Characterization of Arc Welding Fume
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Abstract

Six welding fumes, representing a variety of welding rods and wires, were analyzed for particle size and chemistry by X-ray diffraction, energy dispersive X-ray analysis, scanning transmission electron microscope, and automated electron beam analysis. Four carbon steel fumes (E6010, E7018, E70S-3, E70T-1), a stainless steel fume (E308-16) and an aluminum fume (E5356) were tested. It was found that particle average diameters are all in the respirable range — between 0.1 and 1.0 \( \mu \)M. Few individual particles were greater than 1 \( \mu \)M, but STEM pictures revealed many particles as small as 0.01 \( \mu \)M. The particles appeared to be spheres or clusters of spheres. Even though no crystalline features were observed, all particles examined produced electron diffraction patterns, indicating that they contained crystalline material. There was no correlation between average diameter and particle chemistry or between average diameter and fume type. An analysis of particle chemistry indicates that the potential toxicity of the fumes does vary appreciably.
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I. Introduction

During the process of welding, metal vapors are produced in the electric arc. As these vapors cool and solidify, a fume is formed that may be a potential health hazard to the welder and to others working in the same area. Such fine aerosols are all irritating to the respiratory system. Yet some fumes may potentially be more dangerous than others because of the specific substances present.

The purpose of this study is to provide a data base of chemical, crystallographic, and physical data for representative welding fume types which will aid in the understanding of the interactions of these particles with the human respiratory system. Such interactions are affected by many variables. Therefore, a simple percent weight analysis for various elements does not provide adequate information since individual particle size and chemistry affect toxicity. For example, a few large particles may dominate a percent by weight analysis. However, if these particles were over 10 μM in diameter, they might not reach the lower respiratory system at all, while compounds present in thousands of fine particles would penetrate to the alveoli of the lungs and could be absorbed into the blood. Particle morphology is also significant since particles with sharp edges or fibers are more irritating to the lungs than smooth, sphere-shaped objects. Finally, specific compounds must be identified since such factors as crystallinity, solubility, and oxidation state affect toxicity. Such information may influence the determination of federal standards for occupational exposure.

These objectives were accomplished by using various macro and micro scale techniques. Initially, energy dispersive X-ray analysis (EDXA) and X-ray diffraction (XRD) were used to obtain background information on bulk fume properties. The focus of this work was the analysis of the welding fume on a particle by particle basis. Automated electron beam analysis (SPEC) was used to analyze large numbers of particles, and specially designed computer software sorted the particle data by size and chemistry. Finally, a scanning transmission electron microscope (STEM) was used for a manual examination of a smaller number particles for size, chemical composition, and crystallinity. An examination of all of the data available for a fume can then be used to decide whether toxicological testing may be advisable.

II. Sampling Techniques

Two general types of samples were required for the investigation: bulk fume samples which could be used for the analytical techniques requiring large amounts of sample material, and lightly dispersed samples for the techniques which provide analyses of individual particles.

A. Bulk Samples

The bulk samples were collected by AWS in a conical chamber as described in AWS F1.1-79, Laboratory Method for Measuring Fume Generation Rates and Total Fume Emission of Welding and Allied Processes. This provides a sample of several grams needed for certain analytical procedures such as X-ray diffraction.