Exposure Determination and Respirator Selection Under the OSHA Hexavalent Chromium Standards

On February 28, 2006 the Occupational Health and Safety Administration (OSHA) published the final Hexavalent Chromium Cr(VI) Standard. Three separate standards covering occupational exposures to Cr(VI) were published including general industry (1910.1026), shipyards (1915.1026), and construction (1926.1126). A Permissible Exposure Limit (PEL) of 5 µg/m³ was established in all three versions. OSHA estimates there are approximately 558,000 workers exposed to Cr(VI), of which 352,000 are exposed above the Action Level of 2.5 µg/m³ and 68,000 above the PEL. Potential adverse health effects associated with Cr(VI) exposures include lung cancer, asthma, and damage to the nasal epithelia and skin.

Employers subject to the standards must determine the eight-hour time-weighted average (TWA) exposure for each employee exposed to Cr(VI) using either the scheduled monitoring option or the performance-oriented option. Respirator depends on specific conditions of use, including Cr(VI) concentrations.

Sources of Cr(VI) Exposure
Chromium is a metal that exists in several oxidation or valence states, ranging from Cr²⁺ to Cr⁶⁺ (hexavalent chromium). Chromium compounds of the trivalent state (Cr³⁺) are the most common and occur naturally in ores such as ferrochromite, or chromite ore. Hexavalent chromium or chromate is the second most stable state, however, it rarely occurs naturally. Chromium compounds in higher valence states Cr(VI) are able to undergo reduction to lower valence states in the presence of oxidizable organic matter or the presence of inorganic chemicals such as iron. Likewise, lower valence state chromium compounds are able to undergo oxidation to higher valence states.

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Major users of chromium are the metallurgical, refractory and chemical industries. Chromium is used to produce stainless steel, alloy steel and nonferrous alloys. Cr(VI) is used in the chemical industry in pigments, metal plating, and chemical synthesis as ingredients and catalysts. There are about 30 major industries and processes where Cr(VI) is used. These include producers of chromates and related chemicals from chromite ore, electroplating, welding, painting, chromate pigment production and use, steel mills, and iron and steel foundries. Cr(VI) compounds have a lemon yellow, orange or dark red appearance and are typically crystalline, granular or powder. Their color characteristics and chemical properties make them suitable for use as high quality pigments in textile dyes, paints, inks, and plastics.

**Welding**
Welding operations affected by the Cr(VI) standards are those performed on stainless steel, high-chrome content carbon steel and carbon steel welding in confined and enclosed spaces. Fumes generated from the welding of stainless steel may contain both trivalent chromium and hexavalent chromium compounds. Fume composition and the rate of generation will depend on the welding process used and filler material used, if any. The rate of fume generation during welding of stainless steel depends on a number of factors including welding current (current density), arc voltage (arc length), type of metal transfer (type of filler material and/or welding process), and the shielding gas or welding atmosphere.

The welding processes expected to generate the highest Cr(VI) exposures are shielded metal arc welding (SMAW) and gas metal arc welding (GMAW). It's estimated that Cr(VI) accounts for approximately 4% of the of the total chromium content in GMAW fume and up to 50% of chromium content in SMAW fume. Other types of welding, such as tungsten-arc welding (TIG) and submerged arc welding (SAW), may also present exposure concerns. However, these processes generally present lower fume volumes in comparison to SMAW and GMAW.

**Chrome Plating**
Cr(VI) exposures may also occur in chromium plating operations. Chromium plating includes hard chrome and decorative chrome plating types. Hard chrome plating is done either to increase resistance to rust and corrosion or increase resistance to wear and tear. Decorative chrome plating is used for aesthetic purposes, in order to achieve a shining surface. Most chromium plating is done using chromic acid, a hexavalent form of chromium. The main exposure concern is the chromic acid mist, which is formed when chromic acid is electrolyzed. The amount of chromic acid mist generated depends on a number of variables including the concentration of chromic acid in solution, the surface area of the article treated, the current density, the length of time current is passed through the solution and the surface tension of the bath.

**Painting**
Painting applications where Cr(VI) exposures are expected to be the highest involve the use of strontium chromate coatings on aerospace parts. Certain aerospace applications involving spray painting of large parts or entire planes may make it difficult to achieve compliance with the PEL using engineering and work practice controls only. OSHA anticipates the use of respiratory protection will be necessary to supplement other exposure controls used. Continued use of chromate-containing paints and coatings will present exposure concerns to downstream users, such as automobile repair, construction and shipyard industries, for years to come.

**Exposure Determination and Respirator Selection**
Under the OSHA Hexavalent Chromium Standards (continued from page 1)

OSHA allows employers to comply with exposure determination requirements by using either the scheduled-monitoring option or the performance-oriented option. The scheduled monitoring option requires initial personal breathing zone air sample collection in a sufficient quantity to accurately characterize full shift exposure on each shift, for each job classification and each work area. Subsequent monitoring is also required, with the frequency based on initial results. This approach is similar to that used in previous substance-specific standards, such as the lead (1910.1025) and asbestos (1910.1001) general industry standards.

The following monitoring schedule is required for Cr(VI) under the scheduled monitoring option:
- If initial monitoring indicates that exposures are below the action level (2.5 µg/m³), the employer may discontinue monitoring for those
employees whose exposures are represented by such monitoring.

- If initial monitoring identifies employee exposures to be at or above the action level, the employer must perform periodic monitoring at least every six months.

- If initial monitoring identifies employee exposures to be at or above the PEL, the employer must perform periodic monitoring at least every three months.

An alternate choice for complying with the exposure determination requirements is the performance-oriented option. When selecting this option, the employer determines the eight-hour TWA exposure for each employee based on any combination of air monitoring data, historical monitoring data, or objective data sufficient to accurately characterize employee Cr(VI) exposures. Historical monitoring data means data from Cr(VI) monitoring conducted prior to May 30, 2006, which is obtained from work operations conducted under workplace conditions closely resembling the process, types of material, control methods, work practices, and environmental conditions used in the employer’s current operation. Objective data means information such as air monitoring data from industry-wide surveys or calculations based on the composition or chemical and physical properties of a substance demonstrating employee exposure to Cr(VI) associated with a particular product or material or a specific process, operation, or activity. The data must reflect workplace conditions closely resembling the processes, types of material, control methods, work practices, and environmental conditions in the employer’s current operations.

**Sampling and Analytical Methods**

OSHA requires employers to use monitoring and analytical methods that can measure airborne levels of Cr(VI) to within an accuracy of plus or minus 25%, and can produce accurate measurements with a 95% confidence interval for air concentrations at or above the action level. There are a number of recognized methods, including OSHA method ID-215, NIOSH 7600, NIOSH 7604 and NIOSH 7605 (refer to Table 1). The sampling apparatus for all four methods consists of a 37mm diameter, 5 µm pore size, polyvinyl chloride (PVC) filter contained in a polystyrene cassette holder and a sampling pump operating within a range of 1–4 LPM. Recommended air sample volumes vary slightly.

Cr(VI) analysis is conducted using visible absorption spectrophotometry for NIOSH 7600, and variations of ion chromatography for the NIOSH 7604, NIOSH 7605 and OSHA ID-215 methods. OSHA method ID-215 (1998) and NIOSH 7605 (2003) are the most recently validated methods. Limits of detection are generally lower for these methods, in comparison to NIOSH 7600 and 7604. All three NIOSH methods may require special sample handling that includes removal of the PVC filter from the cassette and placement in a glass vial for shipment. All methods may be used for both soluble and insoluble forms of Cr(VI). However, extraction procedures used may be different for each type. Consult an American Industrial Hygiene Association (AIHA) accredited laboratory for assistance in selecting the most appropriate sampling and analytical method for your work environment.

**Use of Respiratory Protection under the Cr(VI) Standards**

Consistent with many substance-specific standards, OSHA requires employers to use engineering controls to reduce and maintain employee Cr(VI) exposures below the PEL. Where this is not feasible, the use of respiratory protection is required to supplement those exposure controls. Where the employer can demonstrate that employee exposures above the PEL occur fewer than 30 days per year on any specific process or task, the requirement to implement engineering and work practice controls does not apply. Where the employer chooses not to use engineering and work practice controls under these circumstances, the use of respirators is required. OSHA has also given a special exemption to the aerospace industry, where painting of aircraft or large aircraft parts using Cr(VI)-containing paints is performed. Specifically, the employer must use engineering and work practice controls to reduce employee Cr(VI) exposures below 25 µg/m³, and then supplement with respiratory protection to achieve the PEL.

The use of respiratory protection is also required under the following circumstances:

- While engineering and work practice controls are being developed;
- During maintenance and repair activities for which engineering and work practice controls are not feasible;
- When all feasible engineering and work
practice controls are implemented and are still not sufficient to reduce exposures to or below the PEL; and
• During emergencies; and
• When employees are exposed above the PEL for fewer than 30 days per year and the employer has not elected to implement engineering and work practice controls.

Unlike previous practice, OSHA chose not to include a table of assigned protection factors (APF’s) to assist employers in the respirator selection process. This is due to OSHA’s plans to publish an APF table for all respirator types as part of changes to the general industry respiratory protection standard under 29 CFR 1910.134. The APF table will define universal values for the expected workplace level of protection across all respirator types. The addition of an APF table under 1910.134 is expected in 2006.

OSHA specifically requires employers falling under the scope of the Cr(VI) standards to implement a respiratory protection program in accordance with 29 CFR 1910.134. The anticipated APF table will assist employers in selecting the most appropriate respirator for their Cr(VI) exposure. Using the hazard ratio and APF, the employer may select a respirator that is suitable for their exposure conditions. Hazard ratio is calculated by dividing the measured or estimated air concentration by the exposure limit. A respirator with an APF greater than the hazard ratio must be selected. For example, if the measured air concentration for a Cr(VI) exposure is 10 µg/m³ eight-hour TWA, a hazard ratio of two is calculated (HR = measured concentration/PEL = 10/5 = 2). A minimum of a half facepiece respirator with an APF of 10 (e.g., filtering facepiece or half facepiece respirator with appropriate particle filter) would be required for this exposure.

3M Recommendation for Respiratory Protection

Employers using respiratory protection for Cr(VI) exposures must comply with all requirements of 1910.134, including, but not limited to, medical evaluations, training and fit testing, prior to using respirators. Fit testing provisions require that all workers wearing a tight-fitting, half or full facepiece respirator must pass a quantitative or qualitative fit test.

Consistent with current respirator selection practices, 3M offers the general recommendations below for work environments where respirators are required under the Cr(VI) standards.

• An N-Series particle filter (e.g., N95, N100) approved under 42 CFR Part 84 may be used where no oil aerosols are present.
• An R-Series (e.g., R95) or P-Series (e.g., P95, P100) particle filter may be used where oil aerosols are present. Refer to product packaging for time usage limitations.
• A filtering facepiece respirator or half facepiece respirator with appropriate particle filters may be used up to 10 X PEL (50 µg/m³).
• A full facepiece respirator with appropriate particle filters may be used up to 10 X PEL (50 µg/m³) when qualitatively fit tested, and 50 X PEL (250 µg/m³) when quantitatively fit tested.

A powered air purifying respirator (PAPR) or supplied air system with a loose-fitting facepiece may be used up to 25 X PEL (125 µg/m³). A HEPA cartridge/filter is required with a PAPR.

A PAPR or supplied air system with a full facepiece, hood or helmet may be used up to 1000 X PEL (5000 µg/m³). A HEPA cartridge/filter is required with a PAPR.

Compliance with the exposure determination requirements under the OSHA Cr(VI) standards will facilitate the selection process for those operations where respiratory protection is used to control exposures. In addition to the exposure concentration, knowledge of specific workplace conditions such as the physical state of the contaminant (dust, mist or fume), presence of other gases and vapors, potential for oxygen deficiency, and other environmental conditions (temperature and relative humidity) will help optimize selection.

For assistance in helping you select respiratory protection for Cr(VI), please call 3M Technical Service at (800) 243-4630.
### Table 1: Summary of Sampling and Analytical Methods for Airborne Hexavalent Chromium

<table>
<thead>
<tr>
<th>Method</th>
<th>Sampling Equipment</th>
<th>Recommended Pump Flow</th>
<th>Analysis</th>
<th>Sample Handling*</th>
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</thead>
<tbody>
<tr>
<td>NIOSH 7600, issued 8/94</td>
<td>Personal sampling pump with 37mm diameter PVC filter, 5 µm pore size</td>
<td>1 to 4 LPM, 400L max volume</td>
<td>Visible Absorption Spectrophotometry, Extraction Solution Different for Soluble and Insoluble Forms</td>
<td>Remove PVC filter from cassette and place in glass vial prior to shipment</td>
</tr>
<tr>
<td>NIOSH 7604, issued 8/94</td>
<td>Personal sampling pump with 37mm diameter PVC filter, 5 µm pore size</td>
<td>1 to 4 LPM, 1000L max volume</td>
<td>Ion Chromatography, Conductivity Detection</td>
<td>Remove PVC filter from cassette and place in glass vial prior to shipment</td>
</tr>
<tr>
<td>NIOSH 7605, issued 3/03</td>
<td>Personal sampling pump with 37mm diameter PVC filter, 5 µm pore size</td>
<td>1 to 4 LPM, 400L max volume</td>
<td>Ion Chromatography, Post-column Derivatization and UV Detection</td>
<td>Remove PVC filter from cassette and place in glass vial prior to shipment</td>
</tr>
<tr>
<td>OSHA ID-215, issued 6/98</td>
<td>Personal sampling pump with 37mm diameter PVC filter, 5 µm pore size</td>
<td>2 LPM, 960L max volume</td>
<td>Ion Chromatography, UV Detection</td>
<td>If sample is from spray painting, additional extraction required</td>
</tr>
</tbody>
</table>

* Consult an American Industrial Hygiene Association (AIHA) accredited laboratory prior to sample collection.

### References


