4.0

EMISSION INVENTORY METHODS

4.1 EMISSION CALCULATIONS

4.1.1 Emissions From Welding Processes

Welding emissions were calculated with two types of emission factors. For fluxed core arc welding (FCAW), gas metal arc welding (GMAW), and shielded metal arc welding (SMAW), the emission factors vary by metal substrate and pollutant. The units of these emission factors are lb pollutant per 10,000 lb electrode consumed. Let **M** be a matrix in which the rows are the facilities with inventory data and the columns are the types of metal substrates (aluminum, mild steel, etc.). A typical element of this matrix is m_{ik}, where i is the facility and k is the metal substrate. The units of m_{ik} are lb electrode consumed. Let **F** be a matrix in which the rows are the types of metal substrates and the columns are the pollutants of interest. A typical element of this matrix is f_{kj}, where k is the type of metal substrate and j is the pollutant (chromium, nickel, etc.). The units of f_{kj} are lb pollutant per 10,000 lb electrode consumed. Finally, let **E** be an emissions matrix, in which the rows are the facilities with inventory data and the columns are the pollutants. A typical element of this matrix is e_{ij}. Its units are lb pollutant emissions.

Survey respondents reported pounds of electrode materials consumed and *percentages* of the different metal substrates. It was assumed that material use by substrate (m_{ik} above) was proportional to the percentages of substrate; e.g. if 25 percent of the welding was done on aluminum, then 25 percent of the mass of electrode consumed was consumed in welding aluminum. Putting consumption into the same units as the emission factors results in the following equation for the emissions matrix **E**:

$$\mathbf{E} = 0.0001\, \mathbf{M} \times \mathbf{F} \qquad [4\text{-}1]$$

Since the emission factors are available for four metals and four pollutants, a typical row of the emissions matrix would be as follows:

Facility i, Pollutant 1 = $(m_{i1}f_{11}) + (m_{i2}\, f_{21}) + (m_{i3}\, f_{31}) + (m_{i4}\, f_{41})$

Facility i, Pollutant 2 = $(m_{i1}f_{12}) + (m_{i2}\, f_{22}) + (m_{i3}\, f_{32}) + (m_{i3}\, f_{42})$

Facility i, Pollutant 3 = $(m_{i1}f_{13}) + (m_{i2}\, f_{23}) + (m_{i3}\, f_{33}) + (m_{i3}\, f_{43})$

Facility i, Pollutant 4 = $(m_{i1}f_{14}) + (m_{i2}\, f_{24}) + (m_{i3}\, f_{34}) + (m_{i3}\, f_{44})$

These calculations were performed using Microsoft™ workbooks. Since the emission factor matrix **F** varied from one welding process to another, a different worksheet was set up for each process.

The other type of welding emission factor, which was used for gas tungsten arc welding (GTAW), plasma arc welding (PAW) and oxyacetylene welding (OXY), was based on hours of operation. It was assumed that the hours spent on a given metal substrate were proportional to the use of that substrate. Emission factors were in units of grams per minute. These were converted to pounds per hour by the factor (60/453.6). Using the units of hours per year in **M**, the equation for emissions from these types of welding operations is:

$$\mathbf{E} = 0.1323\, \mathbf{M} \times \mathbf{F} \qquad [4\text{-}2]$$

4.1.2 Emissions From Metal Cutting Processes

The emission factors for metal cutting processes are based only upon hours per year of operation, without regard to metal substrate. Each facility's total hours of operation were multiplied by the emission factor for each pollutant to yield pollutant-specific emissions.

4.1.3 Emissions From Metal Spraying Processes

Emission factors for metal spraying processes were available only for nickel and total chromium.[1] These factors are in units of lb emissions per lb *of the pollutant* sprayed. The latter was determined by multiplying the amount of material sprayed by the elemental fraction of nickel or chromium.

4.2 EXTRAPOLATION FROM SURVEY RESULTS

4.2.1 Number of Facilities With Welding or Cutting Operations

For each type of welding (or cutting), the fraction of facilities in each stratum that performed welding (or cutting) was first calculated. The denominator of each fraction was the total number of responses (including those determining that a facility was ineligible). Let p_i^* be the sample proportion for the ith stratum, for a given type of welding or cutting. Let N_i be the total number of facilities[2] and n_i be the sample size for the ith stratum. Then the total number of facilities doing the type of welding or cutting of interest is:

$$F = \sum_i p_i^* N_i \qquad [4\text{-}3]$$

The variance of stratified sample having k strata is (McClave and Benson, 1982):

$$[\sigma^*_{p^*}]_{st} = (1/N) \left[\sum_{i=1}^{k} N_i^2 \frac{(N_i - n_i)}{N_i} \frac{p_i^*(1 - p_i^*)}{n_i - 1} \right]^{1/2} \qquad [4\text{-}4]$$

[1] An estimate of hexavalent chromium emissions was obtained by multiplying the total chromium emissions by a range (determined from the source test data reviewed) of the ratios between hexavalent and total chromium.

[2] The total is the estimate of the universe of facilities in each stratum, not just those that were part of the potential or actual sample.

The 95-percent confidence interval for the number of facilities doing the particular type of welding or cutting is then $F \pm 1.96 N [\sigma^*_{p^*}]_{st}$.

4.2.2 Pounds of Material Used

For a particular welding process, let M_k be the pounds per year of welding material consumed in the kth stratum. The values of M_k were determined by adding the reported material use for all the facilities in each stratum. Let N_k and n_k be the universe of facilities and the number of responding facilities, respectively, in the kth stratum. Then the total pounds per year for the welding process is calculated from:

$$M = \sum_k N_k M_k / n_k \quad [4\text{-}5]$$

4.2.3 Emissions

An equation of the same form as Equation 4-5 was used to extrapolate emissions from responding facilities to the AQMD as whole. In the case of emissions, M_k represented the sum of emissions of a given pollutant from a given process in the kth stratum.