# Controlling Chromium Fumes

*OSHA's lower limits for worker exposure to hexavalent chromium have made providing clean air to the working environment even more important*

**BY ED RAVERT**

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Knowing how to calculate the amount of weld fumes and, in turn, how to capture those fumes and provide clean air in the working environment has become especially important in light of the Occupational Safety and Health Administration's (OSHA's) new regulation for employee exposure to hexavalent chromium (Cr(VI)). Hexavalent chromium is a natural metal used in the manufacture of stainless steel.

Even before the new Cr(VI) exposure regulation, OSHA had established limits of 5 mg/m$^3$ for carbon steel and other types of welding to protect the health of welders and employees in the surrounding area. Hence, knowledge of the weld fume ratios and the calculations provided in this article will be extremely helpful in knowing exactly how much weld smoke is being generated, how much dilution air is required, and the amount of efficiency that will be needed from the dust-collection equipment.

All welding operations, including robotic welding, need careful attention and weld fume monitoring. Consider the example of a plant with a significant number of robotic welding machines. This plant also utilized a number of employees in support of the operation, but, because the equipment was robotic, it was felt there was no initial need for dust and weld smoke control. The company assumed that replacement air for dilution would keep it in compliance with environmental standards. To check, personal monitors were used to see if weld fume exposure was occurring. Indeed it was found that some employees were exceeding the recommended permissible exposure limit (PEL).

The goal of this article is to provide information that will directly help in providing healthful clean air for welders and supporting personnel.

## Importance of Weld Fume Particle Size

Weld fume particle size is important because of OSHA and Environmental Protection Agency (EPA) health and environment air quality control aspects. In welding, the intense heat of the arc or flame vaporizes the base metal and/or electrode coating. This vaporized metal condenses into tiny particles called fumes that can be inhaled. Generally, weld fume is submicron in size with average diameters from 0.3 to 0.7 microns. Lung retention is minimal with particles in this size range. However, thermal effects can cause agglomeration of the particles into particle chains and clusters that exceed one micron that can be deposited in the human respiratory tract. Chromium fume, which is created by welding or cutting on stainless steel or other metals coated with a chromium material, is extremely dangerous, hence the new regulations.

## Weld Fume Generation

The amount of weld fumes generated will vary depending on the welding process used and the metal being welded. The weight of fumes generated is a percentage of the weight of deposited metal. This percentage can be based on the length of weld electrode used. Table 1 lists the typical ratios by welding process and metal type.

If continuously gas metal arc (GMA) welding on carbon steel at the rate of 10 lb/h, the maximum rate of weld fume produced would be 10 lb × 0.009 (0.9%), or 0.09 lb/h. If, however, the welding is done for only 30 min/h, the fume generation rate will be half, or 0.045 lb/h. By comparison, if continuously GMA welding on stainless steel at the rate of 10 lb/h, the maximum rate of weld fume produced would be 10 lb × 0.07 (0.7%), or 0.7 lb/h.

## Air Pollution Control Devices

Electrostatic precipitators (ESP) are ideally suited for collection of weld smoke. The major exception is in dealing with stainless steel and hexavalent chromium. See the two boxed items for more information regarding OSHA's new hexavalent chromium regulations.

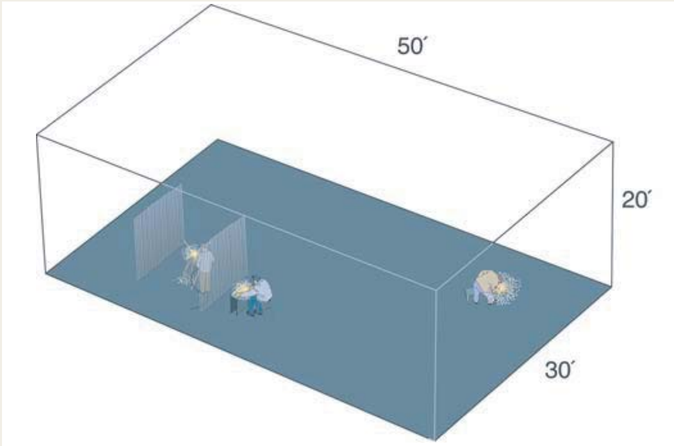


Fig. 1 — A 30,000-cu ft enclosed welding space. Dilution air assumes continuous welding without the use of air pollution collection devices.

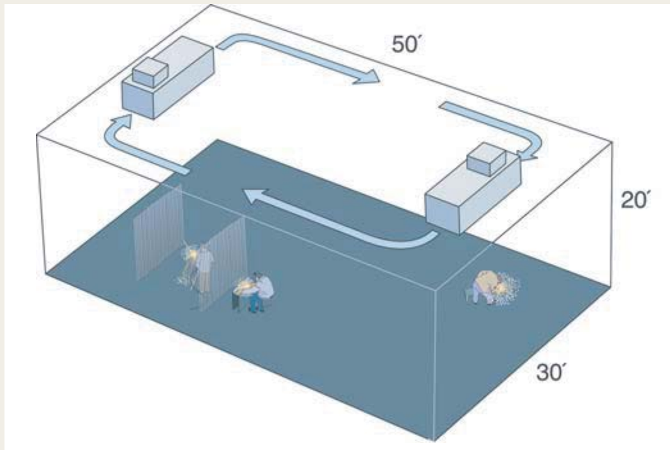


Fig. 2 — Internally filtered air using overhead cartridge dust/fume collectors. Electrostatic precipitators or cartridge dust/fume collectors can be mounted overhead to recirculate the air in a racetrack fashion.

Media filtration units, including cartridge dust collectors, are also ideally suited for collection of weld smoke. Depending on the welding process, source capture systems do the best job of capturing weld fume contaminants using the least amount of cubic feet of air per minute ($ft^3$/min). Source capture systems include hoods, ducting, air-cleaning devices, and air-moving devices (fans). With separate hoods and ducting, an ESP or cartridge collector can be the recommended method of cleaning air because the weld fume is captured before it can escape into the ambient air.

There are, however, many factors that could render a source capture system impractical. These include the following:

- Where work is done on large parts and the worker has no fixed operating position.
- Where workers are unable to use hooded systems. Some source capture systems may require physical positioning by the worker. If it is unlikely the worker will perform that positioning, the system is rendered ineffective.
- Where there are a large number of small weld smoke producers in a confined area.
- Places in which overhead cranes and process obstructions make ducting installation impossible. Unducted systems, designed properly, can keep the air cleaning units out of the craneways and still achieve effective results.
- Where floor layout revisions are anticipated and could result in expensive duct modifications. Unducted systems are more flexible.

Table 1 — Weld Fume Ratios

| Welding Process | Metal Type | Range Weight of Fumes/ Weight of Deposited Metal |
|---|---|---|
| FCAW | Carbon Steel<br>Stainless Steel | 0.9–2.4% |
| SMAW | Carbon Steel | 1.1–5.4% |
| SMAW | Stainless<br>High Alloy | 0.3–1.4% |
| GMAW | Carbon Steel | 0.3–0.9% |
| GMAW | Stainless Steel | 0.6–7% |
| GMAW | Copper<br>Aluminum | 0.5–1.6% |

## Air Pollution Control Device Design Considerations

To select the appropriate air pollution control solution for your operation, the following considerations need to be addressed:

- Size and shape of the space where welding operations are performed.
- Containment generation rate and the desired steady-state containment levels.
- Required number of ambient air changes per hour.
- Existing ventilation and replacement air rates, plus all heating, ventilation, and air-conditioning system air volumes and airflow patterns. This applies more to ambient air than with the use of source capture systems.
- Airflow pattern continuity noting seasonal variations.
- Appropriate filtration technology to match room layout, containment generation, and designed steady-state containment levels.

## Emissions Control Basics

One way to achieve target room contamination levels without using dust/fume control devices is to simply provide enough dilution (replacement) air into the enclosed space. As shown in Fig. 1 and Table 2, to achieve the 5 $mg/m^3$ limit normally required by OSHA or the EPA, the enclosed space would require 8.6 air changes per hour with just one welder continuously welding. With three welders continuously welding, 25.8 air changes (AC) per hour would be required. Stricter room contamination levels would require even higher air change schedules.

Weld fumes and gases calculations for the dilution air example shown in Fig. 1 with a 30,000-cu-ft shop size (50 x 30 x 20 ft), and with three welders operating with E7108 electrodes and generating 0.6 g/min of fumes are as follows:

With an allowable room contamination level of 5 $mg/m^3$

$$\frac{30{,}000 \text{ cu ft} \times 25.8 \text{ AC/h}}{60} = 12{,}900 \text{ ft}^3/\text{min}$$

With an allowable room contamination level of 2 $mg/m^3$

## Overview: New OSHA Regulations For Hexavalent Chromium Exposure

OSHA's new regulation for employee exposure to hexavalent chromium (Cr(VI)) — a natural metal used in the manufacture of stainless steel — has significantly reduced the permissible exposure limit from 52 to 5 micrograms. The regulation (Volume 71, Number 39, 10099–10385) also includes provisions relating to preferred methods for controlling exposure, respiratory protection, protective work clothing and equipment, hygiene, medical surveillance, hazard communication, and recordkeeping. Effective May 30, 2006, the new rule does not require the installation of engineered controls, including air filtration equipment, until May 30, 2010.

This standard applies to all manufacturing processes where hexavalent chromium is present including welding. While all types of welding could be affected, the highest concentration will be from the fumes generated in welding stainless steel. The major health effects associated with exposure to Cr(VI) include lung cancer, nasal septum, ulcerations and perforations, skin ulcerations, and allergic and irritant contact dermatitis.

This new regulation provides for greater employee protection against these health risks by lowering the permissible exposure limit (PEL) for hexavalent chromium, and for all Cr(VI) compounds, from 52 µg to a much more stringent 5 µg of Cr(VI) per cubic meter of air (5 $\mu g/m^3$) as an 8-h time-weighted average.

## Welding Specifics in the New OSHA Hexavalent Chromium Regulations

Complete information and a copy of the 287-page regulation (Volume 71, Number 39, 10099-10385) can be found at the OSHA Web site: www.osha.gov/ SLTC/hexavalentchromium/index.html.

Following are pertinent quotes from the regulation.

"OSHA concludes that engineering controls, such as local exhaust ventilation (LEV), process control, and process modification or substitution can be used to control exposures in most operations." (Vol. 71, No. 39, 10334)

"OSHA has determined that the primary controls most likely to be effective in reducing employee exposure to Cr(VI) are local exhaust ventilation (LEV) and improving general dilution ventilation. … This includes installing duct work, a type of hood, and/or a collection system." (Vol.71, No.39, 10262)

"Paragraph (f) of the final rule, Methods of Compliance, establishes which methods must be used by employers to comply with the permissible exposure limit (PEL). It requires that employers institute effective engineering and work practice controls as the primary means to reduce and maintain employee exposures to Cr(VI) to levels that are at or below the PEL … Engineering controls can be grouped into three main categories: 1) Substitution, 2) isolation; and 3) ventilation, both general and localized." (Vol.71, No.39, 10345)

"Welding: The welding operations OSHA expects to trigger requirements under the new Cr(VI) rule are those performed on stainless steel, as well as those performed on high-chrome-content carbon steel and those performed on carbon steel in confined and enclosed spaces. … OSHA has determined that engineering and work practice controls are available to permit the vast majority (over 95%) of welding operations on carbon steel in enclosed and confined spaces to comply with a PEL of 5 $\mu g/m^3$. … OSHA has determined that the PEL of 5 $\mu g/m^3$ is also feasible for all affected welding job categories on stainless steel. … The two most common welding processes, shielded metal arc welding (SMAW) and gas metal arc welding (GMAW), … may require the installation or improvement of LEV. … There are ongoing efforts to reduce the use of SMAW and replace it with GMAW for both efficiency and health reasons. … OSHA has revised its estimate of the percentage of SMAW welders that can switch to GMAW from 90% to 60%. … For those stainless steel SMAW operations that cannot switch to GMAW and even some GMAW operations, the installation or improvement of LEV may be needed and can be used to reduce exposures. OSHA has found that LEV would permit most SMAW and GMAW operations to comply with a PEL of 5 $\mu g/m^3$, OSHA recognizes that the supplemental use of respirators may still be necessary in some situations." (Vol.71, No. 39, 10262-10263)

$$\frac{30{,}000 \text{ cu ft} \times 63 \text{ AC/h}}{60} = 31{,}500 \text{ ft}^3\text{/min}$$

Following is the same example with just one welder operating with E7108 electrodes:

With an allowable room contamination level of 5 $mg/m^3$

$$\frac{30{,}000 \text{ cu ft} \times 8.6 \text{ AC/h}}{60} = 4300 \text{ ft}^3\text{/min}$$

and with an allowable room contamination level of 2 $mg/m^3$

$$\frac{30{,}000 \text{ cu ft} \times 21 \text{ AC/h}}{60} = 10{,}500 \text{ ft}^3\text{/min}$$

The better way to achieve target room contamination levels is to use dust/fume control devices. Using the same enclosed 30,000-cu ft workspace, electrostatic precipitator or cartridge collectors can be used — Fig. 2. These units can be hung overhead to clean and recirculate the air in a race track fashion.

With this equipment, 4250 $ft^3$/min or 8.5 air changes per hour would be pulled in and recirculated. An additional 750 $ft^3$/min (¼ to ½ $ft^3$/min/sq-ft of floor space) would be bled in and exhausted. The total volume would be 5000 $ft^3$/min, or 10 air changes per hour.

If the welders were generating 0.09 lb/h of weld fume, at 99.99% efficiency, all but 0.000009 lb/h would be captured. This amounts to 0.00000021 grains/$ft^3$ or 0.00048 $mg/m^3$. This is well within the acceptable levels for any of the weld fume contaminants listed in Table 3.

The following is a calculation example for shielded metal arc welding (SMAW) using E7018 electrodes with internally filtered air:

0.2268 g/min welding operation
0.6804 g/min, 0.0015 lb/min
10.5 grains/min, 0.09 lb/h

$$\frac{5000 \text{ ft}^3 \times 0.0021 \text{ grains/ft}^3 \times 60 \text{ min/h}}{7000 \text{ grains/lb}}$$

= 0.09 lb/h generated

$$\frac{5000 \text{ ft}^3 \times 0.00000021 \text{ grains/ft}^3 \times 60 \text{ min/h}}{7000 \text{ grains/lb}}$$

= 0.000009 lb/h generated

0.00000021 grains/$ft^3$ = 0.00048 $mg/m^3$
= 0.48 $\mu g/m^3$
0.00006804 g/min, 0.00000015 lb/min

If you divide the 7% weld fume weight number by the 0.9% carbon steel number (Table 1), and multiply it by 0.48 $\mu g/m^3$, the micrograms per cubic meter for stainless steel now becomes 3.733 µg.

**Table 2 — Dilution Air Requirements**

| Room Contamination Level | | One Welding Operation | | Three Welding Operations | | |
|---|---|---|---|---|---|---|
| $mg/m^3$ | AC/h | std. $ft^3$/min | std. $m^3$/min | std. $ft^3$/min | std. $m^3$/min | AC/h |
| 2.0 | 21 | 10,500 | 297 | 31,500 | 892 | 63 |
| 5.0 | 8.6 | 4,300 | 122 | 12,900 | 365 | 25.8 |
| 10.0 | 4 | 2,000 | 57 | 6,000 | 170 | 12 |
| 20.0 | 2 | 1,000 | 28 | 3,000 | 85 | 6 |

**Table 3 — OSHA Exposure Concentration Limits ($mg/m^3$)**

| Material | 8-h TWA |
|---|---|
| Beryllium | 0.002 |
| Cadmium Oxide (fume) | 0.01 |
| Chromium (Cr(VI)) | 0.005 |
| Copper | 0.2 |
| Manganese (fume) | 0.2 |
| Molybdenum | 0.5 |
| Nickel | 1.5 |
| Vanadium Oxide (fume) | 0.05 |
| Zinc Oxide (fume) | 2.0 |

The formulas and percentages used in this article can be applied to most welding applications. Robotic welding areas follow the same basic formulas. These areas should be enclosed as much as possible. Strip curtains should be used to prevent weld fumes from migrating into other areas of the facility.

Permit guidance: Even if you can achieve 0.00048 $mg/m^3$ in your facility, do not list that capability on your report. Only list what is required for the permit.

## Summary

Depending on the type and quantity of weld fume generated, contaminants can be controlled three different ways:

- Dilution ventilation
- Ambient air collection using dilution air, an air cleaning device (ESP or cartridge collector)
- Source capture using an air cleaning device (ESP or cartridge collector)

Electrostatic precipitators are ideal for the collection of weld fume submicron particles. ESPs are typically used for source capture systems, or ambient air systems on carbon steel welding, and prior to the new OSHA standard, were used for stainless steel welding. ESPs require very little maintenance and are not subject to periodic cartridge filter replacement costs. As ESPs are lower in overall efficiency than cartridge filter collectors, they would not be ideally suited for stainless steel weld fumes, especially if the air is to be returned into the workspace.

If ambient air collection is desired when welding on stainless steel, the welder will be required to wear personal respiratory protection at all times. The source capture system combined with a cartridge collector is the only viable way to deal with stainless weld fumes. Even then, and if the air is to be returned into the workplace, a monitored safety HEPA after filter should be used.◆