

Evaluation of exposures during the welding or flame-cutting of painted steel

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The welding fumes and particulates originating from the electrode and the metal being welded have already been well characterized (3). In some industrial fields, such as shipbuilding and other kinds of metalworking, shop primers are used to minimize steel corrosion during storage and processing. The welding or flame-cutting of coated steel plates gives rise to organic contaminants in addition to the usually measured inorganic fumes and gases. One of the reasons organic contaminants are seldom measured is the lack of adequate methodology. Furthermore, the exposure profile of these compounds is difficult to predict, as it varies depending on the paint used and the temperature of the zone where the contaminants are formed. Pollutant screening shows that decomposition products originate mainly from the binding agent in the paint and that the measured concentrations are relatively low, at least in the case of specific compounds. The airborne pollutants encountered are numerous, and therefore field measurements are unreasonably laborious. We suggest that the assessment of exposure during the welding or flame-cutting of coated steel should be made preferably by measuring a few relevant compounds. A scheme for such a test procedure can be outlined by (i) screening the pollutants emitted, (ii) determining the principal components of various paints, and (iii) selecting compounds relevant to the workers' health.

Screening of pollutants

Different weldable paint formulations are available for use as anticorrosives. To screen pollutants formed during the welding procedure, we chose the most commonly used paints for experimental testing (6). The tests were conducted by welding, flame-cutting and/or heating coated steel plates under a fume hood modified to allow sampling of the concentrated plume of the pollutants emitted. Table 1 shows the organic compounds identified with various analytical techniques (gas chromatography, liquid chromatography, mass spectrometry). The emission of polyaromatic hydrocarbons proved to be insignificant for all the paints tested, and nitrosoamines could not be detected at all.

Of the metals found in the fumes, zinc and lead deserve to be mentioned. The use of lead in weldable paints is not recommended. The concentration of zinc

was found to be directly proportional to the zinc content of the respective paint (6). Thus the fume zinc concentrations for ethyl silicate paint (zinc content of dried film ~15 %) were one-fourth of the corresponding iron levels, whereas in the case of epoxy paint (zinc content ~3 %) the fume zinc concentrations were only one-fortieth of those of iron. It should be emphasized that these paints are not to be confused with what are known as zinc-rich paints.

Health aspects

The choice of a valid method for the assessment of exposure suited for preventive measures is far from self-evident. In traditional occupational hygiene, the emphasis is usually on the determination of exposures to single compounds, which are then compared with occupational limit values, although their application in practice is often problematic. For actual exposures with a wide range of airborne pollutants, no adequate guidelines exist for the application of compound-specific exposure limits to complex interactions between compounds. The situation is further complicated by the fact that many of the encountered compounds lack occupational limit values. Moreover, the overall health

Table 1. Organic compounds emitted from different weldable paints. (Major compounds in boldface type)

Paint type	Organic compounds identified
Epoxy	Alkylated benzenes, aliphatic alcohols (C₁—C₄), bisphenol A, phenol , aliphatic ketones (C ₃ —C ₅), acetophenone, aliphatic aldehydes (C ₁ —C ₄), aliphatic amines (C ₁ —C ₂)
Ethyl silicate	Aliphatic alcohols (C₁—C₄), butyraldehyde , butyric acid, aliphatic aldehydes (C ₆ —C ₉), formaldehyde, acetaldehyde, acetic acid
Polyvinyl butyral	Aliphatic alcohols (C₁—C₄), butyraldehyde, butyric acid, formaldehyde , acetaldehyde, acetic acid, phenol
Modified epoxy ester	Aliphatic aldehydes (C₁—C₉), aliphatic acids (C₅—C₉), methyl methacrylate, butyl methacrylate, phenol, bisphenol A , alkylated benzenes, aliphatic alcohols (C ₁ —C ₄), phthalic anhydride, acrolein, aliphatic hydrocarbons (C ₆ —C ₇)
Modified alkyl	Aliphatic aldehydes (C₆—C₉), acrolein, phthalic anhydride, aliphatic acids (C₅—C₉) , alkylated benzenes, aliphatic alcohols (C ₁ —C ₄), formaldehyde, benzaldehyde)

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risk analysis should not only include the identified compounds, but also risk factors unknown at the moment. This statement refers, for example, to latent risks caused by undetected short-lived intermediate compounds.

It would be desirable to find a few common denominators for the thermal decomposition products of weldable paints which might be exploited in the evaluation of the relative risk presented by these paints. Worker complaints about irritation caused by the fumes makes the presence of irritating compounds appear the most relevant for this purpose. This approach is also supported by the fact that most of the encountered compounds are known sensory irritants. The relation of irritating properties to special molecular features has been assessed in several animal studies based on decreased respiratory rate, which is a characteristic physiological response to airborne chemical irritants (1, 8, 11). For example, the irritation potential of aldehydes is greater with unsaturation (1). Acrolein is thus almost twice as irritating as formaldehyde (8). Other potent groups, though less active, are ketos and esters (1). Another study demonstrated the irritative potency of alkylated benzenes to increase along with chain length up to a length of C_6 (11). The same tendency has been observed for aliphatic alcohols, from methanol to pentanol (10). Phthalic anhydride irritates the skin, the eyes, and the upper respiratory tract. Among workers subject to repeated exposure, both work-related rhinitis and asthma induced by phthalic anhydride have been reported (4, 12). Even methacrylates can have an irritative effect on mucous membranes (5). Workers exposed to fumes from epoxy resins were reported to be photosensitized, with bisphenol A as the probable photoactive compound (2, 7).

Under field conditions during the welding or flame-cutting of coated steel, the levels of airborne organic contaminants vary, but they are usually relatively low (6). The concentrations of the individual compounds measured have been below their occupational exposure limits. Nevertheless, complaints about irritation do occur, and it is therefore tempting to assume the occurrence of additive irritation due to an interaction of the specific compounds. Such simplifications should, however, be made with caution, as the irritation mechanism is probably very complex. It has, for example, been demonstrated that there is competitive antagonism between formaldehyde and acrolein (9). Therefore, the total sensory irritation is not a function of "the total aldehyde present" but rather a function of the specific concentrations of acrolein and formaldehyde. The irritation response is also modified by repeated exposure to high concentrations of formaldehyde or acrolein (8). The evaluation is further complicated by the variable nature of occupational situations; the mode of thermal decomposition leading to a specific exposure profile may vary according to the technique employed, ie, welding, flame-cutting, or straightening.

As illustrated by the aforementioned factors, the information provided by the chemical analysis of thermal decomposition products as such does not seem to be sufficient for establishing the relative health risk presented by various weldable paints. The main value of this information lies in providing guidelines for future studies on toxicity and health. Meanwhile, available experimental toxicity data must be relied upon when compounds are ranked from the point of view of health. This being the situation, we propose that at least acrolein, formaldehyde, and phthalic anhydride be measured for the assessment of exposure. Formaldehyde and acrolein are decomposition products of all weldable paints, whereas phthalic anhydride is emitted from weldable primers (modified alkyd and epoxy ester). In the case of epoxy and epoxy ester paints even bisphenol A and methacrylates, respectively, should be determined. The sampling methods used (6) allow the simultaneous determination of other organic compounds as well.

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