Evaluation of Cr(VI) Exposure Levels in the Shipbuilding Industry

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Project Summary

Metal fabrication operations, such as welding, brazing, cutting, painting, and paint removing which are commonly performed at a shipyard, release air pollutants harmful to the health of workers. To protect the health of workers, the Occupational Safety and Health Administration (OSHA) has established permissible exposure levels (PELs) for various air pollutants released in the workplace. OSHA constantly reviews and revises the PELs on regulated air pollutants and establishes new ones for previously unregulated pollutants based on research studies and public petitions. In July 1993, OSHA was petitioned by the Oil, Chemical, and Atomic Workers (OCAW) union to establish an emergency temporary standard (ETS) that would lower the PEL for Cr(VI) from the existing 100 :g/m^3 to between 5 and 0.5 :g/m^3. OSHA is also considering a revision in PELs for 20 air pollutants from a list of 212 air pollutants that, it had originally intended to revise in 1989. Manganese (Mn) and Nickel (Ni) are among the list of these 20 air pollutants.

The anticipated hundred-fold reduction in the existing Cr(VI) PEL is expected to have a considerable impact on the construction and maritime industry. Shipbuilding activities, in particular Navy shipbuilding operations, are expected to be significantly affected by the anticipated Cr(VI) standards. In anticipation of OSHA's final ruling on the Cr(VI) standard, the Navy and some private shipbuilding industries set up a Task Group to assess the impact of the proposed Cr(VI) standards.

In addition to Cr(VI), the Task Group is also evaluating the impact of the proposed Mn and Ni standards on their shipbuilding operations. An initial study undertaken by the Task Group revealed that the anticipated Cr(VI) standards would have a significant impact on their operations, especially welding. During the study, performance of commercially available local exhaust ventilation (LEV) systems in reducing Cr(VI) exposures was also evaluated. The study revealed the estimated cost of compliance to the new Cr(VI) standards to be as much as $46 million/year, besides a one-time cost of about $22 million.

To further strengthen its findings, the Task Group felt the need for collecting additional exposure data on welding fumes. The Task Group approached the University of New Orleans (UNO) for assistance in this project. The Office of Naval Research (ONR) funded the project through the Gulf Coast Maritime Technology Center (GCRMTC) of UNO. The project was spread over two years and the study was conducted at two major shipyards.

In the first year of the project, UNO collaborated with the Newport News Shipyard (NNS) in Virginia to conduct Cr(VI) exposure studies for two specific welding processes, namely, flux-cored arc welding (FCAW) and gas metal arc welding (GMAW). The tests were conducted under controlled laboratory conditions. Performance of two commercially available LEV systems were also evaluated. Due to the limited scope of the study, the researchers determined a need to collect additional Cr(VI) exposure data. Therefore, the main focus of the second year study was to collect Cr(VI) field exposure data for commonly performed welding processes in a shipyard. The safety department of a local shipyard was contemplating a similar study for its welding operations. Taking advantage of the situation, UNO and the local shipyard initiated an exhaustive study which would provide the much needed Cr(VI) exposure data. The study involved evaluating Cr(VI) exposures during welding operations performed at the shipyard and evaluating the effectiveness of two LEV systems, namely, the Nederman Filterbox and the Binzel fume extractor gun, in reducing Cr(VI) exposures. Four welding processes were evaluated for Cr(VI) exposures during this study: FCAW, GMAW, as well as shielded metal arc welding (SMAW), and gas tungsten arc welding (GTAW).

At the end of the second year study it was found that the Nederman Filterbox was effective in reducing total fume levels but not Cr(VI) levels. It was hypothesized that Cr(VI) was present as fine particles in the welding fumes and, therefore, not being captured by the control equipment. To investigate this phenomenon, a particle-size distribution study was proposed as an additional research activity. The project was extended by 8 months at no additional cost. During the extended period, particle size distribution of welding fumes for two specific welding processes was conducted and the effectiveness of the Binzel gun in reducing Cr(VI) and Mn levels was evaluated.

The results of UNO's second year study are summarized as follows:

1. Total fume concentration was found to be highest for FCAW, followed by SMAW, GMAW, and GTAW in that order.

2. Almost all of the FCAW and GTAW samples showed exposures levels below the anticipated Cr(VI) PEL.

3. Exposures to Cr(VI) due to GMAW performed on stainless steel and SMAW performed on mild steel/galvanized steel were higher than the lower limit of the OSHA proposed Cr(VI) PEL of 0.5 :g/m^3 even with the use of controls.

4. The percentage reduction in total fume using the Nederman Filterbox was found to be significant (41.4% and 10.9% for SMAW in open and enclosed/semi-enclosed conditions, respectively). However, the percentage reduction in Cr(VI) was not appreciable for the same scenarios, i. e., 32.6% and 1.9%).

5. Relationships were developed between Cr(VI) and total Cr/total fume to determine Cr(VI) exposures from historical data.

6. Compliance models were developed for different welding processes to determine arc times which would keep shipyards in compliance with the anticipated Cr(VI) PEL.

7. Confidence levels were determined for all these relations to indicate their applicability. Open scenarios presented lower confidence levels due to a variability in ventilation conditions and errors introduced by the analytical equipment at such low concentration levels.

Results of the particle size distribution study are as follows:

1. For GMAW performed on stainless steel, Cr(VI) concentrations were found to be predominant in the fine particle size range (<0.52 micron). The Cr(VI) concentration in this size range accounted for nearly 80% of the total Cr(VI) concentration.

2. For FCAW performed on AH36, manganese concentrations were found to be predominant in coarse (>1.52 micron) and fine (<0.52 micron) particle size ranges. This suggests a bi-modal distribution in manganese concentration.

3. Irrespective of the welding process, total fume also showed maximum concentration in coarse (>1.52 micron) and fine (<0.52 micron) size ranges, thereby indicating a bi-modal distribution.

4. For GMAW performed on stainless steel, the Cr(VI) concentrations were found to be above the upper limit of the proposed OSHA Cr(VI) PEL of 5 :g/m^3 even with the use of the Binzel gun. The overall reduction in Cr(VI) with use of the Binzel gun was found to be between 50% to 70% with the percentage reduction increasing for the size range between 3.5 and 0.93 microns and decreasing below the 0.93 micron size.

5. For FCAW performed on AH36, Mn concentrations were found to be less than the existing OSHA ceiling limit of 5 mg/m^3 with or without use of the Binzel gun. The percentage reduction in Mn with use of the Binzel gun was found to be between 13% to 45% with the percentage reduction increasing up to the seventh stage (>0.93 micron) and decreasing thereafter. The Mn concentration observed was greater than the American Conference of Governmental and Industrial Hygienists (ACGIH) level of 200 :g/m^3 which is expected to be near OSHA's proposed PEL for Mn.

6. The percentage reduction in total fume with use of the Binzel gun was found to be 50% to 80% and 13% to 46% for GMAW on stainless steel and FCAW on AH36, respectively.