Welding Operations

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1.0 PROCESS DESCRIPTION

Welding is a process used regularly by many industrial and manufacturing facilities with a variety of welding processes and materials. These processes typically consist of electrodes, filler metals, wire, coatings, and/or gases that may contain and emit several air contaminants including nitrogen oxides, carbon monoxide, cadmium, cobalt, copper, chromium, manganese, nickel, lead, zinc, fluorides, and other toxic air contaminants (TACs).

The most common welding method with the greatest emission potential is electric arc welding however there are variety of different welding processes used in commercial and industrial operations. The San Diego County Air Pollution Control District (District) has identified the following welding processes as those most frequently used within San Diego County:

- Gas Metal Arc Welding (GMAW) - a. k. a. Metal Inert Gas (MIG) Welding
- Gas Tungsten Arc Welding (GTAW) - a. k. a. Tungsten Inert Gas (TIG) Welding
- Shielded Metal Arc Welding (SMAW) - a. k. a. Manual Metal Arc (MMA) Welding
- Flux Core Arc Welding (FCAW)
- Submerged Arc Welding (SAW)
- Arc Spot Welding,
- Electrogas Welding,
- Electrostag Welding,
- Brazing,
- Thermal Cutting,
- Resistance Welding,

- Plasma Arc Welding,
- Electron Beam Welding,
- Laser Beam Welding

The majority of common welding processes can be classified as either gas metal arc welding (GMAW) or shielded metal arc welding (SMAW). GMAW generally uses an electrical current to melt and apply a filler metal under a blanket of inert gas. SMAW traditionally uses an electrical current to melt specially coated electrodes which form a protective flux over the weld during application. Both processes use electrodes, filler metals, wire, coatings, and/or gases that may contain and emit several different pollutants.

Welding operations release fumes and particulates with diameters of 0.001 to 100 microns. Previous studies of welding emissions have been primarily focused on worker exposure and safety. Many technical difficulties have been identified regarding proper sampling and analytical procedures due, in part, to the wide variety of processes, welding materials, and field conditions. Most existing test data which can be used to quantify welding emissions is based on studies performed by the American Welding Society (AWS).

1.1 CALCULATION OF WELDING EMISSIONS

The calculation method for estimating emissions for welding operations are primarily dependent on the emission factor, fume generation rate, and concentration of listed substance in each welding rod. The District utilizes several sources, including:

- American Welding Society (AWS)
- California Air Resources Board (CARB) Expert – Dr. Richard Bode (1993)
- Industry Study (NASSCO) – Dr. Richard Be11 (1995)
- AP-42 Section 12.19 Electric Arc Welding (1/95)
- Journal of the Air & Waste Management Association – Serageldin & Reeves (2012)
- Miscellaneous Material Safety Data Sheets (MSDS)

1.1.1 Complete AP-42 (Section 12.19)

If emission factors are listed in AP-42 (1/95) Final Section Table 12.19-2 for the welding rod, with correct welding process, and the trace metal components, the following procedure will be used:

Ea = Ua x EF x (1 - e)
Eh = Uh x EF x (1 - e)

Where:

Ea = Annual emissions of each listed toxic air contaminant per welding rod, (lbs/year)

Eh = Maximum hourly emissions of each listed toxic air contaminant per welding rod, (lbs/hour)

Ua = Annual usage of each welding rod, (lbs/year)

Uh = Maximum hourly usage of each welding rod, (lbs/hour)

EF = Listed substance emission factor from AP-42 Table 12.19-2, (lbs listed substance/lb rod consumed)

e = Control equipment PM10 overall collection and removal efficiency, (%)

1.1.2 Partial AP-42 (Section 12.19)

If an emission factor is listed in AP-42 (1/95) Final Section Table 12.19-1 for the welding rod fume generation rate with correct welding process, but not Table 12.19-2 for the trace metal component, the following procedure will be used:

Ea = Ua x EF x FCF x Ci x (1 - e)

Eh = Uh x EF x FCF x Ci x (1 - e)

Where:

Ea = Annual emissions of each listed toxic air contaminant per rod, (lbs/year)

Eh = Maximum hourly emissions of each listed toxic air contaminant per rod, (lbs/hour)

Ua = Annual usage of each welding rod, (lbs/year)

Uh = Maximum hourly usage of each welding rod, (lbs/hour)

EF = Particulate (PM10) emission factor from AP-42 Table 12.19-1, (lbs fume/lb rod consumed)

FCF = Fume correction factor per NASSCO - Richard Bell, (lbs metal/lb fume)

= 0.5464 for GMAW

= 0.2865 for SMAW

Ci = Concentration of listed substance in each welding rod per MSDS, (lbs substance/lb metal)

e = Control equipment PM10 overall collection and removal efficiency, (%)

If a hexavalent chromium emission factor does not exist, a Cr to Cr+6 conversion rate of 5% for GMAW, 55% for SMAW, 0.05% for SAW, and 10% for FCAW will be applied per AWMA Study (2012). It is assumed that MIG and TIG welding are similar to GMAW per ARB – Richard Bode.

1.1.3 AP-42 information does not exists but the welding process is identified: If AP-42 (1/95) Final Section Tables 12.19-1 and 12.19-2 does not assess the type of welding process but it is identified by a facility (i.e., GMAW, SMAW, etc.), the following procedure will be used:

Ea = Ua x EF x FCF x Ci x (1 - e)

Eh = Uh x EF x FCF x Ci x (1 - e)

Where:

Ea = Annual emissions of each listed toxic air contaminant per rod, (lbs/year)

Eh = Maximum hourly emissions of each listed toxic air contaminant per rod, (lbs/hour)

Ua = Annual usage of each welding rod, (lbs/year)

Uh = Maximum hourly usage of each welding rod, (lbs/hour)

EF = Fume emission factor per ARB - Richard Bode, (lbs fume/lb rod consumed)

= 0.01 for GMAW / MIG / TIG

= 0.02 for SMAW / FCAW

FCF = Fume correction factor per NASSCO - Richard Bell, (lbs metal/lb fume)

= 0.5464 for GMAW / MIG / TIG

= 0.2865 for SMAW / FCAW

Ci = Concentration of listed substance in each welding rod per MSDS, (lbs substance/lb metal)

e = Control equipment PM10 overall collection and removal efficiency, (%)

If a hexavalent chromium emission factor does not exist, a Cr to Cr+6 conversion rate of 5% for GMAW, 55% for SMAW, 0.05% for SAW, and 10% for FCAW will be applied per AWMA Study (2012). It is assumed that MIG and TIG welding are similar to GMAW per ARB – Richard Bode.

1.1.4 AP-42 information does not exist and the welding process is unidentified: If no emission information is listed in AP-42 (1-95) Final Section 12.19 and the type of welding process is not identified by the facility (i.e., GMAW, SMAW, etc.), the following procedure will be used:

Ea = Ua x EF x Ci x (1 - e)
Eh = Uh x EF x Ci x (1 - e)

Where:

Ea = Annual emissions of each listed toxic air contaminant per rod, (lbs/year)

Eh = Maximum hourly emissions of each listed toxic air contaminant per rod, (lbs/hour)

Ua = Annual usage of each welding rod, (lbs/year)

Uh = Maximum hourly usage of each welding rod, (lbs/hour)

EF = Fume emission factor, (lbs fume/lb rod consumed)

= 0.05 for unidentified welding processes (District default assumption)

Ci = Concentration of listed substance in each welding rod per MSDS, (lbs substance/lb metal)

e = Control equipment PM10 overall collection and removal efficiency, (%)

If a hexavalent chromium emission factor does not exist, a Cr to Cr+6 conversion rate of 10% will be assumed by the District for unidentified welding processes.

2.0 ASSUMPTIONS / LIMITATIONS:

- MSDS documentation contains information regarding welding rod material composition. While past studies indicate a difference in particulate emission rates between GMAW and SMAW, this may be due to flux coatings, flux cores, particulate dimensions, sampling techniques, and/or analytical procedures. Past test results also indicate welding emissions are generally composed of the same compounds as the consumed material. Fumes may also include oxygen in a metallic oxide form that is created during the welding process. Fume correction factors proposed by Dr. Bell is intended to account for this added mass balance component. While it is highly unlikely that a single fume correction factor would accurately apply to the wide variety of welding rods used in a given process, this is the best emission estimation approach currently available given the minimal test data which exists. Additional studies to determine accurate fume generation rates are needed.

- Measured fume weights for various welding processes have varied from 0.1% to 15% of the consumed electrode. Additionally, 1% to 50% of the electrodes were not recovered or discarded as un-weighed slag. The hexavalent fraction of collected chromium emissions varied from 0.1% to 95% by weight and may have been affected by the sampling and/or analytical techniques used. In general, GMAW produced smaller quantities of collectable particulates and had a lower proportion of hexavalent chromium in collected fume samples than SMAW. Additional studies to determine accurate component specific emission factors are needed.

- Welding emission rates depend upon process type, materials used, current, voltage, electrode angle, weld speed, arc length, deposition rate, and operator technique. Sufficient test data does not currently exist to adjust emission estimates for the many field variables that affect fume generation rates and compositions.

- Emissions from the host part are generally assumed to be negligible and/or indistinguishable from the consumed electrode. Typically, the host part and the consumed electrode have similar metallic compositions and the source of specific emissions cannot be confirmed. This assumption does not apply to cutting and brazing operations.

- The proportion of hexavalent chromium in the released fumes is critical to the overall significance of a facility's welding emissions in a health risk assessment. Previous studies have investigated the interference of other fume components (especially iron) in the collection, preparation, and analysis of hexavalent chromium emissions. Sample collection and preparation methods using acidic solutions (pH < 5) apparently reduce hexavalent chromium to the trivalent state before quantification. Dry filters may also have the same effect. The ability of various inert gases and shielding materials to limit the formation of hexavalent chromium is not known.

- The District is not aware of any studies involving control device efficiencies for welding. While welding emission particle sizes and size distributions are critical to determining control device efficiencies, little information apparently exists. Some studies speculated particle sizes of >2 microns for coating and flux materials and <0.2 microns for metallic emissions. Removal efficiencies for filters and scrubbers may vary considerably for different pollutants. Low capture efficiencies are expected for all but enclosed operations based upon reported plume configuration studies. The District will assess new studies on control devices for welding as they become available.

- Emissions of welding and cutting torch processes which do not consume electrodes are unquantifiable at this time. These processes may include: submerged arc welding, arc spot welding, braze welding, thermal cutting, electron beam welding, and laser welding. Emissions from these processes should be identified by the facility and District as unquantified until preliminary estimation techniques are developed.

- Welding nomenclature is an organized classification system created by the American Welding Society (AWS) that, at minimum, contains information on product type, tensile strength, welding position, and composition, but can also include required current, gas type, and other measures of welding performance. Currently, the District does not distinguish emissions between product prefixes “E” (electrode) and “ER” (electrode or rod). The District also does not distinguish emissions from suffixes related to hydrogen, absorbed moisture, shielding gas, and temperature impact. The District will assess welding calculation nomenclature for default rods as emissions data becomes available.