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Use of Methanol as a Coolant During Machining of Aluminum in a Shipbuilding Environment: A Failure to Assess and Manage Risk

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Abstract. Minimization of harm during the conduct of work is one of the most important tenets of industrial hygiene. Organizations make changes to solve perceived problems. What appears to be expedient for solving a problem can create serious risks totally unrecognized by the proponent. This investigation reports on such a situation involving the use of methanol as a lubricant during machining of aluminium panels using a router. Spot samples for methanol were measured using colorimetric detector tubes and samples of long duration by colorimetric diffusion tubes utilizing similar chemistry. Both were positioned in the breathing zone. Most of the spot samples exceeded the 8-hour TLV-TWA (Threshold Limit Value–Time-Weighted Average) of 200 ppm and the TLV-STEL (Short-Term Exposure Limit) of 250 ppm. The two long duration samples also exceeded the TLV-TWA. A change in the operation prevented collection of additional long duration samples. By these measures, workers were overexposed to methanol during this activity. An additional serious consequence from use of methanol in this manner was risk of fire. This situation illustrates the complexity of decisions affecting workplace operations. What appears to be expedient for solving a problem may be totally inappropriate..

Introduction

Minimization of harm during the conduct of work is one of the most important tenets of industrial hygiene [1], [2]. This concept functions through application of the hierarchy of control. In descending order, the hierarchy mandates substitution, engineering controls, work practices, administrative controls, and personal protective equipment.

As often is the case, the hierarchy of control is applied after discovery of a situation in which a problem exists or is suspected. This approach to management of the workplace is reactive and not proactive. Accident prevention in such circumstances depends extensively on the element of luck.

Hazard communication and other initiatives world-wide attempt to reverse this situation [3]. (Material) Safety Data Sheets contain extensive information about the physical, chemical, and toxicological hazards of substances and products used in the workplace. They also provide the means for protection against harmful use.

Organizations often make changes because they must do so following the threat of sanction. Fortunate are the organizations that employ individuals to audit and investigate the system of work on the shop floor in an attempt to discover inappropriate choices prior to identification during inspection by a regulatory authority and imposition of sanctions or worse, occurrence of a calamitous event.

This document illustrates these concepts through a situation that occurred at a shipyard engaged in fabrication of large structures and vessels from aluminum. Some of this work involved machining and saw cutting. At some level, someone learned that methanol [CAS: 67-56-1] was suitable for use as a lubricant/coolant because of rapid, residue-free, evaporation The decision to use methanol occurred in the absence of consideration about its physical, chemical, and toxicological properties.

Small quantities were used infrequently by a number of individuals. The largest and most frequent use occurred during machining using a router to bevel the edges of metal used in frames (transverse structures used to provide the shape of the hull). The panels used in the frames were 6 mm and 10 mm in thickness. The 6 mm panels required a single pass of the router. A single pass required 5 to 10 minutes. The 10 mm panels required two passes, one in each direction. Completion of both passes in large frames containing 10 mm panels required 20 to 25 minutes. Total exposure time was about 1.5 hours per shift.

An assistant sprayed methanol from a hand-operated spray bottle into the region of the rotating bit and onto the metal in the path of the cut. The assistant and the router operator worked close to the wetted surfaces.

Materials and Methods

Spot and shift-length samples were measured using colorimetric detector tubes. Spot samples were measured using Alcohol 25/a tubes (Dräger Safety, Pittsburgh (PA), Cat. # 8101631). These tubes are multipurpose for alcohols and contain a dedicated scale for methanol. Shift-length samples were measured using Ethanol 1000/a-D diffusion tubes (Dräger Safety, Pittsburgh PA, Cat. # 8101151). The documentation for these tubes provides a conversion for exposure involving methanol.

All samples were obtained in the breathing zone on the lapel just outside the faceshield worn during operation of this equipment. These tubes contain aggressive chemistry involving chromate reduction. There were no obvious interferences in the vicinity to bias the readings [4].

Measurement of spot samples required at least 5 minutes. This precluded assessment of exposure of casual users of methanol in activities, such as sawing. However, assessment during machining using a router, where the geometry is similar, should provide a reasonable estimate of concentration during activities of short duration.

Statistical calculation was performed using IHDA-LE (Industrial Hygiene Data Analyst – Lite Edition, Version 1.25) published by Exposure Assessment Solutions, Inc., Morgantown, WV)

Results and Discussion

Table 1 provides results from spot sampling for methanol. Statistical calculation indicated that the lognormal distribution applies to both samples. Lognormal distributions typically model industrial hygiene data [5].

Table 1. Spot Samples for Methanol

Description	Measured Concentrations [ppm]	Geometric Mean [ppm]	Geometric Standard Deviation
Router operator	100, 700, 600, 1500, 300, 500, 500, 500, 500, 50, 750, 200, 1000	409	2.5
Helper	400, 300, 500, 700	453	1.4

Most of the spot samples and the geometric means exceeded the 8-hour Threshold Limit Value – Time-Weighted Average (TLV–TWA) of 200 ppm and the 15-minute Threshold Limit Value –

Short-Term Exposure Limit of 250 ppm for methanol [6]. Many jurisdictions have adopted these values as regulatory limits. The TLV paradigm limits short-term exposures at the TLV−STEL to no more than four per 8-hour shift. By this measure, the workers are overexposed to methanol vapour during this work.

Methanol carries a ‘Skin’ designation [6]. The Skin designation indicates that the substance can cause significant exposure by passage through intact skin.

A change in work practices limited collection to only two long-duration samples. Time-weighted average exposures of the router operator and helper during the duration of the samples were 286 ppm (2000 ppm•h/ 7.0 h) and 261 ppm (1750 ppm•h/ 6.7 h), respectively. These values are consistent with levels measured during spot samples. By this measure, the router operator and helper likely were overexposed to methanol vapor during this work.

Both individuals wore half-facepiece respirators equipped with pancake-style filter pads containing a layer of charcoal impregnated material under the faceshield. Protection against organic vapors of alcohols normally requires use of a cartridge containing activated charcoal, NIOSH-approved for this purpose. However, the service life of organic vapour cartridges against methanol is very short [7].

Methanol also provides poor warning properties to the senses. In this context, warning properties include odour, taste and eye or respiratory irritation. The odor threshold for methanol ranges from 4 to 6,000 ppm [8]. While many individuals in the population would be able to detect methanol at levels well below the 8-hour TLV-TWA of 200 ppm, many others would not. For this reason, organizations such as NIOSH that set standards for respiratory protection recommend against use of organic vapor cartridges in this application [9].

Another issue with the use of methanol in this situation is fire. The flash point of methanol is 11 ℃ (53 ℉) [10]. This is less than the normal temperature in the building where the work was occurring. This means that under appropriate conditions of geometry an ignitable vapor-air mixture can develop. Mists containing methanol are ignitable at temperatures below the flash point. Both vapor clouds and mists can develop during hand spraying and the rotating action of the router.

The vapor pressure of methanol at room temperature is 96 mmHg (millimetres of mercury) [10]. NIOSH indicates this as being a high vapor pressure. Methanol is highly volatile and readily forms ignitable mixtures.

The minimum spark ignition energy of a methanol-air mixture is 0.14 mJ (millijoules) [11]. The corresponding minimum spark ignition energy of hydrocarbon-air mixtures is about twice the value for methanol. The autoignition temperature of methanol is 385° C [12]. The corresponding autoignition temperature of gasoline is about 440° C [11].

Possible ignition sources include hot metal surfaces and arcs generated by the motor in electrical equipment such as the router. Vents in the casing of the router permit exposure of the arc to the methanol-air mixture. As this equipment ages, arcing involving electrical contacts is increasingly likely to occur and to become more severe. Other potential causes of arcing include failed insulation and broken contacts. The latter can occur through inappropriate practice in handling portable power tools of raising and lowering by the electrical cord. The operator of one tool was observed to twist the cord in order to establish electrical contact.

The need for fire prevention directly conflicts with the use of highly volatile flammable solvents for lubrication during the machining of aluminum. One option for ending this conflict is to eliminate the use of lubricants. Another is to reduce the flammability of the lubricant. The latter may be achievable through the use of water-alcohol blends. Distilled or deionized water should leave no residue on the aluminum. To illustrate, rubbing alcohol sold for consumer use is a 70% solution of isopropyl alcohol and water. Even with 30% water content, this solution is highly volatile and dries rapidly without leaving a residue. Further dilution along with acceptable performance likely is possible.

This situation illustrates the complexity of decisions affecting workplace operations. What appears to be expedient for solving a problem can create serious risks totally unrecognized by the proponent.

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