Advice & Counsel

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Welding & Lead Emissions

Dear Advice & Counsel,
Your articles on TRI reporting issues relating to the lowering of the lead threshold have been quite useful, but last month you mentioned air emissions from welding, brazing, and soldering operations without discussing how one can estimate these. Is there any information out there?

Signed,
I. M. Awelder

Dear Ms. Awelder,
As I mentioned in the last article, your options are rather limited. USEPA AP-42 offers some help on welding. We downloaded the most recent section on welding, and as a service to our readers, the following is extracted information from the most recent AP-42 revision (11/9/01):

Electric Arc Welding

Welding is the process by which two metal parts are joined by melting the parts at the points of contact and simultaneously forming a connection with molten metal from these same parts, or from a consumable electrode. In welding, the most frequently used methods for generating heat employ either an electric arc or a gas-oxygen flame.

There are more than 80 different types of welding operations in commercial use. These include not only arc and oxyfuel welding, but also brazing, soldering, thermal cutting, and gauging operations. Of the various processes, electric arc welding is, by far, the most often found. It is also the process that has the greatest emission potential. Although the national distribution of arc welding processes by frequency of use is not now known, the percentage of electrodes consumed in 1991, by process type, was as follows:

Shielded metal arc welding (SMAW)—45%
Gas metal are welding (GMAW)—34%
Flux cored arc welding (FCAW)—17%
Submerged arc welding (SAW)—4%

Shielded Metal Arc Welding (SMAW)

SMAW uses heat produced by an electric arc to melt a covered electrode and the welding joint at the base metal. During operation, the rod core both conducts electric current to produce the arc, and provides filler metal for the joint. The core of the covered electrode consists of either a solid metal rod of drawn or cast material, or a solid metal rod fabricated by encasing metal powders in a metallic sheath. The electrode covering provides stability to the arc and protects the molten metal by creating shielding gases by vaporization of the cover.

Gas Metal Arc Welding (GMAW)

GMAW is a consumable electrode welding process that produces an arc between the pool of weld and a continuously supplied filler metal. An externally supplied gas is used to shield the arc.

Flux Cored Arc Welding (FCAW)

FCAW is a consumable electrode welding process that uses the heat generated by an arc between the continuous filler metal electrode and the weld pool to bond the metals. Shielding gas is provided from flux contained in the tubular electrode. This flux-cored electrode consists of a metal sheath surrounding a core of various powdered materials. During the welding process, the electrode core material produces a slag cover on the face of the weld bead. The welding pool can be protected from the atmosphere either by self-shielded vaporization of the flux core, or with a separately supplied shielding gas.

Submerged Arc Welding (SAW)

SAW produces an arc between a bare metal electrode and the work contained in a blanket of granular, fusible flux. The flux sub-

merges the arc and welding pool. The electrode generally serves as the filler material. The quality of the weld depends on the handling and care of the flux. The SAW process is limited to the downward and horizontal positions, but it has an extremely low fume formation rate.

Emissions & Controls

Emissions

Particulate matter and particulate-phase hazardous air pollutants are the major concerns in welding processes. *Only electric arc welding generates these pollutants in substantial quantities.* The lower operating temperatures of the other welding processes cause fewer fumes to be released. Most of the particulate matter produced by welding is submicron in size and, as such, is considered to be all PM-10 (*i.e.*, particles ≤10 micrometers in aerodynamic diameter).

The elemental composition of the fume varies with the electrode type and workpiece composition. Hazardous metals designated in the 1990 Clean Air Act Amendments that have been recorded in welding fume include manganese (Mg), nickel (Ni), chromium (Cr), cobalt (Co), and lead (Pb).

Gas phase pollutants are also generated during welding operations, but little information is available on these pollutants. Known gaseous pollutants (including "greenhouse" gases) include carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NOx), and ozone (O_3).

Actual emissions will depend not only on the process and the electrode type, but also on the base metal material, voltage, current, arc length, shielding gas, travel speed, and welding electrode angle.

Controls

The best way to control welding fumes is to choose the proper process and operating variables for the given task. Capture and collection systems may also be used to contain the fume at the source, and to remove the fume with a collector. Capture systems may be welding booths, hoods, torch fume extractors, flexible ducts, and portable ducts. Collection systems may be high-efficiency filters, electrostatic precipitators, particulate scrubbers, and activated carbon filters.

A Final Note ...

If you are doing electric arc welding, consider an alternate welding technology (or stick with electric arc welding, but make sure that the electrodes are lead-free) to eliminate the bulk (or all) of the lead emissions.

Hazardous Air Pollutant (HAP) Emission Factors For Lead in Welding Operations

Welding Process	Electrode Type (with last 2 digits of SCC)		HAP Emission Factor (10^{-1} g/kg of electrode consumed) Cr	Cr^{+6}	Co	Mn	Ni	Pb
SMAW	E310	(-16)*	25.3	18.8	ND	22.0	1.96	0.24
(SCC 3-09-051)	E7028	(-52)	0.13	ND	ND	8.4612	ND	1.62

* Includes E310-15

Notes:
SMAW = shielded metal arc welding; ND = no data.
HAP Emission Factor = Mass of pollutant emitted per unit mass of electrode consumed.
HAP emissions are in the PM-10 size range (particles ≤ 10µm in aerodynamic diameter)
Current = 102 to 225 A; Voltage = 21 to 34 V.

The accompanying table is a reproduction of the Hazardous Air Pollutant Emission data found in AP-42, as related to lead emissions. AP-42 is not helpful in providing estimates for emissions from brazing and soldering operations, unfortunately. If any readers know of a source for this information, please contact me. I have included selected references listed in AP-42 for the section on welding, in an effort at providing additional places to look for help. ***P&SF***

Bibliography

Welding Handbook, Welding Processes, Vol. 2, Eighth Edition, American Welding Society, Miami, FL, 1991.

"Criteria for a Recommended Standard Welding, Brazing & Thermal Cutting," Publication No. 88-110, National Institute for Occupational Safety & Health, U.S. Department of Health & Human Services, Cincinnati, OH, April 1988.

R.M. Evans, *et al.*, *Fumes & Gases in the Welding Environment*, American Welding Society, Miami, FL, 1979.

R.F. Heile & D.C. Hill, "Particulate Fume Generation in Arc Welding Processes," *Welding Journal*, **54** (7), 201s-210s, July 1975.

J.F. McIlwain & L.A. Neumeier, *Fumes from Shielded Metal Arc (MMA Welding) Electrodes*, RI-9105, Bureau of Mines, U.S. Department of the Interior, Rolla Research Center, Rolla, MO, 1987.

I.D. Henderson, *et al.*, "Fume Generation & Chemical Analysis of Fume for a Selected Range of Flux-cored Structural Steel Wires," AWRA Document P9-44-85, Australian Welding Research, 15:4-11, December 1986.

K.G. Malmqvist, *et al.*, "Process-dependent Characteristics of Welding Fume Particles," presented at the International Conference on Health Hazards & Biological Effects of Welding Fumes & Gases, Commission of the European Communities. World Health Organization & Danish Welding Institute, Copenhagen, Denmark, February 1985.

J. Moreton, *et al.*, "Fume Emission When Welding Stainless Steel," *Metal Construction*, **17**(12), 794-798, December 1985.

R.K. Tandon, *et al.*, "Chemical Investigation of Some Electric Arc Welding Fumes & Their Potential Health Effects," *Australian Welding Research*, **13**:55-60, December 1984.

R.K. Tandon, *et al.*, "Fume Generation & Melting Rates of Shielded Metal Arc Welding Electrodes," *Welding Journal*, **63**(8), 263s-266s, August 1984.

E.J. Fasiska, *et al.*, *Characterization of Arc Welding Fumes*, American Welding Society, Miami, FL, February 1983.

R.K. Tandon, *et al.*, "Variations in the Chemical Composition & Generation Rates of Fume from Stainless Steel Electrodes Under Different AC Arc Welding Conditions," AWRA Contract 90, Australian Welding Research, 11:27-30, December 1982.

The Welding Environment, Parts IIA, IIB, & III, American Welding Society, Miami, FL, 1973.

"Development of Environmental Release Estimates for Welding Operations," EPA Contract No. 68-C9-0036, IT Corporation, Cincinnati, OH, 1991.

L. Henning & J. Kinsey, "Development of Particulate & Hazardous Emission Factors for Welding Operations," EPA Contract No. 68-DO-0123, Midwest Research Institute, Kansas City, MO, April 1994.