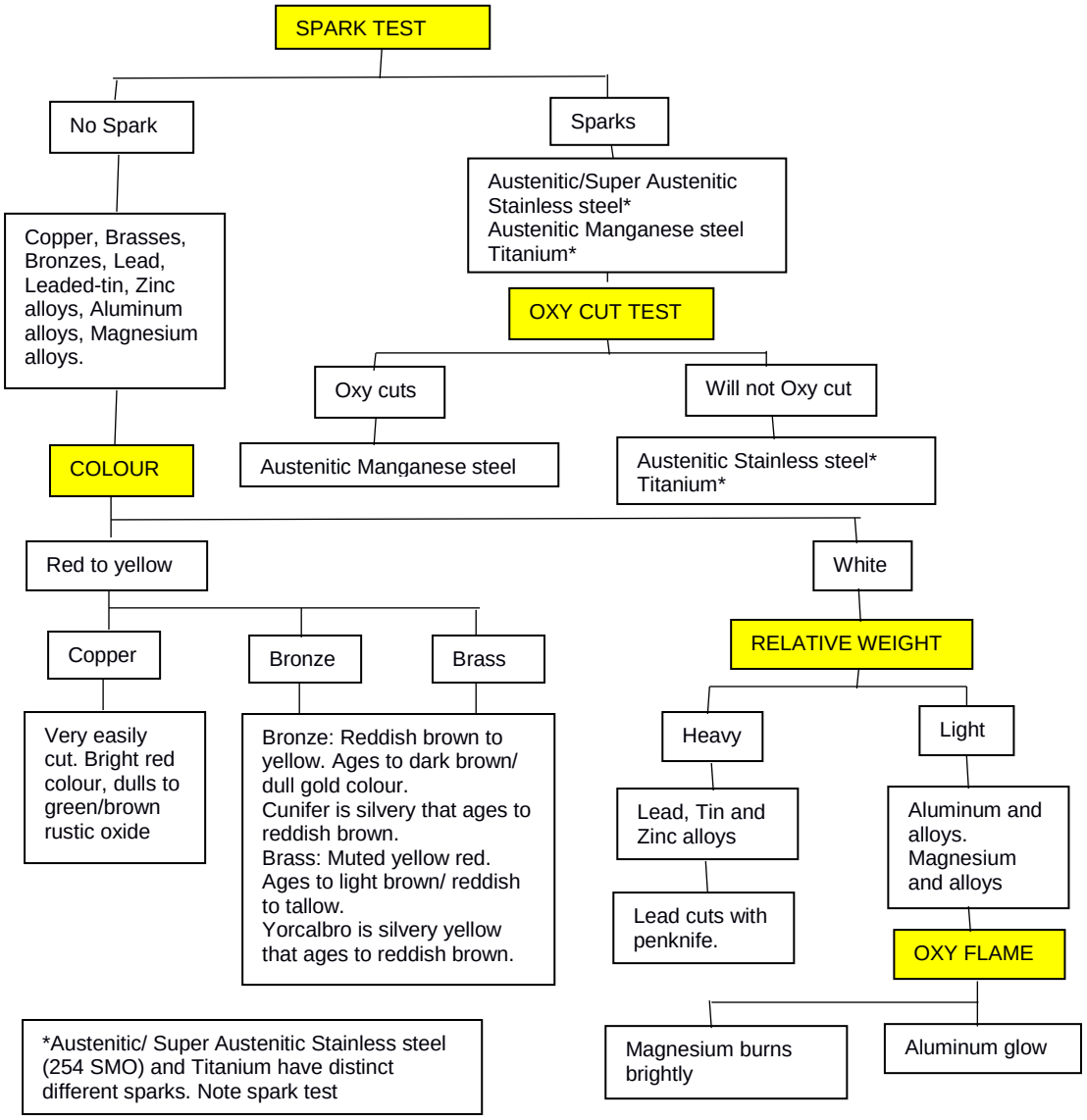
**Brass can range in colour from red to yellow depending of amount of zinc. The more zinc the more yellow.

***Metals like Magnesium and Zinc quickly oxidise therefor important to file or scrape surface.

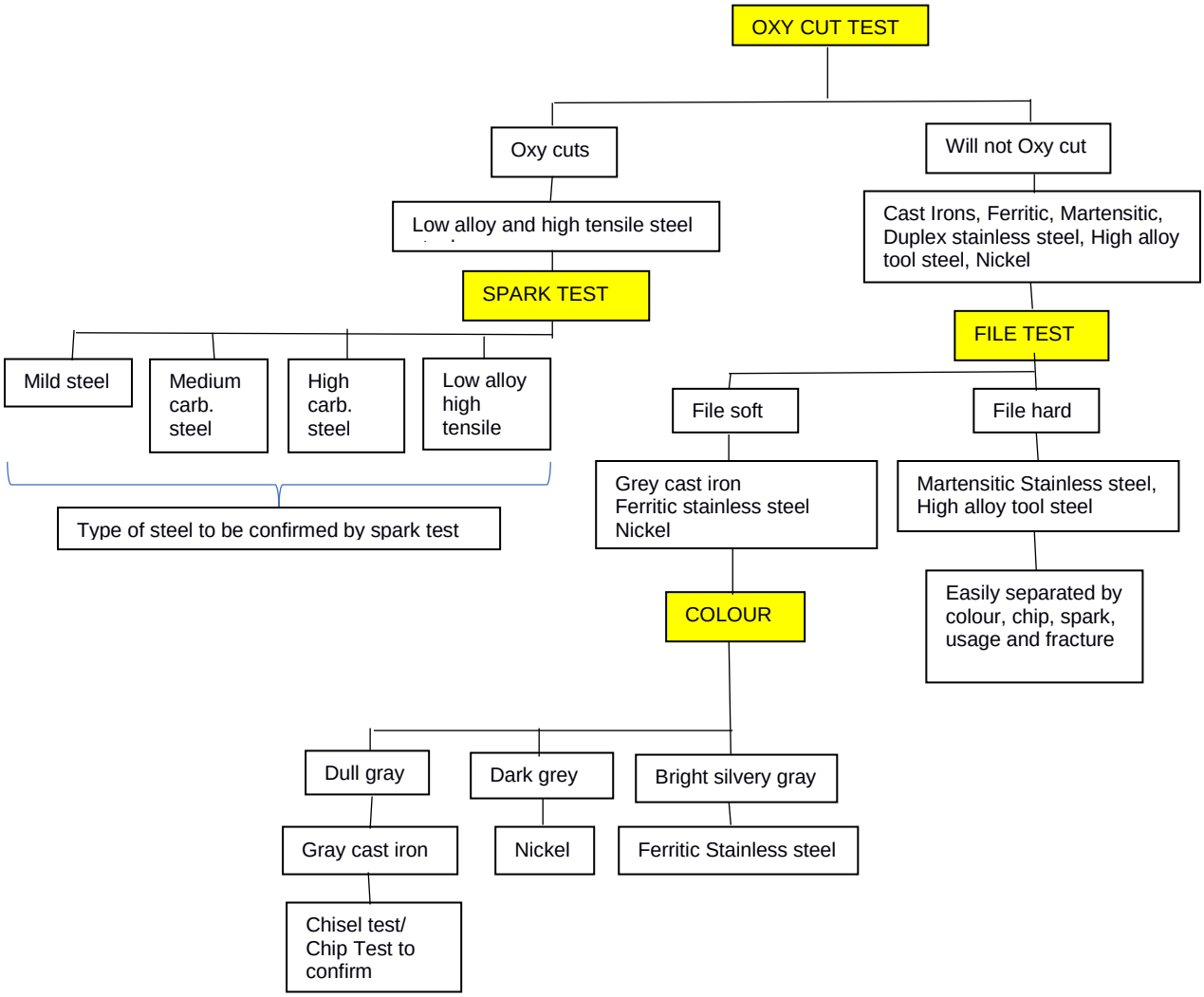
THE MAGNET TEST

The easiest way of performing metal identification is by using a small pocket magnet. This test can be performed where with experience, it is possible to distinguish between a material that is slightly magnetic with one that has a strong magnetic pull.

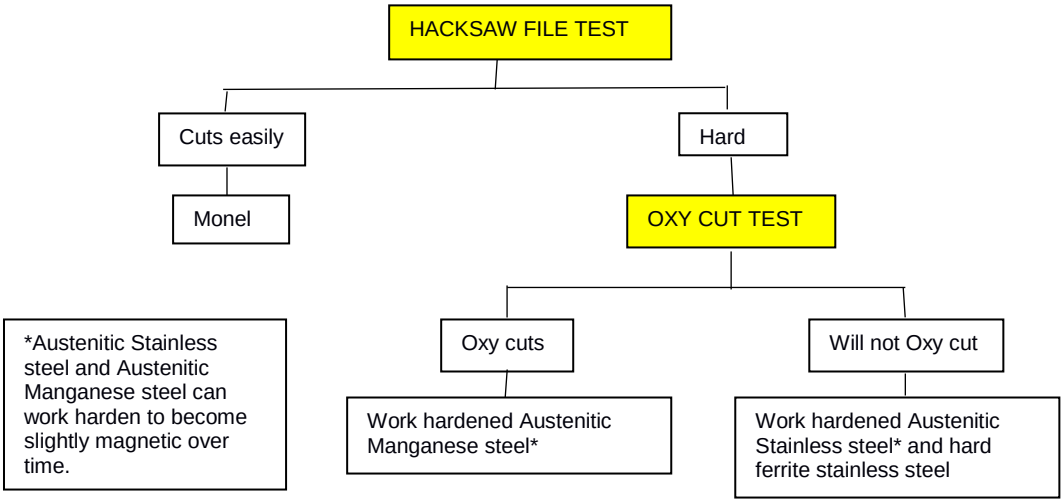
If the metal is **not magnetic** follow this test sequence:



For **magnetic metals** follow this test sequence:



For **slightly magnetic** metals follow this test sequence:



Summing up Magnetic testing:

Nonmagnetic materials include:

- Aluminum and alloys
- Austenitic/Super Austenitic Stainless
- Brass, Navy
- Bronze, alu. Yorcalbro (90%Cu-9%Al)
- Bronze, phosphor (90%Cu-10%Sn)
- Bronze, silicon (96%Cu-3%Si)
- Copper (deoxidized)
- Copper nickel (70%Cu-30%Ni)
- Copper nickel (90%Cu-10%Ni)
- Inconel (76%Ni-16%Cr-8%Fe)
- Lead
- Magnesium
- Manganese steel (14%Mn)
- Tin
- Titanium
- Zink
- Yorcalbro

Slightly magnetic reactions from metals:

- Monel (67%Ni-30%Cu)
- High-nickel alloys

Strongly magnetic materials include:

- Iron, Cast
- Steel, Low alloy
- Steel, high tensile
- Pure Nickel
- Stainless steel Duplex (2205)
- Stainless steel Martensitic
- Stainless steel Ferritic

A note on Stainless Steel:

The alloy make-up of the stainless steel will determine if it is magnetic or non-magnetic. Chromium negates the magnetic properties of nickel and iron, making the stainless steel non-magnetic. Three things to know about stainless steel:

Stainless steel that contains nickel will sometimes be magnetic.

An alloy made of nickel and chromium will, in most cases, not be magnetic.

An alloy made of nickel and copper will also not be magnetic in most cases.

The Aluminum Confusion:

Identifying stainless steel from aluminum can be confusing – and embarrassing when you get it wrong. There are a couple of tests that can be done to make sure.

Test 1 – Perform the magnet test. If it sticks to the item, it is not going to be aluminum, but will most likely be steel or a special type of stainless steel known as Martensitic or Ferritic. This should be your first step in identifying stainless steel from other types of metal.

Test 2 – The spark test. If you grind a bit on the item in question using an angle grinder and it throws a “glow” of sparks, then it is steel. If it is non-magnetic and gives off sparks, the item is most likely Austenitic grade of stainless steel.

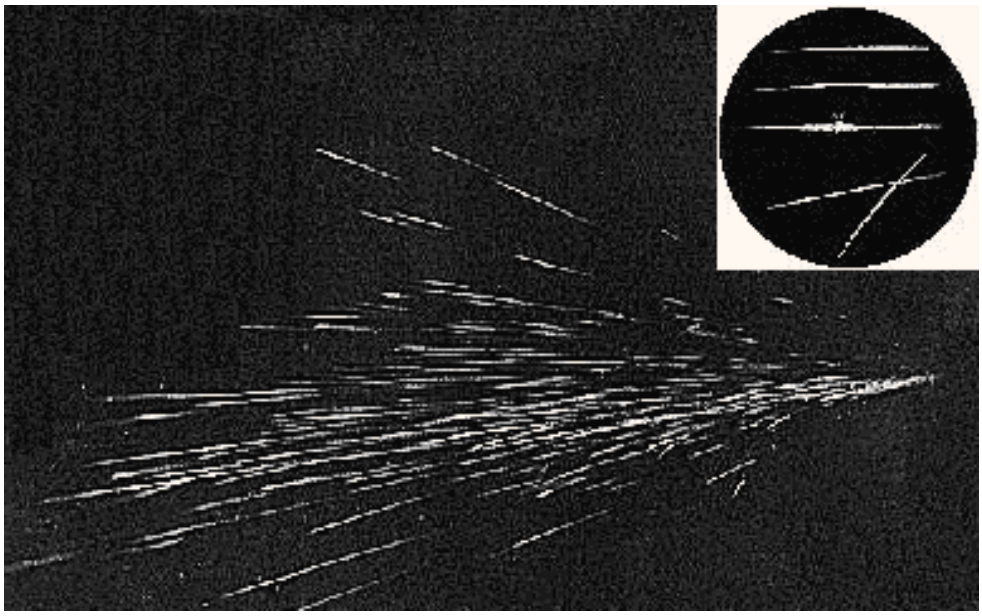
Test 3 - If you still not sure whether something is aluminum or stainless steel, rap your knuckles against the side of the metal and listen. Aluminum produces a dull sound, while stainless steel makes a more ringing sound.

Depending on the outcome of the Magnetic test follow the test sequins for Not magnetic, Slightly magnetic or Strongly magnetic.

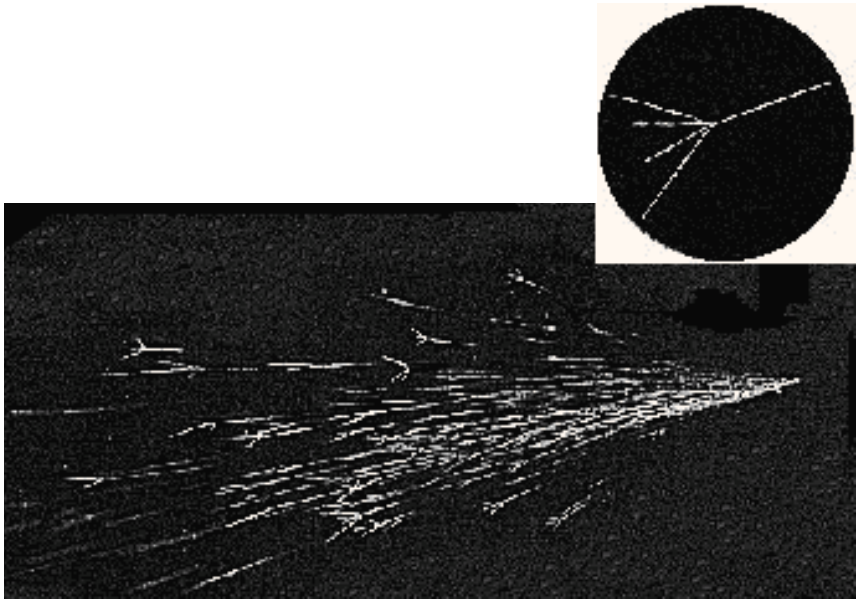
SPARK TEST:

The Spark Test is a simple identification test used to observe the colour, spacing, and quantity of sparks produced by grinding. It is a fast and convenient method of sorting mixed steels with known spark characteristics. This test is best conducted by holding the steel stationary and using a high-speed angle grinder to the steel surface with sufficient pressure to throw a spark stream about 30cm (12”) long. The characteristics of sparks generated by grinding are shown on the following pages. These spark patterns provide general information about the type of steel, cast iron, or alloy steel. Do not use Spark Test on non- ferrous metals. Spark test is not helpful for identifying nonferrous metals such as nickel-base alloys, aluminum, and copper. These metals do not show significant spark stream. It should be noted that steels alloyed with manganese show markedly increased spark activity, both in number, thickness and intensity of the rays; while steels alloyed with chromium show the opposite effect, i.e., less activity. Nevertheless, it is not difficult to distinguish them from ordinary carbon steels, as these show a multitude of explosions, which the manganese and chromium alloyed steels do not. The higher the carbon in the carbon steel, the more vivid the explosions are. Steels alloyed with tungsten, finally, show a markedly red colour.

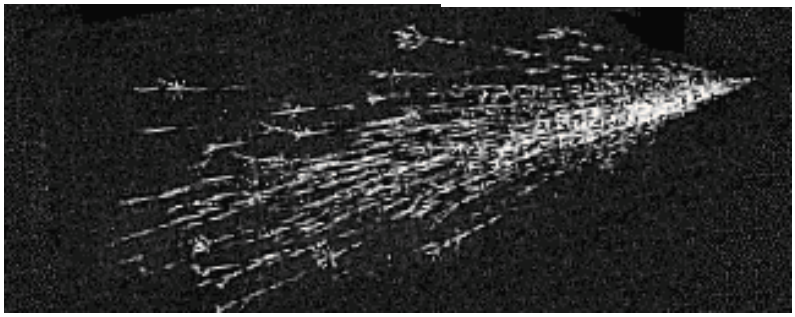
Mild steel/Low carbon and Cast steel: Sparks flow out in straight lines with tiny forks with varying lengths. The sparks will be white in colour.



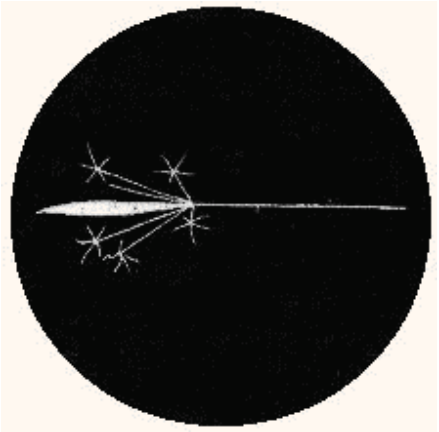
Medium carbon steel: with 0,5% to 0,85% carbon. This steel has more forking than mild steel and a wide variety of spark lengths, with more near the grinding disc.



High carbon steel: High-carbon steel has a bushy spark pattern (lots of forking) that starts at the grinding disc. The sparks are not so bright as the medium-carbon steel ones.

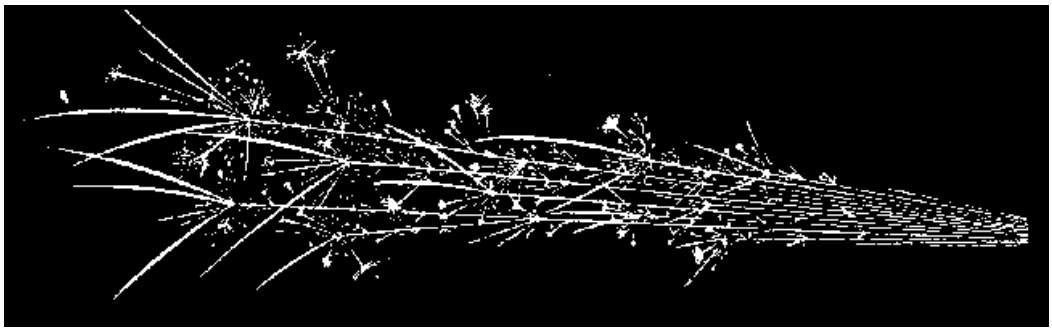


Grey cast iron: Cast iron has very short sparks that begin at the grinding disc. Cast iron make a dull red, non-explosive spark that thickens towards the end.

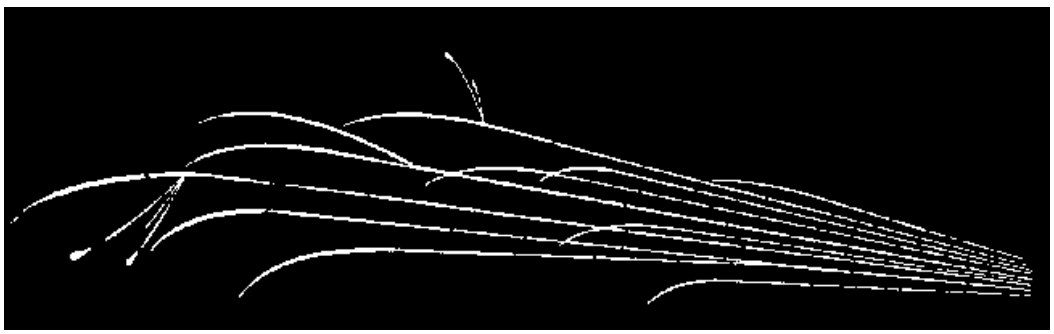


Nickel, Monel, Inconel: Monel metal have faint red streaks quickly tailing off. Inconel metal have short reddish sparks. Nickel high temperature alloys have thin and very short sparks. Dark red in colour and do not fork.

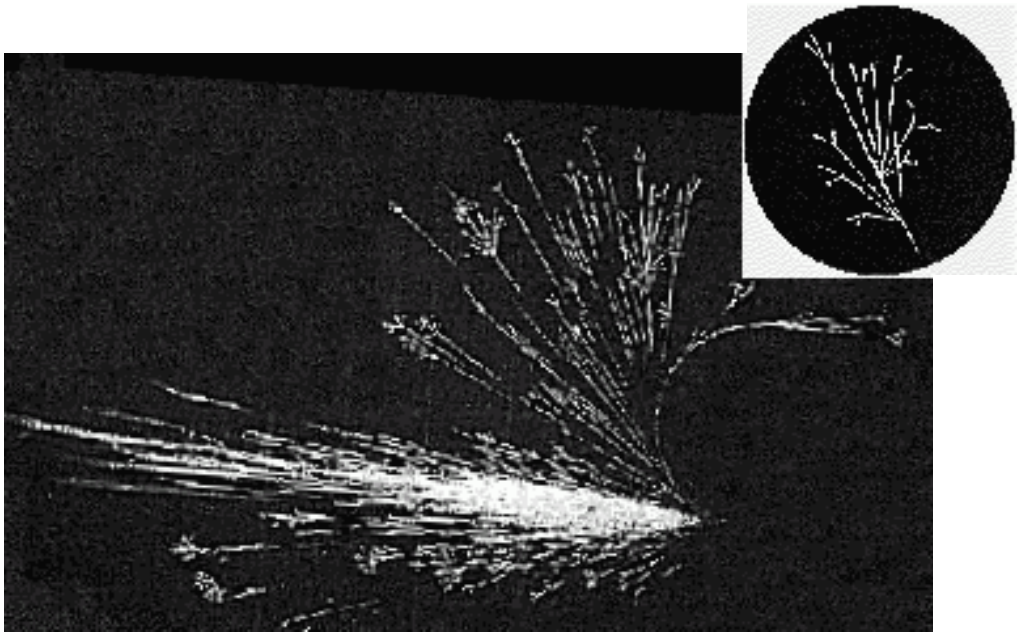
Stainless steel, Austenitic (304, 316): Few forks- short and orange to red forks.
Stainless steel, Austenitic (317): Red forks.
Stainless steel, Martensitic: Long white forks.
Stainless steel, Ferritic (430): Long white forks.
Stainless steel, Ferritic (446): Red, many forks.



High Speed steel: Faint red streaks forking at the tip.



Manganese steel: Manganese steel has medium length sparks that fork twice before ending.



Titanium: Although titanium is a non-ferrous metal, it gives off a great deal of sparks. These sparks are easily distinguishable from ferrous metals, as they are a very brilliant, blinding, white colour.

Regarding the spark test: Take the same precautions as for any other hot work job before the test is commencing. Always wear a face shield/ safety goggles and proper clothing when using the grinder. Use a grinding disc that has a hardness to last for some time, but soft enough to maintain a free grinding edge. Conduct spark tests in little light to make it easier to see the spark colour.

OXY-CUT TEST:

By carefully using an oxy- acetylene cutting torch one can distinguish a number of different materials apart. The oxy- acetylene cutting torch is used to heat metal by increasing the temperature to its ignition point and then introducing a stream of pure oxygen to create the burning or rapid oxidation of the metal. The stream of oxygen also assists in removing the material from the cut.

For a material to be flame cut using an oxy- acetylene torch the following conditions must apply:

1. The melting point of the material must be above its ignition temperature in oxygen.
2. The oxides of the metal should melt at a lower temperature than the metal itself and below the temperature that is developed by cutting.
3. The heat produced by the combustion of the metal with oxygen must be sufficient to maintain the oxygen cutting operation.
4. The thermal conductivity must be low enough so that the material can be brought to its ignition temperature.
5. The oxides formed in cutting should be fluid when molten so the cutting operation is not interrupted.

- Iron and low-carbon steel fit all of these requirements and are readily oxygen flame cut. Cast iron is not readily flame cut, because the ignition temperature is above the melting point. It also has a refractory silicate oxide which produces a slag covering. Chrome-nickel stainless steels cannot be flame cut with the normal technique because of the refractory chromium oxide formed on the surface. Nonferrous metals such as copper and aluminium have refractory oxide coverings which prohibit normal oxygen flame cutting. They have high thermal conductivity.

  Oxy cut materials: Low alloy and plain carbon steel, Austenitic manganese steel.

  Will not oxy cut: Cast iron, Austenitic/ Super Austenitic/ Ferritic/ Martensitic/ Duplex stainless steel, Copper and copper alloys, Aluminum and aluminum alloys, Nickel, Monel, Inconel, Titanium.

OXY-FLAME TEST:

A simple test to find out whether the component is of aluminum, magnesium-alloyed aluminum or magnesium is as follows: Place the component on a piece of paper and file some shavings onto the paper. Hold the paper over a flame (Propane or Oxy- Acetylene) and let the filings fall into the flame.

If the filings glow the metal is aluminum.

If some of the filings spark in the flame the aluminum is alloyed with magnesium (seawater resistant aluminum).

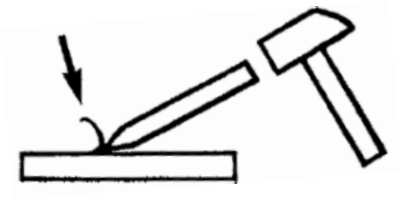
If all the filings spark in the flame, the metal is magnesium and must not be welded.

Bronze and Brass: Lead alloys will show boiling lead under oxy flame test. Higher zinc alloys fume.

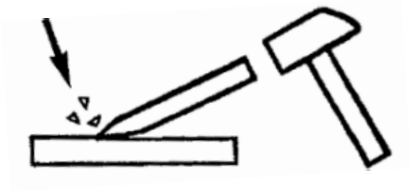
CHISEL TEST (CHIP TEST):

The chip test or chisel test may also be used to identify metals. The only tools required are human beings' oldest tools, hammer and a chisel. Use the cold chisel to hammer on the edge or corner of the material being examined. The ease of producing a chip is an indication of the hardness of the metal. If the chip is continuous, it is indicating a ductile metal, whereas if chips break apart, it indicates a brittle material. On such materials as aluminum, mild steel and lead, the chips are continuous. They are easily chipped and the chips do not tend to break apart. The chips for grey cast iron are so brittle that they become small, broken fragments. On high-carbon steel, the chips are hard to obtain because of the hardness of the material, but can be continuous.

METAL	CHIP CHARACTERISTCS
Grey Cast Iron	Chips are about 3mm (1/8") in length. Metal not easily chipped. Chips break off and prevent smooth cut.
Mild steel/Low carbon and Cast steel	Chips have smooth edges. Metal is easily cut or chipped, and chip can be made as continuous strip.
High Carbon Steel	Chips show a fine-grain structure. Edges of chips are lighter in colour than chips of low carbon steel. Metal is hard, but can be chipped in a continuous strip.
Copper	Chips are smooth, with sawtooth edges where cut. Metal is easily cut as continuous strip.
Brass and Bronze	Chips are smooth, with sawtooth edges where cut. These metals are easily cut, but chips are more brittle than chips of copper. Continuous strip is not easily cut.
Aluminum and Aluminum Alloys	Chips are smooth, with sawtooth edges. A chip can be cut as continuous strip.
Monel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Nickel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Lead	Chips of any size may be obtained because material is so soft that it can be cut with a knife.



CAST STEEL



CAST IRON

Materials that are difficult to tell apart is Cast steel and Cast iron. They are both casted items with no welded joints and have a mould line and casted surface. By using hammer and chisel they can easily be identified. Cast steel will have a continues chips. Cast iron will have small brittle fragments.

HACKSAW FILE TEST:

The file test is a less precise test of hardness. The file test is a method of determining the hardness of a piece of material by trying to cut into it with the corner edge of a file. The hardness is indicated by the file bite. This is the oldest and one of the simplest methods of checking hardness; it will give results ranging from quite soft to glass hardness. The principal objection to the use of the file test is that no accurate record of results can be maintained as numerical data.

Hard to file: Martensitic and Austenitic stainless steel, High alloy tool steel, Manganese steel.

Soft to file: Grey cast iron, Ferritic stainless steel, Nickel, Monel.

CHEMICAL TEST:

Some metals can be identified using a chemical test. The chemicals needed might not be easily accessible onboard but the test is never the less worth mentioning.

Monel vs. Inconel Identification:
Inconel can be distinguished from monel with one drop of nitric acid applied to the surface. It will turn blue- green on Monel but will show no reaction on Inconel.

Stainless Steel Identification:
Magnetic testing, spark testing and hardness testing can distinguish between certain grades of stainless steel. They cannot however, distinguish between Austenitic 304 and Austenitic 316 grades because both are non-magnetic, produce the same short, orange to reddish sparks, and have similar hardness.
Acid testing is one test that will separate 304 and 316 grades of stainless steel.

Sulphuric acid strongly attacks 304 grades, producing green crystals and a dark surface, but its attack on 316 grades is slow and produces a brown surface.

Hydrochloric acid attacks 304 grade very rapidly and produces gas, but attacks 316 grade only very slowly.

Magnesium vs. Aluminum Identification:
Aluminum can be differentiated from Magnesium by using silver nitrate, which will leave a black deposit on magnesium, but not on aluminum.

Alternative Magnesium vs. Aluminum identification:

1. Clean a small area of the metal.
2. Drip onto it one or two drops of 20% caustic soda (NaOH) solution.
3. Wait 5 minutes and wash with clean water.

Black: Al + Cu, Al + Ni, Al + Zn.
Grey/brown: Al + Si (over 2%).
White: Pure aluminum.
Unchanged: Magnesium (Mg).

ADVANCED METAL TESTING METHODS:

If it is of the uppermost importance to find out the exact type of metal one is to weld, for example in connection with welding of a boiler pipe or other critical components, there are advanced metal testing method available. No longer relying on just the eye or the personal experience, modern metal testing methods incorporate technology to improve the process speed and result accuracy while protecting the samples. One popular technique is called the Positive Metal Identification (PMI) that uses X-ray Fluorescence (XRF) and Optical Emission Spectrometry (OES). PMI is the analysis of metallic alloy to establish its composition and alloy grade identification by reading the quantities by percentage of its elements. PMI analysers provide detailed element analysis of materials for uses from industrial to research.

Hand held metal analysers provide fast an accurate material chemistry identification for metals.

To recap follow this sequence for identifying a metal:

1) **AVAILABLE DOCUMENTATION ONBOARD.**

2) **APPEARANCE TEST:** Colour, Surface appearance, the metals Practical application, Relative weight, imprint in material.

3) **MAGNET TEST:** Not Magnetic, Slightly Magnetic, Magnetic.

Depending on result of magnet test follow the recommended test sequence that can be one or more of the following:

Spark test, Oxy-Cut test, Oxy-Flame test, Chisel test/ Chip test, Hacksaw file test, Chemical test, repetition of the Appearance test.

Having done your best identifying the metal you can move to the Recommended Welding Process, Welding Consumable and Procedure.

Recommended Welding Process, Welding Consumable and Procedure depending on your metal identification results:

Metal	**Go to T.E Andersen Consulting Welding Library for recommended pdf file: Welding Process, Welding Consumable and Procedure.**
Aluminum and alloys.	• Maintenance welding of aluminum.
Brass, Navy Bronze, alu. (90% Cu- 9% Al) Bronze, phosphor (90% Cu- 10%Sn) Bronze, silicon (96%- 3%Si)	• Arc welding of copper alloys. • What you should know about brazing.
Copper (deoxidized)	• What you should know about brazing.
Copper nickel (70%Cu-30%Ni) Copper nickel (90%Cu-10%Ni)	• Repair Welding of seawater pipes.
Inconel (76%Ni- 16%Cr-8%Fe)	• Welding of nickel, nickel alloys.
Iron, Cast	• Welding of cast iron.
Lead	*Toxic fumes. Possible to Gas weld but require special technic. Wear respirator.*
Magnesium	*Not weldable.*
Monel (67%Ni-30%Cu) Nickel	• Welding of nickel, nickel alloys.
Steel, Low alloy Steel, Cast Steel, High tensile	• The need for pre-heating when welding. • Heat input and interpass temperature during welding. • Way do welds crack? • The no.1 maintenance welding electrode.
Steel, Manganese (14%)	• Hard surfacing
Stainless steel, Austenitic Stainless steel, Martensitic Stainless steel, Ferritic Stainless steel, Duplex	• How to weld stainless steel. • Maintenance of stainless steel.
Tin	• What you should know about brazing.
Titanium	*Require special welding equipment/vacuum chamber.*
Zink	*Toxic fumes. Possible to TIG and Gas weld but require special technic. Wear respirator.*
Yorcalbro	• Repair Welding of seawater pipes.

NB. If the job require that an old weld needs to be removed or that a crack needs to be gouged out before welding, check out the pdf file in the welding library:

- Methods for removal of welds and opening of cracks.