Preface

The subject of welding and welding consumables, as well as the metallurgy that goes into them, is far more complicated than most would suspect. The disparities between AWS codes, SAE codes, and several other more esoteric methods of identifying consumables result in a fairly obnoxious learning process. This document seeks to help simplify that learning process in a fair manner by presenting this information in a condensed and hopefully more digestible format. Within this document, there is an assumption of knowledge about certain basic terms that will be used. Most terminology will be localized to terms in the United States, however when available (and known to the author) the terms per ISO 4063 will be displayed in parenthesis. The scope will primarily be restricted to processes and equipment that the average hobbyist would be able to acquire, with other topics touched on for interest and advanced learning.

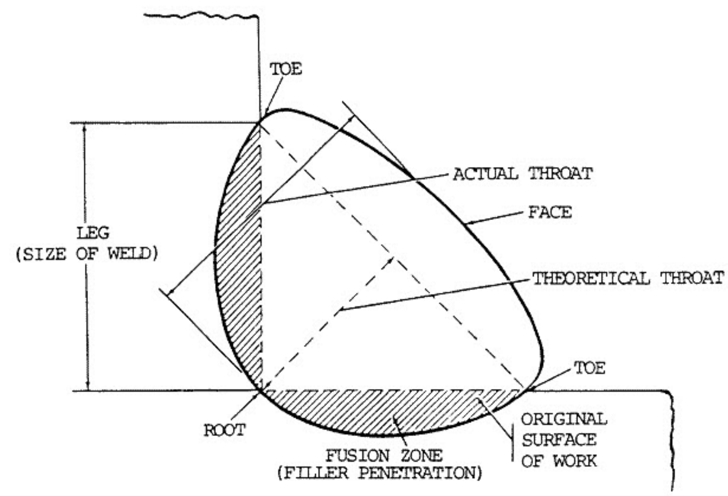
Definition of Terms

Alloy. A material having metallic characteristics and made up of two or more elements, one of which is a metal.
Arc Force / Dig. A setting on a CC (constant current) weld machine that increases voltage the closer to the base metal the electrode gets in order to maintain an arc.
AWS. American Welding Society
Base metal. Often called parent metal, the metal used in work pieces being joined together.
Brazing. A joining or fixing process involving soldering with a non-ferrous alloy at high temperatures.
Electrode. The primary electrical conductor of an arc. Not always the consumable.
Flux. A coating or material that is added during a welding process to prevent formation of oxides.
Fusion. Melting of metal to the liquid state, permitting two contacting or neighboring surfaces to partially exchange their contents with the result that there is a thorough blending of the compositions after cooling.
Hot Start. A setting on a CC (constant current) welding machine that increases amperage for a certain length of time after an arc is struck. Typically represented by percentage and seconds.
Penetration. The depth into the base metal that a welding arc will affect.
SAE. Society of Automotive Engineers, also known as SAE International.
Slag cap. A glassy ceramic substance that forms over a weld during cooling to protect it from oxides during the cooling process.
Tensile strength. The resistance to a material breaking under tension, typically measured in ksi or psi.
Working positions. Referring to one of the four different working positions, these being flat (1), horizontal (2), vertical (3), or overhead (4). A position designation also includes a letter designator, showing if the weld is a fillet (F) or a groove (G).

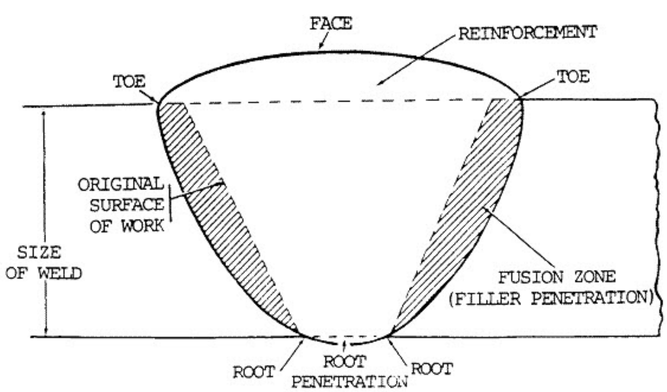
What makes up a weld?

When boiled down to the metallurgic fundamentals, nearly every single weld is a casting. Heat is applied to metal in order to turn it to a liquid state and then this is allowed to solidify. Some exceptions exist (such as EXW, also known as explosion welding) however these are specialty processes that are outside the scope of this document. It is the knowledge that a weld is a casting that sets the context for the rest of this document.

Before discussing the anatomy of a weld, we must first distinguish between a groove weld and a fillet weld. There are other further types of welds, but their anatomy can be roughly correlated to these two forms of welds. The primary distinction is the following - if the weld is between the work pieces, it is a groove weld. If it is beside the two work pieces, it is a fillet weld. One thing that does not change no matter what form of weld is being performed is something called the HAZ, or Heat Affected Zone. This is how far outside of the weld is significantly metallurgically affected by the welding arc.



FILLET WELD



Starting with the simpler weld anatomy, a fillet weld has seven different components. These are the root, the legs, the toes, the face, the fusion zone, the theoretical throat, and the actual throat. Out of these, the only important ones for a beginner to know immediately are the root, the legs, toes, and the face. The root is the deepest part of the weld, where the two work pieces originally contact. The legs are the length of how far the weld extends from the root in a cross section. The toes are where the weld meets base metal at the end of the leg. And finally the face is the outer surface of the weld that we are able to see.

A groove weld adds two terms that a beginner should keep track of. These terms are root penetration and reinforcement. Root penetration is how much metal buildup is present on the back of the weld. Typically in a code welding environment, this is no more than 3/32” or 1/16”. Reinforcement is how much face material is built up. In a code environment this is typically no more than ⅛”.

Methods of Welding

For the beginner and hobbyist, there are only a few processes which should be considered. Any processes outside of the ones listed here are either too expensive to run, too advanced for a beginner, or require particularly specialized equipment that may be difficult to acquire.

SMAW - Shielded Metal Arc Welding (111)

Also known as MMA (manual metal arc) or stick welding, SMAW is the most common and oldest arc welding process in the world. It involves manual striking and maintenance of an arc via a rigid flux coated electrode that is clamped in an electrode holder that is sometimes referred to as a stinger. SMAW is the arc welding process least affected by environmental influence as it uses only flux to protect the weld. It has a rather sharp learning curve compared to other introductory processes, typically considered difficult to learn but easy to master.

GMAW - Gas Metal Arc Welding (131/135)

A wire welding process that also can be known by MIG (metal inert gas) or MAG (metal active gas) depending on specific application. This is a semi-autonomous process where arc ignition and electrode feed is performed by the machine and the weld gun, however arc manipulation and maintenance is still done by the welder. It feeds the electrode from a spool of solid uncoated wire. Somewhat environmentally sensitive as this welding process relies on a shielding gas to prevent atmospheric contamination in the welds that can be blown or sucked away if not careful. A fairly easy process to learn, but one that can be somewhat difficult to master depending on the specific sub-process.

FCAW - Flux Cored Arc Welding (136/137)

The other most common semi-automatic wire welding process. Instead of a solid wire, this process utilizes a tubular wire that is filled with a flux compound that helps protect the weld from the atmosphere. On average slightly less sensitive to the environment compared to GMAW, however some forms of FCAW do still require shielding gas. The flux element of this welding process introduces a couple quirks that can be tricky for a complete beginner to pick up, however once these quirks are learned this process can be fairly easy to learn and master.

GTAW - Gas Tungsten Arc Welding (141)

A manual welding process that is also known as TIG (tungsten inert gas) or WIG (wolfram inert gas) depending on locale. This process utilizes a torch with a non-consumable tungsten based electrode that strikes an arc to melt the base metals while a rod of uncoated filler metal is manually fed with the non-torch hand. The most environmentally sensitive of the common welding processes and can be disturbed with even a common room fan. This process is the hardest to learn and hardest to master of the common processes, however it also has the widest set of applications. For the most part this process is capable of doing everything that SMAW and wire welding processes are capable of and more, however it is a slower process as a whole.

OAW - Oxyacetalyne Welding (311)

Not an arc welding process, however its technique is similar to GTAW. Instead of a torch that strikes an electrical arc, instead a regular torch is utilized with a welding tip on it. Requires flammable gasses on-hand and can be quite hazardous without proper care. Does not utilize electrodes and instead only uses consumables with the RG (for Rod Gas) designation, typically sold as RG-45 or RG-60.

Basics of AWS Filler Metal Codes

As a whole, filler metal codes and regulations described here are published by AWS. Although some relatively common filler metals are not described here, they do still exist. The following designation codes are only covering the filler metals for carbon steels. Typically for carbon steel electrodes there are three components to a filler metal code. The letters at the front that tell you if it’s an electrode, a rod, or both. The numbers that tell you the materials tensile strength. And then the numbers that designate conditional items such as specific alloying designations or different flux codes.

A5.1 Electrodes / Coated SMAW Electrodes for Carbon Steels

A5.1 electrodes are solid rod electrodes that are coated with different forms of flux. They are classified with a single letter and four numbers. This is formatted like E6010 or E7018 with the different numbers changing the designation code.

- The letter “E” indicates that this is an electrode.
- The first two digits indicate the minimum tensile strength of the weld. This is measured in psi. A rod designated with a 60 at the start will produce a weld with a minimum tensile strength of 60,000 psi.
- The third digit indicates the electrode’s working positions. 1 means all positions while 2 means horizontal and flat only. 3 and 4 codes also exist, but should be ignored for anybody who doesn’t work in fields that utilize them.
- The fourth digit indicates coating type and the polarities (DCEP, DCEN, AC) that the welding rod can be used with. A small chart is provided below for the coating types.

Classification	Polarity	Arc	Penetration	Coating	Iron Powder
EXX10	DC+	Digging	Deep	Cellulose-Sodium	0-10%
EXXX1	AC, DC+	Digging	Deep	Cellulose-Potassium	0%
EXXX2	AC, DC-	Medium	Medium	Titania-Sodium	0-10%
EXXX3	All	Light	Light	Titania-Potassium	0-10%
EXXX4	All	Light	Light	Titania-Iron Powder	25-40%
EXXX5	DC+	Medium	Medium	Low Hydrogen-Sodium	0%
EXXX6	AC, DC+	Medium	Medium	Low Hydrogen-Potassium	0%
EXXX8	AC, DC+	Medium	Medium	Low Hydrogen-Iron Powder	25-40%
EXX24	All	Light	Light	Titania-Iron Powder	50%
EXX28	AC, DC+	Medium	Medium	Low Hydrogen-Iron Powder	50%

Common Rods:
E6010 - A deep penetrating fast freezing rod with a cellulosic flux. They are commonly used for open root welding. They produce heavy spatter and a lot of heat. Can only be used with DC power sources.
E6011 - Similar to an E6010 electrode, however E6011 is able to be used with an AC power source.

E6013 - A soft arcing rod with shallow to moderate penetration and minimal spatter. Very thin E6013 electrodes can be used for welding sheet metal. Has a slightly runnier flux than other rods that form a slag cap.
E7014 - Shallower penetration profile with a high deposition type flux, designed for use on low carbon and low alloy steels. They can be utilized at a higher amperage.
E7018 - Low hydrogen rods that must be baked to keep moisture out of the flux. Produce a smooth and quiet arc with medium levels of weld penetration. Forms a slag cap that can peel itself if the weld is good enough. Considered a more popular rod due to its welding performance.
E7024 - High deposition rod with an iron powder flux. Typically used for high speed horizontal or flat fillet welds.

A5.12 / Non-consumable Tungsten Electrodes for GTAW

A topic that is as endlessly argued over as the true lore behind the origins of varying Star Wars details, A5.12 electrodes (or TIG tungstens) are an endless source of discourse. Each and every person has their own opinions on what type of tungsten is best.

Pure Tungsten (EWP) Electrodes

This type of tungsten electrode typically utilizes a green band as its designation. Although it has good arc stability and can obtain a clean balled end for AC welding, pure tungsten has the least resistance to heat of any type of tungsten electrode and is thus not recommended for us with anything other than a transformer based constant current power supply.

Thoriated Tungsten (EWth-1 and EWth-2) Electrodes

This type of tungsten electrode typically utilizes a red band as its designation. These electrodes are manufactured with thorium alloyed into the tungsten. More useful for a wider range of currents due to increased temperature stability of the tip of the tungsten. Easily able to start an arc, likely due to the excitation of particles between the tip and the workpiece due to alpha radiation emissions, as well as possessing a high current capacity. Overheating can cause spitting of tungsten droplets into the weld. **THORIATED TUNGSTEN ELECTRODES PRODUCE RADIOACTIVE DUST WHEN GROUND OR SHARPENED. WEAR APPROPRIATE PPE.**

Zirconiated Tungsten (EWZr) Electrodes

This type of tungsten electrode typically utilizes a brown band as its designation. These electrodes contain anywhere between ¼% and ½% zirconium. This gives the electrodes a combination of the good characteristics of pure tungsten with the arc start properties and capabilities of thoriated tungsten. Usually used for AC welding, when tungsten inclusions are not tolerated.

Ceriated Tungsten (EWCe-2) Electrodes

This type of tungsten electrode typically utilizes a grey band as its designation. These electrodes contain 2% cerium and have very good starting characteristics, with excellent performance in the low amperage range and for extended periods with either AC or DC current. Well suited to metal and delicate precision work.

Lanthanated Tungsten (EWLa-1, EWLa-1.5, and EWLa-2) Electrodes

This type of tungsten electrode typically utilizes a gold band for 1.5% and a blue band for 2% as their respective designations. These electrodes contain lanthanum, which is a non-radioactive rare earth material. Roughly the same operating characteristics as ceriated tungsten, these are good general shop electrodes. They do not form a ball on the tip on AC current.

Rare Earth Tungsten (EWG, Tri-Mix, and LaYZr) Electrodes

This category of tungsten electrodes does not have much of a standardized color band, with currently known to the author available color bands being cyan, purple, or chartreuse depending on specific grade and manufacturer. These electrodes are produced with varying rare earth elements alloyed into the tungsten to produce the final product. The goal of these electrodes is to use advanced metallurgy to find the optimal blend of elements for machine welding, however they still make for good general purpose electrodes. The author of this document uses “Tri-Mix” electrodes due to them having a competitive pricepoint.

A5.18 Electrodes / Solid Wire & Rod Electrodes for Carbon Steels

Unlike A5.1 electrodes, A5.18 electrodes neither contain nor are coated with flux. The designations for solid wire and rod electrodes are formatted a little differently than A5.1 electrodes, with an example being ER70S-6.

- The letters ER stand for “Electrode Rod”. These are present on both spooled filler metals for wire feed welding that uses solid wire and rod for gas tungsten arc welding.
- Like A5.1, the first two numerical digits indicate the tensile strength and use the exact same system.
- The “S” stands for Solid wire.
- The final numerical digit indicates chemical additions to the wire’s composition to facilitate different welding conditions.
- Alloys not used for welding mild or carbon steel do not always follow this format.

Common Wire Examples:

ER70S-2 - Primarily used for single pass welding. Because of the added deoxidants, can be used for rusty or dirty steels with a potential sacrifice of weld quality depending on the conditions of a surface. Used for high quality, high toughness welds with the GTAW process. Also well suited for use in single-side, melt through welding with no protective shielding gas on the backside of the weld joint.

ER70S-3 - Intended for both single pass and multipass welding. Base metal specifications are often the same between this designation and the ER70S-2 designation.

ER70S-4 - Intended for welding steel where conditions require more deoxidants than ER70S-3. Base metal specifications are often the same as for the ER70S-3 designation.

ER70S-6 - Intended for both single pass and multipass welding. Especially suited for sheet metal applications where smooth weld beads might be desired, as well as for structural and plate steels that have moderate amounts of rust or mill scale. These permit the use of higher welding currents with either CO2 or shielding gas blends of argon and oxygen.

A5.20 Electrodes / Tubular Electrode Wires for Carbon Steels

Akin to A5.1 electrodes and processes, A5.20 electrodes and processes utilize flux. Unlike A5.1, this flux is contained within a tubular wire. The designations for A5.20 utilize a slightly different format than A5.1, with an example being E71T-11.

- Unlike A5.18, A5.20 wires only utilize the “E” designation. This means Electrode.
- Instead of S for solid wire, you will instead see “T” or “C”. These refer to tubular and composite respectively.
- In the first two numerical digits, the first number refers to the tensile strength while the second refers to the positions the wire can be used in. E70C-6 has 70,000 psi of tensile strength and can only be used in the horizontal or flat positions. E71T-8 also has 70,000 psi of tensile strength, however it can be used in all positions.
- The third (and sometimes fourth) numerical digit on a flux cored wire shows its usability specification, typically referring to its slag composition.
- Some forms of flux core can require gas like wire welding. Please refer to the manufacturer’s instructions for your wire to figure out if gas is required for your wire or if it is self shielded.

The most common flux core wire the average hobbyist will run across is E71T-11. This is a self shielded flux core wire that is good for all positions.

Generalizations for Electrodes Other Than Carbon Steel

As stainless steel, aluminum, and other ferrous/non-ferrous materials are not covered in the aforementioned codes published by the AWS, a good general rule of thumb if you do not have access to the appropriate publishings is to try to match your filler metal as closely to your base metal as possible. If you are welding 308L stainless steel, use a 308L stainless steel filler. If welding Inconel 625, use an Inconel 625 filler metal. Though some circumstances may require getting creative, as a generality this is a good rule of thumb. Cast iron should only be welded with a 100% nickel rod (or as close to that as possible) or brazed with low fuming bronze. The following chart tells AWS specifications for various forms of GTAW filler metals, which usually also function the same for GMAW with a few exceptions.

Metal	AWS Specifications	Classification
Copper alloys	A5.7	ERCu, ERCuSi-A, ERCuAl-A1
Stainless steel	A5.9	ER308, ER309, EC409, ER2209
Aluminum alloys	A5.10	ER1100, ER2319, ER4043, ER5356
Nickel alloys	A5.14	ERNi-1, ERNiCr-3, ERNiCrMo-3
Titanium alloys	A5.16	ERTi-1, ERTi-5, ERTi-6ELI, ERTi-15
Magnesium alloys	A5.19	ERAZ101A, ERAZ61A, EREZ33A
Zirconium alloys	A5.24	ERZr-2, ERZr-3, ERZr-4
Low-alloy steels	A5.28	ER80S-B2, E80C-B2, ER80S-D2

Shielding Gasses by Process

Welding processes that utilize a shielding gas in order to protect the weld puddle from the atmosphere have differing requirements based on the desired arc characteristics and intended process. As a generality, wire feed processes and gas tungsten arc welding do not use the same gas mixes. Outside of specific applications, GTAW trends towards utilizing completely inert shielding gasses while wire feed processes trend towards using an inert and active gas mix.

GMAW and FCAW Gasses

In the GMAW and FCAW processes, the gasses used for shielding are argon, carbon dioxide, helium, nitrogen, and oxygen. FCAW wires that require gas shielding will state so in the usage instructions, typically including the type of shielding gas they require. Axial spray transfer, a type of GMAW, has specific shielding gas requirements.

GMAW Shielding Gases		
Shielding gas or mixture	**Chemical behavior**	**Metals and applications**
Argon	Inert	Virtually all metals except steels.
Helium	Inert	Aluminum, magnesium, and copper alloys for greater heat input and to minimize porosity.
Ar + He (20–80% to 50–50%)	Inert	Aluminum, magnesium, and copper alloys for greater heat input and to minimize porosity (better arc action than 100% helium).
Nitrogen		Greater heat input on copper (Europe).
Ar + 25–30% N_2		Greater heat input on copper (Europe); better arc action than 100% nitrogen.
Ar + 1–2% O_2	Slightly oxidizing	Stainless and alloy steels; some deoxidized copper alloys.
Ar + 3–5% O_2	Oxidizing	Carbon and some low-alloy steels.
CO_2	Oxidizing	Carbon and some low-alloy steels.
Ar + 20–50% CO_2	Oxidizing	Various steels, chiefly short circuiting arc.
Ar + 10% CO_2 + 5% O_2	Oxidizing	Various steels (Europe).
CO_2 + 20% O_2	Oxidizing	Various steels (Japan).
90% He + 7.5% Ar + 2.5% CO_2	Slightly oxidizing	Stainless steels for good corrosion resistance, short circuiting arc.
60–70% He + 25–35% Ar + 4–5% CO_2	Oxidizing	Low-alloy steels for toughness, short circuiting arc.

GTAW Gasses

In the GTAW process, the gasses used for shielding are argon, helium, hydrogen, and nitrogen. Typically used is either pure argon or an argon helium mix.

Metal	Shielding Gas	Advantages
Aluminum	Argon	Better arc starting, cleaning action, and weld quality; lower gas consumption
	Helium	High welding speeds possible
	Argon-helium	Better weld quality, lower gas flow required than with straight helium
Magnesium	Helium	Metal thickness 0”-1/16” – Controlled penetration
	Argon	Metal thickness 1/16”+ – Excellent cleaning, ease of pool manipulation, low gas flows
Mild Steel	Argon	• Better pool control, especially for position welding • Metal thickness 0”-⅛” – Ease of manipulation, freedom from overheating • Spot welding – Generally preferred for longer electrode life, better nugget contour, ease of starting, lower gas flows
	Argon-helium	Helium addition improves penetration on heavy gauge metal
Stainless Steel	Argon	Permits controlled penetration on thin gauge material (up to 14 gauge)
	Argon-helium	Higher heat input, higher welding speeds possible on heavier gauges
	Argon-hydrogen (65%-35%)	Prevents undercutting, produces desirable weld contour at low current levels, requires lower gas flows
	Helium	Provides highest heat input and deepest penetration
Copper and Nickel Alloys	Argon	Ease of obtaining pool control, penetration, and bead contour on thin gauge metal
	Argon-helium	Higher heat input to offset high heat conductivity of heavier gauges

	Helium	Highest heat input for welding speed on heavy metal sections
Titanium	Argon	Low gas flow rate minimizes turbulence and air contamination of weld, improved metal transfer, improved HAZ
	Helium	Better penetration for manual welding of thick sections (inert gas backing required to shield back of weld against contamination)
Silicon Bronze	Argon	Reduces cracking of this “hot short” metal
Aluminum Bronze	Argon	Less penetration of base material

Different Metal Grades

Although not data that will assist in choosing a filler metal, this metallurgical data is provided here for reference. Not all metals on this list are weldable (in fact, many are not) and many of them would be problematic if one attempted to weld the base metal.

Steel

Number	Type of Steel	Alloying Elements (%)
10 - -	Plain carbon	None, 0.4 Mn
11 - -	Sulfurized free-machining	0.7 Mn, 0.12 S
12L - -	Leaded free-machining	Pb added
13 - -	Manganese	1.60-1.90 Mn
2 - - -	Nickel steels	3.5-5.0 Ni
3 - - -	Nickel-chromium	1.0-3.5 Ni, 0.5-1.75 Cr
40 - -	Molybdenum	0.15-0.30 Mo
41 - -	Chrome-molybdenum	0.80-1.1 Cr, 0.15-0.25 Mo
43 - -	Nickel-chromium-molybdenum	1.65-2.0 Ni, 0.4-0.9 Cr, 0.2-0.3 Mo
46 - -	Nickel-molybdenum	1.65 Ni, 1.65 Mo
5 - - -	Chromium	0.4 Cr
6 - - -	Chromium-vanadium	
7 - - -	Unused	
8 - - -	Low nickel-chromium-molybdenum	
9 - - -	Nickel-chromium with small percentage of molybdenum	

Stainless Steel

No.	Composition (%)	Uses
	Austenitic	
201	0.15 C, 17 Cr, 7.5 Mn, 3.5-5.5 Ni	General-purpose
202	0.15 C, 18 Cr, 10 Mn, 4-6 Ni	General-purpose
301	0.15 C, 17 Cr, 2 Mn, 6-8 Ni	Trim-general
302	0.15 C, 18 Cr, 2 Mn, 8-10 Ni	General-purpose
303	0.15 C, 18 Cr, 2 Mn, 8-10 Ni	Free machining
304	0.08 C, 19 Cr, 2 Mn, 8-12 Ni	Weldable
308	0.08 C, 20 Cr, 2 Mn, 10-12 Ni	Corrosion resistant
316	0.08 C, 17 Cr, 2 Mn, 2 Mo, 10-14 Ni	Chemical resistant
	Ferritic	
405	0.08 C, 11-15 Cr, 0.1-0.3 Al	Weldable
430	0.12 C, 14-18 Cr	General-purpose
445	0.2 C, 23-28 Cr	High temerature
	Martensitic	
403	0.15 C, 11-13 Cr, 0.5 Si	Turbine blades
410	0.15 C, 12 Cr, 1.0 Si	General-purpose
420	0.15 C, 12-15 Cr	Heat treatable

Aluminum

Number	Major Alloying Element
1 - - -	None
2 - - -	Copper
3 - - -	Manganese
4 - - -	Silicon
5 - - -	Magnesium
6 - - -	Magnesium and silicon
7 - - -	Zinc
8 - - -	Other
9 - - -	Unused

Nickel

Designation	Composition (%)
Alnico I	67 Fe, 20 Ni, 12 Al, 5 Co
Alnico VIII	35 Co, 34 Fe, 15 Ni, 7 Al, 5 Ti, 4 Cu
Alumel	95.3 Ni, 1.75 Mn, 1.6 Al, 1.2 Si, 0.1 Fe
Chromel A	80 Ni, 20 Cr
Chromel C	60 Ni, 24 Fe, 16 Cr
Chromel D	47 Fe, 35 Ni, 18 Cr
Chromel P	90 Ni, 9.5 Cr, 0.4 Si, 0.2 Fe
Constantan	55 Cu, 45 Ni
Duranickel	94 Ni, 4.5 Al, 0.5 Ti, 0.25 Mn, 0.15 Fe, 0.15 C
Hastelloy A	53 Ni, 22 Fe, 22 Mo, 2 Mn
Hastelloy C	55 Ni, 17 Mo, 6 Fe, 4 W, 1 Mn

Hastelloy X	45 Ni, 24 Fe, 22 Cr, 9 Mo
Inconel 600	76 Ni, 16 Cr, 7 Fe, 0.2 Mn, balance C, S, Cu
Inconel X-750	73 Ni, 15 Cr, 7 Fe, 2.5 Ti, 0.85 Nb, 0.8 Al
H monel	63 Ni, 31 Cu
K monel	66 Ni, 29 Cu, 2.75 Al, balance Fe, Si, Mn, Ti
R monel	67 Ni, 30 Cu
Z monel	98 Ni, 2 Cu
Nichrome V	80 Ni, 20 Cr
Nickel silver	57 Cu, 25 Zn, 15 Ni, 3 Co
Permanickel	98.6 Ni, 0.5 Ti, 0.35 Mo, 0.25 C, 0.1 Fe, 0.1 Mn

Copper & Alloys

Name	Composition (%)	Application
Coppers		
Electrolytic tough pitch copper (ETP)	94.40 Cu, 0.04 O	Roofting, nails, rivets, cotter pins, kettles
Phosphorus deoxidized copper (DHP)	94.40 Cu, 0.02 P	Piping, tubing, heat-transfer equipment, tanks
Free-cutting copper	99.5 Cu, 0.5 Te or 0.6 Se, 1.0 Pb	Electrical connectors, motor and switch parts, oxyacetylene torch tips
Oxygen-free (OF) copper	99.92 Cu	Electrical conductors, bus bars, tubing
Brasses		
Red brass	80 Cu, 20 Zn	Trim, conduit and sockets, fire extinguishers
Cartridge brass	70 Cu, 30 Zn	Radiator cores and tanks, reflectors, munitions

Yellow brass	65 Cu, 35 Zn	Radiators, lamp fixtures, plumbing supplies
Medium-leaded brass	64 Cu, 34.75 Zn, 1 Pb	Engravings, gears, nuts, couplings
High-leaded brass	62.5 Cu, 35.5 Zn, 1.75 Pb	Nuts, gears, wheels, clock parts
Free-cutting brass	61.5 Cu, 35.5 Zn, 3 Pb	Gears and pinions
Muntz metal	60 Cu, 40 Zn	Hardware, panels and sheets, forgings
Naval brass	60 Cu, 39.25 Zn, 0.75 Sn	Nuts and bolts, propeller shafts
Forged brass	60 Cu, 38 Zn, 2 Pb	Forgings, valve stems, plumbing supplies
Bronzes		
Aluminum bronze	95 Cu, 5 Al	Sheets, wire, tubing
Silicon bronze–grade A	95 Cu, 3 Si, 2 Mn	Hydraulic lines, marine hardware
Silicon bronze–grade B	95 Cu, 2 Si, 1 Mn	Hydraulic lines, marine hardware
Phosphor bronze–grade A	95 Cu, 5 Sn	Bearing plates, clutch discs, bushings
Phosphor bronze–grade C	92 Cu, 8 Sn	Springs, brushes, textile machine parts
Aluminum-silicon bronze	91 Cu, 7 Al, 2 Si	Forgings and extrusions
Phosphor bronze–grade D	90 Cu, 10 Sn	Bars and plates, fittings
Commercial bronze	90 Cu, 10 Zn	Munitions, jewelry, plaques and awards
Leaded commercial bronze	89 Cu, 9 Zn, 2 Pb	Screws, hardware
Cupro-nickel	88.5 Cu, 10 Ni, 1.5 Fe	Condensers, ferrules, tanks, valves, auto parts
Nickel-silver	65 Cu, 18 Ni, 17 Zn	Camera parts, plates, fixtures, tableware, zippers
Manganese bronze	59 Cu, 39 Zn, 1.5 Fe, 1 Sn,	Shafts, clutch parts, valve

	0.1 Mn	stems, forgings, welding rods
Architectural bronze	57 Cu, 40 Zn, 3 Pb	Trim, extrusions, hinges, auto parts

Reference Material & Further Reading

(All images in this document are whole-heartedly stolen from Google)

The Procedure Handbook of Arc Welding (14th Edition) - The James F. Lincoln Arc Welding Foundation
Gas Tungsten Arc Welding Handbook (6th Edition) - William H. Minnick & Mark A. Prosser
Fundamentals of Materials Science for Technologists (Second Edition) - Larry Horath