

and semipermeable EPC. Participants worked in each EPC under two conditions: a) Drinking ad libitum from the hands-free through-the-gas-mask hydration system, and b) Using typical rest and rehabilitation drinking wherein participants worked until a termination criterion was met, then were removed from the work environment, doffed the EPC, and were permitted to drink as much as desired. Termination criteria were: rectal temperature  $\geq 38.7$  C, HR  $\geq 90\%$  of age-predicted maximum, participant volition, symptom of heat illness, or total trial time equaling four hours. For the impermeable EPC trial, when using the portable hands-free system, participants drank 242% of what they drank during the rest and rehabilitation trial. In the semipermeable EPC, all but two participants were able to work four hours. In the semipermeable EPC participants drank on average 1,267 ml and dehydrated only 0.6% (of bodyweight) compared to 1.5% under the no-hydration condition (no involuntary termination criterion met with semipermeable EPC). Total work times were unchanged between trials for either condition, but there was a trend for work duration in impermeable EPC to be longer when utilizing the through-gas-mask drinking system. Dehydration with through-the-gas-mask hydration was only 21% of that of the rest and rehabilitation impermeable trial and only 41% of that in the semipermeable EPC. Under these conditions, hypohydration was effectively mitigated using the through-the-gas-mask system.

### 143.

**CERTIFICATION OF PPE HAZARD ASSESSMENTS AND TRAINING, A BENCHMARKING SURVEY.** G. Miller, Lawrence Livermore National Laboratory, Livermore, CA.

It became necessary to determine how organizations governed by the Federal OSHA regulation for personal protective equipment (PPE), 29 CFR 1910.132, "certificate" the hazard assessments that underlie PPE selections and the training that PPE users receive. The standard requires certification of both activities. A benchmarking survey was conducted using a questionnaire that was developed for the purpose. The questionnaire was circulated electronically circulated to the full memberships of AIHA's Laboratory Health and Safety, Personal Protective Clothing and Equipment, and Respiratory Protection Committees. The questionnaire was divided into three parts: 1) Defining the type and size of the organization, 2) Determining how PPE hazard assessments are certificated, and 3) Determining how PPE user training is certificated. Responses were received from an array of large and small organizations representing industry, academia, and government. The results show that many organizations find it is necessary to resort to a variety of tools to perform the required hazard analyses (usually a Job Hazard Analysis or similar process), document the decision (often using standard forms, SOPs, or e-mails), and perform the formal certification (often using the tool used to select the PPE or a special form). A variety of tools are also used to pro-

vide training (i.e., stand up and electronic training depending on the type of PPE) and document understanding of the training (usually quizzes and/or practical demonstrations). This work performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

### 144.

**SUSPENSION TOLERANCE IN MEN AND WOMEN WEARING SAFETY HARNESS-ES.** N. Turner, D. Weaver, R. Whisler, J. Zwiener, NIOSH, Morgantown, WV.

Workers wearing full-body safety harnesses are at risk for suspension trauma if they are not rescued in five to 30 minutes after a successfully arrested fall. Suspension trauma, which may be fatal, occurs when a person's legs are immobile in a vertical posture, leading to pooling of blood in the legs and the reduction of return blood flow to the heart. To measure suspension tolerance time, 22 men and 18 women with construction experience were suspended from the front O-ring (CHEST) and back D-ring (BACK) of full body fall-arrest harnesses. Fifteen men and 13 women were then suspended using a newly-developed NIOSH harness accessory which supports the upper legs. There were no significant gender differences in suspension time. Mean suspension times for all subjects were  $24.4 \pm 13.5$  min (range four-60 min) and  $29.2 \pm 12.1$  min (range five-56 min,  $p < 0.05$ ) for the CHEST and BACK conditions, respectively. Medical symptoms were the cause of suspension termination in 69% of CHEST tests and 81% of BACK tests, while suspensions were voluntarily terminated in 28% of CHEST tests and 19% of BACK tests. One subject completed a 60-min CHEST suspension. Mid-thigh circumference changes were 1.4 and 1.9 cm ( $p < 0.05$ ), and changes in minute ventilation were 1.2 and 1.5 L/min for CHEST and BACK, respectively. Suspension time was  $57.9 \pm 5.6$  min (range 39-60 min) for all subjects for the harness accessory test. There were no medical symptoms during tests with the accessory, and 85% of accessory wearers completed 60-min suspensions. There were no significant changes in mid-thigh circumference or minute ventilation with the accessory. These data provide information on tolerance time for wearers of full-body harnesses for standards-setting organizations and demonstrate the potential of a harness accessory to delay or prevent suspension trauma.

Disclaimer: "The findings and conclusions in this abstract have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy."

## Podium Session 120: Engineering and Control Technologies

Papers 145-151

### 145.

**REDUCING RESPIRABLE DUST EXPOSURES OF WORKERS USING AN IMPROVED CLOTHES CLEANING PROCESS.** A. Cecala, D. Pollock, NIOSH, Pittsburgh, PA; A. O'Brien, Unimin Corporation, Winchester, VA; J. Howell, Unimin Corporation, Marston, NC.

A quick, safe, and effective process has been developed that allows workers to clean their dust laden work clothing periodically throughout the day. Contaminated work clothing has been a known major contributor to increased employee respirable dust exposure for many years. This newly designed process is relatively inexpensive and can be easily installed at any operation to allow workers to clean their clothing without contaminating the worker, the work environment, or co-workers to elevated respirable dust levels. This clothes cleaning process uses an air spray manifold to blow dust from a worker's clothing in an enclosed booth. Since the booth is under negative pressure, no dust escapes to contaminate the work environment and or other workers. The worker performing the cleaning process is required to wear a half-mask fit-tested respirator, hearing protection, and full seal goggles. Dust samples taken inside the respirator of test personnel performing the clothes cleaning process showed very minimal to no respirable dust exposure. During field testing, the clothes cleaning process was 10 times faster (taking less than 20 seconds) and was approximately 50% more effective than either the federally approved method of vacuuming, or the most commonly used method of using a single air hose. This new process was developed under a cooperative research effort by National Institute for Occupational Safety and Health (NIOSH) and Unimin Corporation. This clothes cleaning process has tremendous applicability to any industry where workers' clothing becomes contaminated with any type of dust or product.

### 146.

**LABORATORY EVALUATION TO REDUCE RESPIRABLE CRYSTALLINE SILICA DUST WHEN CUTTING CEMENT ROOFING TILES USING A MASONRY SAW.** R. Valladares, W. Sieber, J. Kratzer, CDC/NIOSH, Cincinnati, OH.

Respirable crystalline silica dust exposure in residential roofers is a recently recognized hazard resulting from cutting cement roofing tiles. Roofers, cutting tiles using masonry saws, can be exposed to high concentrations of respirable dust. Silica exposures remain a serious threat to nearly two million U.S. workers. Although it is well established that respiratory diseases associated with exposure to silica dust are preventable, they continue to occur and cause disability or death. The effectiveness of a commercially available local exhaust ventilation (LEV) sys-

tem and a water suppression system to reduce silica exposures were evaluated separately. The LEV system exhausted 500 cubic feet per minute (CFM), while the water suppression system supplied two gallons per minute (GPM) to the saw blade. Using a randomized block design, implemented under laboratory conditions, three trials were conducted (no control, water control, and ventilation control) on two types of cement roofing tiles using the same saw. Each treatment was replicated for a total of eight 30-sec runs per treatment per tile. Analysis of variance was performed using mean concentration levels from each run and control. The use of water controls and ventilation controls resulted in a statistically significant ( $p < 0.05$ ) reduction of mean respirable dust concentrations for each tile. Mean concentrations using the water control were statistically significantly less than that of the ventilation control. The percentage reduction for respirable dust concentrations was 99% for the water control and 91% for the LEV. Water is a good method for reducing crystalline silica exposures. However, water source and disposal requirements, water damage potential, surface discolorations, material expansion, cleanup, and other requirements make use of water in many situations problematic. LEV may be more desirable, but designing a system with a sufficient capture velocity that will control silica concentrations below occupational criteria might be difficult.

#### 147.

**THE PROCESS AND EFFECT OF FORKLIFT ENGINE ADJUSTMENTS ON CARBON MONOXIDE LEVELS IN A WAREHOUSE.** T. Rimmer, University of Arkansas for Medical Sciences, Little Rock, AR; S. Yarnell, Pactiv Corporation, Fresno, CA.

Occupational exposure to carbon monoxide (CO) from liquefied petroleum gas (LPG) powered forklifts is a common concern in warehouse operations. Engine tune-ups of five LPG forklift engines utilizing an exhaust gas probe with CO detection based on either colorimetric tubes or a nondispersive infrared detector were found to be effective in reducing the exhaust concentration from a mean value of 5.0% (range 3.0 to 7.0%) to a mean of 0.82% (range 0.7 to 0.9%). However, the tune-up process utilizing detector tubes was found to be too time consuming to be practical, leaving the use of the infrared instrument as the only viable alternative. As an evaluation of the effect of the emission reduction on warehouse personnel exposures, breathing zone and area CO measurements were made before and after the tune-up process in a large warehouse with no mechanical ventilation. For forklift operator and trailer loading helpers, the observed full-shift time-weighted-average mean reduction was 65% (27.8 ppm to 9.8 ppm,  $n = 5$ ). Area sample concentrations showed a similar mean reduction of 54% (14.2 ppm to 6.5 ppm,  $n = 6$ ). Although the environmental concentration reductions were both practically and statistically significant, they were less than the observed mean exhaust gas concentration reduction of 84%.

#### 148.

**PROFESSIONAL PRACTICE IN MAINTAINING THE ACCURACY, PERFORMANCE AND CALIBRATION OF AIR QUALITY INSTRUMENTS.** E. Hudson, Fluke Corporation, Everett, WA.

Air quality instruments depend on precise, complex and sometimes delicate electronic and mechanical systems. They must operate in changing and challenging environments, yet deliver consistently accurate results. Instrument performance affects the results achieved by the air quality professional and results are directly linked to reputation. Without the ability to measure air quality factors accurately and link measurements to known standards, one may as well hold a wet finger in the air. Yet air quality instruments vary in their inherent accuracy, in the range of environmental conditions in which they stay 'in spec,' and in their stability over time. To be confident in their tools and the data they produce, air quality professionals need to understand:

- What constitutes 'accuracy.' Accuracy vs. uncertainty.
- Traceability to national standards.
- Factors, including time and the environment, that can compromise instrument performance.

IAQ professionals can resolve issues of instrument performance by considering these issues when choosing, operating and maintaining instruments.

- Workload—The instrument's specification must match your requirements.
- Reliability—Ask for a Mean-Time-To-Fail (MTTF) rate.
- Instrument maintenance and calibration—Keep instruments calibrated in accordance with manufacturer's instructions. If renting, ask to see proof of calibration for the instruments you will use.
- Manufacturer support—Can the manufacturer provide support as your needs change? Are in-house experts available?
- Service philosophy—Consider proximity of service center locations, spare parts stocks and availability of service manuals.
- Reputation—How credible are the manufacturer's claims with respect to performance, reliability, and service? Will the company still be in business five years from now?

Conclusion: By understanding the factors that influence instrument performance, choosing instruments carefully, and maintaining them correctly, IAQ professionals can ensure themselves and their employers of accurate data and effective air quality remediation.

#### 149.

**PREMATURE DETERIORATION OF HOSPITAL AIR-HANDLING UNITS.**

S. Rucker, G. Smith, H.C. Nutting Company, Cincinnati, OH.

After installation and fit-up of eleven new air-handling units (AHUs) for a 500,000 SF addition for a major metropolitan hospital, double walled panels of galvanized steel were cor-

roding and insulation inside the panels was water soaked. These conditions prompted an assessment of causation and indoor air quality. Manufacture's representatives recommended replacement of damaged panels without determination of cause. Panel replacement was time consuming and expensive with no assurance of finding all the damage. Is this corrective action appropriate for a health care facility who will assume responsible for equipment maintenance? The failure to identify the source of water and corrosion prevented accurate estimates of maintenance costs. In addition, areas of microscopic damage may have gone undetected, but could become a future problem. At a cost of between \$1,200 and \$2,500 per ton, a 50-ton AHU is approximately \$90,000. Annual preventative maintenance (PM), inclusive of filter changes and belts, can be estimated at 10% of initial costs. Electric operational costs, assuming continuous operation, can be estimated at 20% of initial costs. These expense estimates do not include premature mechanical failure and emphasize the need to identify the source(s) of causation. The results of visual inspection were a useful indicator of exterior corrosion damage, but will fail to identify interstitial damaged inside double wall insulated panels. Drilling holes caused problems with warranty coverage. Thermal imaging was not useful. The options for confirmatory testing of problems with AHU panel assemblies are discussed. The application of tests such as G90 galvanizing, chemical assays of corrosive salts, and microbial induced corrosion are presented, including attributes and limitations. Findings from testing specialized materials are coupled with indoor airborne mold results and presented in a manner that illustrates the link between mechanical systems and indoor air quality.

#### 150.

**ESTIMATING EMISSION FACTORS IN A CAPACITOR FACTORY USING A MODIFIED TWO-ZONE MODEL.** C. Feigley, N. Schnauffer, T. Do, E. Lee, M. Venkatraman, J. Khan, University of South Carolina, Columbia, SC.

Various deterministic models have been used to estimate emission rates and emission factors. Here models were compared for estimating emission factors for isoamyl acetate (IAA) after dipping batches of capacitors to seal them. IAA concentrations were measured on three days with different production rates in the near-field and far-field using both charcoal tubes and diffusive samplers. Supply and exhaust air flowrates, and air speed and direction at various points near the source were measured as well. The two-zone model was selected as most applicable to the workroom studied and was adapted to improve the accuracy of emission rate estimates. This model's standard formulation for concentration in the near field is:  $C = (G/Q) + (G/\beta)$ , where  $C$  is the near-field concentration,  $G$  is emission rate,  $Q$  is the flow of clean air into the workroom, and  $\beta$  is the rate of air exchange between the near and far fields.  $G/Q$ , which represents the far field concentration, was replaced by the average measured concentration upwind of the source. Also,  $\beta$

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