

length of the shift. Data from four workplace protection factor studies on four disposable and two elastomeric half facepiece respirators were analyzed. Each study measured WPFs for three or four sampling periods during the shift on 60 different workers. All studies were conducted in a similar manner: respirators properly selected, fit tested and worn, maintained with respiratory protection programs that met the requirements of 29 CFR 1910.134. When possible the WPF from the first sampling period was compared to the last sampling period. Using a Student's t-test of paired data, the results showed no significant difference in WPFs between sampling periods for all respirators studied ( $p = 0.21$  to  $0.99$ ). The assumption that wearing a respirator at different times during the day does not cause deterioration in performance appears to be correct.

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### WORKPLACE PROTECTION FACTOR STUDY ON A CONTINUOUS FLOW SUPPLIED AIR RESPIRATOR DURING AIRCRAFT SANDING. C. Colton, J. Bidwell, 3M, St. Paul, MN.

The National Institute for Occupational Safety and Health (NIOSH) has recommended an assigned protection factor (APF) of 25 for all loose fitting supplied air respirators. This study evaluated the performance on a continuous flow supplied air respirator equipped with a helmet against zinc in dust during aircraft sanding. Zinc was the most abundant metal. Workplace protection factor (WPF) measurements were determined by simultaneous sampling inside and outside the respirator during the 10-hr work shift. Twenty-seven measurements were collected over four days on four different workers. Inside respirator samples were analyzed for metals by proton induced x-ray emission (PIXE) analysis. Due to the potential for sample overloading, outside respirator samples were analyzed by inductively coupled plasma (ICP) emission spectroscopy. Outside respirator zinc concentrations ranged from 81  $\mu\text{g}/\text{m}^3$  to 415  $\mu\text{g}/\text{m}^3$ . No zinc was detected on any of the inside respirator samples. Using the PIXE detection limit for zinc for inside respirator mass, the geometric mean WPF was greater than 4000 and the fifth percentile WPF was greater than 827. A Monte Carlo simulation, using the sampling data from this study and an assumption that 15% of the in-respirator samples were above the zinc detection limit, predicts a geometric mean WPF greater than 20,000. These results support an APF much greater than the 25 assigned by NIOSH.

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## 176

### NUMERICAL INVESTIGATION OF BREATHING ZONE EXPOSURE TO A REMOTE PARTICULATE SOURCE. J. Richmond-Bryant, M. Flynn, University of North Carolina, Chapel Hill, NC.

Computational fluid dynamics (CFD) can allow the ventilation engineer to predict breathing zone (BZ) concentrations from various constituent sources. In this study, CFD was employed to examine the impact of a remote source on a worker's BZ exposure. A Lagrangian particle-tracking algorithm was combined with a discrete vortex method airflow model to demonstrate the effect of time-dependent vortex shedding on the concentration of particulate

matter in the BZ of a worker. Convective and diffusive airflow behavior was considered. 3.4 micron particles having density of 2.5  $\text{kg}/\text{m}^3$  were released from a line source located ten diameters upstream of the "worker," which was represented by a circular cylinder. A Reynolds number of 5000 was selected for the airflow; this value is appropriate for the low-turbulence environment typical of an industrial setting. The aerosol, having Stokes number on the order of 10-3, was expected to follow the pattern of air movement. Time-averaged particle concentration was computed throughout the computational domain, and the BZ was defined as the square region extending one diameter from the cylinder center.

Analysis of the time-averaged concentration at various times during the simulation reveals that the particles first convect past the near-wake region, which forms directly behind the cylinder. At this time, a void can be seen in the BZ. Particles first collect in a downstream eddy at a high concentration of approximately 7 concentration units, made nondimensional by the upstream particle concentration. Subsequently, the particles diffuse across the wake and back upstream. This diffusion causes the maximum particle concentration to decrease slightly to approximately 5 units; this maximum level is distributed over the mid-wake region. Because the recirculating region encompassing the BZ allows little material to infiltrate, the BZ concentration contains approximately the same amount of material as that found upstream; i.e. a concentration of roughly 1 unit.

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### REPLICATION OF HUMAN TRACHEO-BRONCHIAL HOLLOW AIRWAY MODELS USING A SELECTIVE LASER SINTERING RAPID PROTOTYPING TECHNIQUE. R. Clinkenbeard, D. Johnson, University of Oklahoma Health Science Center, Oklahoma City, OK; R. Parthasarathy, C. Altan, K. Tan, University of Oklahoma, Norman, OK; R. Crawford, S. Park, University of Texas, Austin, TX.

Exposures to toxic or pathogenic aerosols are known to produce adverse health effects. The nature and severity of these effects are often governed in large part by the location and amount of aerosol deposition within the respiratory tract. Morphologically detailed replica hollow lung airway casts are widely used in aerosol deposition research; however, techniques are not currently available which allow replicate deposition studies in identical, morphologically detailed casts produced from a common reference anatomy. The aim of this project was to develop a technique for the precision manufacture of morphologically detailed human tracheo-bronchial airway models based on high-resolution anatomical imaging data. Detailed physical models were produced using the selective laser sintering (SLS) Rapid Prototyping process. Input to the SLS process was a 3D computer model developed by boundary-based 2D to 3D conversion of anatomical images from the original NIH/NLM Visible Human male data set. The SLS process produced replicate models that were identical to one another and corresponded exactly with the anatomical section images, within the limits of the measurement. At least five airway generations were achievable, corresponding to airways less than 2 mm in diameter. It is anticipated that rapid prototyping manufacture of respiratory tract structures based on reference anatomies such as the Visible Male and Visible Female may provide

'gold standard' models for inhaled aerosol deposition studies. Adaptations of the models to represent various disease states may be readily achieved, thereby promoting exploration of pharmaceutical research on targeted drug delivery via inhaled aerosols.

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### LABORATORY EVALUATION OF VENTILATED SHROUDS FOR MORTAR GRINDING. W. Heitbrink, D. Watkins, NIOSH, Cincinnati, OH.

As brick buildings age, mortar deteriorates and needs to be replaced. Before replacing the mortar, the existing mortar is removed to a depth of 1.5 to 3 cm. Typically, an 11-cm diameter grinder, operated at 10,000-12,000 rpm, is used to remove mortar, causing worker exposures to respirable crystalline silica concentrations as high as 10  $\text{mg}/\text{m}^3$ . Also, a tool resembling a router can be used to remove mortar. For four different shrouds, the effect of exhaust flow rate upon respirable dust emissions was experimentally evaluated. To conduct this testing, a small brick wall was built and enclosed in a hall-shaped, ventilated test chamber. The grinder was mounted on a mechanical trolley which moved the grinder horizontally down the wall at constant velocity of approximately 1 m/min and the mortar was removed at a fixed depth cut of 1.2 or 2 cm. A vacuum cleaner equipped with high efficiency filters exhausted air from the shrouds to a location outside of the enclosure. The vacuum cleaner's exhaust air flow was varied by controlling the voltage applied to the vacuum cleaner. An air flow rate of 1.3  $\text{m}^3/\text{sec}$  was drawn through the test chamber and past mixing baffles and into an exhaust duct. A time-of-flight aerosol spectrometer was used to measure the respirable dust concentration in the duct. Dust emissions per volume of mortar removed were plotted as a function of exhaust flow rate. For uncontrolled grinding, respirable dust emissions were 20  $\text{mg}/\text{cm}^3$  of mortar removed. As flow rates increased, respirable dust emissions were reduced to under 0.2 mg of respirable dust per  $\text{cm}^3$  of mortar removed. For the 11-cm diameter grinding wheel and the router, 80 and 40 cfm, respectively, were the minimum exhaust volumes which provided this emission reduction. Further flow rate increases did not provide useful emission reduction.

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### THE EFFECT OF TWO VENTILATION METHODS ON WELD FUME EXPOSURE IN A SHIPYARD CONFINED-SPACE WELDING TASK. S. Wurzelbacher, O. Johnston, S. Hudock, L. Blade, S. Shulman, NIOSH, Cincinnati, OH.

Recent NIOSH studies have indicated that shipyard confined-space welding presents unique fume exposure control problems. Limited options for worker positioning (in reference to the air flow direction) and posture (in regards to the weld fume plume) can significantly affect weld fume exposure, resulting in eight-hour TWAs for PBZ concentrations that exceed evaluation criteria for welding fume and individual metals. To determine the effectiveness of available ventilation options for a specific shipyard, two ventilation methods were studied on three volunteer welders (2 male, 1 female) who performed confined-space stick welding as part of their typical work. The first method, which was currently being employed at the shipyard for this task, was a type of forced turbulence which directed air into the confined space with an electric blower. The second method, which was suggested by NIOSH, involved

local exhaust of the confined space through a newly placed opening in the bulkhead via an air horn. In addition to evaluating ventilation methods, the welders' full shift exposures to welding fume were also assessed. Local exhaust was associated with significantly lower ( $p < .05$ ) PBZ total particulate concentrations than forced turbulence for subjects using the same air horn. Although the performance of air horns varied, the overall reduction due to local exhaust method versus the current method was estimated to be 75 % (two sided confidence limits = 58 %, 85 %). Eight-hour TWAs for PBZ concentrations were determined to exceed evaluation criteria for welding fume (ACGIH: 5 mg/m<sup>3</sup>) and individual metals using either ventilation method. Current PPE (half-face respirator) that was being used provided adequate protection at these levels.

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**CONTROLLING THE AIRBORNE CONCENTRATIONS OF NITROSAMINES THROUGH IMPROVED PROCESS CONTROL AND VENTILATION AT A RUBBER PRODUCTS COMPANY.** F. Boelter, J. Ruhl, Boelter & Yates, Inc., Park Ridge, IL.

A manufacturer of extruded rubber products was challenged to meet an internally established nitrosamine in air concentration of 1 ug/M<sup>3</sup>. Personal and area sampling showed concentrations ranging from 2.5 to 8.5 ug/M<sup>3</sup> for the NDMA isomer. The nitrosamines are created when uncured rubber is extruded and drawn through a 350°F molten nitrate/nitrite salt bath. An evaluation was made to change the salt bath composition and it was concluded that for the cost, little benefit would result without other process control and ventilation changes. The existing ventilation system was comprised of 4,500 CFM of local exhaust on the totally enclosed baths, several wall mounted exhaust fans and 70,000CFM of undistributed makeup air in the 40,000ft<sup>2</sup> facility. With regard to the enclosed salt baths, the air movement was out of the baths into the facility since the volume exhausted was inadequate to overcome the volumetric expansion created by the hot salt baths. The fans were also inadequate to overcome the significant resistive losses due to the system configuration. Also, existing canopy hoods at the bath exit were improper for the application. Consequently, nitrosamine concentration control would need to have been accomplished by dilution in the facility. It was determined that greater than 250,000CFM of general ventilation would be necessary to achieve the 1 ug/M<sup>3</sup> goal. Several experiments were conducted to verify theoretical calculations and a plan established for upgrading the existing systems without adding to the overall general exhaust. The plan called for increasing the volume of salt bath exhaust, distributing the supply air, reducing the number of wall exhaust fans, eliminating the use of man-cooler fans, covering cooling tanks more completely, enclosing the exit of the salt baths, and providing localized spot cooling for workers. Post-modification air sampling results show the modifications were successful in meeting the design objectives.

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**THE EFFECT OF LOCAL EXHAUST VENTILATION CONTROLS ON DUST EXPOSURES DURING MASONRY ACTIVITIES.** G. Croteau, M. Flanagan, N. Seixas, University of Washington, Seattle, WA; S. Guffey, West Virginia University, Morgantown, WV.

This study assessed the effectiveness of commercially available local exhaust ventilation (LEV) systems for controlling respirable dust and crystalline silica exposures during concrete cutting and grinding activities. Work activities were performed by union-sponsored apprentices and included tuck point grinding (angle grinder), surface grinding (surface grinder), paver block and brick cutting (masonry saw) and concrete block cutting (hand-held saw). In a randomized block design, implemented under controlled field conditions, three ventilation rates (0, 30 and 75 CFM) were tested for each tool/LEV system. Each ventilation treatment was replicated three times in random order for a total of nine 15-minute work sessions per study subject. With the exception of the hand-held saw, the use of LEV resulted in a significant ( $p < 0.05$ ) reduction in respirable dust exposure. Mean exposure levels for the 75 CFM treatments were less than that of the 30 CFM treatments; however, differences between these two treatments were only significant for paver block cutting ( $p < 0.01$ ). Although exposure reduction was significant (70 - 90% at the low ventilation rate and 80 - 95% reduction at the high ventilation rate), personal respirable quartz exposures remained very high (1.5 - 2.5 × PEL at the low ventilation rate and 0.5 to 1.5 × PEL at the high ventilation rate). Exposure levels found under actual field conditions would likely be lower due to the intermittent nature of most job tasks. Despite incomplete control, this dust control alternative has merit as it would reduce the risk of workers developing disease, allow workers to use a lower level of respiratory protection, protect workers during short duration work episodes, potentially allow the effective use of administrative controls, reduce exposure to nearby workers and reduce cleanup associated dust exposures. Additional research is planned for determining the effectiveness of LEV under true field conditions.

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**COMPARISON OF MIST GENERATION RATES FOR MICRO-LUBRICATION AND FLOOD APPLICATION OF CUTTING FLUIDS DURING MILLING AND DRILLING.** M. Gressel, S. Shulman, NIOSH, Cincinnati, OH; T. McClure, R. Adams, M. Gugger, Institute of Advanced Manufacturing Sciences, Cincinnati, OH.

While cutting fluids have been used since the mid-1800's, their use and formulation have changed dramatically over the years, for both performance and health and safety reasons. In addition to the potential occupational hazards associated with cutting fluids, disposal of the used cutting fluids is also a concern to many machining operations. Micro-lubrication, also known as near-dry and semi-dry machining, is one approach to reducing the volume of cutting fluids used. More traditional approaches to fluid application have been to flood the part and tool with fluid. Micro-lubrication provides the machining process with a limited amount of cutting fluid as a mist, at flow rates that are orders of magnitude lower than for flooding. One question surrounding micro-lubrication is the impact on occupational exposures to the cutting fluid mist. The primary study objective was to compare the respirable aerosol generation rate of cutting fluids from micro-lubrication and flood application under standardized testing conditions. Two machining processes were studied, milling and drilling, with five different cutting fluids, all soluble oils. Cutting fluid mist was monitored by an Aerodynamic Particle Sizer® sampling from the exhaust duct of the machining cen-

ter's enclosure. Particle sizes 10 mm and smaller were used to calculate the concentrations and mist generation rates. When compared to flood application, micro-lubrication resulted in 16 to 180 times the mist generation for drilling and 4.3 to 5.3 times the rate for milling, depending upon the cutting fluid. These results suggest that mist collection systems are more critical for micro-lubrication than with flood application. In addition, these data also suggest that modification of the micro-lubrication application equipment should be explored to increase the size of the mist applied to the machining interface. Such modifications may lead to reduced mist generation rates for micro-lubrication.

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**LIBRARY OF CONGRESS HALON PROBLEMS.** S. Mallinger, Office of Compliance, Washington, DC.

Halon is a gaseous fire suppression agent used to extinguish fires instead of using water. Buildings containing valuable or rare objects use Halon systems instead of water-based sprinkler systems to minimize any damage that might be done by water from a sprinkler head. Like sprinkler head protection, many Halon systems are fully automatic and are designed to be used safely. They require a significant initial outlay of money for their design and installation and they require periodic maintenance to assure their proper functioning. However, if the individuals in charge of the work areas where Halon systems are installed do not understand their operational limitations, much of the benefit that could be offered by these systems can be compromised and the environment could become hazardous to workers in the immediate vicinity. Many large Halon systems are explosion suppression systems and are designed to suddenly blast the affected area with a minimal concentration of Halon. The Halon works by inerting the gas around the flame by replacing H atoms and OH radicals with bromine and fluorine molecules. However, changes to a room structure can inhibit the spread of the gaseous agent and prevent it from reaching the fire. Leaving too many doors open or not confining the space may allow the agent to dissipate prior to extinguishing the fire. The Library violated all three conditions including lack of maintenance on entire systems, constructing temporary walls inside the designated spaces, and removing door closures off most of the storage vaults. The result is the vault doors stay open all the time. Because since April 1998 Halon and its blends can not be manufactured, a replacement agent or new system is needed. The upgrade will have to address all three existing problems.

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**THE FORMATIVE YEARS: HISTORICAL PERSPECTIVES OF CHILD LABOR REFORM IN THE UNITED STATES.** J. Thelen, Michigan Department of Consumer and Industry Services, Lansing, MI.

Step back one hundred years into the shoes of immigrant children and social reformers. Life was difficult for immigrant families trying to survive in their new country. All members of immigrant families were expected to contribute to the family income. Children as young as four years old labored

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# ABSTRACTS