APPENDIX B

DESCRIPTION OF WELDING, CUTTING AND SPRAYING PROCESSES

B.1 METAL WELDING

A weld is defined by the American Welding Society (AWS) as a "localized coalescence (the fusion or growing together of the grain structure of the materials being welded) of metals or nonmetals produced either by heating the materials to the required welding temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of filler materials." The filler materials are from rods or wire that also serve as the electrode to conduct current to create heat.

Welding process include arc welding, brazing, resistance welding, soldering, oxy-fuel and solid state welding. This emissions inventory is based primarily on arc welding, since the temperatures associated with arc welding are higher than in the other welding techniques. The types of welding used in manufacturing by the participants in this survey included the following.

B.1.1 Gas Metal Arc Welding (GMAW)[1]

Gas metal arc welding (GMAW) uses a gun, and an electrode or wire supply/feed unit, power source, and shielding gas. The power source for stationary equipment can be either a transformer or rectifier. For portable equipment, a motorized generator unit is used. The power supply produces a direct current that can range from 40 to 600 amperes, with voltages ranging from 10 to 40 VDC. It can be configured with the positive lead connected to the gun and the negative lead connected to the work product. The leads can also be reversed so that the gun is negative and the work product is positive. The electrode can be either a rod or a continuous feed wire. When shielding gases are used, the gas is usually carbon dioxide or argon.

B.1.2 Shielded Metal Arc Welding (SMAW)

Shielded metal arc welding (SMAW) is an electric arc welding process that uses a flux covered electrode to carry an electrical current. The current forms an arc across the gap between the end of the electrode and the work. Molten metal from the electrode travels across the arc to the molten pool of metal to be welded. The end of the electrode and molten pool of metal are surrounded, purified, and protected by a gaseous cloud and a covering of slag produced as the flux coating of the electrode burns or vaporizes. SMAW is widely used because of its low cost, flexibility, portability and versatility. The SMAW process is very flexible in terms of the metal thickness that can be welded and the variety of positions in which it can be used.

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[1]GMAW is also known as metal inert gas (MIG) welding.

B.1.3 Fluxed Core Arc Welding (FCAW)

Fluxed core arc welding (FCAW) is a welding process in which the heat to produce the molten metal is created by the electric arc between the filler material and the metal product. Shielding gases are produced from the flux to protect the work from atmospheric gases during the welding process. The shielding gas is released from a tubular space inside the electrode.

B.1.4 Gas Tungsten Arc Welding (GTAW)

Gas tungsten arc welding (GTAW) is more commonly known as heliarc welding or tungsten inert gas (TIG) welding. This process is based on the use of a non-consumable tungsten electrode that is used to generate an arc between the metal surface to be welded and the electrode. The filler material is from either a rod or a continuous feed wire. GTAW became popular during 1930s and 1940s, when it was used by the aviation industry to weld magnesium and aluminum. Helium is commonly used as a shielding gas to protect the work from atmospheric gases. The tungsten electrode is held within the welding gun by a "collet." The collet protects the welding gun from the hot gases at the welding surface. The tungsten electrode allows for relatively clean welds since fluxes are not required to facilitate the welding process.

B.1.5 Submerged Arc Welding (SAW)

Submerged arc welding (SAW) is a welding process based on fusion that also incorporates metal wire as a filler material. Heat is produced from the arc that is created between the electrode and the work surface. The molten metal within the work area is protected from atmospheric gases by a blanket of molten flux and slag from granular fluxing material placed on the work before welding begins. SAW was one of the first welding techniques that incorporated a continuously fed wire as the electrode and filler material. The granular flux material can be placed automatically on the work surface from a hopper just ahead of the arc that creates the molten pool of metal.

B.1.6 Resistance Welding (RW)

Resistance welding (RW) is defined as a process wherein coalescence is produced by the heat obtained from the resistance of the workpiece to the flow of low voltage, high-density, electric current in a circuit of which the workpiece is a part. The two surfaces that are to be welded are held together with pressure cylinders. The electrodes are usually located within the pressure cylinders on both sides of the surfaces to be welded. Spot welding (RSW) is the most common of the various resistance welding processes. This is technique is generally automated when mass produced items are needed. It does require highly skilled technicians to produce high quality welds. Fluxes and filler materials are not required for this type of welding process.

B.1.7 Plasma Arc Welding (PAW)

Plasma arc welding (PAW) is the use of a high temperature flame that is created by forcing gas to flow along an arc restricted electromagnetically as it passes through a nozzle. The high temperature is produced in a torch comprised of an electrode (in the center) and a plasma gas that surrounds the torch tip. An additional "gas lens" is used to deliver shielding gas that is used to further focus the flame on the work surface. Therefore a relatively thick weld, up to 0.5 inch can be accomplished in a single pass of the torch. No edge or surface preparation or filler metal is required with this type of welding process. The advantages to generating a plasma instead of a conventional flame or arc are that much higher temperatures can be achieved and heat transfer to the workpiece is significantly improved. These advantages allow for much faster heating of the workpiece and reduced welding times especially in high volume manufacturing process.

B.1.8 Oxygen-Acetylene Welding (OXY)

Oxygen-acetylene welding (OXY) is a welding process that does not require a power supply or the need for an electric arc. The elevated temperatures are generated by acetylene as the fuel and oxygen as the oxidant for the fuel. The metal surface to be welded is heated by the high temperature flame and a metal rod is the filler material that is melted into the work face. The flame produced by the torch can be either an oxidizing or reducing flame depending on the mix of oxygen and acetylene the technician chooses for the type of surface being welded. The primary advantage for this type of welding is that electricity and or a motor generator are not required. The gases are delivered to the torch by rubber hoses from cylinders containing the gases compressed to high pressures.

B.2 METAL CUTTING

Metal cutting is another allied process associated with welding. Usually the metal surfaces that are to be welded are cut into the appropriate sizes using oxygen based cutting methods or, in recent years, high tech cutting methods such as electron beam or laser beam cutting. Oxygen based cutting methods usually include the use of a fuel such as acetylene, hydrogen, natural gas or propane. A stream of pure oxygen is used to essentially burn a slot through the metal surface. The metal surface can also serve as the fuel by catching fire. By keeping the torch in the area to maintain the flame the width of the slot being cut can be controlled. The tools used for metal cutting can be either hand-held or machine controlled for more precise and accurate cutting. Other metal cutting methods include use of lathes, circular or band saws. However, since most emissions from cutting operations will occur with high temperature methods such as the oxygen based cutting none, of the mechanical cutting methods were included in this study.

B.3 METAL SPRAYING

Metal spraying is used to coat a surface with one or more layers of metal. It includes electric arc spraying, flame spraying and plasma spraying. Molten metal is created by passing metal wire or powder under elevated pressure through a high temperature flame. The molten metal, either an alloy or pure metal is then sprayed as a coating onto the metal surface. Since the metal surface being sprayed is not heated significantly, this process is also known as a cold method of building up metal on a surface. The primary components for thermal spraying are an air compressor, a gun, oxyfuel gas or arc equipment and an air control unit. Two types of guns that are commonly used for metal spraying are wire guns and powder guns.

The wire gun uses a metal wire that ranges in size from 0.035 to 0.1875 inch that is delivered to the tip of the gun, heated, and vaporized for spraying onto the part. The limitation of the wire spray method is that the metal to be sprayed through the gun must be in the form of a wire. Some metal alloys cannot be made into wire and therefore need to be sprayed as a powder.

Powder spray is similar to the wire spray except the metal to be sprayed is delivered under high pressure to the tip of the gun. The powder is then vaporized and sprayed onto the part. The tip of the gun can be changed to accommodate the rate at which the powder can be sprayed. Metal is sprayed on to the part about 0.01 inch in thickness per pass. The gun is usually mounted on a track and makes multiple passes over the part until the desired finished thickness is achieved.

Acetylene or hydrogen is generally used as the fuel. Compressed oxygen is commonly used as the oxidant and carrier to propel the vaporized metal from the tip of the gun.

Plasma spraying is very similar to the powder metal spraying processes described above except that the temperature of the flame is much higher. An electric arc is used to create the high temperature and an inert or chemically inactive gas such as argon is used to propel the metal powder through the flame. The particles of metal being sprayed with this technique are smaller and are more suitable for spraying parts that will be used in high temperature service such as rocket engine cones, jet engine exhaust cases, and other aircraft parts.