employees and patients may experience nausea, dizziness, dermatitis, and eye and respiratory irritation through exposure to directly humidified air. The University of Minnesota used a process hazard analysis (PHA) to review proposals for adding amines, and determine potential faults that could lead to overdosing. The PHA provided assurance that University staff and patients in the nearby teaching hospital would not be exposed to significant amounts of amines in air. **Problem(s).** Staff reluctance to addition of amines was paramount because of concerns for sensitive patients and research being affected. The hospital uses 15% of about 22,000 pounds per hour of peak steam usage as humidification during the coldest time periods. **Resolution.** Health effects with amines have tended to occur when the chemicals are being added by slug feeding rather than by proportioning to steam amounts. Installation of a real-time monitor, precise feed pumps, and control systems were specified. The control equipment will respond quickly to excursions in amine concentrations measured downstream from the injection point. **Benefit.** PHA has typically been used for the most hazardous processes, as required by OSHA's Process Safety Management Standard. We learned that failure analysis was useful for assessing the control measures planned for a less hazardous process, but one that has a potentially large impact across a university campus.

206.

REDUCING ENCLOSED CAB DRILL OPERATOR'S RESPIRABLE DUST EXPOSURE WITH EFFECTIVE FILTRATION AND PRESSURIZATION TECHNIQUES. A. Cecala, J. Organiscak, J. Zimmer, NIOSH, Pittsburgh, PA; W. Heitbrink, University of Iowa, Iowa City, IA; E. Moyer, NIOSH, Morgantown, WV; M. Schmitz, E. Ahrenholtz, Clean Air Filter Company, Defiance, IA; C. Coppock, Red Dot Corporation, Seattle, WA; E. Andrews, U.S. Silica Co./Better Minerals & Aggregates Co., Midlothian, TX.

Many types of surface mining equipment use enclosed cabs to protect equipment operators from health and safety hazards. The overburden removal and mining process can be extremely dusty and can cause excessive dust exposures to workers. A cooperative research effort was established between the National Institute for Occupational Safety and Health, U.S. Silica Company, Clean Air Filter Company, and Red Dot Corporation in an effort to lower an operator's respirable dust exposure while working in an enclosed cab on an older surface drill. Since this study was performed at a silica sand operation, crystalline silica was the most prevalent dust being liberated and thus, there was a need to maximize dust protection for workers. Throughout this research effort, a number of changes were incorporated into the drill's filtration and pressurization system, as well as in other areas to improve its design and performance. Comparing gravimetric sampling taken on the outside and inside of the cab on the final design showed a substantial reduction with an average "cab efficiency"of 93.4 percent. This research was not intended to be a case study but to identify improvements that can be universally implemented on all types of enclosed cabs to reduce respirable dust concentrations. Critical components for an effective enclosed cab system are having a properly designed, installed, and maintained filtration and pressurization system, maintaining structural cab integrity, which allows it to be positively pressurized, and maintaining cab cleanliness. Although this research was originally directed toward the mining industry, it is also applicable to agricultural or construction equipment. By minimizing respirable dust levels inside enclosed cabs, the potential for workers developing silicosis or other debilitating lung diseases can be significantly decreased.

207.

EVALUATION OF LOW-FUMING ASPHALT TO REDUCE WORKER ASPHALT FUME EXPOSURE DURING BUILT-UP ROOF INSTALLATION. D. Marlow, T. Jennifer, NIOSH, Cincinnati, OH.

Asphalt fumes exposure can cause irritation of the eyes, nose, and throat. Recent studies also report evidence of acute lower respiratory tract symptoms among workers exposed to asphalt fumes. Engineering controls to reduce asphalt fume emissions from the roofing kettle are available, but none have been evaluated for their effectiveness in reducing workers' exposure. Recently, NIOSH researchers conducted a study on the use and effectiveness of low-fuming roofing asphalt as an engineering control. The results are presented here.

Four industrial hygiene surveys were conducted to evaluate the effectiveness of using low-fuming asphalt to reduce worker exposure to asphalt fumes during asphalt roofing operations. Personal breathing zone samples were collected and analyzed for total particulates (TP), benzene-soluble fraction (BSF) of the TP, and polycyclic aromatic compounds (PAC). The combined results from the four surveys showed that the kettle operators' TP, BSF, and PAC exposures were reduced by 75%, 85%, and 77%, respectively. All of these reductions were statistically significant at 95% confidence. The combined results from the four surveys showed that the roof level workers' TP, BSF, and PAC exposures were reduced by 28%, 25%, and 27%, respectively. None of these reductions, however, were statistically significant at 95% confidence.

The use of low-fuming asphalt in asphalt roofing kettle reduces the kettle operator's exposure to asphalt fumes by 75%. With a slight increase in the cost of the asphalt and no changes to the kettle, any contractor can significantly reduce worker exposure to asphalt fumes.

208.

DETERMINING AIR EXCHANGE RATES IN SCHOOLS THROUGH CARBON DIOXIDE MONITORING. C. Feigley, D. Salzberg, B. Childers, R. Semeniuc, University of South Carolina, Columbia, SC.

The outdoor air exchange rate (AER) is a fundamental determinate of indoor air quality. Here, three methods for estimating AERs in occupied rooms were compared using data from seven elementary school rooms over a 3-week period. The percent outdoor air (OA) method calculates the AER as the product of measured supply air flowrate and percent outdoor air. The physical attributes (PA) method first estimates CO_2 emissions from occupant activity levels and body surface areas, then calculates AER by mass balance using measured CO_2 concentrations. The CO_2 method estimates the emission and AERs from CO_2 measurements by nonlinear least-squares. AER was estimated once for the 14-day sampling period in each room by the OA method, while daily values were determined by the PA and CO_2 methods.

The overall average AERs (±SD) were 118±92, 150±53, and 126±46 m^3/h [illegible] PA, and CO_2 me[illegible] "snapshot" AER. [illegible] only outdoor air e[illegible] HVAC sytem is es[illegible] methods estimate [illegible] sources. PA-method AERs were significantly higher than CO_2-method AERs for three classrooms, and lower for one. [illegible] method does nc[illegible] room occupanc[illegible] jective estimate[illegible] physical activit[illegible] computes an AER for the entire school day based upon all 10-minute measurements during the day; whereas the PA method uses hourly measurements to estimate average AERs. In conclusion, both the PA and CO_2 methods were preferred over the OA method; and the CO_2 method requires less field time and has fewer assumptions than the PA method.

209.

EFFECT OF INLET AND EXHAUST LOCATIONS AND DENSITY OF CONTAMINANT GAS ON INDOOR AIR CONTAMINANT CONCENTRATION. M. Ahmed, S. Tamanna, E. Lee, C. Fiegley, J. Khan, University of South Carolina, Columbia, SC.

The steady-state contaminant concentration in a workroom is a function of several factors, two of the most important of which are the relative position and type of the ventilation inlets and exhausts. Here, several different inlet and exhaust locations and types (with or without diffuser) were investigated using computational fluid dynamics (CFD) simulations to determine the best locations for a source at the room's center. Other variables studied were the contaminant gas density and dilution air flow rates in air changes per hour (ACH). Room average, average breathing zone, and near-source

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