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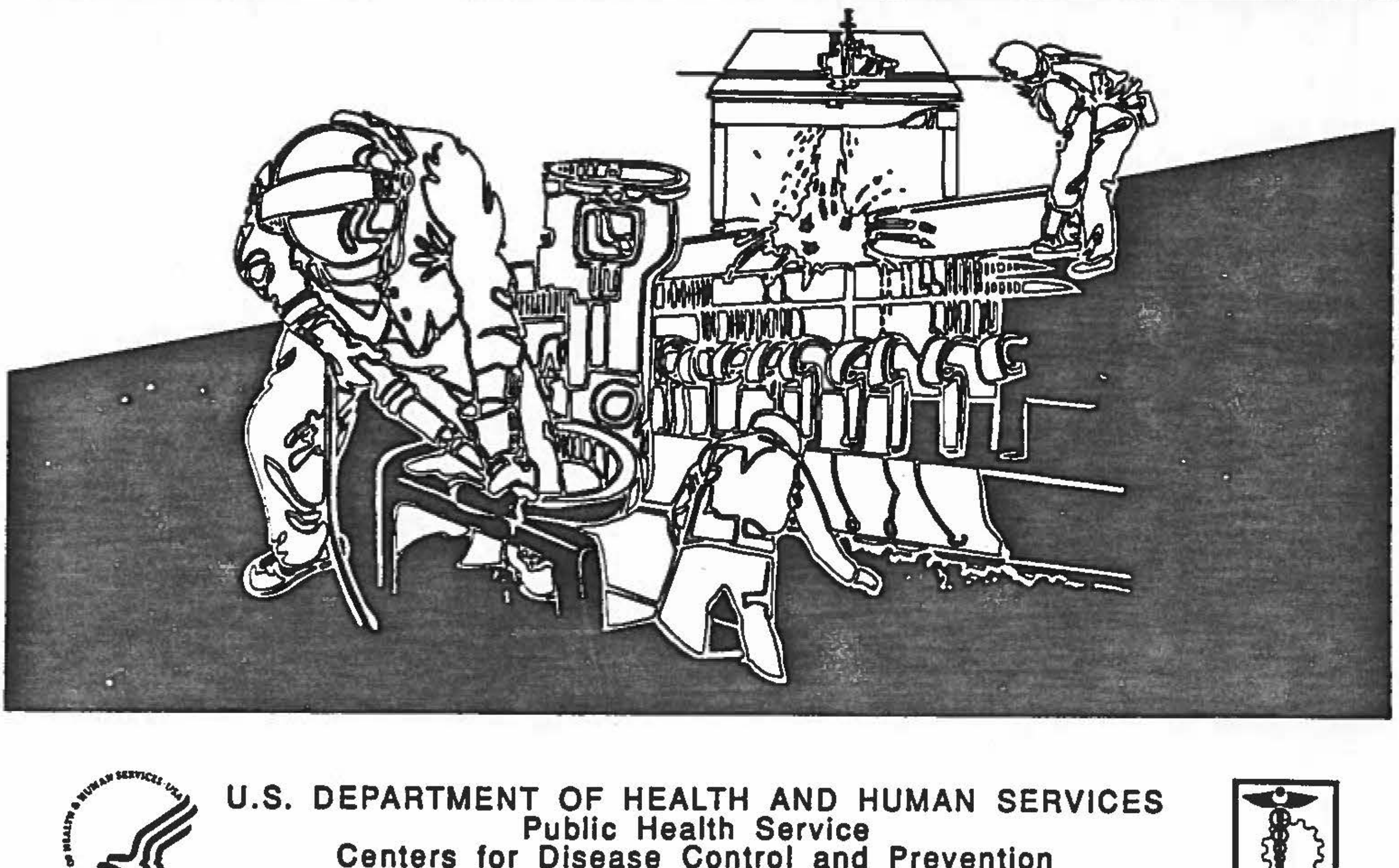
CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 90-0286-2428
KAISER ALUMINUM, TRENTWOOD WORKS
SPOKANE, WASHINGTON



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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PREFACE

The Hazard Evaluation and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 660(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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SUMMARY

In May 1990, the National Institute for Occupational Safety and Health (NIOSH) received an employer request to conduct a health hazard evaluation (HHE) at Kaiser Aluminum, Trentwood Works, located in Spokane, Washington. The request expressed concern about exposures to the metalworking coolants used to cool and lubricate hot aluminum ingots as they are reduced in thickness in the Hot Line Department. The requestor stated that a large number of employees in the Hot Line Department are exposed to the coolant mist and complain of skin, eye and throat irritation. and that isolated respiratory problems have been documented.

In August 1990, a NIOSH industrial hygienist made an initial site visit to the Trentwood facility to conduct a walk-through survey of the plant. During March 12-27, 1991, a medical and industrial hygiene survey was conducted. The medical portion of the survey was designed to identify Hot Line employees exhibiting acute airway responses and chronic respiratory effects by means of a questionnaire, cross-shift spirometry, and serial peak flow monitoring. The dermatological effects of coolant exposure were also examined. The industrial hygiene portion of the survey consisted of collecting personal breathing zone and area air samples to characterize the make-up of the aerosols generated in the Hot Line Department and determine potential worker exposures.

This investigation identified 11 participants that had acute, work-related respiratory effects as defined by the results of the questionnaire, cross-shift spirometry, or serial peak flow measurements. Six participants reported at least one work-related acute respiratory symptom, one participant had a cross-shift decrease in FEV_1 of greater than 10%, and four exhibited a ≥ 20% change in peak flow temporally associated with work. No specific Hot Line jobs or work areas appeared to be associated with these effects.

Seventy percent of participating production workers, and 54% of maintenance workers reported experiencing eye irritation (red, itchy, or watery eyes) on more than two occasions in the 12 months preceding the evaluation. The prevalence of skin irritation (a report of rash, dermatitis, hives, or eczema) among maintenance workers was 44%, and 19% among production workers for the same time period. A similar pattern emerged when work-related criteria were applied: the prevalence of eye irritation was

higher among production workers while the prevalence of skin irritation was higher among maintenance workers.

The workers throughout the Hot Line Department are exposed to the mist/aerosol of the metalworking coolant solution. The coolant is a soluble oil, water-based fluid. Review of the Material Safety Data Sheets (MSDSs), general literature, and analysis of the coolant indicated potential exposure to chemicals such as aldehydes (formaldehyde, glutaraldehyde), triethanolamine, diethanolamine, isothizaolinone (Kathon MW886), nitrosamines, and bacteria. Many are either irritants or sensitizers, known to cause rhinitis, acute respiratory symptoms such as chest tightness, and occupational asthma. However, no specific exposures to the chemicals used in the metalworking coolant were measured in excess of evaluation criteria. Recommendations to control exposures are made in this report.

Although the industrial hygiene survey results did not indicate an overexposure to specific substances contained in the coolant at the time of our survey, it was obvious from visual observation that the workers throughout the Hot Line Department were exposed to the mist/aerosol of the metalworking coolant. The coolant mist contains numerous substances which are known to cause acute respiratory effects and pulmonary impairment, and/or irritant or allergic dermatitis.

The high prevalence of reported work-related eye irritation among production workers and skin irritation among maintenance workers indicates a need to institute measures to reduce their exposures to the coolant.

Keywords: SIC 3355, metalworking, coolant, biocides, aluminum, spirometry, irritation, dermatitis, chest tightness, peak flow, glutaraldehyde, rolling coolant, endotoxins, microorganisms.

INTRODUCTION

In May 1990, the National Institute for Occupational Safety and Health (NIOSH) received a management request from Kaiser Aluminum, Trentwood Works for a health hazard evaluation. This request asked NIOSH to characterize both chemical and biological exposures from coolants used in the Hot Line Department.

The Trentwood facility was built in 1942. It is located on 500 acres on the northeast side of Spokane, Washington, and has approximately 70 acres of building space. It has approximately 1,800 employees (includes hourly and salaried). There are 3 work shifts per day (7-3, 3-11, 11-7). The major products are aluminum sheet and plate for beverage can production, commercial and private aircraft, and building products. The Hot Line Department was the main area of concern for this HHE.

In August 1990, a NIOSH industrial hygienist made an initial site visit to the Trentwood facility to conduct a walk-through survey of the plant and interview employees. All 21 workers interviewed reported eye irritation, respiratory irritation, and/or skin irritation. In particular, these employees reported experiencing a measles - like rash on the lower part of their legs, in the calf and ankle area. Occasionally, the rash would occur on the arms and face. These effects were reported to be worse after biocide was added to the coolant, and improved when away from work.

During March 12-27, 1991, a medical and industrial hygiene survey was conducted. The medical portion of the survey was designed to identify Hot Line employees exhibiting acute airway responses and chronic respiratory effects by means of a questionnaire, cross-shift spirometry, and serial peak flow monitoring. The dermatological effects of coolant exposure were also examined. The industrial hygiene portion of the survey consisted of collecting personal breathing zone and area air samples to characterize the make-up of the aerosols generated in the Hot Line Department and determine potential worker exposures.

An interim report containing the results of the industrial hygiene survey was issued by NIOSH in December 1991. Personal results of spirometry testing were provided to individual workers in June 1991 and peak flow meter results were provided in July 1992.

PROCESS DESCRIPTION

Remelt

Molten or sowed aluminum is combined with mill-generated scrap in 80,000 pound capacity melting furnaces. Alloying materials, such as silicon, iron, copper, manganese, magnesium, chromium, and zinc are added to produce various aluminum alloys.

From these furnaces the aluminum alloys are cast into ingots, weighing as much as 43,000 pounds. These ingots are either cast using a chill process in which water sprays solidify the molten metal as it passes through a sleeve-like mold or by a newly developed process of electromagnetic casting in which the ingot is formed by casting through an electromagnetic mold.

Scalping and Soaking

Cast ingots are "scalped," a process in which approximately one-quarter inch of the surface is removed to produce a smooth rolling surface. Electromagnetically cast ingots do not require the scalping process. The scalped ingots are then soaked in a temperature bath in large pits, a homogenization process necessary to obtain proper metallurgical properties and to achieve rolling temperature, or processed through the Pusher furnace.

Hot Line

Ingots are transferred to the 132" reversing mill in which they are reduced into a long slab, approximately 6 inches thick. This ingot then passes to a 112" reversing mill, which further reduces the thickness to approximately 1 inch. Length increases proportionately as thickness is reduced. At this point, plate products with a finish gauge of 0.8 inches and over are removed from the line, their rolling process is complete.

Other product application ingots continue to a 5-stand 80"-wide tandem mill in which the final hot rolling reduction occurs in a single pass. The 80"-mill was a major portion of a mill-wide modernization project completed in 1983-84. Ingots from the 80"-mill are normally wrapped into coil form.

On the Hot Line, metalworking coolants (soluble oil, water-based cutting fluids) are used to cool and lubricate hot aluminum ingots (800°-900°F) as they are reduced by the mills. This operation releases large quantities of coolant mist into the work area. The coolant composition according to plant officials and MSDS is:

Demineralized Water - 93%
White Mineral Oil
Various Proprietary Additives
Various Metalworking Fluids
Biocides - Glutaraldehyde, Isothiazolinone (Kathon MW886)

There are approximately 150 workers (hourly and salaried combined) employed in either maintenance or production, in the Hot Line Department. The number of employees are evenly distributed between these two job classifications.

Annealing

To enable further reduction of thickness, most coils are annealed in large furnaces to soften the metal.

Cold Rolling

Cooled to room temperature, coils are then cold rolled in one of five cold mills to achieve finish gauge. The 5-stand tandem cold mill is a computer controlled mill which has the capability of continuous operation. A welder automatically joins coils for a continuous operation.

Heat Treating

Hardness and strength are imparted to the metal through heat treatment as well as cold rolling. Heat treatment occurs in either the vertical, horizontal, or continuous heat treat furnaces. In the two continuous heat treat lines, a continuous sheet of metal passes through the furnaces, floated on a cushion of air to free the metal from contact marks and scratches. Following heating, the metal is quenched with water to impart special strength characteristics.

Finishing and Processing

Heavy plate is heat-treated in the Salem Furnace. Sheet is also processed through the 2-High Department, where it is passed through the 2-high mill, removing buckles caused by the heat treating process. The desired finish is also imparted to these sheets, depending on the angle of entry and roll pressure.

The Can Line Department consists of a continuous coil processing line where the metal is trimmed, leveled, and passed through five staging tanks. In the first tank, the metal is degreased; second tank, rinsed; third tank, conversion coated; fourth tank, water rinsed; and fifth tank, hot water rinsed. This line is similar to the 5-stand cold mill in that it runs continuously. Metal is also processed through the coater line, where it is degreased (washed), conversion coated (acid-etched), and painted. The metal passes through four oven temperature zones after painting.

Aluminum plate is also sawed to proper dimensions in the plate saw area. Aluminum coil is normally slit into various widths by coil slitters, a part of the Finish Mill Department. Also in Finishing, aluminum plate may be stretched which further flattens the metal, removing buckles and relieving internal stress caused by thermocouple deficiencies during the quenching process. The largest stretcher has an 8 1/2 million-pound pull, which may stretch a 3" plate as much as 6."

Inspection and Shipping

Final checks are made of metallurgical quality as well as physical appearance. In heavy plate product uses, plates are immersed in a tank of water and sonically tested with sound vibrations to locate inclusions and internal defects. Coils are wrapped and flat sheet banded and packaged for shipment either by truck or rail.

METHODS

Industrial Hygiene

It was apparent that the workers in the Hot Line Department were exposed to the mist/aerosol of the metalworking coolant. The Material Safety Data Sheet (MSDS) for practically every substance used in the coolant states that exposures to the mist may cause irritation, especially to the mucous membranes of the upper respiratory tract. Review of the MSDSs, general literature, and qualitative analysis of the coolant indicate potential exposure to many chemicals. These chemicals include aldehydes (formaldehyde, glutaraldehyde), triethanolamine, isothizaolinone (Kathon MW886), diethanolamine, and possibly nitrosamines.

Biohazards of the coolant mist are also recognized. While biocides are used to suppress the bacterial growth in the coolant, they are not always effective. The control of microbial populations in metalworking fluids is related to the type of fluid, size of the system, and metalworking operation. Three major groups of organisms have attracted attention in the metalworking industry. These are obligative anaerobic sulfate reducers, more specifically *Desulfovibrio desulfuricans*; aerobic bacteria, especially *Pseudomonas* species and coliforms; and imperfect fungi, including members of the genus *Fusarium*, *Cephalosporium*, and *Candida*.[1]

Environmentally ubiquitous species such as *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* are found not only in the fluid but also in aerosols from metalworking operations; however, the latter organism survives poorly in mists.[1]

Bacterial levels in metalworking fluids from 10^5 to 10^7/ml have been accepted as reasonable. This figure applies to the aerobic bacterial population and does not include either the anaerobic sulfate-reducing bacteria or the fungi.[1]

Other potential exposures, not necessarily expected in the Hot Line Department, but in adjacent areas (operations) were chlorine, alloying metals, sulfur dioxide, and hydrogen chloride.

The industrial hygiene assessment attempted to characterize the physical, chemical, and biological make-up of the aerosols generated in the Hot Line Department and determine potential worker exposures. To accomplish this, both area and personal monitoring were conducted. Area sampling stations were located within the Hot Line Department. Each station was monitored the full 8 hour shift and contained sampling devices for formaldehyde, glutaraldehyde, amineoethanol compounds (triethanolamine, diethamolamine), nitrosamines, metals, chlorine, sulfur dioxide, hydrogen chloride, respirable aerosols (endotoxin analysis), and inspirable aerosols (endotoxin analysis). Samples for viable microorganisms were also collected at five of the stations. Personal sampling for respirable and inspirable endotoxins were also collected. Sampling for mineral oil mist per NIOSH Method 5026 was not conducted because the method is not applicable to synthetic or semi-synthetic fluids as used in this operation.

Sampling and analytical methods used in this evaluation are presented in summary form in Table 1.[2-8]

Medical

All workers (hourly and salaried) assigned to the Hot Line Department were invited to participate in the medical survey. The medical survey was designed to identify workers exhibiting acute and chronic respiratory effects related to coolant exposure on the hot line. The dermatological effects of coolant exposure were also examined. Three methods were used to evaluate workers for possible health effects: 1) a supervised, self-administered questionnaire; 2) cross-shift spirometry performed on the last day of the participant's work week and again on the first day of the following work week; and 3) serial peak expiratory flow monitoring.

Questionnaire

A modified version of the Medical Research Council (MRC) questionnaire[9] on respiratory symptoms, supplemented with questions concerning asthma and acute respiratory symptoms, dermatological symptoms, smoking habits, and demographic information was distributed to each worker for self-administration upon receipt of a signed consent at an informational meeting. The questionnaire was reviewed and work history obtained by a trained NIOSH employee when the participant returned for spirometry.

The following definitions were established for the purpose of questionnaire analysis:

ACUTE RESPIRATORY SYMPTOMS	
Wheeze	wheezing or whistling in the chest other than that associated with a cold.
Attacks of shortness of breath with wheezing or whistling	any previous attack.
Attack of shortness of breath or cough	Unprovoked shortness of breath or cough in the last year with indication that either were the most troublesome symptom.
CHRONIC RESPIRATORY SYMPTOMS	
Chronic cough	a cough on most days for as much as 3 months during the year.
Chronic phlegm	the production of phlegm on most days for as much as 3 months during the year.
Chronic Bronchitis	cough and phlegm on most days for as much as 3 months for 2 or more years.
Chronic shortness of breath	shortness of breath walking with similar age individuals on level ground.
OTHER SYMPTOMS	
Rhinitis	blocked, itchy, or runny nose on 2 or more occasions within the past 12 months.
Eye irritation	red, itchy, or watery eyes on more than two occasions within the past 12 months.
Skin Irritation	a report of skin rash, dermatitis, hives, or eczema during the previous year.

Eye and skin irritation, rhinitis, and acute symptoms, including chest tightness, were determined to be work related if participants reported either occasional or routine exposure to metal working fluids or coolants, symptoms began after starting work at

Kaiser Aluminum, and were reportedly brought on or exacerbated by exposures at work, and improved when away from work.

Spirometry

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. At least five maximal expiratory maneuvers were recorded for each person each time spirometry was performed. All values were corrected to BTPS (body temperature, ambient pressure, saturated with water vapor). The largest forced vital capacity (FVC), and forced expiratory volume in one second (FEV_1) were the parameters selected for analysis, regardless of the curves on which they occurred. Testing procedures conformed to the American Thoracic Society's recommendations for spirometry.[10] Predicted values were calculated using the Knudson reference equations.[11] Predicted values for blacks were determined by multiplying the value predicted by the Knudson equation by 0.85.[12] Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry patterns of obstruction and restriction.[11] Five percent of the population will have predicted values that fall below the normal range, or LLN, while 95% will have predicted values above the lower limit.

Using this comparison, obstructive and restrictive patterns are defined as:

Obstruction: Observed ratio of FEV_1/FVC% below the LLN.
Restriction: Observed FVC below the LLN; and FEV_1/FVC% above the LLN.

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, is based on the NIOSH classification scheme (available upon request from the Division of Respiratory Disease Studies). For those persons with values below the LLN, the criteria are:

Classification	Obstruction (FEV_1/FVC x 100)	Restriction (% Predicted FVC)
Mild	>60	> 65
Moderate	≥ 45 to ≤ 60	≥ 51 to ≤ 65
Severe	< 45	< 51

Cross-shift spirometry was used to document acute airway response and was performed pre- and post-shift on the last day of the participant's work week and again on the first day of the following work week. A decrement of 10% or greater in FEV_1 across a work shift on either the last day of the work week or the first day, or an improvement of 10% or greater over a weekend (weekend improvement) was considered an acute response and suggestive of a relationship with work place exposures.

Peak Flow Monitoring

Peak flow meters were used to document the variability and pattern (immediate, delayed, nocturnal, or progressive decline) of acute airway responses. All study participants were given log sheets and instructed in a standardized manner in the use of the Mini-Wright Peak Flow Meter. Subjects were asked to record flow results from three blows every 2 hours while awake, for 6 consecutive days. An attempt was made to obtain data from the 2 days at the end of work week, 2 days off, and the first 2 days of the next work week. In addition, participants were asked to record the presence of symptoms and use of medication during the 2 hours prior to the recording of their peak flow measurements.

Peak flow logs from each worker were reviewed for completeness. An individual workers' record from a 24-hour survey day was considered valid (interpretable) if it contained peak flow results from at least three recording times that spanned at least 8 hours that day. A worker's entire record was included in the analysis if valid records from a minimum of 3 of the 6 survey days were present, including at least 1 day off work. Logs which failed to meet these minimal criteria were excluded from analysis.

At each peak flow recording time, only the best value (largest of the three recorded values) was used for calculations and subsequent interpretation. For each worker, an *overall mean* peak flow was calculated, using the best value from all available recording times. In addition, for each survey day with valid results, a *daily mean* was calculated from the best values on that day. Diurnal variation in peak flow was calculated as the difference between the daily maximum and minimum best values for the survey day divided by the daily mean. Overall variation in peak flow was calculated as the difference between the maximum and minimum best values for the entire survey, divided by the overall mean. Both the overall mean and daily mean are expressed as a percentage. Overall variation of $\geq$ 20% is suggestive of increased airway responsiveness. If the observed pattern of daily mean peak flow values is lower on work days compared to days away from work, or variation $\geq$ 20% is seen on work days and absent on days off work, a relationship between airflow changes and workplace exposures is suggested.

Response pattern(s) were evaluated when the overall variation on peak flow was greater than or equal to 20%. Response patterns are described as follows:

Immediate:	occurs within minutes of exposure maximum response - 30 minutes recovery - within 1 hour.
Delayed:	occurs after several hours of exposure maximum response - 5 to 8 hours recovery - within 24 hours or more.
Nocturnal:	daily early morning drop
Progressive decline:	observed decline in the daily mean peak flow over the period the meter was used.

Individuals with increased airway responsiveness may exhibit one or more of the response patterns listed above.

EVALUATION CRITERIA

Evaluation criteria are used as guidelines to assess the potential health effects of occupational exposures to substances and conditions found in the work environment. These criteria are generally established at levels that can be tolerated by most healthy workers occupationally exposed day after day for a working lifetime without adverse effects. Because of variation in individual susceptibility, a small percentage of workers may experience health problems or discomfort at exposure levels below these existing criteria. Consequently, it is important to understand that these evaluation criteria are guidelines, not absolute limits between safe and dangerous levels of exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria considered in this report are: 1) NIOSH recommended exposure limits (RELs)[(13,14)], 2) the 1993-1994 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs)[(15)], and 3) the U.S. Department of Labor (OSHA) Permissible Exposure Limits (PELs).[(16)] The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by OSHA.

The exposure criteria are reported as: time-weighted average (TWA) exposure recommendations averaged over the full work shift; short-term exposure limit (STEL) recommendations for a 10-15 minute exposure period; and ceiling levels (C) not to be exceeded for any amount of time. For dusts or related substances, these exposure criteria and standards are commonly reported as parts contaminant per million parts air (ppm), or milligrams of contaminant per cubic meter of air (mg/m^3). The exposure criteria for many of the chemical compounds monitored during this investigation and reported in the NIOSH interim report were compared to OSHA PELs, as revised in 1989 under the Air Contaminants Standard. However, in 1992, the 11th Circuit Court of Appeals vacated the 1989 Air Contaminants Standard and Federal OSHA is currently enforcing the previous transitional limits. Some states operating their own OSHA-approved job safety and health compliance programs may continue to enforce the 1989 limits. Although vacated, OSHA recommends that occupational exposures be maintained according to the 1989 Air Contaminants Standard. For the substances monitored during this survey, the environmental criteria are listed in Table 2.

RESULTS

Industrial Hygiene

Formaldehyde

A total of 138 consecutive 4-hour area samples were collected. Trace concentrations of formaldehyde were detected in 36 of the samples but were quantifiable in only 3 cases (0.03 ppm, 0.06 ppm, and 0.06 ppm). Trace concentrations are reported when the level falls between the analytical limit of detection (LOD) and the limit of quantitation (LOQ). In other words, the material being measured is present but at a level which is too low to be accurately quantified. The LOD for these samples varied from 0.008 ppm to 0.016 ppm and the LOQ varied from 0.027 ppm to 0.052 ppm depending on the sampling time.

Cigarette smoke contains as much as 40 ppm of formaldehyde by volume.[17] Sixteen of the 39 samples in which formaldehyde was detected, including all three with quantifiable amounts, were exposed to cigarette smoke in the operators' control booths.

Formaldehyde is an irritant of the upper respiratory passages. For this reason, systemic poisoning in unlikely since workers would be compelled to leave the exposure area before levels sufficient to cause systemic poisoning were reached. Acute exposure to formaldehyde can cause a variety of symptoms. The first symptoms noticed on exposure at concentrations ranging from 0.1 to 5 ppm are burning of the eyes, tearing, and general irritation of the upper respiratory passages.[17] Exposure to formaldehyde has been determined to be a cause of occupational asthma.[18] NIOSH recommends that, "formaldehyde be handled as a potential occupational carcinogen" and that occupational exposure be reduced to "the lowest feasible limit."[17]

Glutaraldehyde

Glutaraldehyde is the primary biocide added to the coolant fluid used in the 80"- mill. Results of the area sampling for glutaraldehyde are presented in Table 3. Glutaraldehyde was detected in 10 of the 16 samples analyzed and was quantifiable in 6. The full shift concentrations were minimal ranging from 0.0007 ppm to 0.084 ppm.

Glutaraldehyde has a pungent odor, an odor recognition threshold of 0.04 parts per million (ppm) by volume in air, and an irritation response level of 0.3 ppm (0.7 mg/m^3). Glutaraldehyde is a relatively strong irritant to the nose and a severe irritant to the eyes. It can produce staining and may be slightly irritating to the skin. It can also cause skin sensitization (allergic contact dermatitis), as well as occupational asthma.[19] Recent information suggests that glutaraldehyde is teratogenic in animals, producing central nervous system, musculoskeletal, and craniofacial abnormalities.[20]

Aminoethanol Compounds

Many studies have been reported in the literature regarding the effect of triethanolamine on human skin. Triethanolamine has been identified as causing both irritant and allergic contact dermatitis. There are no inhalation data available.[21] Triethanolamine has been reported to cause cancer in mice at a concentration of 300 ppm in the diet. Therefore, the ACGIH has recommended that triethanolamine be considered a suspected human carcinogen.[21]

Diethanolamine is widely used in industry as a detergent in paint, cutting oils, shampoos, and other cleaners. It has been characterized as being of low toxicity.[20] Thirty-four full shift area samples were collected for diethanolamine and triethanolamine. Diethamolamine was not detected on any of the samples (LOD - 0.002 ppm). Triethanolamine was detected and quantifiable on two of the samples. These two samples were collected near the 112"-mill on Thursday, March 14 and Friday, March 15. The two samples indicated 8-hour TWAs of 0.005 ppm and 0.01 ppm. These levels are well below the proposed ACGIH TLV of 0.5 ppm.

Nitrosamines

Nitrosamines as a class are considered to be the most potent and widespread of animal carcinogens. Although nitrosamines are suspected to be human carcinogens, their carcinogenic potential in man has not been proven.[22]

Nitrosamines are frequently found as either additives or contaminants (formed most commonly from nitrites and amines in acid solution) in cutting fluids. Many of these are well known carcinogens, although their potency varies. Nitrosamine formation from the metalworking coolant used in this operation was considered unlikely but sampling was conducted for confirmation.

Thirty-four air samples were collected and analyzed for seven nitrosamines (N-nitrosodimethylamine, N-nitrosodiethylamine, N-nitrosodipropylamine, N-nitrosodibutylamine, N-nitrosopyrrolidine, N-nitrosopiperidine, N-nitrosomorpholine). There were no N-nitrosamines detected in any of the samples. The analytical LOD was 0.05 mg/sample or 0.07 mg/m^3.

Chlorine

Chlorine gas is a severe irritant of the eyes, mucous membranes, and skin. The odor threshold for chlorine appears to be between 0.02 and 0.2 ppm. Nasal irritation and coughing occur at about 0.5 ppm.[13] Inhalation of chlorine has been found to cause asthma.[23] Twenty-three samples were collected. No chlorine was detected on any of the samples. The LOD was 0.13 ppm.

Hydrogen Chloride

Hydrogen chloride gas and solution of hydrogen chloride (hydrochloric acid) may cause severe irritation of the upper respiratory tract resulting in cough, burning of the throat, and a choking sensation; effects are usually limited to inflammation and occasionally ulceration of the nose, throat, and larynx. Inhalation of hydrogen chloride has been found to cause asthma.[23] Exposure of the skin to a high concentration of the gas or to a concentrated solution of the gas will cause burns; repeated or prolonged exposure to dilute solutions may cause dermatitis.[13] Results of the hydrogen chloride sampling are shown in Table 4. Hydrogen chloride concentrations ranged from none detected to 1.6 ppm, all below the NIOSH REL of 5 ppm.

Sulfur Dioxide

Sulfur dioxide gas is a severe irritant of the eyes, mucous membranes, and skin. Its irritant properties are due to the rapidity with which it forms sulfurous acid on contact with moist membranes. In combination with certain particulate matter and/or oxidants, the effects may be markedly increased. Approximately 90% of all sulfur dioxide inhaled is absorbed in the upper respiratory passages, where most effects occur. Exposure to concentrations of 10 to 50 ppm can cause irritation to the eyes and nose, choking, cough, nosebleeds, and in some instances, reflex bronchoconstriction with increased pulmonary resistances.[13] The results of the sulfur dioxide sampling are shown in Table 5. Sulfur dioxide was present throughout the Hot Line Department, but during normal hot line operations the concentrations did not exceed the evaluation criterion of 2 ppm. However, a sample collected on 3/14/91 above the 112"-mill did indicate an excessive level (18.7 ppm). On 3/14/91, something on the 112"-mill broke and had to be repaired by welding. Since this is the only time we detected an elevated level, we feel it was likely the result of the welding operation.

Elemental Metals

The results of the elemental analysis, along with specific criteria for each element, are shown in Table 6. Twenty-four samples were collected and analyzed for trace metals using inductively coupled plasma-atomic emission spectroscopy (ICP-AES) to determine qualitatively and quantitatively the elements present. Nine elements were detected in quantifiable amounts. The concentrations measured were very low and well below OSHA PELs and NIOSH RELs.

Microorganisms/Endotoxin

Many water-based metalworking fluids are capable of growing large varieties of microorganisms, which can deteriorate the fluids and corrode machinery. In addition, the generation of slime and foul odors can cause unpleasant working conditions. Frequently, the Gram-negative species are the dominant bacterial group found. Some of these are "opportunistic pathogens" due to their ability to produce infections in people with depressed immune response systems. The "opportunistic pathogens" may also play a role in dermatitis as they can destroy the skin structure by virtue of their enzymes and hence affect its permeability to chemical and biological irritants.[24] The same organisms are potent endotoxin producers.

Endotoxin makes up part of the cell wall of Gram-negative bacteria and its biological activity is not dependent on bacterial viability. Clinically, little is known about the response to inhaled endotoxins. Exposure of subjects never before exposed to airborne endotoxins can result in acute fever, dyspnea, coughing, and small reductions in pulmonary function (FEV).[25] Some animal studies have demonstrated that repeated exposure to aerosols containing endotoxins resulted in a chronic inflammatory response similar to chronic bronchitis. Another clinical concern regarding exposure to endotoxins is the development of hyper-reactive airways. Some researchers have found that aerosols of endotoxin increased bronchial hyper-reactivity which may enhance the susceptibility of workers to toxic exposures.[25]

Aerosols were collected using respirable and inspirable aerosol samplers. The samples were collected on polyvinyl chloride and mixed copolymer filter media using portable sampling pumps operated at 1.7 liters per minute (lpm) and 2.0 lpm, respectively.[6,26] These samples were analyzed gravimetrically with an electrobalance. These respirable and inspirable samples were also analyzed for endotoxin content by the chromogenic modification of the Limulus amebocyte lysate gel test.[27] Endotoxin results were reported in terms of endotoxin units (EU) that were compared to the standard, EC-5. A conversion factor of 10 endotoxin units per nanogram (10EU/ng) was used.

The aerosol, respirable and inspirable, and endotoxin concentrations measured during this survey are presented in Tables 7 and 8, respectively. Respirable aerosol concentrations ranged from 0.02 mg/m^3 to 2.23 mg/m^3 and inspirable concentrations ranged from 0.03 mg/m^3 to 4.81 mg/m^3.

Currently there are no standards for airborne exposure to endotoxins. Research on acute respiratory health effects of exposure to endotoxins in inspirable cotton dusts demonstrate a threshold exposure level of approximately 9 ng/m^3.[28] Of the 40 respirable and inspirable endotoxin results only 3 (13.96 ng/m^3, 23.0 ng/m^3, 30.02 ng/m^3) exceeded the 9 ng/m^3 threshold.

Bulk samples of the coolant were collected on March 15 and 18 from each roller mill and each coolant storage room. Also, samples for viable mesophilic aerobic and anaerobic bacteria and fungi in air were collected at the same times and locations as the bulks. The air samples were collected using the All Glass Impinger (AGI) operated at 12.5 lpm with sterile distilled water.[5]

Serial (ten fold) dilutions of the bulk liquids and the impinger media were made, and a 0.5 ml portion of each dilution were plated in triplicate for each type of organism per dilution strength. Following the dilution plating, the agar plates were incubated according to the type of microorganism to be grown. After an appropriate incubation period, the number of colonies were counted and the predominant organisms were identified on the basis of colony and microscopic morphology.

Viable organisms were identified only in the bulk liquid samples, as indicated in Table 9. Both Gram-positive and Gram-negative bacteria were identified in the bulk liquids. They were predominantly Gram-positive, and the number of organisms appeared to be very low.

Since no viable organisms were found in the air samples (impingers), we felt there was a possibility that the biocide in the coolant had also been collected in the impinger and had killed any organisms that may have been collected. Therefore, the impinger samples were further analyzed microscopically using the Collection of Airborne Microorganisms on Nuclespore Filters, Estimation and Analysis (CAMNEA) method to determine if there were any nonviable bacteria present.~29~ Results of the microscopic analysis were negative. No organisms (viable or nonviable) were found in any of the impinger samples.

Medical

Questionnaire

Of the approximately 150 Hot Line Department employees, 78 (52%) completed the questionnaire. Male workers comprised 88% (69/78) of the participants. Participants ranged from 26 to 61 years of age, with a median age of 42 years. The prevalence of current cigarette smoking was 26% (20/78), and current smokers had a median of 37 pack-years (a pack-year is equivalent to smoking an average of one pack per day for a year). Twenty-nine percent (23/78) of participants reported that they were former smokers and had a median of 15 pack-years. Forty-five percent (35/78) of the participants had never smoked.

The median employment tenure at Kaiser Aluminum, Trentwood Works was 13 years with a range of less than 6 months to 38 years. The job classification of participants was nearly evenly divided between maintenance (53%) and production (47%), similar to the distribution in the Hot Line Department as a whole. Participants were asked to indicate their usual work area in the Hot Line Department. Thirteen percent (10/78) of the participants reported working only on the 80" mill, 15% (12/78) reported the 112/132" or reversing mill as their usual work area, and 14% (11 /78) reported working mainly in the area of the soaking pits or scalper room. The remainder, 58% (45/78), did not indicate a specific area, but reported working along the entire hot line.

Acute Respiratory Symptoms

Forty-one percent (32/78) of participants reported at least one acute respiratory symptom (chest tightness, wheezing, attacks of shortness of breath with wheezing or cough). The prevalence of current cigarette use among workers reporting at least one acute symptom was 34% (11/32).

The prevalences of acute symptoms by job classification (maintenance or production) and cigarette smoking history are presented in Table 10 and Table 11, respectively. Acute symptoms of highest prevalence were wheeze (19%) and chest tightness (23%), and each appears evenly distributed between the two job classifications. Nine of the 18 participants with chest tightness also reported a history of asthma, hay fever, and/or other allergies. In addition, one participant indicated a prior occupational exposure to a known asthma-causing agent (cedar dust).

Table 11 reveals that each individual symptom, except chest tightness, appears more prevalent among cigarette smokers. Chest tightness, however, was as common among non-smokers as among current or former smokers.

Nineteen percent (6/32) of the participants with at least one acute symptom met the criteria for a work-related symptom; the overall prevalence of each individual work-related symptom was 5% or less (Table 12). There was one current smoker among those defined as having a work-related acute symptom. Of the four with work-related chest tightness, three were atopic or had other, non-occupational risk factors.

Chronic Symptoms

The prevalence of chronic respiratory symptoms among participants by job classification and cigarette smoking history are presented in Table 13 and Table 14, respectively. Chronic symptoms with the highest prevalence were cough (19%) and phlegm (18%). Prevalences of all chronic symptoms were higher among maintenance employees and smokers.

Other Symptoms

Overall, 62% (48/78) of participants reported eye irritation and 62% (48/77) reported rhinitis during the previous year. Eye irritation was higher among production workers, (70%), than among maintenance workers, 54% (Table 15).

Maintenance and production workers had similar prevalences of rhinitis, 63% and 61% respectively.

Thirty-two percent (25/78) of participants reported developing skin irritation (a rash, dermatitis, hives, or eczema) during the previous year. The prevalence of skin irritation among maintenance workers (44%) was more than twice that of those working in production (19%).

When work-related criteria were applied, the prevalences of eye irritation, rhinitis, and skin irritation were as follows: eye irritation 28% (22/78), rhinitis 5% (4/77), and skin irritation 14% (11/78). Fourteen of the 22 participants with work-related eye irritation were production workers; 10 of the 11 with work-related skin irritation were maintenance workers.

Of the 11 participants who reported a potentially work-related skin condition, seven (64%) used a cream or medicine for their skin condition. Only two of the 11 had consulted a physician regarding their skin condition.

Spirometry

Fifty-one percent (77/150) of the Hot Line employees performed spirometry at least once. Thirty percent (23/77) had an abnormal result: 17 had a mild obstructive lung pattern, and six had a moderate obstructive lung pattern. Table 16 contains summary statistics of spirometry results by cigarette smoking history. Current smokers had a lower mean percent predicted FEV_1 and FEV_1/FVC ratio than did former or never smokers. Nineteen of those participants with abnormal spirometry were current or former smokers.

When spirometry status (normal versus abnormal) was examined by job classification (Table 17), the proportion of maintenance workers with an abnormal pattern was only slightly higher (36%) than those participants who worked in production (24%).

Of the four participants who exhibited abnormal spirometry results and had never smoked cigarettes, all were mildly obstructed. Three worked in the maintenance department, and one worked in production. All four reported being routinely exposed to coolant. One of the four reported experiencing acute, work-related chest-tightness and wheeze. None of the four reported chronic respiratory symptoms. All reported experiencing rhinitis, and three reported eye-irritation. The reports of eye-irritation and rhinitis did not meet the criteria for being work-related.

Cross-shift spirometry data was collected on at least one work day for 76 participants, and 63 performed cross-shift spirometry on both the last day of the work week and again on the first day of the following work week. Because of their work schedules, two participants were evaluated initially at the beginning of their work week (i.e., the order of testing was reversed).

Only one participant had an observed FEV_1 decline across a work shift that exceeded 10% – this participant experienced a 530 ml decline upon returning to work after a weekend off. Results from peak flow monitoring were neither complete nor acceptable and could not be interpreted. The participant was a current smoker who reported 86 pack-years of smoking and respiratory symptoms that were not work-related. Of the 63 participants who performed spirometry on both the last day of the work week and again on the first day, none exhibited a $\geq$ 10% improvement over a weekend. Neither did the other two participants exhibit a $\geq$ 10% decline in FEV_1 over their work week.

Peak Flow Monitoring

Peak flow meters were used by a total of 76 participants. Data from 72 of the 76 (95%) met the criteria to allow for an overall interpretation. Altogether, nine (12.5%) participants had a $\geq$ 20% change in peak flow. However, the accuracy of this determination for four of these participants was questionable due to insufficient data or possible measurement, or recording errors. Fifty-two of the 72 who met the criteria for overall interpretation had data that was both sufficient and acceptable to allow for the evaluation of possible work-related effects.

Four participants had a 20% or greater change in peak flow that was temporally associated with work. Two exhibited a delayed airway response pattern, one had an immediate response pattern, and one exhibited both a delayed response and progressive decline over the 6 days the peak flow meter was used. Only one of the four indicated experiencing symptoms associated with a change in peak flow. None of the four had a past history of asthma and none reported acute, work-related respiratory symptoms. One person reported a history of seasonal allergies. Two of the four were former smokers, one was a current smoker, and one had never smoked. Three of the four worked in production, and one worked in maintenance.

The percent change in peak flow for these four participants ranged from 20.8% - 44%. The participant with the greatest percent change, 44%, reported exposure to chlorine while working (welding) an extra shift in the Remelt area. The maximum response occurred 5 hours after the exposure reportedly began.

CONCLUSIONS

There are numerous reports in the literature of adverse health effects from exposure to metalworking fluids.[24,30,31,32,33,34] Effects that have been reported include dermatitis, irritation, and respiratory impairment including asthma. The large variety of additives used in any one of the three types of metalworking fluids (straight, emulsified, or synthetic) studied makes comparison of results difficult. Occupational asthma has been reported in a toolsetter and machine operator exposed to an emulsified oil. The asthma was confirmed through use of serial peak flow measurements.[32] A second study found that 13 of 25 workers with asthmatic symptoms exposed to oil mists had work-related asthma as determined by serial peak flow measurements. The most common type of oil mist exposure was to "suds" oil (oil mixed with water). It was further determined that the provoking agent within the particular oil varied from worker to worker.[33] A 1989 study of automobile machinists found that 23.6% exposed to machining fluid aerosols experienced a 5% cross-shift decrease in FEV_1. Study subjects were exposed to a single type of machining fluid. The strongest association (OR=6.9) occurred among those exposed to synthetic fluids.[34]

This investigation identified 11 participants that had acute, work-related respiratory effects as defined by the results of the questionnaire, cross-shift spirometry, and/or serial peak flow measurements. Six participants reported at least one work-related acute respiratory symptom, one participant had a cross-shift decrease in FEV_1 of greater than 10%, and four exhibited a ≥ 20% change in peak flow temporally associated with work. The participants identified by each of these methods did not coincide. That is, those participants identified by questionnaire were not the same as those identified through cross-shift spirometry or serial peak flow measurements. No specific work areas or jobs on the Hot Line appeared to be associated with these documented or reported effects.

It is possible that these effects are due to sensitization, irritation, or exacerbation of pre-existing conditions from the coolant. It is also possible that the 11 participants identified are an underestimate, given the criteria established for an acute, work-related response for cross-shift spirometry (≥ 10% change) and for peak flow variability (≥ 20%).

Although spirometry results revealed that 30% of participants had abnormal patterns, this appeared to be associated more with smoking than occupational exposures. Of the four non-smokers with abnormal patterns, it is impossible to attribute these changes to coolant exposure alone since the job duties of three of the workers included welding.

The high prevalence of reported work-related eye irritation among production workers and skin irritation among maintenance workers indicates a need to institute measures to reduce these effects.

Generally speaking, our survey results did not indicate an overexposure of the hot line workers to any of the individual chemical agents evaluated. One area sample collected March 14, 1991, for sulfur dioxide near the 112"-mill did indicate an unusually high concentration, apparently as a result of a breakdown and subsequent maintenance activity (welding).

Although no exposure exceeded a NIOSH REL, or OSHA PEL, with the exception of one SO_2 area sample associated with a welding operation, it was obvious from visual observation that the workers throughout the Hot Line Department were exposed to the mist/aerosol of the metalworking coolant. The MSDSs for coolant ingredients and general literature indicate potential exposures to compounds known to cause respiratory effects and pulmonary impairment, and/or irritant or allergic dermatitis. It is possible that these substances in combination, may have a more pronounced effect on the health of workers.

Biohazards of the coolant mist are also recognized. There are studies which have implicated Gram-negative bacteria or endotoxin as a possible cause of pulmonary function abnormalities or respiratory symptoms. While biocides are used to suppress the bacterial growth in the coolant, they are not always effective. The control of microbial populations in metalworking fluids is related to the type of fluid, size of the system, and metalworking operation.

The results of the microbiological sampling were unremarkable. Minimal amounts of Gram-positive and Gram-negative organisms were found in the bulk liquids, and no organisms (viable or nonviable) were found in the air samples.

It is important to realize that the environmental sampling was conducted only during a 4 day period and at a time when efforts were being made to reduce the amount of biological contamination in the fluid, thereby reducing the amount of biocide needed. Several of the workers expressed concern that during our visit and during the recent months prior to our survey, the mist was not as irritating as in previous years. The workers felt that in the past, the coolant engineers would "batch dose" the coolant with biocides at various times, which resulted in very uncomfortable and irritating work conditions. Our discussions with management confirmed that this had occurred. Currently though, improved operating procedures are in place to better control the amount of biocide added to the coolant.

In January and February 1991, just prior to our survey, the company conducted experiments to determine the possible causes of bacterial contamination of the coolant and methods to reduce the bacterial count in order to reduce amounts of biocides required. From the results of their experiments, it appears that by altering the temperature of the coolant and performing better preventive maintenance (cleaning, repairing leaking valves, etc.) they were able to reduce the bacterial count and biocide usage. However, this does not mean they have totally eliminated the possibility of bacterial count excursions and the need at times to "batch treat."

RECOMMENDATIONS

- A no-smoking policy should be implemented. Cigarette smoking may exacerbate the respiratory effects of the coolant as documented in literature and as indicated on the MSDSs for substances contained in the coolant.

- A medical surveillance program should be established for individuals assigned to the Hot Line Department. A medical history should be obtained prior to assignment and should include questions regarding pre-existing respiratory symptoms and disease, especially asthma, as well as previous exposure to known asthma-causing agents. Workers assigned to the Hot Line Department should receive baseline spirometry performed in accordance with the American Thoracic Society criteria, if this is not already being done. As part of this surveillance, follow-up medical examinations should be conducted and should include a brief respiratory symptoms questionnaire. Any worker who develops episodic respiratory symptoms at any time during assignment to the Hot Line Department should be thoroughly evaluated.

- Continue the efforts to both reduce bacterial contamination of the fluids and minimize use of chemical biocides.

- Determine the feasibility of using local exhaust ventilation or other methods to reduce/eliminate worker exposure to the coolant mist.

- Sulfur dioxide was present throughout the Hot Line Department. During normal operations, the sulfur dioxide concentrations did not exceed the NIOSH REL, but two area sample concentrations were very close to it, and another collected during a welding operation greatly exceeded it. Therefore, additional samples should be collected by the company industrial hygienist, especially during welding operations on the mills and plate line, to evaluate sulfur dioxide exposures. If personal exposures are found to be in excess of environmental criteria, appropriate control measures should be taken.

- Irritant and allergic contact dermatitis are real concerns for individuals working with metalworking fluids. Use of personal protective clothing/equipment should be mandatory when handling metalworking fluids, and a written program on proper use of protective equipment is recommended. Employees who work with metalworking fluids should be required to wear protective gloves, goggles, impervious aprons and lab coats for the extent of the process. The ACGIH recommends a variety of different materials, including butyl rubber and neoprene rubber (described as an excellent barrier with a break-through time greater than 8 hours). The rubber materials described above should be considered when selecting the appropriate aprons and gloves. Personal cleanliness is important in preventing dermatoses. Employees should be afforded shower facilities, and overalls or work clothes that become saturated with coolant should be changed.

- Emergency eye wash stations, if not already installed, should be installed in all areas which use the metalworking fluids solution. Skin contact should be avoided, and the solution should be promptly washed off if skin contact is made.

- Employees should be encouraged to visit the on-site health clinic for evaluation of dermatological conditions. Any employee with severe, unremitting skin problems should have the opportunity to transfer to another area of the plant with less coolant exposure.

- The training and education of employees regarding safe work practices is essential to reducing and/or eliminating chemical exposures. Therefore, each employee should be instructed on the potential hazards associated with metalworking fluids, proper use of personal protective clothing, work practices and avoidance of confined space exposures. Most of this information, as well as recommended personal protective equipment can be found on the MSDSs supplied with the chemical.

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1. Kaiser Aluminum, Trentwood Works
2. USWA Local 338
3. OSHA Region X

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Table 1
Sampling and Analytical Methodologies

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

ANALYTE	SAMPLING MEDIA	ANALYTICAL METHOD	METHOD/REFERENCE
Formaldehyde	Impinger/Sodium Bisulfite	Visible Absorption Spectrometry	NIOSH Method 3500 [2]
Glutaraldehyde	5% Dinitrophenylhydrazine hydrochloride	HPLC, UV	NIOSH Method 2532[2]
Aminoethanol	Impinger/Hexanesulfonic Acid	ION Chromatography	NIOSH Method 3509[2]
Elements	CE Filter	Inductively coupled argon Plasma, Atomic	NIOSH Method 7300[2]
Chlorine	Drager Long Term Detector Tube	Direct Reading	Drager[3]
Hydrogen Chloride	Drager Long Term Detector Tube	Direct Reading	Drager[3]
Sulfur Dioxide	Drager Long Term Detector Tube	Direct Reading	Drager[3]
Inspirable Aerosol	25mm Mixed Copolymer	Gravimetric Analysis, Endotoxin Analysis	ACGIH[4]
Respirable Aerosol	Cyclone & PVC Filter	Gravimetric, Endotoxin Analysis (KLAL)	NIOSH Method 0600[2]
Viable Microorganisms	AGI-30 Impinger with sterile distilled	Enumeration and Identification of Bacteria	Wolfe[7]
Nitrosamines	Thermosorb /n Tube	Gas Chromatography, TEA	NIOSH Method 2522 [2]

Table 2
Environmental Exposure Criteria

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

ANALYTE	NIOSH	OSHA	ACGIH
Formaldehyde	0.016 ppm (TWA) 0.1 ppm (C) *(Suspect Human Carcinogen*)*	0.75 ppm (TWA) *(29CFR 1910:1048)*	0.3 ppm (C) *(Suspect Human Carcinogen*)*
Glutaraldehyde	0.2 ppm (C)	None (0.2 ppm (C) - Vacated)	0.2 ppm (C)
Triethanolamine	None	None	5 ppm (TWA)
Diethanolamine	3 ppm	None (3 ppm (TWA) - Vacated)	3 ppm (TWA) Intended change - 0.46 ppm
Nitrosamines	None; *(Suspect Human Carcinogen*)*	None	None
Metals	Depends on Specific Element (See Table 4)		
Chlorine	0.5 ppm (C)	1 ppm (C) (0.5 ppm (TWA) - Vacated)	0.5 ppm (TWA)
Hydrogen Chloride	5 ppm (C)	5 ppm (C)	5 ppm (C)
Sulfur Dioxide	2 ppm (TWA)	5 ppm (TWA) (2 ppm (TWA) - Vacated)	2 ppm (TWA)
Inspirable Aerosols	None	None	10 mg/m^3 (Particulates Not Otherwise Classified)
Respirable Aerosols	None	5 mg/m^3	None
Viable Microorganisms	None	None	None
Endotoxin	None	None	None

TWA - Time weighted average exposure averaged over 8 hours
C - Ceiling level that should not be exceeded for any amount of time
ppm - Parts per million parts of air
mg/m^3 - Milligrams per cubic meter of air
*- NIOSH recommends that exposure to carcinogens be reduced to the lowest feasible level

Table 3
Glutaraldehyde Sampling Results

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

DATE	SAMPLE#	VOLUME (ℓ)	LOCATION	CONCENTRATION (ppm)
3/13/91	GU 1	360	Above 132 mill	ND
	GU 6	424	Haulageway 30' from mill	ND
	GU 8	478	Beside 80 mill	0.004
	GU 3	480	80 mill control booth	ND
3/14/91	GU 21	480	Above 132 mill	ND
	GU 22	475	Haulageway 30' from 112 mill	<LOQ
	GU 19	480	Beside 80 mill	0.004
3/15/91	GU 38	467	Above 132 mill	ND
	GU 39	477	Haulageway 30' from 132 mill	ND
	GU 40	475	132 mill control booth	<LOQ
	GU 25	465	Above 112 mill	<LOQ
	GU 36	475	Beside 80 mill	0.006
3/18/91	GU 32	454	Above 132 mill	<LOQ
	GU 27	475	Haulageway 30' from 112 mill	0.0007
	GU 64	470	80 mill coolant room	0.031
	GU 35	465	Beside 80 mill	0.084

ppm - parts per million part of air
ND - None detected - Limit of Detection was .0001 ppm
<LOQ - Below the Limit of Quantitation (.0005 ppm)

Table 4
Hydrogen Chloride Sampling Results

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

Date	Location	Concentration (ppm)
3/18/91	Above 132 mill	ND
	Haulageway 30' from 132 mill	ND
	132 mill Control Booth	0.1
	Westside 112 mill	ND
	Haulageway 30' from 112 mill	0.2
	Beside 80 mill	1.6
	80 mill Control Booth	ND
	112/132 mill Coolant Room	0.5
	80 mill Coolant Room	0.1

ND - Less than the Limit of Detection 0.1 ppm

Table 5
Sulfur Dioxide Sampling Results

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

Date	Location	Concentration (ppm)
3/13/91	Above 132 mill	Trace
	132 mill Control Booth	1.2
	Haulageway 30' from 132 mill	0.7
	Haulageway 30' from 112 mill	0.8
	Westside 112 mill	1.0
	Beside 80 mill	1.0
	80 mill Control Booth	0.8
	80 mill Coolant Room	0.7
3/14/91	Above 132 mill	1.2
	132 mill Control Booth	1.2
	Haulageway 30' from 132 mill	0.6
	Haulageway 30' from 112 mill	0.9
	Above 112 mill	18.7*
	Beside 80 mill	1.2
	80 mill Control Booth	0.6
	80 mill Coolant Room	0.6
3/15/91	Above 132 mill	0.6
	132 mill Control Booth	Trace
	Westside 112 mill	1.2
	Haulageway 30' from 112 mill	0.9
	Beside 80 mill	1.9
	80 mill Control Booth	0.6
	80 mill Coolant Room	0.6
3/18/91	Above 132 mill	1.3
	Haulageway 30' from 132 mill	0.6
	Westside 112 mill	1.0
	Haulageway 30' from 112 mill	1.0
	Beside 80 mill	1.9
	80 mill Control Booth	1.2
	112/132 mill Coolant Room	0.9
	80 mill Coolant Room	0.9

*Sample collected during welding repair to 112 mill - appears that the welding operation contributed significant amounts of sulfur dioxide

Table 6
Elemental Metals Sampling Results (mg/m³)

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

DATE	SAMPLE #	VOL (ℓ)	LOCATION	Aluminum	Calcium	Phosphorous	Lead
3/13/91	20048	960	Above 132 mill	.010	.006	.003	.001
	20057	960	132 Mill Control Booth	.004	.004	.001	<LOQ
	20042	960	Haulageway 30' from 132 mill	.002	.002	.001	<LOQ
	20062	960	Haulageway 30' from 112 mill	.002	.001	.002	<LOQ
	20043	960	Above 112 mill	.008	.011	.012	.001
	20056	956	Beside 80 mill	.002	.002	.001	<LOQ
	20045	960	80 mill Control Booth	<LOQ	<LOQ	.001	<LOQ
	20050	960	80 mill Coolant Room	<LOQ	<LOQ	.001	<LOQ
3/14/91	20059	948	Haulageway 30' from 132 mill	.006	.002	.002	<LOQ
	20071	952	132 mill Control Booth	.003	.004	.001	<LOQ
	20069	960	Above 132 mill	.004	.003	.004	<LOQ
	20052	960	Haulageway 30' from 112 mill	.002	.002	.003	<LOQ
	20058*	960	Above 112 mill	.015	.025	.043	<LOQ
	20076	960	Beside 80 mill	.003	<LOQ	.001	<LOQ
	20061	960	80 mill Control Booth	<LOQ	.004	.001	<LOQ
	20047	940	132/112 Coolant Room	<LOQ	<LOQ	.002	<LOQ
3/15/91	20075	934	Above 132 mill	.010	.010	.007	<LOQ
	20072	954	Haulageway 30' from 132 mill	.006	.006	.002	<LOQ
	20053	950	132 mill Control Booth	<LOQ	<LOQ	.001	<LOQ
	20042	960	Above 112 mill	.021	.021	.033	.001
	20063	960	Haulageway 30' from 112 mill	.006	.006	.004	<LOQ
	20055	950	Beside 80 mill	<LOQ	<LOQ	<LOQ	<LOQ
	20051	952	80 mill Control Booth	<LOQ	<LOQ	<LOQ	<LOQ
	20078	912	80 mill Coolant Room	.004	.004	.002	<LOQ
OSHA PEL				15	15	0.1	0.05
NIOSH REL				10	15	0.1	<0.1

<LOQ - Below the Limit of Quantitation (.001 mg/m³)
*Sample #20058 - Above 112 mill - For approximately 3 hours during the sampling, maintenance workers were welding on the 112 mill
All reported values are well below the OSHA Permissible Exposure Levels (PEL) and NIOSH Recommended Exposure Levels

Table 7
Respirable Aerosol and Endotoxin Sampling Results

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

Date	Sample #	Volume (ℓ)	Location	Aerosol Concentration (mg/m³)	Endotoxin Concentration (ng/m³)
3/15/91	20026	793.9	Above 132 mill	0.91	13.96
	20005	810.9	Haulageway 30' from 132 mill	0.21	0.58
	20003	807.5	132 mill Control Booth	0.19	ND
	20027	816	Above 112 mill	2.23	3.25
	20016	816	Haulageway 30' from 112 mill	0.61	0.91
	19999	807.5	Beside 80 mill	0.09	0.10
	20001	809.2	80 mill Control Booth	0.23	ND
	20024	775.2	80 mill Coolant Room	0.09	0.08
	20022	705.5	Personal (Labor Service)	0.21	0.11
	20017	688.5	Personal (Maintenance)	0.09	1.26
	19998	788	Personal (Truck Operator)	0.27	0.17
3/18/91	20000	771.8	Above 132 mill	1.14	2.63
	19994	785.4	Haulageway 30' from 132 mill	0.30	0.36
	20010	785.4	132 mill Control Booth	0.13	1.07
	19996	793.9	Westside of 112 mill	0.26	0.71
	20023	804.1	Haulageway 30' from 112 mill	0.35	1.96
	20018	790.5	Beside 80 mill	0.78	0.68
	20020	819.4	80 mill Control Booth	0.43	0.07
	20011	795.6	112/132 Coolant Room	0.16	23.10
	20012	799	80 mill Coolant Room	0.02	ND

ND - None Detected
mg/m^3 - milligrams per cubic meter of air
ng/m^3 - nanograms per cubic meter of air

Table 8
Inspirable Aerosol and Endotoxin Sampling Results

Kaiser Aluminum, Trentwood Works
Spokane, Washington
HETA 90-286

Date	Sample	Volume (ℓ)	Location	Aerosol Concentration (mg/m³)	Endotoxin Concentration (ng/m³)
3/15/91	19802	934	Above 132 mill	2.11	2.48
	19800	954	Haulageway 30' from 132 mill	0.17	0.04
	19815	950	132 mill Control Booth	0.21	ND
	19792	816	Above 112 mill	4.81	30.02
	19806	960	Haulageway 30' from 112 mill.	1.08	0.09
	19809	950	Beside 80 mill	0.45	ND
	20033	952	80 mill Control Booth	0.26	ND
	19793	912	80 mill Coolant Room	0.21	ND
	20041	814	Personal (Labor Service)	0.63	0.05
	19791	796	Personal (Maintenance)	0.21	0.08
	19796	780	Personal (80 mill Floor Op.)	0.36	0.04
3/18/91	20038	908	Above 132 mill	1.19	8.34
	20037	924	Haulageway 30' from 132 mill	0.03	ND
	19816	924	132 mill Control Booth	0.18	0.03
	19799	934	Westside of 112 mill	0.39	0.04
	20040	946	Haulageway 30' from 112 mill	0.86	1.42
	19811	894	Beside 80 mill	2.74	0.06
	19798	964	80 mill Control Booth	0.45	ND
	19808	936	112/132 Coolant Room	0.29	1.94
	19794	940	80 mill Coolant Room	0.17	0.03

ND = None Detected
mg/m³ - milligrams per cubic meter of air
ng/m³ - nanograms per cubic meter of air

Table 9
Viable Sampling Results

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

DATE	TIME	SAMPLE LOCATION	SAMPLE TYPE	ORGANISMS	CONCENTRATION (cfu/ml) [1]
3/15/91	8:00 AM	132 MILL	Bulk Liquid	Bacillus subtilis	1026
				Bacillus pulvifaciens	906
				Bacillus brevis	293
				Pseudomonas putida	100
				Facultative Anerobes	286
	8:00-8:30 AM	Beside 132 Mill	Impinger	None	
	8:51 AM	112 Mill	Bulk Liquid	Bacillus subtilis	433
				Bacillus cereus	186
				Bacillus pulvifaciens	130
				Bacillus brevis	130
				Pseudomonas putida	210
				Facultative Anerobes	320
	8:51-9:21 AM	Beside 112 Mill	Impinger	None	
	9:30 AM	80 Mill	Bulk Liquid	Bacillus subtilis	140
				Bacillus pasteurii	23
				Yersinia pseudotuberculosis	50
				Bacillus polymyxa	30
				Pseudomonas putida	10
				Facultative Anerobes	38
	9:30-10:00 AM	Beside 80 Mill	Impinger	None	
	10:10-10:40 AM	80 Mill Coolant Room	Impinger	None	
	10:50-11:20 AM	112/132 Coolant Room	Impinger	None	

(1) cfu/ml - colony forming units per milliter

Table 9 (Continued)
Viable Sampling Results

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

DATE	TIME	SAMPLE LOCATION	SAMPLE TYPES	ORGANISMS	CONCENTRATION (cfu/ml)
3/18/91	5:40 AM	132 Mill	Bulk Liquid	Bacillus subtilis	860
				Yersinia pseudotuberculosis	263
				Aeromonas hydrophilia	1393
				Pseudomonas putida	56
				Micrococcus variens	156
				Facultative Anerobes	49
	5:40-6:10 AM	Beside 132 Mill	Impinger	None	
	6:20 AM	112 Mill	Bulk Liquid	Bacillus subtilis	56
				Aeromonas hydrophilia	163
				Micrococcus variens	23
				Pseudomonas putida	20
				Facultative Anerobes	72
	6:20-6:50 AM	Beside 112 Mill	Impinger	None	
	6:58 AM	80 Mill	Bulk Liquid	Bacillus subtilis	20
				Yersinia pseudotuberculosis	13
				Aeromonas hydrophila	53
				Pseudomonas putida	10
	6:58-7:28 AM	Beside 80 Mill	Impinger	None	
	7:34-8:04 AM	80 Mill Coolant Room	Impinger	None	
	8:13-8:43 AM	112/132 Mill Coolant Room	Impinger	None	

cfu/ml - colony forming units per milliliter

Table 10
Prevalence of Acute Respiratory Symptoms by Job Classification

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

	JOB CLASSIFICATION				TOTAL	
	Maintenance (Number=41)		*Production (Number=37)*		*(Number=78)*	
	YES	%	YES	%	YES	%
Wheeze	8	20	7	19	15	19
Attacks of Shortness of Breath	7	17	4	11	11	14
Acute Cough and/or Shortness of Breath	6	15	4	11	10	13
Chest Tightness	9	22	9	24	18	23

Table 11
Prevalence of Acute Respiratory Symptoms by Cigarette Smoking History

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

	CIGARETTE SMOKING HISTORY						TOTAL	
	Current (Number = 20)		*Former (Number = 23)*		*Never (Number = 35)*		*(Number = 78)*	
	YES	%	YES	%	YES	%	YES	%
Wheeze	8	40	3	13	4	11	15	19
Attacks of Shortness of Breath	4	20	4	17	3	9	11	14
Acute Cough and/or Shortness of Breath	4	20	4	17	2	6	10	13
Chest Tightness	4	20	5	22	9	26	18	23

Table 12
Prevalence of Work-Related Acute Respiratory Symptoms

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

		Work-Related	
SYMPTOM	*Total number with symptom*	*Number*	*Prevalence (N = 78)*
Wheeze	15	3	4%
Attacks of Shortness of Breath	11	2	3%
Acute Cough and/or Shortness of Breath	10	2	3%
Chest tightness	18	4	5%

Table 13
Prevalence of Chronic Respiratory Symptoms by Job Classification

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

RESPIRATORY SYMPTOMS	JOB CLASSIFICATION				SURVEY TOTALS (Number = 78)	
	Maintenance (Number = 41)		*Production (Number = 37)*			
	YES	%	YES	%	YES	%
Chronic Cough	10	24	5	14	15	19
Chronic Phlegm	9	22	5	14	14	18
Chronic Shortness of Breath	4	10	2*	6	6*	8
Chronic Bronchitis	6	15	2	5	8	10

* One participant did not complete the question(s) concerning shortness of breath.

Table 14
Prevalence of Chronic Respiratory Symptoms by Cigarette Smoking History

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

RESPIRATORY SYMPTOMS	CIGARETTE SMOKING HISTORY						SURVEY TOTALS (Number = 78)	
	Current (Number = 20)		*Former (Number = 23)*		*Never (Number = 35)*			
	YES	%	YES	%	YES	%	YES	%
Chronic Cough	7	35	4	17	4	11	15	19
Chronic Phlegm	7	35	4	17	3	9	14	18
Chronic Shortness of Breath	4	20	1*	5	1	3	6*	8
Chronic Bronchitis	5	25	2	9	1	3	8	10

* One participant did not complete the question(s) concerning shortness of breath.

Table 15
Prevalence of Eye and Skin Irritation, and Rhinitis by Job Classification

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

	JOB CLASSIFICATION				TOTAL	
	Maintenance (Number = 41)		*Production (Number = 37)*		*(Number = 78)*	
	YES	%	YES	%	YES	%
Eye irritation	22	54	26	70	48	62
Rhinitis	26	63	22*	61	48*	62
Skin irritation	18	44	7	19	25	32

* One participant did not complete the question concerning rhinitis

Table 16
Summary Statistics of Spirometry Measurements
by Cigarette Smoking History

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

SPIROMETRY MEASUREMENT	CIGARETTE SMOKING HISTORY						SURVEY TOTALS (Number = 77)	
	Current (Number = 19)		*Former (Number = 23)*		*Never (Number = 35)*			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Percent Predicted FVC	109.2	15.1	115.4	15.4	105.3	10.0	109.3	13.6
Percent Predicted FEV_1	86.8	17.4	106.9	17.5	100.4	10.6	99.0	16.4
FEV_1 / FVC Ratio (%)	64.8	8.9	75.9	7.0	78.6	5.5	74.4	8.8

Table 17
Spirometry Status by Job Classification

Kaiser Aluminum Trentwood Works
Spokane, Washington
HETA 90-286

		Spirometry Status			
Job Classification	*N*	*Normal*		*Abnormal*	
		n	*%*	*n*	*%*
Production	41	31	76%	10	24%
Maintenance	36	23	64%	13	36%