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Shielding Gases for Welding

Welding processes will typically result in melting of the metals at the weld interface before cooling back to room temperature. At high temperatures approaching melting point and in a molten state, the metal atoms are very reactive and can quickly combine with any willing and able gas molecules floating around near the surface to form reaction products that are usually detrimental to the weld. And hence the use of shielding gases during welding – their primary goal is to shield the molten metal. As far as pure shielding goes, the two most commonly used inert gases are Argon and Helium, and are used extensively in practically all welding processes where molten metal is exposed including arc/plasma welding and laser welding. Electron beam welding is an exception since it is performed in vacuum environment. Resistance welding is also an exception where the melt is not exposed and hence does not typically employ any shielding gases, except under unusual circumstances discussed later.

Choice of shielding gas is most critical in **arc welding** applications where the shielding gas provides multiple functions. At the onset, the gas provides a path for the arc to be established between the electrode and workpiece. Argon has low ionization potential (15.7 eV) and produces a stable arc that is easy to start; in comparison, helium, which has a higher ionization potential (24.5 eV) is difficult to initiate and is not so stable. Pure helium, which is the most expensive of all shielding gases, arc produces deep penetration with higher heat input, and is restricted to GTAW applications for non-ferrous materials with DCEN current. Shielding for most welding applications are often a mixture of helium, argon, oxygen, carbon-dioxide, hydrogen, and nitrogen; mixture of two gases is quite common with tri-mixes becoming increasingly popular as users try to finesse the welding process to best results.

Gases can be divided into two groups – active and inert. Helium and argon are truly inert; even if their atoms ionize in the arc, they don't react with the molten metal. When an inert gas is required, a mixture of argon and helium can be used such as a 75/25 He/Ar mix that gives good penetration with Helium and stability with Argon. However, inert gases do not provide good control and fluidity of the weld puddle for steels, and hence active gases are added to the mix.

Carbon Dioxide is inert only in its molecular state at room temperature but once it is ionized in the arc, it dissociates into CO, O_2, and oxygen ions – the components can react with molten metal to form oxides. CO_2 is the only active gas that is used in pure form (100% CO_2) in GMAW/MIG welding of carbon steels. Price is one of the main factors as CO_2 is cheap and it also produces strong penetration and good wetting; on the downside, it produces more spatter which is unacceptable in some applications. For stainless steels, which require good protection from oxidation, gas used is primarily argon. Oxygen is sometimes added in small quantities, for example 98/2 Ar/O_2 mix; presence of small amount of oxygen provides fluidity and improves wetting by the molten metal without causing significant oxidation. Hydrogen can be added in limited quantities when welding stainless steels that are not affected hydrogen embrittlement; presence of hydrogen helps reduce oxides and produces a very clean looking weld. Nitrogen is added when welding steels that have nitrogen in their composition so as to reduce any loss during welding. In addition to shielding gas introduced in the arc, an inert backing gas is sometimes required to prevent oxidation of the root pass. If weld surface appearance is important, a trailing shield is sometimes employed to protect the weld as it cools.

Shielding gases are also used in **laser welding**, albeit the functions are little bit different. Since there is no electric arc, the function of shielding gas is more for conventional shielding. Argon is the most commonly used shielding gas for YAG and fiber lasers, whereas helium is used for high-power CW welding with CO2 lasers. A not-so-common shielding gas that can be used is nitrogen which is quite inert and provides good protection while welding aluminum while being much cheaper than argon. In addition to shielding, the gas also has the job of blowing away the plume that is formed during laser welding process. The plume, which is a cloud of ionized particles right above the weld location, hinders the passage of laser light thus affecting weld penetration. By blowing the shielding gas over the weld, the plume is washed away and ensures that the laser light is not blocked or diffused as it travels towards the weld. Removing the plume by a jet of argon may be necessary even if the welding is being done inside a glove box. An unusual option when welding carbon steels is to use compressed air to blow away the plume.

Shielding gases are not commonly used during **resistance welding** since the molten metal is shielded from the environment. However, there are situations where external discoloration can be an issue such as when welding stainless steels; an inert argon shielding works well, Ar + 5% H_2 produces an even cleaner looking welding. As long as hydrogen is at 5% level, the gas can be vented safely to atmosphere and does not need special handling. One of the most unusual applications of shielding I have seen is the use of small drop of methanol when welding fine wires or Molybdenum and Tungsten. The drop is placed on the weld prior to welding; when the weld energy is sent through the stack, the methanol evaporates and produces a cleaner looking weld. It is possible that two factors may be at play – one is the evaporation of methanol creates some amount of hydrogen that produces a reducing atmosphere around the weld to prevent oxidation. Another factor is the evaporative cooling of the wires that might be keeping bulk wires from overheating and becoming embrittled, while focusing the heat at the weld interface.

While composition of the shielding gas is important, proper delivery of the gas is also crucial. Shielding gas should have a smooth laminar flow towards the weld so as to not disturb the arc and the melt puddle; turbulent flow can cause porosities in the weld and also produce uneven weld surface. The gas flow area should also be wide enough to cover the weld in order to prevent oxidation and porosity at the edges. It is tempting to think that a high rate of gas flow will produce better shielding but it tends to have the opposite effect – high flow rate can actually draws more air/oxygen into the weld. Diffusers and gas lenses are commercially available and should be properly selected. Keep in mind that a gentle gas flow, something even milder than that required to extinguish a candle, is usually sufficient for proper shielding.