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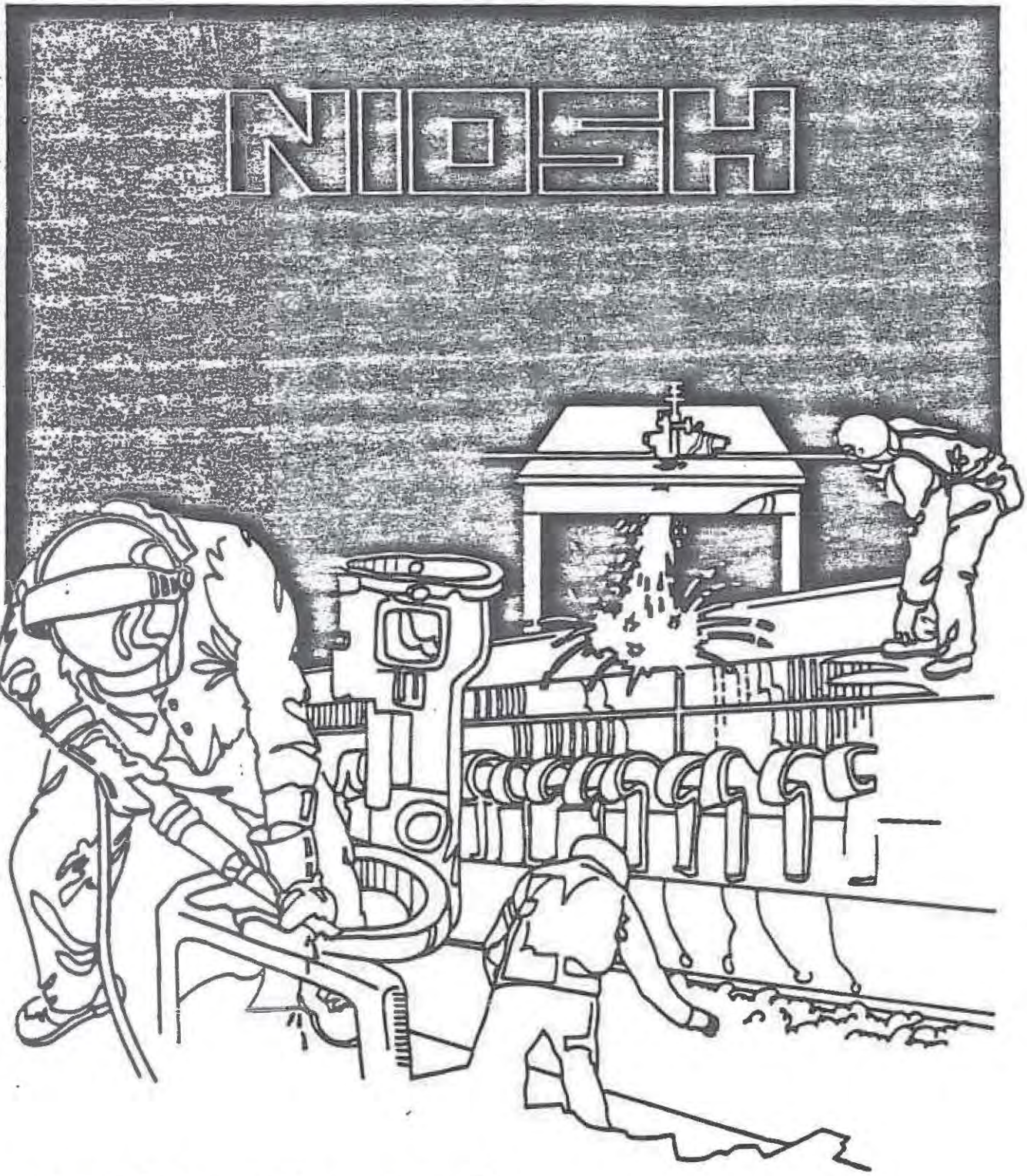

Health Hazard Evaluation Report

HETA 80-073-1589
MARION POWER SHOVEL
MARION, OHIO

PREFACE

The Hazard Evaluations 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. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or 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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NIOSH INVESTIGATORS:
Richard L. Stephenson, I.H.
Gary M. Liss, M.D., M.S.

I. SUMMARY

In March 1980, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate exposures throughout Marion Power Shovel Foundry, Marion, Ohio. The primary concern involved the core and mold areas where methylene bisphenyl isocyanate (MDI) binders are used. Reported employee symptoms included eye irritation, headache, chest pain and respiratory problems.

Long-term personal and area air sampling was performed to characterize coreroom and molding department employees' exposure to MDI, triethylamine, and mineral spirits. Also, NIOSH investigators collected personal air samples to measure exposure to metal fumes during arc air burning, arc welding, and gas burning/cutting operations in the cleaning/finishing department.

The medical evaluation regarding isocyanate exposure included a confidential physician interview; pre- and post-shift auscultation of the chest; and pre- and post-shift pulmonary function testing. Blood samples were obtained for determination of specific IgE and IgG antibodies to MDI conjugated to human serum albumin (MDI-HSA). Skin testing with MDI-HSA was also performed on workers exposed to isocyanates. Company chest x-rays of employees with greater than 10 years seniority were read by two NIOSH contract "B" readers according to the ILO/UC system for pneumoconioses. NIOSH performed x-rays when existing company films were not of adequate quality for interpretation.

Analysis of the air samples revealed the following concentration ranges, which are compared to their respective environmental criteria (EC): core and mold areas; mineral spirits, nondetectable (ND) - 77.7 mg/m^3 (EC - 350 mg/m^3); monomeric MDI, 8.9 - 28.4 ug/m^3 (EC - 50 ug/m^3); total reactive isocyanate groups, ND - 558 ug/m^3, using NCO radical, ND - 187 ug/m^3, EC - none in U.S; the British standard is 20 ug/m^3; the difference between total reactive isocyanate groups and monomeric MDI, 100 - 530 ug/m^3 (EC - none in U.S.); cleaning/finishing area; chromium, ND - 0.04 mg/m^3 (EC - 0.5mg/m^3); copper fume, 0.01 - 0.19 mg/m^3 (EC - 0.1 mg/m^3); iron oxide fume, 0.5 - 8.6 mg/m^3 (EC - 5.0 mg/m^3); manganese fume, 0.01 - 1.04 mg/m^3 (EC - 1.0 mg/m^3); and nickel, 17 - 190 ug/m^3 (EC - 15 ug/m^3). Although no environmental measurements were made by NIOSH for silica exposures, the findings of surveys performed by the Industrial Commission of Ohio and federal OSHA indicated a history of excessive silica exposure. No detectable concentrations were found for triethylamine.

Lower respiratory tract symptoms compatible with occupational asthma were reported by 7 (27%) of 26 current core or mold room workers and by none of 14 employees who had never worked in these areas (p=0.035). Symptoms compatible with hypersensitivity pneumonitis were reported by one employee who formerly worked in the core room. The mean pre- to post-shift change in FEV_1 in the currently exposed group (decrease of 0.049 liter) was a significant decrease compared to that in the never exposed group (increase of 0.065 liter) (p=0.043). Declines in FEV_1 of 10% or more occurred in one of 23 currently exposed and in none of 13 nonexposed workers. The change in FEV_1 over the shift did not correlate with personal airborne monomeric MDI exposures, but there was a negative association with personal exposure to polymeric isocyanate (rank correlation coefficient, r = 0.57). A positive skin prick test and positive MDI-HSA specific IgE result were observed in one mold worker who had symptoms of occupational asthma and who had previously been exposed to an MDI spill. Positive MDI-specific IgG results were observed in five workers, two symptomatic and three asymptomatic. Interpretation of 76 chest x-rays revealed five cases (7%) consistent with silicosis. One of these, however, had biopsy-proved sarcoidosis which could explain the findings.

The sampling data from this study indicated employee exposure to isocyanates, significant portions of which were other than monomeric. Symptoms compatible with isocyanate-associated lung disease and evidence of immunologic reactions to MDI in a subset of exposed workers were observed despite the absence of exposures exceeding the existing monomeric isocyanate standard. In addition, overexposures to metal fumes were found. Based on the data from previously performed environmental surveys, it has been determined that there is a health hazard from excessive exposures to free silica. Measures to further evaluate silica and isocyanate exposure, reduce exposures to metal fumes and improve working conditions are recommended in Section VIII of this report.

KEYWORDS: SIC 3325 (Steel Foundries), methylene bisphenyl isocyanate, MDI, coremakers, molders, Lino-cure®, no-bake binder, total isocyanates, nickel, metal fumes, silica,

II. INTRODUCTION

On February 19, 1980, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Molders and Allied Workers, Ohio State Local No. 45, to evaluate exposures in the core and mold areas of the Marion Power Shovel Steel Foundry, Marion, Ohio, where methylene bisphenyl isocyanate (MDI) binders are used. Reported symptoms among the employees in the core and mold areas included eye irritation, headache, chest pain and respiratory problems. On March 19, 1980, NIOSH received a request from the Molders Union to expand the health hazard evaluation to include the entire foundry.

Initial environmental/medical surveys were conducted in March/April 1980. Interim Report #1 was distributed in January 1981. Follow-up surveys were performed in March and September 1983. Interim Report #2 was issued in August 1983, and Interim Report #3 was distributed in February 1984. Notification letters informing employees of chest x-ray interpretations, and of blood and breathing test results were distributed in July 1983 and in January 1984.

III. BACKGROUND

The Marion Power Shovel Foundry, Plant #3, has nearly 105,000 square feet of building under one roof and is located on about 10 acres of land in Marion, Ohio. Steel parts for large power shovels, specifically, drag lines, are manufactured, including gears and gear cases, shoes, pinions, and hubs. Occasionally special steel castings for purposes other than power shovels are produced. The plant workforce fluctuates with production demands; it included about 110 production and 20 administrative/clerical personnel at the time of NIOSH's September 1983 surveys. The general work processes and operations found in Plant #3 are similar to most foundries.

A. Coreroom

Nine employees work on first shift (0800-1600) in the coreroom, located just north of and parallel to the molding floor. The coreroom workers mix predetermined amounts of core components such as core sand (silica sand) along with chromite sand, the resin or binder, and catalyst in a mixer/muller. The method utilized involves an alkyd-isocyanate "no-bake" resin binder system. The binders are used in combination with a catalyst which causes the sand mixture to cure at room temperature.

The Ashland Lino-Cure® resin binder system used consists of 3 parts:

1. An oil-modified alkyd component, designated Lino-Cure® A, AW or AWR (binder);

2. An organometallic drier, designated Lino-Cure® B, BW-3 or 2-B: may contain triethylamine (catalyst); and

3. A polymeric MDI-type isocyanate, designated Lino-Cure® C.

Lino-Cure® A is most often used at 1 to 2% of the sand weight. Lino-Cure® C is always 18-20% of Lino-Cure® A (by weight) and Lino-Cure® B is varied according to the weight of Lino-Cure A, approximately 5% (± 3%) based on desired core sand work time and core box strip time.

The isocyanate component is stored in the core and mold areas in 55-gallon drums. The binder is stored within the plant in 80-gallon tanks in the core area and is stored outside the plant in a 6000-gallon bulk storage container. The catalyst, which is used in small amounts as compared to the resin, is also stored within the core area in 55-gallon drums adjacent to the core muller. The quantity of catalyst required depends somewhat upon the ambient temperature and humidity. During the summer months, or when the sand is hot, lesser amounts of catalyst are used. In the winter months, both materials, binder and catalyst, are heated if necessary before introduction into the core sand mixer.

Core finishers use several hand tools such as mallets, hammers, trowels, clamps, and shovels to hand pack the sand into the core box. The core takes about 1 1/2 hours to "set up", and when solidified, the core assembly is completed when the two core halves are glued together. Cores are then washed white with a water miscible compound and baked in gas-fired ovens for nearly 30 minutes at 400°F to promote further curing. After baking, the cores are ready for use in the molds. The cores, solid reproductions of the hollow spaces desired within the finished casting, must be highly refractory to stand up under the intense heat of the molten metal and they must be capable of being easily broken up so that they can be removed from inside the finished casting.

B. Mold Floor and Dry Floor

Molds are assembled on the first shift, during which most of the 14 molding employees work.

Components of the molding sand are essentially the same as those used making cores, with the exception that 2-3% iron oxide (Fe_2O_3) by volume is added to the molding sand mixture. The Fe_2O_3 is used to improve metal hot strength and eliminate surface porosity or excessive lustrous carbon deposits.

A mold sand mixer or Fordath sand mixer is used to mix the mold sand, about 1000 pounds of sand mixture per minute, nearly 40 tons per day. It is equipped with internal heaters which are capable of warming the sand compound to 85°F if necessary. Mold sand is supplied to each flask (form which shapes the mold) via a hopper to top off flasks.

A coating compound, previously described in the coreroom processes is also used in the mold floor area for the same purpose. In addition, compressed air is used repeatedly in this area to blow excess sand from the mold pattern.

Briefly, the process of making a sand mold consists of compacting prepared sand around a pattern and then withdrawing the pattern so as to leave an opening in the sand which reproduces the outside contours of the pattern. To facilitate the subsequent withdrawal of the pattern, both the pattern and the flask are generally divided into two sections. The bottom, or drag section of the flask is usually rammed first in an inverted position. Then the drag is turned over, the upper, or cope, section is placed on top, and the packing of the sand is completed. The cope section is then removed from the drag, the pattern sections are withdrawn from the sand, and any necessary cores are set in position within the opening left by the pattern. Then the cope is placed on the drag and the two sections are clamped together.

After the flask assembly process has been completed, the flask is then transferred via crane from the mold floor to the adjacent dry floor area, where all the flasks of various shapes and sizes are filled with the molten steel. The metal is poured into the mold cavity through a sprue (tile) set into the sand. During the pouring operation, the flasks are stationary on the floor while the ladle full of molten metal is emptied (by manually controlled bottom-pour spout) into them. Once pouring begins, it continues until all available molds have been cast. In order to hold the molten metal on top of the mold thereby reducing the cooling rate of the hot metal and shrinkage, a mixture of substances which react exothermically are placed on the mold riser (Hot Top and High Heat). When the casting solidifies, the entire flask is then transferred to the shakeout area for further processing.

C. Shakeout

At the time of NIOSH's September 1983 surveys, the shakeout department operated on first shift with only two employees. Generally, 10-12 molds per day are processed through the shakeout area, where residual molding sand is removed from the casting.

The shakeout operation begins when the previously cooled individual flasks are transported via an overhead crane system from the dry floor to the shakeout area. The flasks are placed on a vibration table, and the castings are separated from the mold material by vibrating or tumbling the mold. Castings, along with large lumps of sand and excess metal, remain on top while fine materials drop through holes in the vibration table. Return sand is conveyed through a pit area to the crusher and is screened before it is recycled. Processed castings are sent to the adjacent finishing/cleaning area, and the flasks are returned to the mold floor.

The shakeout "push/pull" exhaust ventilation system consists of positive pressure air supply ducts located on the two side walls and at the top of the back wall, and negative pressure slot-type exhausts arranged in the ceiling.

D. Furnace Area

The melt shop, located adjacent to the finishing/cleaning room and shakeout area, covers about 17,000 square feet. Melt operations occur on the third shift (2300-0700 hours) and seven employees work in the furnace area.

Two direct electric arc furnaces, one of 6-ton and the other of 20-ton capacity, are used alternately. Both are equipped with three solid graphite electrodes and top side-draft exhaust ventilation systems.

Low-carbon scrap steel is purchased and cut to eighteen inch squares before introduction into the furnace. Each melt consists of about 40% return scrap steel and 60% purchased scrap. Most heats are made up of 5-10% alloys. The following alloying materials are routinely added manually to the molten steel: nickel, molybdenum, vanadium, chromium, copper, silicon, iron, aluminum, sulfur, phosphorus, manganese, and magnesium. All of these are used in amounts of less than 3.5%; the highest alloy content are melts consisting of 3.5% nickel.

Lancing (to oxidize impurities), slagging (to skim off the impurities) and sampling/analysis of the molten steel for specific alloy content, occurs frequently throughout the melting process. Molten metal is tapped into ladles at 2950°F and transported to the dry floor. The melt process from start to tap out takes about three hours, and pours usually occur twice per shift.

E. Finishing/Cleaning

The largest of all departments in the foundry is the finishing/cleaning room. All operations in this area occur on first shift (0800-1600 hours), with a total of 39 workers. In the cleaning department, the basic processes involve removing molding sand and excess metal from the casting. These operations are accomplished by combinations of a series of the following operations: annealing, shot blasting, cutting with an oxy-gas torch, scarfing and arc-air burning, chipping, magnafluxing, grinding, quenching, and welding.

The annealing process, performed in large gas-fired ovens, functions to alter the mechanical and/or physical properties of the metal and to "normalize" the metal after welding.

Shot blast operations, wherein metallic shot is directed against the casting surface (to knock off any flashing and sharp edges, and to remove adhered materials from the casting surface) to provide a suitable finish, are performed repeatedly throughout the finishing/cleaning process.

When castings are first removed from the mold, they are generally rough and have arm-like spurs resulting from the molten metal filling the gates, risers, and sprues. Oxy-gas torches are used to cut off these metal projections from the casting and to cut scrap castings for recharging back into the furnace.

A non-destructive inspection testing procedure (Magnaflux®) is used to check for cracks in the casting. The magnaflux® test, a form of magnetic particle inspection, is performed with two electrically energized electrodes and iron oxide. The arc-air and welding operations follows the magnaflux® test to correct any defects found in the casting.

The scarfing and arc-air processes are quite similar in function. Both are utilized to burn excess sand, slag, or metal from the casting and to remove surface defects in the metal. However, the method of operation differs slightly in that the scarfing process utilizes iron oxide powder, while the arc-air procedure uses a consumable copper-clad graphite electrode.

Chipping and grinding are performed using portable pneumatic hand-held equipment. Various sized chisels and cones on the chipping hammers and grinders, respectively, are used to remove excess metal and burnt-in sand and to smooth out the casting surface.

One of the final stages in the cleaning/finishing operations is that of quenching. In this process of metal hardening, the casting is initially heated within or above the transformation range and rapidly cooled by immersion into a liquid. The quenching has a direct relationship to the metal's Brinell hardness value.

Gas metal arc welding is performed in the finishing department. Both gas-shielded flux-cored wire and low hydrogen electrodes are used as are stationary semi-automatic and portable welding apparatus.

Following a final inspection, the castings are shipped.

IV. EVALUATION DESIGN AND METHODS

The health hazard evaluation request included the entire foundry but expressed a major interest in the evaluation of coreroom and molding department employee exposures to contaminants. Therefore, NIOSH's environmental/medical evaluation efforts focused on exposures in these areas and assessed exposures in other foundry areas on a worst-case basis.

A. Initial Survey

In March 1980, NIOSH contract medical investigators administered a non-directed health questionnaire and informally reviewed chest x-ray films of active employees of Plant # 3, who were born on or before 1935.

In April 1980, NIOSH made carbon monoxide measurements, using short-term detector tubes, in the shakeout, dry floor, molding, and furnace areas. In addition, sound level meter measurements (for noise) were taken in the finishing/cleaning, shakeout, dry floor, molding, and furnace areas.

B. First Follow-up Survey:

During the March 1983 survey, NIOSH personnel conducted an in-depth walk-through and systematically gathered information regarding changes in work processes, conditions of exposure, and numbers of employees. Available Material Safety Data Sheets were obtained to aid in development of an air sampling protocol. In addition, all information concerning environmental surveys conducted in the foundry since NIOSH's initial survey was obtained.

NIOSH investigators conducted informal interviews with employees in the molding department, core room and cleaning/finishing room, in particular seeking individuals who had apparently been transferred for medical reasons. The medical records of those individuals with respiratory problems were examined. NIOSH obtained chest x-rays that had been taken by the company in the past on employees with 10 or more years seniority (both active employees and those on lay-off). The chest x-rays were reviewed for possible pneumoconiosis independently by two NIOSH contract "B readers" according to the ILO/UC classification. In the event of differences between the findings of the two radiologists, a consensus determination was obtained.

C. Second Follow-up Survey:

A. Environmental

On September 12 and 19, 1983, long-term personal and area air sampling was performed to characterize coreroom and molding department employees' exposure to methylene bisphenyl isocyanate (MDI), triethylamine, mineral spirits, and other organics. On September 13, 1983, NIOSH investigators collected personal air samples for metal fumes in the cleaning/finishing department. Stationary area bulk air samples were taken on all three dates to aid in the laboratory analysis of the personal air samples.

The sampling and analytical methods[1] for the substances sampled, including collection device, flow-rate, and referenced analytical procedures, are presented in Table 1.

NIOSH personnel conducted air sampling for isocyanates, namely MDI, on September 12 and 19, 1983, with a multi-fold purpose: (1) to evaluate employee exposure to monomeric MDI (using a 13 millimeter (mm) glass fiber filter impregnated with N - p - nitrobenzyl - N - propylamine "nitro-reagent") (2) to field test a newly developed NIOSH air sampling/analytical method for total reactive isocyanate groups (midget impinger containing 15 milliliters (ml) of 1-(2-methoxyphenyl)-piperazine in toluene)[2]; and (3) to compare the resulting "field" isocyanate values obtained from the impinger with those of the glass fiber filter. The following is a synopsis of the newer isocyanate air sampling/analytical method:

A known volume of air is bubbled through a midget impinger containing a known quantity of a toluene solution of 1-(2-methoxyphenyl)-piperazine. An aliquot of the toluene solution is acetylated and then evaporated to dryness. The residue is dissolved in methanol, and an aliquot is injected into a high-performance liquid chromatograph equipped with a ultraviolet detector capable of detection at 254 nm.

The change in concentration of 1-(2-methoxyphenyl)-piperazine is quantitated, and the number of moles of reactive isocyanate groups present is determined. The isocyanate groups are quantitated regardless of the size of the molecule to which they are attached. The limit of quantitation (LOQ) for monomeric MDI is 0.7 ug/sample. The LOQ for the total reactive isocyanate groups (TRIG) corresponds to 50 ug of monomeric MDI.

B. Medical

A medical evaluation designed to assess possible health effects associated with exposure to MDI was offered to all employees working in the mold and core departmens; and employees who worked in the core or mold departments in the past, including those identified in March 1983 as having symptoms possibly iscoyanate-related; and individuals in departments not likely to have current expsoure to either isocyanates or silica, i.e. inspection, pattern shop, and plant engineering.

The medical evaluation also included: a confidential structured interview; pre- and post-shift auscultation (listening with a stethoscope) of the chest; pre- and post-shift pulmonary function tests; and venipuncture to obtain samples for serological tests. Skin testing was also performed on employees exposed to isocyanates. The clinical interview was administered privately by a NIOSH physician and included assessment of occupational history, smoking status, and symptoms associated with disease of the upper and lower respiratory tract and with hypersensitivity pneumonitis. When symptoms judged by the interviewer to be occupational in origin were elicited, the clinical history was corroborated by a second physician. During performance of spirometry, forced vital capacity (FVC), one-second forced expiratory volume $(FEV)_1$, and the average rate of flow over the middle two quarters of the expiratory effort (FEF_{25-75}) were measured, and FEV_1/FVC ratio was calculated. We used an Ohio Medical Products Model 822 dry-rolling seal spirometer connected to a Spirotech dedicated computer which records the flow curves as well as calculates expected values based on age, height, sex and race. A test was considered adequate for interpretation only if there were three acceptable trials and the best two curves differed by no more than 5% with respect to both FVC and FEV_1. Predicted normal values were calculated according to the method of Knudson[3].

The sera were coded so that the laboratory personnel perfoming the serological tests had no knowledge of exposures or symptoms. The serological tests included specific IgE antibody to MDI conjugated to human serum albumin (MDI-HSA) by the radioallergosorbent test (RAST);[4,5] and specific IgG antibody to MDI by the enzyme-linked immunosorbent assay (ELISA).[6,7]

Skin testing was performed with ragweed and cat dander antigen, MDI-HSA, HDI-HSA and TDI-transferrin. Saline was used as the negative control; histamine as the positive. Prick skin testing was performed first, and negative prick tests were followed by intradermal tests.

The participants in the medical evaluation were divided into the following exposure groups on the basis of history of exposure to MDI in the mold and core areas: currently exposed; previously exposed (having worked at any time in the core room after the introduction of the no-bake system in 1967 or in the mold room after the introduction of the no-bake system in 1974); or never exposed.

Finally, as part of the evaluation of exposure to silica, NIOSH personnel took chest x-rays of 37 employees whose company x-rays were not of adequate quality for interpretation.

V. EVALUATION CRITERIA

Environmental Criteria and Toxicological Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposure, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are not usually considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall 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 for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienist (ACGIH) Threshold Limit Values (TLV's)®, and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) occupational health standards. Ofen, the NIOSH recommendations and ACGIH TLV's® are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's® usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposure in various industries where the agents are used; the NIOSH-recommended standards, 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 required legally to meet only those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

A. Chromium

Chromium compounds can cause an allergic dermatitis in some workers. Acute exposure to chromium dust and mist may cause irritation of the eyes, nose, and throat. Chromium exists as chromates in one of three valence states: 2+, 3+, and 6+. Chromium compounds in the 3+ state are of a low order of toxicity. In the 6+ state, chromium compounds are irritating and corrosive. This hexavalent form may be carcinogenic or non-carcinogenic, depending on solubility. The less-soluble forms are considered carcinogenic. Workers in the chromate-producing industry have been reported to have an increased risk of lung cancer.[8]

ACGIH has adopted an 8-hour TLV® of 0.5 mg/m^3 for chromium (3+) compounds,[9] whereas the OSHA standard[10] for chromium metal and insoluble salts is 1.0 mg/m^3. NIOSH's recommended standard for carcinogenic chromium (6+) compounds is 0.001 mg/m^3. NIOSH also recommends a standard[11] of 0.025 mg/m^3 for non-carcinogenic hexavalent chromium compounds, along with a 15-minute ceiling level of 0.05 mg/m^3.

B. Iron Oxide Fume[12]

Inhalation of iron oxide fume or dust causes an apparently benign pneumoconiosis termed siderosis. Iron oxide alone does not cause fibrosis in the lungs of animals, and the same probably applies to humans. Exposure of six to ten years are usually considered necessary before changes recognizable by x-ray can occur; the retained dust gives x-ray shadows that may be indistinguishable from fibrotic pneumoconiosis. In one study, eight of 25 welders exposed chiefly to iron oxide for an average of 18.7 (range 3 to 32) years had reticulonodular shadows on chest x-rays consistent with siderosis but no reduction in pulmonary function; exposure levels ranged from 0.65 to 47 mg/m^3. In another study, 16 welders with an average exposure of 17.1 (range seven to thirty) years also had x-rays suggesting siderosis and spirograms which were normal; however, the static and functional compliance of the lungs was reduced. Some of the welders were smokers. The welders with the lowest compliance complained of dyspnea.

ACGIH[9] recommends an 8-hour TLV® of 5.0 mg/m^3 for iron oxide fume. The OSHA[10] standard for iron oxide fume is an 8-hour TWA of 10 mg/m^3.

C. Nickel[12]

Metallic nickel and certain soluble nickel compounds as dust or fume cause hypersensitivity dermatitis, and nickel compounds have been associated with cancer of the paranasal sinuses and lung.[12] Nickel fume in high concentrations is a respiratory irritant. Severe but transient pneumonitis in two workers resulted from exposure to nickel fume; in one case, exposure lasted six hours, and post-incident sampling suggested a nickel concentration of 0.26 mg/m^3. "Nickel itch" is a dermatitis resulting from sensitization to nickel. The first symptom is usually itching, which occurs up to seven days before skin eruption appears. The primary skin eruption is erythematuous or follicular; it may be followed by superficial discrete ulcers, which discharge and become crusted, or by eczema. In the chronic stages, pigmented or depigmented plaques may be formed. Nickel hypersensitivity, once acquired, is apparently not lost. Recovery from the dermatitis usually occurs within seven days of cessation of exposure, but may take several weeks. A worker who had developed cutaneous sensitatization also developed apparent asthma from

inhalation of nickel sulfate. Immunologic studies showed circulating antibodies to the salt, and controlled exposure to a solution of nickel sulfate resulted in decreased pulmonary function and progressive dyspnea. The possibility of developing hypersensitivity pneumonitis could not be excluded.

In animals, finely divided metallic nickel was carcinogenic when introduced into the pleural cavity, muscle tissue, and subcutaneous tissues; rat and guinea pigs exposed to a concentration of 15 mg/m^3 of powdered metallic nickel developed malignant neoplasms. Several epidemiologic studies have shown an increased incidence of cancer of the paranasal sinuses and lungs among workers in nickel refineries and factories; suspicion of carcinogenicity has been focused primarily on respirable particles of nickel subsulfide, nickel oxide, and on nickel carbonyl vapor.

NIOSH's recommended standard[13] for nickel is 15 micrograms of nickel per cubic meter of air (15 ug/m^3). The ACGIH[9] TLV® and OSHA[10] standard for nickel is an 8-hour TWA of 1.0 mg/m^3.

D. Manganese[14]

Manganese affects the central nervous system, and intoxication occurs mostly in chronic form (manganism); inhalation of high concentrations of nascent manganese oxide causes an influenza-like illness (metal fume fever).

Manganism is quite similar to Parkinsonism and usually occurs after exposure to manganese oxides for one to two years or more. However, it may develop after only a few months. The onset of symptoms is usually insidious. Initially there is headache, asthenia, restless sleep or somnolence, change in personality with psychomotor instability associated with restlessness, irritability, and pathologic laughter. This is followed by an intermediate phase with visual hallucinations, double vision, impaired hearing, uncontrollable impulses, mental confusion, and euphoria.

In the advanced phase, the subject exhibits excessive salivation and Parkinsonian-like disorders of the basal ganglia, such as masklike facies, muscle weakness, muscle rigidity, tremor of the upper extremities and head, and impaired gait.

In manganism with neurologic symptoms, the course is frequently progressive, although some patients' cases are stationary and others recover. Prognosis is more favorable in the young and in those with only a few years of exposure.

The current ACGIH[9] TLV® for manganese fume is 1.0 mg/m^3 for an 8-hour TLV® and a STEL of 3.0 mg/m^3. ACGIH[9] defines an STEL, short term exposure limit, as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day. Exposures at the STEL should not be longer than 15 minutes, should not be repeated more than four times per day, and there should be at least 60 minutes between successive exposures at the STEL.

The OSHA standard[10] for manganese is expressed as a ceiling value of 5.0 mg/m^3: ceiling value is a concentration that should not be exceeded, even instantaneously.

E. Copper Fume[15,16]

Inhalation of dusts, fumes, and mists of copper salts may cause congestion of the nasal mucous membranes, and on occasions, ulceration with perforation of the nasal septum. Inhalation of copper fume results in irritation of the upper respiratory tract and an influenza-like illness termed metal fume fever. Signs and symptoms of metal fume fever include chills, muscle aches, nausea, fever, dry throat, cough, weakness, and lassitude. Recovery is usually rapid. Most workers develop a tolerance to these attacks, but it is quickly lost; attacks tend to be more severe on the first day of the work-week. Other effects from copper fume are metallic or sweet taste, and in some instances, discoloration of the skin and hair or dermatitis. Exposure of workers to concentrations of 1 to 3 mg/M^3 for short periods resulted in altered taste response but no nausea; levels of from 0.02 to 0.4 mg/M^3 produced no complaints. Transient irritation of the eyes has followed exposure to a fine dust of oxidation products of copper produced in an electric arc.

The ACGIH[9] TLV® for copper fume is an 8-hour TWA of 0.2 mg/m^3, whereas, the OSHA[10] standard for such is an 8-hour TWA of 0.1 mg/m^3.

F. Methylene Bisphenyl Isocyanate

Methylene bisphyenyl isocyanate (MDI), chemical formula $C_{15}\ H_{10}\ N_2\ O_2$, normally a solid material at room temperature, is white to pale yellow in color. This odorless substance, with a molecular weight of 250.3, has a low but significant vapor pressure of 0.05 mm/Hg at 20°C (68°F). High molecular weight diisocyanates like MDI present significant vapor hazards when heated or used in exothermic production processes.[17,18]

MDI vapor is a potent respiratory sensitizer. It is also a strong irritant of the eyes, mucous membranes, and skin and can cause pulmonary edema. Excess exposure to humans causes cough, dyspnea, increased pulmonary secretions, and chest pain. Isocyanates cause pulmonary sensitization in susceptible individuals. Should this occur, further exposure should be avoided, since even extremely low concentrations can trigger an asthmatic episode.[12]

The pathogenesis of isocyanate-induced lung disease remains somwewhat controversial, involving both immunologic and non-immunologic aspects. Evidence for years has suggested immunologic hypersensitivity is involved (latent period of exposure before sensitization, the fact that a minority of exposed workers are affected, and recurrence of symptoms after exposure to very low (subtoxic) levels of isocyanate).[19,20] Thus, it is felt that isocyanates have the potential for sensitizing certain subpopulations of exposed workers. [4,19] With TDI, both humoral (as indicated by skin testing and occasional specific antibody) and cell-mediated immunity appear to be involved.[4] However, it has been emphasized that the response is heterogeneous and that some symptomatic workers display no detectable immunologic reactions.[4]

Although adverse effects of MDI have been reported less frequently than those associated with TDI, asthmatic reactions have been reported.[20-22,35] Recently, hypersensitivity pneumonitis has been described in workers exposed to MDI.[20,23] Finally, a recent study of MDI-induced asthma in 78 workers in a steel foundry[24] described the results of bronchoprovocation with MDI in 11 asthmatic subjects and the immunologic studies revealed a small number of positive test results for specific IgE and IgG antibodies.

The current federal OSHA standard[10] and ACGIH[9] TLV® for MDI is a ceiling limit of 0.02 parts of MDI per million parts of air (ppm) (0.2 milligrams per cubic meter of air, mg/m^3). The current NIOSH recommended standard for occupational exposure to MDI is 0.005 ppm (0.05 mg/m^3) for up to a 10-hour workshift, 40-hour workweek, and a ceiling limit of 0.02 ppm (0.2 mg/m^3) for any 10-minute sampling period.[17]

The NIOSH recommended standard applies to diisocyanate monomers only and not to higher polymers of these compounds. Little is known about the toxicological effects of polymeric isocyanates. No long-term studies of the effects on humans of polymeric isocyanates have been conducted.[26]

On February 2, 1983, the United Kingdom Health and Safety Commission set a "common control limit" for workplace exposure to all isocyanates. This new control limit is 20 ug of isocyanate group per cubic meter of air, expressed as an eight-hour time-weighted average, and 70 ug of isocyanate group per cubic meter of air, as a 10-minute TWA. This new control limit, in units of ug (NCO)/m^3, requires that the analytical methods be applicable to "total isocyanate" i.e., the sum of all isocyanate species, including monomers and prepolymers.[27]

G. Silica

Crystalline silica, usually referred to as free silica, is defined as silicon dioxide (SiO_2) molecules arranged in a fixed pattern, as opposed to a nonperiodic, random molecular arrangement referred to as amorphous silica. The three most common crystalline forms of free silica encountered in industry are quartz, tridymite, and cristobalite, with quartz being by far the most common of these. The principle adverse health effect of crystalline silica is the dust-related respiratory disease, silicosis. Silicosis is a form of diffuse interstitial pulmonary fibrosis resulting from the deposition of respirable crystalline silica in the lung. Conditions of exposure may affect both the occurrence and severity of silicosis. Although it usually occurs after 15 or more years of exposure, latent periods of only a few years are well recognized and are associated with intense exposures to respirable dust high in free silica. Early, simple silicosis usually produces no symptoms. However, both acute and complicated silicosis (progessive massive fibrosis, PMF) are associated with shortness of breath, intolerance for exercise, and a marked reduction in measured pulmonary function. Diagnosis is most often based on a history of occupational exposure to free silica and the characteristic appearance of a chest radiograph. Respiratory failure and premature death may occur in advanced forms of the disease. Individuals with silicosis are also at increased risk of contracting tuberculosis. No specific treatment is available, and the disease may progress even after a worker is no longer exposed to silica.[28]

NIOSH, in its recommendations for a free silica standard, has proposed that exposures to all forms of free silica be controlled so that no worker is exposed to respirable airborne concentrations greater than 0.05 mg/m^3, as averaged over a 10-hour working day, 40-hour work week. This recommendation was designed to protect workers from silicosis. Exposures to free silica greater than one-half the recommended standard, or "action level", should initiate adherence to the environmental, medical, labeling, recordkeeping, and worker protection guidelines contained in the NIOSH criteria document, "Occupational Exposure to Crystalline Silica".[29]

The current federal, or OSHA standard[10] for respirable free silica exposure is an 8-hour time-weighted average based upon the 1968 ACGIH TLV® formula of 10 mg/m^3 divided by the sum of the percent SiO_2 and 2 [10 mg/m^3 - %SiO_2+2] for respirable quartz. One-half this amount was established as the limit for cristobalite and tridymite. As can be seen from the calculation, the OSHA regulation is based on the percentage of free silicacontained in the respirable particulate exposure, whereas the NIOSH recommended standard applies directly to the airborne concentrations of respirable free silica. In its 1984-85 nocie of intended changes, ACGIH lists a 100 ug/m^3 TLV for respirable quartz and a 50 ug/m^3 TLV for respirable cristobalite and tridymite.

H. Noise[30,31]

Hearing occurs when sound waves cause vibrations of the ear drum, the middle ear bones, and the fluids of the inner ear. The resulting movement of delicate hair cells in the inner ear produces electrical impulses that are transmitted to the brain via the auditory nerve.

Noise, commonly defined as unwanted sound, covers the range of sound which is implicated in harmful effects. Exposure to intense noise causes hearing losses which may be temporary or permanent. These impairments are reflected by elevated thresholds of audibility for discrete frequency sounds, with the increase in dB required to hear such sounds being used as a measure of the loss. Temporary hearing losses, also called auditory fatigue, represent threshould losses which are recoverable after the period of time away from the noise. Such losses may occur after only a few minutes of exposure to intense noise. During prolonged and repeated hazardous noise exposures, some of the nonregenerative hair cells of the inner ear may gradually be destroyed, leading to nonrecoverable threshold losses and further hearing impairment. Thus, noise-induced hearing loss, although slow, painless, and insidious at its onset, becomes permanent.

OSHA's existing standard for occupational exposure to noise (29 CFR 1910.95) specifies a maximum permissible noise exposure level of 90 decibels (dBA) for a duration of 8 hours, with higher levels allowed for shorter durations. The current NIOSH recommended standard for noise exposure is an 8-hour TWA of 85 dBA, TWA, 5 dB less than the OSHA standard. Figure I can also be used to help determine permissible durations of exposure to noise levels above 85 dBA. OSHA requires that no worker shall be exposed in excess of the limit described as line B in Figure I. NIOSH recommends that noise exposure not exceed the limits described in line A in Figure I. For noise exposures consisting of two or more periods of exposure at different levels, the daily noise dose should not exceed unity. Line A or line B, as applicable, should be used in computing the daily noise dose.

When workers are exposed to sound levels exceeding the NIOSH recommended standard, feasible engineering controls should be implemented to reduce levels to permissible limits. The current OSHA noise standard requires employers to administer a continuing effective hearing conservation program whenever employee noise exposures equal or exceed an 8-hour TWA sound level of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of fifty percent. For workers exposed at or above an 8-hour TWA level of 85 dBA, OSHA's hearing conservation program requires noise exposure monitoring and employee notification of exposures, audiometric testing, the use of hearing protective devices where necessary, and employee education.

I. Mineral Spirits[32,33]

Mineral spirits, petroleum spirits, refined petroleum solvent, or white spirits, compose a fraction slightly lower in boiling point than Stoddard solvent; the names however, are sometimes used interchangeably. The NIOSH criteria document for refined petroleum solvents defines mineral spirits as a refined petroleum solvent with a boiling range of 150-200°C and a typical chemical composition of 80-86% saturated hydrocarbons, 1% olefins, and 13-19% aromatics.

In its recommendations for a refined petroleum solvents standard, the NIOSH criteria apply to occupational exposure to the following solvents: petroleum ether, rubber solvent, varnish makers' and painters' naphtha, mineral spirits and Stoddard solvents; all with a total aromatic content of less than 20%. The NIOSH recommended standard for all of these solvents is 350 mg/m^3 as a time-weighted average concentration for up to a 10-hour workshift with a 15-minute ceiling value of 1,800 mg/m^3. The limits of 350 and 1,800 mg/m^3 are the same as those recommended for C_5-C_8 alkanes.

Eye, nose, and throat irritation: dermatitis; and nervous system effects have been found in workers exposed to some refined petroleum solvents.

VI. RESULTS

A. Initial Survey

Environmental

The results of NIOSH's sound level meter measurements for noise and detector tube measurements for carbon monoxide (CO) (taken in April 1980 and included in Interim Report No. 1) indicated excessive noise levels in the finishing/cleaning area (89-112 dBA) and the furnace area (100-104 dBA). One short-term area sample for CO taken immediately after a metal pour in the dry floor area revealed 150 parts of CO per million parts of air (150 ppm). The NIOSH recommended standards for occupational exposure to noise and CO are 85 dBA, as an 8-hour TWA, and 35 ppm for a 10-hour TWA with a 200 ppm ceiling, respectively.

Medical

The initial survey found that 24 (38%) of 64 employees interviewed reported respiratory symptoms and that some employees had been transferred from coremaking because of such symptoms. An informal review of availble x-rays suggested the presence of silicosis at the plant.

B. First Follow-up Survey

Environmental

A brief review of the results of some non-NIOSH environmental surveys conducted in the foundry are as follows:

May 1974 - Columbus, Ohio OSHA Office
excessive noise levels in the cleaning/finishing department; sand mill operator exposed to excessive silica.

June and August 1976 - Columbus, Ohio OSHA Office
an overall deficient respirator program (welders wore respirators not approved for metal fumes); excessive exposure to silica in the cleaning/finishing area.

February 1979 - Industrial Commission of Ohio
excessive exposure to iron oxide fumes [5.2-12.6 mg/m^3 (2 burner/cutters and 2 arc-air operators] and noise [93.8 & 101.1 dBA (welder and arc air operator)] in the cleaning/finishing department; exposure to excessive noise levels in the furnace area, 93.7 dBA. All values were full-shift TWA exposures. The Industrial Commission's report resulting from their survey implied that grinders and arc air operators in the cleaning/finishing department and the burner/cutter in the scrap yard may have been exposed to excessive silica levels.

March 1979 - Industrial Commission of Ohio
air samples in the coreroom revealed detectable methylene bisphenyl isocyanate (2 ppb) by Marcali method.
October and November 1982 - Toledo, Ohio OSHA Office
a respirator program was not implemented at the shakeout operation where two employees were exposed to excessive silica levels in the (1) shakeout area: hooker exposed to silica at 1.21 mg/m^3 (OSHA PEL 0.9 mg/m^3); shakeout operator exposed 1.26 mg/m^3 (OSHA PEL 0.76 mg/m^3); (2) cleaning/finishing area: rough chipper exposed to silica at 1.76 mg/m^3 (OSHA PEL 2.08 mg/m^3) and; (3) molding area: molders exposed to silica at 0.15 mg/m^3 (OSHA PEL 0.58 mg/m^3); sand muller exposed to silica at 0.33 mg/m^3 (OSHA PEL 0.63 mg/m^3). All values were full-shift TWA exposures. The NIOSH recommended standard for occupational exposure to free silica is 0.05 mg/m^3, for up to a 10-hour, TWA exposure.

The use of hearing protection was not enforced in high noise areas where the company's own monitoring showed excessive noise exposures in the shakeout, mold floor (rod and gagger operator), and the cleaning/finishing department (chipper).

March 1983 - Industrial Commission of Ohio
exposure to excessive silica in and around the shakeout area; 2 shakeout operators, 1.3 & 1.8 mg/m^3 (OSHA PEL 1.05 mg/m^3), sand system operator 4.3 mg/m^3 (OSHA PEL 0.63 mg/m^3), and burner/cutter 4.9 mg/m^3 (OSHA PEL 0.77 mg/m^3). Excessive iron oxide fume exposures were found in the cleaning/finishing area; burner/cutter exposed to 12.0 mg/m^3. Nickel fume overexposures were found during burner/cutter operations; 3 workers exposed to 110 ug/m^3, 160 ug/m^3 and 280 ug/m^3. All concentrations were full-shift TWA exposures. The OSHA standard for occupational exposure to iron oxide fume is 10.0 mg/m^3 and the ACGIH TLV® is 5.0 mg/m^3, both 8-hour TWA's. The NIOSH recommended standard for occupational exposure to nickel is 15 ug/m^3 for up to a 10-hour, TWA, whereas the OSHA PEL and ACGIH TLV® is 1.0 mg/m^3 for an 8-hour TWA.

Medical

Of the x-rays obtained for 89 individuals with 10 or more years seniority, 49 (55%) were not of adequate quality to determine whether early signs of pneumoconiosis were present. The results of those x-rays which were interpretable are combined with those performed by NIOSH during the September 1983 and are described below. We found two individuals who gave histories of having had respiratory symptoms compatible with isocyanate effects when they formerly worked in the core or mold departments. One of these had been transferred out for breathing-related health reasons.

There were several general practices of the existing occupational health program of the plant that were noteworthy: 1) the chest x-rays performed by the company in the past were of very poor quality and were read by a physician who was apparently neither a radiologist nor a "B reader"; 2) the practice of obtaining pre-employment x-ray films of the spine had occurred at the plant; 3) workers were not routinely informed of the results of their medical tests.

C. Second Follow-up Survey

Environmental

Results of the personal and area air samples taken during coreroom and molding department operations to determine employee exposure to mineral spirits, total reactive isocyanate groups, monomeric MDI, and the difference between total reactive isocyanate groups and monomeric MDI are presented in Table II. Airborne mineral spirit concentrations in the coreroom area ranged from nondetectable

(ND) to 77.7 mg/m^3, number of air samples (N) of 5, a mean ($\bar{x}$) of 35.4 mg/m^3, standard deviation (s) of 28.7 mg/m^3, and (2) mold and shakeout areas, range ND-42.6 mg/m^3, N of 10, $\bar{x}$ of 22.4 mg/m^3, and s of 16.3 mg/m^3. All air samples collected for mineral spirits were within the NIOSH recommended standard of 350 mg/m^3 (200 ppm).

Personal air samples for isocyanates collected in the coreroom revealed the following levels: monomeric MDI, N of 8, range 13.3-21.9 ug/m^3, $\bar{x}$ of 16.5 ug/m^3, s of 3.05 ug/m^3; total reactive isocyanate groups, N of 8, range ND-233 ug/m^3, $\bar{x}$ of 44 ug/m^3, s of 87 ug/m^3, and; the difference between total reactive isocyanate groups and monomeric MDI, N of 2, range 104-216 ug/m^3, $\bar{x}$ of 160 ug/m^3.

Concentrations of isocyanates found on personal air samples taken in the molding department (includes shakeout) were as follows: monomeric MDI, N of 13 range 8.9-28.4 ug/m^3, $\bar{x}$ of 15.7 ug/m^3, s of 4.9 ug/m^3; total reactive isocyanate groups, N of 13, range ND-558 ug/m^3, $\bar{x}$ of 175 ug/m^3, s of 171 ug/m^3, and; the difference between total reactive isocyanate groups and monomeric MDI, N of 9, range 100-530 ug/m^3, $\bar{x}$ of 237, and s of 143 ug/m^3. The only applicable NIOSH recommended standard in this instance 50 ug/m^3 for monomeric MDI, was not exceeded. The lower number of positive values for polymeric MDI (impinger) results from the differences in analytical sensitivities of this method for the two different forms, monomer vs. total reactive isocyanate groups.

The analytical results for the total reactive isocyanate groups were originally reported in micromoles of NCO per sample. These values were converted to micrograms per cubic meter (as shown in Table II) using the molecular weight of MDI as 250.3. In order to compare these results with the United Kingdom's new standard[27] for total isocyanate groups, 20 ug/m^3, for an 8-hour TWA, a conversion was made using the NCO radical and molecular weight of 42 to derive ug NCO/m^3. The range of total isocyanate groups found following the NCO radical ug/m^3 conversion was nondetectable to 187 ug/m^3 TWA, or overexposure to the United Kingdom isocyanate standard.

Of the thirty-three air samples obtained for monomeric MDI in the core and mold departments using glass fiber filters impregnated with "nitro-reagent", only four had detectable isocyanate (analytical limit of detection: 0.1 ug/sample): mold floor clean-up (1.8 ug/m^3); line coremaker (0.4 ug/m^3); foundry helper on mold floor (1.3 ug/m^3), and; chainmain on mold floor (0.3 ug/m^3). All nine comparison air samples taken outside the core and mold departments had no detectable monomeric MDI.

No detectable triethylamine (analytical limit of detection 0.01 mg/sample) was found on any of the 18 air samples (15 personal and 3 area) collected in the core and mold areas.

Results of the environmental air samples obtained in the cleaning/finishing department for assessment of employee exposures during arc air burning, gas shielded arc welding, and gas burning/cutting operations are presented in Table III. The personal air samples collected during these operations were taken at breathing zone locations inside the employees' welding helmets. Chromium levels ranged from ND to 0.04 mg/m^3, all below the ACGIH 0.5 mg/m^3 TLV® and OSHA 1.0 mg/m^3 standard. Copper fume concentrations ranged from 0.01-0.19 mg/m^3. Of the seven personal air samples for copper fume, two, at 0.14 mg/m^3 and 0.19 mg/m^3, exceeded the federal OSHA standard of 0.1 mg/m^3, 8-hour TWA. Iron oxide fume concentrations ranged from 0.5-8.6 mg/m^3 of which two, 5.8 and 8.6 mg/m^3, were in excess of the ACGIH TLV® of 5.0 mg/m^3 but were below OSHA's 10 mg/m^3 standard. Manganese fume concentrations ranged from 0.01-1.04 mg/m^3; one of the seven personal air samples, 1.04 mg/m^3, exceeded the ACGIH 8-hour TLV® of 1.0 mg/m^3. Nickel fume levels ranged from 17-190 ug/m^3. All seven of the personal samples for nickel fume were in excess of the NIOSH recommended standard of 15 ug/m^3. None of the nickel fume air samples exceeded the ACGIH TLV® or OSHA standard of 1.0 mg/m^3.

In Interim Reports No. 1 and No. 2 we reported deficiencies in the respirator protection program and a casting shakeout ventilation system which did not effectively exhaust contaminants. Both of these shortcomings existed throughout NIOSH's initial and follow-up surveys.

Medical

Results of x-ray interpretations

Of the 76 interpretable x-rays for employees with greater than 10 years seniority, interpretation by two independent "B" readers revealed five cases (7%) in which the chest x-ray was consistent with silicosis (Table IV). Ages of the cases with silicosis ranged from 50 to 61 (mean 55). Total years at Marion Power Shovel ranged from 14 to 40 years (mean 30). Three of the five had short histories of employment in other foundries or a railroad; one of these had been a machinist for 22 years at a metal company where there was little or no dust exposure. Four were cases of simple pneumoconiosis and one case showed the larger lesions of complicated pneumoconiosis. Examination of work histories showed that three had spent the majority of time in the core room (one of whom also had worked on the molding floor) where respiratory protection was not normally used; one had worked largely in the cleaning room (blast operator); and the fifth, with the shortest duration of employment of all the cases at Marion, had worked in foundry/maintenance as a machinist and briefly as a welder. This last worker, however, has biopsy-proven sarcoidosis (according to his private physician) and this may explain (in whole or in part), the x-ray findings.

Medical evaluation regarding MDI:

(a) Demographic data

Forty-six employees participated in the medical evaluation: 26 who currently, six who previously, and 14 who never worked in the mold or core areas. The currently exposed group was comparable to the never exposed group (Table V) with respect to mean age; proportion of older individuals; proportion of individuals completing school; duration of employment in current job, current department and total years in plant; and packs per day smoked among current smokers. There were only two non-whites. The currently exposed group had, on average, fewer years of school, a shorter duration of smoking by current smokers, a greater duration of smoking among former smokers, and a greater proportion of current smokers. These differences did not reach "statistical significance" at the conventional 0.05 level but the group size is small.

(b) Symptoms

Lower respiratory symptoms judged by the investigators to be of occupational origin (i.e. occupational asthma or cough, wheezing or shortness of breath), were reported by 7 (27%) of 26 current mold or core room workers, by three (50%) of six former mold or core room employees, and by none of 14 employees who had never worked in these departments (Table VI) [$p=0.035$ by Fisher's exact test for current vs never; $p=0.016$ for ever (current and former) vs never]. Among these 10 symptomatic workers, the time of onset of symptoms was reported to be within one hour of starting work (immediate) found to be greater than one hour (non-immediate) by four; and dual in nature (immediate and delayed) by two.

Symptoms of nasal stuffiness, itchy or irritated eyes or runny nose judged by the investigators to be work-related were reported by 5 (19%) of currently exposed, by 2 (33%) of formerly exposed, and by 4 (29%) of employees who never worked in the core or mold departments (Table VI). Symptoms were attributed to the MDI-related "fumes" in all symptomatic current and former workers. Among the never exposed, the symptoms were attributed to non-isocyanate materials by two (to a flux and to arc-air welding) and to "fumes at the north end" - i.e. mold and core area by one. The cause could not be identified by one.

Symptoms of muscle aches associated with work were reported by one employee who formerly worked in the core room.

Symptoms recorded before and near the end of the shift at the time of spirometry were infrequent, and not markedly different between pre- and post-shift or between exposure groups (Table VII). There was however an increase over the shift in symptoms referable to the eyes and to chest tightness and wheezing/shortness of breath in the currently exposed group. No differences in wheezing on examination between groups or over time were apparent (Table VII).

(c) Pulmonary function data

Baseline spirometry findings, by smoking status and exposure group, are displayed in Table VIII. Inferences about comparisons between the groups may not be meaningful due to the small numbers, the absence of non-smokers among the currently exposed group, and the differences in mean duration of smoking. However, with these caveats in mind, there were no significant differences between the currently and never exposed group in mean percent of predicted FEV_1 (92 $\pm$ 19 in currently exposed vs 94 $\pm$ 16 in never exposed), percent of predicted FVC (97 $\pm$ 18 vs 98 $\pm$ 17), or FEV_1/FVC ratio (75 $\pm$ 8 vs 77 $\pm$ 7) (all $p>0.5$ by t-test). If non-smokers in the never exposed group are excluded, the respective mean values become closer to and even less than those in the currently exposed (93 $\pm$ 18, 96 $\pm$ 19 and 76 + 6 for currently, formerly, and never exposed respectively).

Abnormal baseline spirometry was defined as FEV_1<80% predicted or FEV_1/FVC <70% = obstructive; FVC <80% predicted = restrictive; or mixed. Of 24 currently exposed workers, 10 (42%) had abnormal PFTs (obstructive in six, restrictive in one, mixed in two). All were smokers or ex-smokers. Of 13 never exposed, 4 (31%) had abnormal PFTs (obstructive in two, mixed in two). Three of the four were smokers; the fourth was a non-smoker who had FEV_1 and FVC greater than 100% of predicted but FEV_1/FVC ratio was 69%.

The mean pre- to post-shift change in FEV_1 and FVC was negative (i.e. a decrease) in the currently exposed group but was positive (i.e. an increase) in the never exposed group (Table IX). The mean change in FEV_1 in the currently exposed group (a decrease of 0.049 $\pm$ 0.167 liters) was significantly decreased from that in the never exposed group (an increase of 0.065 $\pm$ 0.135 liters) ($t=2.102$, $df=34$, $p=0.043$). However, neither of these changes were significantly different from zero by paired t-test analysis. Within the currently exposed group, the FEV_1 and FVC decreased more among those with symptoms (n=7, 0.071 and -0.221 liters, respectively) than in those without symptoms (n=16, -0.038 and -0.010 liters, respectively). These differences, however, were not statistically significant.

Of the 23 employees in the currently exposed group with paired spirometry, 5 (22%) had a decrease in FEV_1 of 5% or more; one had a decrease of greater than 10 (14.9%). By comparison, only one (8%) of 13 workers in the never exposed group had a decline of 5% or more in FEV_1. Four (17%) of 23 currently exposed workers demonstrated declines of FVC of 5% or more; two had declines exceeding 10% (18.3% and 13.9%). By comparison, none of the never exposed had declines of 5% or more.

There was no significant correlation between change in FEV_1 over the shift and personal airborne MDI concentrations for monomeric MDI (Spearman rank correlation coefficient, r_s = 0.19, n=21) but there was a moderately strong negative association with polymeric isocyanate (i.e. total reactive isocyanate minus monomeric MDI) (r_s = -0.57, n=11). If one considers only those workers with symptoms of occupational asthma, a similar pattern is observed (for monomeric, r_s = 0.19, n=7; for polymeric, r_s = -0.62, n=5).

(d) Immunologic studies

All prick and intradermal skin tests for common inhalants were negative.

Positive skin prick test results for MDI-HSA and HDI-HSA were observed in one employee, who currently worked in the mold area. This employee had symptoms judged by the investigators to be occupational asthma and gave a history of being exposed to an MDI spill four years previously that resulted in acute respiratory symptoms necessitating a visit to a local hospital. Chronic asthmatic symptoms developed nine months prior to the NIOSH study and were clearly related to MDI exposure at work.

Antibody studies: A positive MDI-HSA-specific IgE result (by RAST) was noted in the skin test-positive mold room worker. Positive MDI-HSA-specific IgG results by ELISA were obtained in five workers, including the above mold room worker and a former core area worker with symptoms of occupational asthma, rhinitis, conjunctivitis and muscle aches. The three others, one currently in the core room, two currently in the mold department, were asymptomatic. The symptomatic skin test-positive mold room employee showed a decrease over the shift of 6.1% in FEV_1, but the changes in the asymptomatic workers were mixed: a decrease of 4.7% in one, an increase of 1.9% in the other.

VII. DISCUSSION

The documentation of health effects from silica in this foundry is compatible with the long and repeated history of excess silica exposures. Despite improvement in environmental conditions as a result of changes made to the ventilation system in 1980, (particularly extensive changes attempted at the shakeout ventilation system), more recent measurements continued to exceed the OSHA standard as well as the NIOSH recommended standard for crystalline silica. However, unlike previous health hazard evaluations demonstrating silicosis in foundries[34,25], the majority of cases at this foundry had not worked in the cleaning department.

A review of the company's system for surveillance for silicosis showed that over one-half of the chest x-rays performed by the company were of inadequate quality, that they were not read by "B readers", and that results of x-rays were not routinely communicated to employees.

Long-term (full-shift) noise sampling by the Industrial Commission of Ohio found excessive noise levels in the cleaning/finishing and furnace areas. Short-term noise monitoring by NIOSH in 1980 corraborated this finding.

The results of the environmental air samples obtained in the cleaning/finishing department for assessment of exposures to metal fumes during arc-air burning, gas-shielded arc welding and gas burning/cutting operations revealed excessive levels of copper fume, iron oxide fume, manganese fume and nickel fume. The overexposures to nickel could present an increased risk of lung and nasal cancer among the cleaning department employees.

Flexible ducts were available for local exhaust ventilation systems at every welding site, but the hoods were plain opening (i.e., without any hoods for more efficient contaminant capture/control). NIOSH recommends that employees engaged in arc-air burning, gas shielded arc welding, and gas burning/cutting operations in the cleaning/finishing area be provided with respiratory protective equipment similar in nature to that described in Appendixes I and II of this report: full-face or hood type supplied-air, positive pressure respirators with the welding lens incorporated into the facepiece of the respirator.

In this study, we found that occupational exposure to MDI in the core and mold areas of the foundry is associated with the reporting of occupational asthma. Upper respiratory symptoms compatible with rhinitis (irritation of the nose) and conjunctivitis (irritation of the eyes) attributed to work with MDI were also documented, but the prevalence of these latter symptoms was not greater than that in a group not exposed to MDI. Symptoms compatible with hypersensitivity pneumonitis were also elicited in one employee; this has been previously reported in studies of MDI-exposed workers.[20,23]

Work in the core and mold departments was also associated with physiologic changes consisting of small mean decreases in FEV_1 and FVC which were not observed in the nonexposed group. Among the currently exposed employees, the changes (decreases) in FEV_1 was greater among the symptomatic than among the asymptomatic individuals. Substantial declines in FEV_1 and FVC (greater than 10%) were seen only among mold and core room employees. In this study, however, there was no evidence of lower baseline pulmonary function in the isocyanate-exposed workers.

The change in FEV_1 over the shift correlated negatively with personal airborne exposure to polymeric, but not monomeric, MDI. Correlation of polymeric MDI exposure with changes in spirometry in man have not previously been reported. There is little data on the health effects of polymeric isocyanates. Weyel et al.[26] have recently examined pulmonary irritation in mice of a polymeric isocyanate based on MDI (DES-N) with aerodynamic diameter of 0.6 micron. The concentration needed to reduce the respiratory rate 50% due to pulmonary irritation was 57.1 mg/m^3. They noted that the finding of a decrease in respiratory rate with a pattern indicating pulmonary irritation due to an action on the lower airways was unexpected, as previously tested monomeric isocyanates failed to induce a pattern of respiratory irritation in normal mice but did induce a pattern of sensory irritation on the upper respiratory tract. They felt that the potency of DES-N was six times that of nitrogen dioxide.[26] However, it is unclear whether the changes in PFTs observed in the present study are mediated by irritation or sensitization mechanisms.

The immunologic findings support previous data that isocyanates (and MDI in particular) have the potential for sensitizing certain subpopulations of exposed workers.[35] Specific IgE was observed in a symptomatic employee. However, only 50% of those developing MDI-specific IgG were symptomatic; the role of IgG in the immunopathogenesis of MDI-associated respiratory disorders is not clear.

Acute (peak) exposures, as suggested in the past with the one employee with positive skin (and IgE) testing, may have a role in producing pulmonary sensitization.

VIII. RECOMMENDATIONS

In view of the findings of the environmental and medical investigations, the following recommendations are made to ameliorate existing or potential hazards and to provide a better work environment.

A number of the following recommendations were also made in the Interim Reports.

1. NIOSH does not recommend the practice of pre-employment screening x-ray examinations of the spine. They involve a substantial radiation exposure, and unless done for a specific diagnostic purpose (not routine screening) have no appreciable predictive value in the assessment of future back problems.

2. Employee exposure to excessive metal fumes in the cleaning/finishing area should be reduced through effective engineering controls. The available ductwork for the local exhaust ventilation systems for the arc air burning, gas shielded arc welding, and gas burning/cutting operations should be equipped with flanged hoods. Also, the exhaust ventilation systems should be used at all times when work is being performed and the hoods placed as close as possible to the point of generation of the metal fumes. During the interim period, while effective engineering controls are being implemented, respirators (described previously and in Appendix I & II) should be worn by employees engaged in arc air burning, arc welding, and gas cutting/burning operations.

3. Further monitoring of employee exposure to noise in the foundry (especially the cleaning/finishing area and melt shop) should be conducted. If excessive noise levels exist, a continuing hearing conservation program, including pre-employment and periodic audiometric tests, periodic environmental monitoring, utilization and maintenance of hearing protective equipment, and employment of feasible engineering controls, should be implemented.

4. Plant management should implement a respiratory program consistent with the guidelines found in DHEW (NIOSH) Publication No. 76-189, "A Guide to Industrial Respiratory Protection", and the requirements of the General Industry Occupational Safety and Health Standards (29 CFR 1910.134). In addition, it should be ascertained that the compressors used for supplying air are equipped with the necessary safety and standby devices and meet minimum air quality specifications.

5. Current Material Safety Data Sheets and all available information concerning products used (including health effects) should be obtained and made available to all personnel. Furthermore, a continuing education program conducted by qualified persons should be instituted to ensure that all employees have current knowledge and understanding of health and safety hazards, proper work practices, and maintenance procedures. Specifically, efforts should be made jointly by union and management to encourage education of workers concerning the materials to which they are exposed.

6. Periodic environmental evaluation of employee exposures to isocyanates, silica, metal fumes, and noise should be conducted to assure that the above recommendations are adequate to protect the affected employees.

7. Recommendation regarding silica

   a. An effective medical and environmental monitoring process to detect cases of pneumoconiosis (silicosis) should be instituted at Marion Power Shovel. The components of this program are described in the NIOSH criteria document, a Recommended Standard for Occupatonal Exposure to Crystalline Silica [29] and include the following:

      1. Exposure to crystalline silica should be controlled so that no worker is exposed to a time-weighted average (TWA) concentration of respirable free silica greater than 50 ug/m^3 of air as determined by a full-shift sample of up to a 10-hour workday, 40-hour workweek. Exposure should be determined by a personal (breathing zone) sample. Procedures for sampling, calibration and analyses of environmental samples are specified in Appendices in the NIOSH criteria document for occupational exposure to crystalline silica.[29]

      2. Engineering controls should be used to maintain free silica dust exposure within the NIOSH recommended standard. Periodic air sampling for silica is necessary in order to determine the extent of the potential silica problem and the effectiveness of engineering controls and work practices, and to identify particularly hazardous work areas where more frequent monitoring or examination of workers is necessary. Preferably, this should be done at least once every six months. Proper respiratory equipment should be available, evaluated and maintained when its use becomes necessary.

      3. A medical examination should be made available to all workers subject to "exposure to free silica" at preplacement. The examination should include (1) a medical and occupational history to elicit data on worker exposure to silica and other fibrogenic dusts, other significant occupational exposures, significant past medical illness, smoking history, and symptoms and signs of respiratory disease; (2) a baseline chest roentgenogram (14" x 17" posteroanterior x-ray), interpreted according to the ILO/UC International Classification of Radiographs of pneumoconiosis;

and (3) pulmonary function testing including FVC, FEV_1 and FEV_1/FVC ratio to provide a baseline for evaluation of pulmonary function and to help determine the advisability of workers using negative- or positive-pressure respirators. Standardized procedures for calibrating the spirometer, performing the tests, calculating the results, interpreting the observed spirograms, and using accepted normal values are available and should be utilized. Comments regarding pulmonary function testing programs are made below in MDI/isocyanates section.

4. A periodic medical examination should be performed at least once every three years and should include the three elements described above. Results of pulmonary function should be compared to the previous best tests. A 10% reduction in FEV_1 of FVC over a 2-3 year period should be considered a significant change.

b. Chest x-rays performed should be of adequate quality. Chest x-rays should be compared to baseline x-rays and should be interpreted by trained "B readers", or radiologists or chest physicians who are familiar with the use of the ILO/UC classification. Independent reading by three "B readers", or by two "B readers" followed by a consensus interpretation may be a reasonable approach.

c. Medical records should be of such a form that information is easily accessible and retrievable, so that comparisons can be made from one examination to the next and should be maintained for at least 30 years following the employee's termination of employment.

d. Medical management of an employee with or without x-ray evidence of silicosis who has significant respiratory symptoms or signs or significant abnormalities on pulmonary function testing should be fully evaluated by a physician (preferably by a chest physician) qualified to advise the employee whether he should continue working in a dusty trade. Employees with definite or suspected silicosis should be promptly evaluated by a chest physician.

e. Any workers with simple or complicated silicosis should be notified of this finding and warned of the hazards of further exposure. They should be removed from further "exposure" to silica dust. If no pulmonary function impairment is noted, this may be accomplished by a combination of environmental dust control, reduced exposure time, and adequate respiratory protective equipment (if the silica dust level meets the NIOSH recommend standard).

8. Recommendations regarding MDI/Isocyanates

A program for medical surveillance of workers potentially exposed to isocyanates should be instituted. This has a number of components, most features of which have been summarized in a NIOSH publication.[17] New employees should have medical histories to seek pre-existing respiratory symptoms and disease, especially asthma, and occupational histories to seek evidence of previous exposure to isocyanates. They should have baseline PFTs including, at least, FEV_1, and FVC, (and calculation of the FEV_1/FVC ratio). Worker education concerning possible effects of isocyanates and work practices to minimize exposure should be instituted. Any worker reporting symptoms such as persistent cough, cough at night, wheezing, shortness of breath or difficulty breathing should be further evaluated, including pre- and post-shift PFTs. Those with greater than 10% decrease in FEV_1 over the shift should be referred to a pulmonary physician for determination of sensitization. Current employees should also have pre- and post-shift PFTs performed (after two consecutive work days if possible) at the beginning of the program and should be questioned about symptoms of isocyanate sensitization. Referral should be as for new employees. Workers determined to be sensitized should be removed from further exposure. All workers potentially exposed should be interviewed and undergo PFTs at least annually. Again, symptoms compatible with isocyanate sensitization should be investigated and significant pre- to post-shift decrements in FEV_1 or loss of FEV_1 greater than about 10% from one year to the next, should be further evaluated. Anyone with documented hypersensitivity to isocyanate should not have a work assignment involving exposure to isocyanates and may even be unable to tolerate working in the general area of isocyanate use or production. Because evidence of symptomatic (and some apparently sensitized) employees exposed to MDI was found, the above recommendations are applicable at the present time.

For proper performance of spirometry, a number of technical considerations should be addressed, including the use of a spirometer meeting ATS specifications,[36] employing a trained and enthusiastic technician, and, to the extent feasible, doing the tests with same machine, technician and time of day from year to year. Other features of an occupational pulmonary disease surveillance program include education of workers, maintenance of medical records and records of environmental exposure, and epidemiologic evaluation of data.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:

Richard L. Stephenson
Industrial Hygienist
Industrial Hygiene Section

Gary M. Liss, M.D., M.S.
Medical Officer
Medical Section

Field Assistance:
Environmental

Steven H. Ahrenholz, M.S., C.I.H.
Industrial Hygienist
Industrial Hygiene Section

James M. Boiano
Industrial Hygienist
Industrial Hygiene Section

Laurence D. Reed
Industrial Hygienist
Industrial Hygiene Section

Field Assistance:
Medical

James Lockey, M.D. (initial survey)
Resident, Environmental Health
University of Cincinnati
Medical Center

David Moller, M.D. (final survey)
David I. Bernstein, M.D.
Department of Medicine
University of Cincinnati
Medical Center
Paul Blanc, M.D.
Resident, Cook County Hospital
Chicago, Illinois

Special Laboratory
Assistance: Environmental

Martha J. Seymour
Chemist
Organic Methods Development Section
Measurement Research Branch

Special Laboratory
Assistance: Medical

Immunology Laboratory of
I. Leonard Bernstein, M.D.
University of Cincinnati
Medical Center

Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies
Report Typed By:	Patty Johnson Secretary Connie Kidd Clerk-Typist Kathy Conway Clerk-Typist Industrial Hygiene Section

XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Marion Power Shovel Dresser Foundry Plant #3
2. International Molders & Allied Workers, Local #45
3. NIOSH, Region V
4. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

FIGURE 1
Permitted Duration vs Noise Level

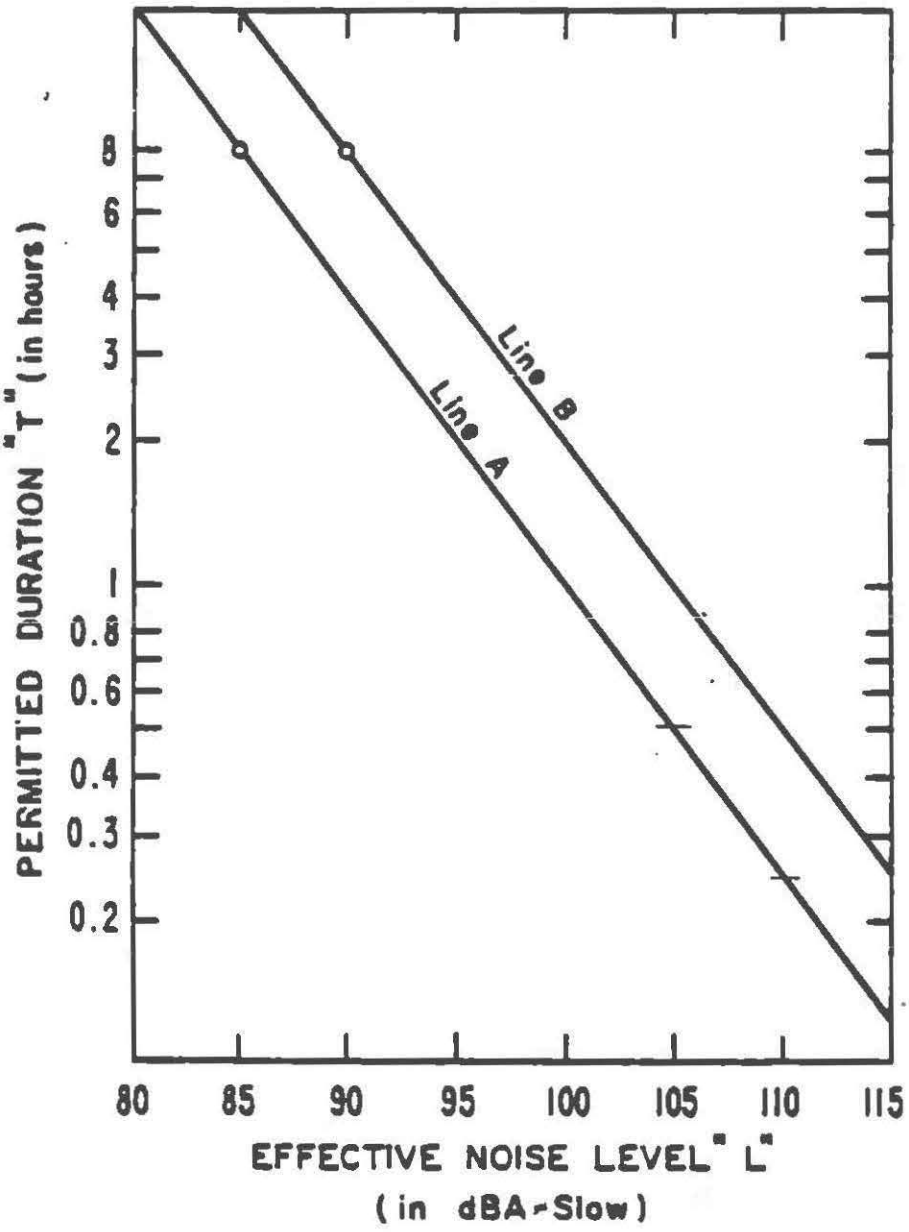


Table I

Air Sampling and Analysis Methodology

Marion Power Shovel
Dresser Foundry Plant #3
Marion, Ohio
HETA 80-073

Substance	Collection Device	Flow Rate (liters per minute)	Analysis	References[1]
Cr, Cu, Fe_2O_3, Mn, and Ni as fume	AA-MCEF Filter	1.5	Atomic Absorption Spectroscopy	NIOSH P&CAM 173
Methylene Bisphenyl Isocyanate	Midget Impinger with 15 ml of 1-(2-methoxyphenyl)-piperazine in toluene	1.0	High Performance Liquid Chromatography	NIOSH Method 5505 Total Isocyanates
	OR			
	13 mm Glass Fiber Filter impregnated with nitro-reagent**	1.0	High Performance Liquid Chromatography	NIOSH P&CAM 347 with modifications*
Mineral Spirits	Charcoal Tube	0.05	Gas Chromatography	NIOSH P&CAM 127 with modifications*
Triethylamine	Silica Gel Tube	0.05	Gas Chromatography	NIOSH P&CAM 221 with modifications*

* The modifications included sample preparation, instrument condition settings, and/or column selection.
** Nitro-reagent (N-p-nitrobenzyl-N-propylamine)

Table II

Results of Environmental Air Samples For Isocyanates[1] and Mineral Spirits[1]

Marion Power Shovel
Dresser Foundry Plant # 3
Marion, Ohio
HETA 80-073

Sample Location	Personal Sample (P) or Area Sample (A)	Date/Time	Sample Volume Isocyanates/Mineral Spirits (liters)		Mineral Spirits (mg/m^3)[2]	Total Reactive Isocyanate Groups (ug/m^3)[3]	Monomeric MDI (ug/m^3)	Difference between Total Reactive Isocyanate Groups and Monomeric and MDI (ug/m^3)
Coreroom								
Line Coremaker Worker A	P	9/12/83 1022-1544[5]	322	10.3	77.7	233	16.8	216
Worker B	P	9/19/83 0803-1434 & 1447-1547	451	15.3	45.8	ND[4]	13.8	-
Worker C	P	9/19/83 0747-1122 & 1132-1535	458	17.8	28.1	ND	14.9	-
Bench Coremaker Worker D	P	9/19/83 0840-1341 & 1353-1547	315	-	-	ND	21.9	-
Corepaster Worker E	P	9/19/83 0812-1140 1147-1419 1430-1531	421	-	-	119	14.3	104
Worker F	P	9/19/83 0912-1548	396	-	-	ND	17.7	-
Coreroom Helper Worker G	P	9/19/83 0826-1549	443	14.3	ND	ND	13.3	-
Sand Mill/Mixer Operator Worker H	P	9/19/83 0917-1433	316	11.9	25.2	ND	19.6	-

(continued)

Table II (continued)

Sample Location	Personal Sample (P) or Area Sample (A)	Date/Time	Sample Volume Isocyanates/Mineral Spirits (liters)		Mineral Spirits (mg/m^3)(2)	Total Reactive Isocyanate Groups (ug/m^3)(3)	Monomeric MDI (ug/m^3)	Difference between Total Reactive Isocyanate Groups and Monomeric and MDI (ug/m^3)
Mold Floor								
Rod & Gagger Worker I	P	9/19/83 0821-1245 1320-1515	379	-	-	168	16.6	151
Chainman Worker J	P	9/19/83 0926-1528	362	14.8	40.5	ND[4]	19.1	-
Large Floor Molder Worker K	P	9/12/83 1611-2246	395	15.7	12.7	234	19	215
Worker L	P	9/12/83 0754-1447	413	15.8	30.9	ND	13.8	-
Worker M	P	9/12/83 1222-1825	363	14.1	27.3	300	17.9	282
Worker N	P	9/12/83 0755-1514	439	-	-	114	13.7	100
Sandslinger Worker O	P	9/12/83 0750-1445(6)	415	11.8	8.4	183	11.3	173
Foundry Helper	P	9/12/83 0742-7517	455	17.4	22.9	ND	16.7	-
Mold Floor (continued)								
General Clean-up Person Worker Q	P	9/12/83 1428-2300(7)	512	9.4	42.6	415	12.3	403
Machine clean-up person Worker R	P	9/12/83 1606-1903 1915-1940 1947-2245	381	15.4	39.1	558	28.4	530
Crane Operator Worker S Sample located on Platform	P	9/19/83 1025-1607	342	13.6	ND[4]	171	15.8	156
Outside Crane cab	A	9/19/83 1029-1610	341	12.8	ND	190	17	173

(continued)

Table II (continued)

Sample Location	Personal Sample (P) or Area Sample (A)	Date/Time	Sample Volume Isocyanates/Mineral Spirits (liters)		Mineral Spirits (mg/m^3)(2)	Total Reactive Isocyanate Groups (ug/m^3)(3)	Monomeric MDI (ug/m^3)	Difference between Total Reactive Isocyanate Groups and Monomeric and MDI (ug/m^3)
Shakeout								
General Labor Worker T	P	9/12/83 0802-1506	424	-	-	135	11.6	124
Crane Operator Worker U	P	9/13/83 0948-1547	359	15.3	ND	ND	8.9	-
Sample Located on plateform outside Crane Cab	A	9/13/83 0945-1547	362	13.6	ND	ND	14.4	-
Evaluation Criteria								
(normal workday, 40 hr/wk, time-weighted average:					350	-	50	-
(ceiling limit for any 15 minute sampling period:					1800	-	-	-
(ceiling limit for any 10-minute sampling period:					-	-	200	-
Laboratory analytical limit of detection (mg/sample):					0.1	-	-	-
Laboratory analytical limit of quantitation in ug/sample:						50	0.7	-

1. All concentrations are time-weighted averages for the period sampled.
2. mg/m^3 = milligrams per cubic meter of air.
3. ug/m^3 = micrograms per cubic meter of air.
4. ND = nondetectable concentration.
5. Sample time for the mineral spirits was 1130-1544.
6. Sample time for the mineral spirits was 0916-1508.
7. Sample time for the mineral spirits was 1428-2013.

Table III

Results of Environmental Air Samples For Metals
Cleaning/Finishing Department

Marion Power Shovel
Dresser Foundry Plant #3
Marion, Ohio
HETA 80-073

September 13, 1983

Sample Location	Time	Sample Volume (liters)	Chromium (mg/m^3)	Copper (mg/m^3)	Iron Oxide (mg/m^3)	Manganese (mg/m^3)	Nickel (ug/m^3)
Arc Air Operator	0741-1604	754	0.04	0.14	5.8	0.24	190
Arc Air Operator	0746-1604	747	0.03	0.19	8.6	0.53	150
Gas Shielded Arc Welder	0803-1548	698	0.01	0.03	1.4	0.20	61
Gas Shielded Arc Welder	0809-1601	708	0.01	0.01	1.5	0.62	40
Gas Shielded Arc Welder	0812-1553	692	0.004	0.01	2.3	1.04	20
Burner/Cutter	0820-1553	680	N.D.	0.01	0.5	0.01	17
Burner/Cutter	0830-1552	651	0.01	0.03	1.4	0.04	78
Evaluation Criteria (normal workday, 40 hr/wk, time-weighted average)			0.5	0.1	5.0	1.0	15
Laboratory analytical limit of detection in micrograms (ug)/sample:			2	1	10	1	2

All concentrations are time-weighted averages for the period sampled and are personal breathing-zone samples.

mg/m^3: milligrams per cubic meter of air
ug/m^3: micrograms per cubic meter of air
N.D.: nondetectable concentrations

Table IV

Summary of chest X-ray interpretations

Marion Power Shovel
Marion, Ohio
HETA 80-073

Total employees with 10 or more years seniority having X-rays available for interpretation		77
X-rays of inadequate quality of interpretation		1
X-rays of adequate quality of interpretation		76
No evidence of pneumonoconiosis		71 (93%)
Evidence of pneumonoconiosis		5 (7%)
Simple:	Category 1 - small, rounded opacities	2
	Category 2 - small, rounded opacities	2
Complicated:	Type A (background Category 3)	1

Table IV-A

Characteristics of cases of pneumoconiosis

Case #	Chest x-ray Interpretation	Age	Relevant Prev Occup History	Yr at Marion	Occupation Current	Occupation Former	Stage of Silicosis
1	q 1/1	61	core x 1 yr	> 35 yr	core maker	core maker	simple
2	q 1/2	50	none	> 30 yr	crane blast op	cleaning room (blast op)	simple
3	q 2/3	52	Railroad x 1yr	> 30 yr	core setter	various core & mold room jobs	simple
4	q/r 2/3	58	Machinistx22y Millwrightx1m History of includes sarcoidosis	14 yr	Maintenance (repairs machines)	(welder, machinist)	simple
5	r 3/2, A	53	none	> 30 yr	core	core	complicated

Table V

Demographic Data

Marion Power Shovel
Marion, Ohio
HETA 80-073

September 1983

Characteristic	Exposure Group: Current	Never	Exposed in Past
	Categorical Data		
N	26	14	6
Age: < 40	9 (35)*	4 (29)	4
≥ 40	17 (65)	10 (71)	2
Race: White	24 (92)	14 (100)	6
Black	2 (8)	-	-
School: 1-11	16 (62)	7 (50)	3
12 +	10 (38)	6 (43)	4
Smoking Status:			
current	16 (62)	7 (50)	3
ex	10 (38)	4 (29)	
never	-	3 (21)	3
Symptoms of seasonal rhinitis:			
Yes	4 (15)	3 (21)	3
No	22 (85)	11 (79)	3
	Continuous Data		
Age, year:			
Mean ± SD	46 ± 11	49 ± 12	39 ± 13
Range	27 - 61	31 - 62	25 - 56
School, years:			
Mean ± SD	9 ± 3	11 ± 2	11 ± 2
Range	2 - 12	7 - 13	8 - 12

Table V (continued)
Demographic Data

Marion Power Shovel
Marion, Ohio
HETA 80-073

September 1983

Characteristic	Current	Never	Exposed in Past
		Continuous Data	
Current job, year			
Mean ± SD	14 ± 13	14 ± 9	6 ± 4
Range	0.2 - 38	0.1 - 36	0.5 - 10
Current Department, year			
Mean ± SD	17 ± 13	15 ± 9	6 ± 5
Range	0.2 - 38	0.1 - 36	0.6 - 12
Total years in plant:			
Mean ± SD	20 ± 13	22 ± 12	17 ± 16
Range	3.5 - 38.5	5 - 42	1.9 - 41.5
Packs/day, current smokers:			
Mean ± SD	1.3 ± 0.7	1.2 ± 0.4	1.2 ± 0.6
Range	0.1 - 3	0.8 - 2	0.5 - 1.5
Years smoked, current smokers:			
Mean ± SD	22 ± 12	33 ± 15	29 ± 9
Years smoked, former smokers:			
Mean ± SD	15 ± 9	10 ± 10	-

*Numbers in parentheses represent percentages

Table VI

Work-associated symptoms, by exposure group

Marion Power Shovel
Marion, Ohio
HETA 80-073

September 1983

Symptom	Exposure Group: Currently #	Currently %	Former #	Former %	Never #	Never %	P-value a	P-value b
Lower respiratory Tract*	7	(27)	3	(50)	0	(0)	0.035	0.016
Upper Respiratory Tract**	5	(19)	2	(33)	4	(29)	0.383	0.444
Fever, chills, muscle aches	0		1	(17)	0		-	-

* wheezing, cough, or shortness of breath
** nasal stuffiness, itchy or irritated eyes, runny nose
a Fisher's exact test, 1-tailed: currently (in mold or core) vs never
b Fisher's exact test, 1-tailed: ever (currently or formerly in mold or core) vs never

Table VII

Symptoms and signs on days of study at time of pre- and post-shift spirometry, by exposure group

Marion Power Shovel
Marion, Ohio
HETA 80-073

September 1983

	Exposure Group		
	Current (N = 24)*	Former (N = 6)	Never (N = 14)**
Itchy or stuffy nose:			
(pre-shift)	3	1	4
(post-shift)	1	0	0
Burning, itchy or watery eyes:			
(pre-shift)	0	0	1
(post-shift)	3	0	0
Cough or bringing up phlegm:			
(pre-shift)	4	1	2
(post-shift)	4	0	2
Chest tightness, wheezing or shortness of breath:			
(pre-shift)	1	0	0
(post-shift)	4	0	2
Wheeze on examination:			
(pre-shift)	2	0	1
(post-shift)	1	0	2

* only 23 post-shift
** only 13 post-shift

Table VIII

Baseline pulmonary function by exposure and smoking status

Marion Power Shovel
Marion, Ohio
HETA 80-073

September 1983

	Currently Exposed (N = 24)*			Formerly Exposed (N = 6)			Never Exposed (N = 13)*		
	Never Smokers	Former Smokers	Current Smokers	Never Smokers	Former Smokers	Current Smokers	Never Smokers	Former Smokers	Current Smokers
Subjects, no.		10	14	3		3	3	4	6
FEV_1 % of predicted		93 ± 19	90 ± 19	86 ± 13		80 ± 23	100 ± 9	106 ± 14	84 ± 14
FVC_1 % of predicted		94 ± 16	99 ± 20	89 ± 8		82 ± 15	103 ± 3	112 ± 17	86 ± 13
FEV_1/FVC ratio		78 ± 5	73 ± 9	79 ± 15		77 ± 9	78 ± 8	76 ± 3	77 ± 8
FEF_{25-75}, % of predicted		67 ± 22	55 ± 26	85 ± 50		64 ± 41	71 ± 24	65 ± 9	64 ± 38

* Two currently exposed workers and one never exposed worker did not participate in spirometry
** Mean ± S.D.

Table IX

Pulmonary function changes over the shift, by exposure group

Marion Power Shovel
Marion, Ohio
HETA 80-073

September 1983

Parameter	Exposure Group: Current (N = 23)	Never (N = 13)	P **
FEV_1 (post-pre) liters	-0.049 ± 0.167*	+0.065 ± 0.135	0.043
FVC (post-pre) liters	-0.060 ± 0.333	+0.047 ± 0.144	0.187
FEF_{25-75} (post-pre) liters/sec	0.025 ± 0.655	+ 0.128 ± 0.436	0.614

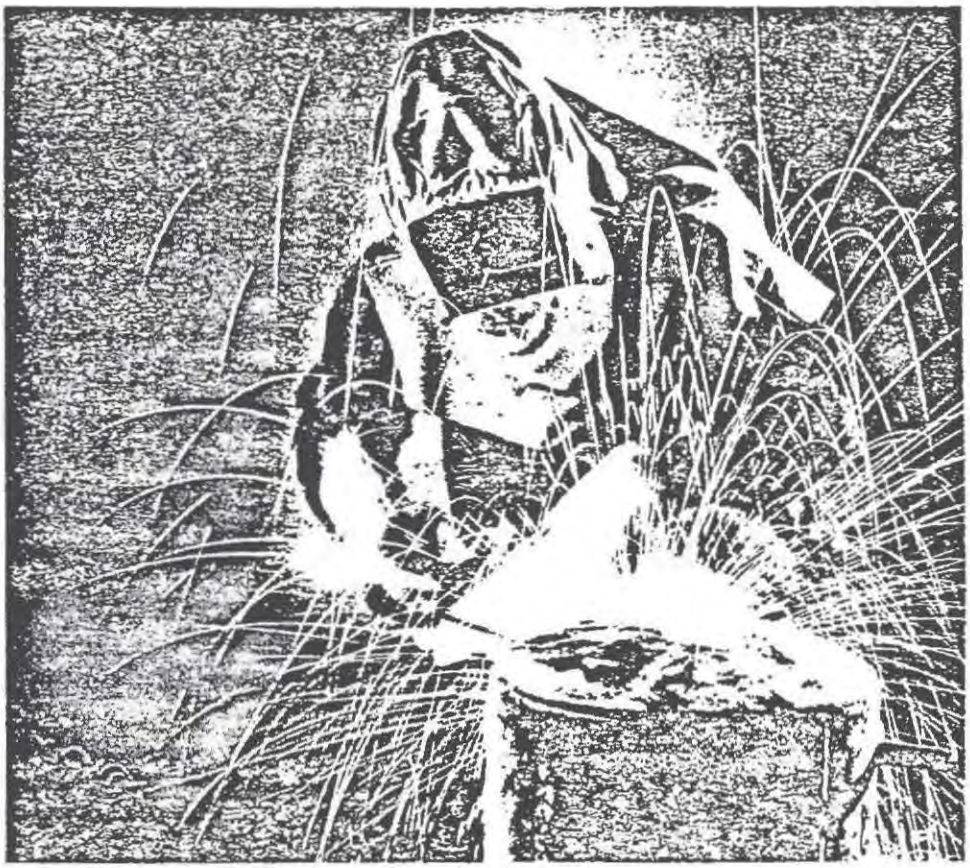
* Mean ± S.D.
** pooled t-test, two-tailed

High-impact-resistant cover lens is inserted in the outer position.

Rayfoe Filter Plate is inserted in the inner position.

Optional accessory

A heat-resistant chrome leather hood that connects to snap-type fasteners on the sides of the Welders Adapter protects the welder's neck and shoulders from welding splatter, sparks, and intense heat.



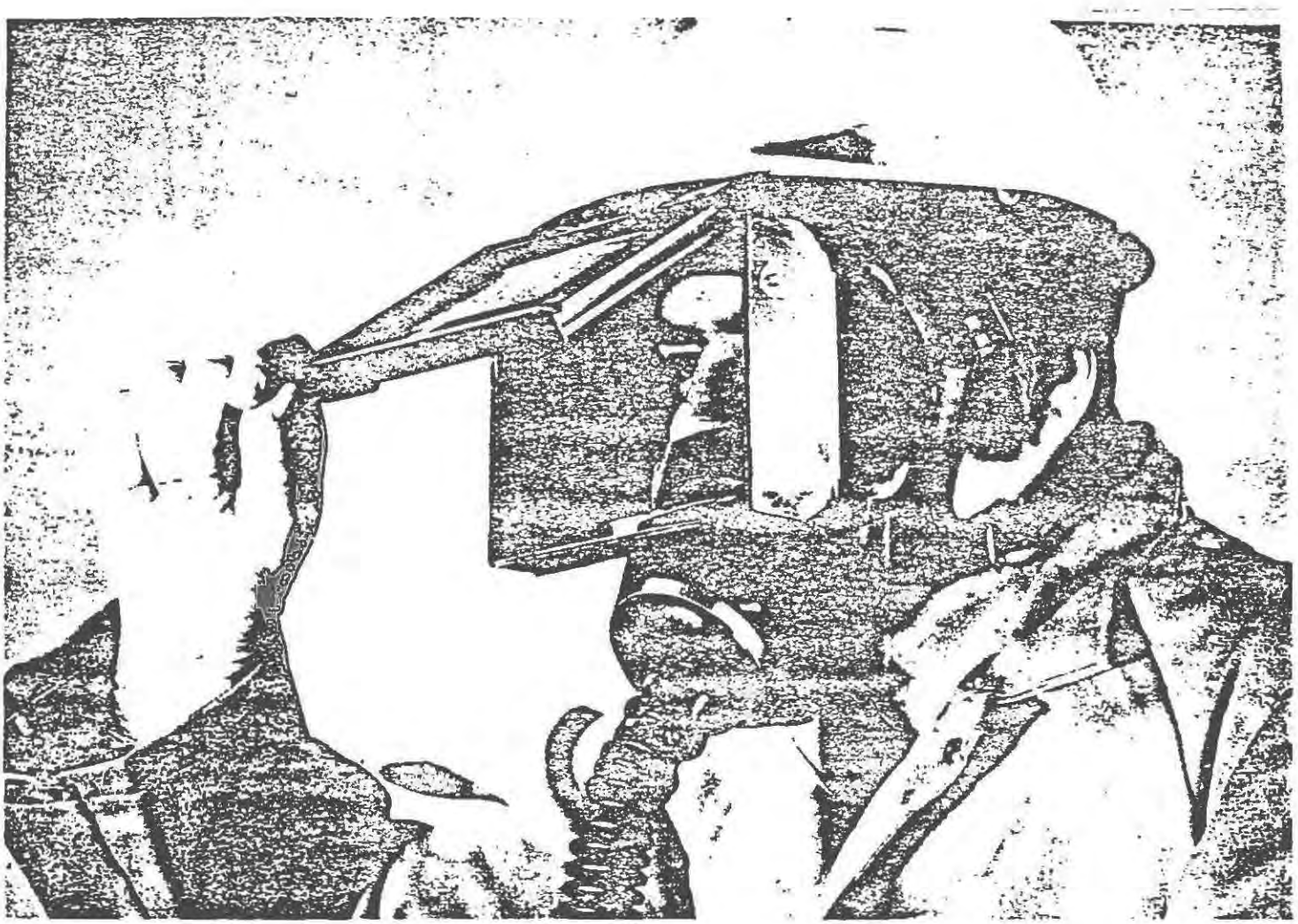
Optional chrome leather hood protects neck and shoulders.

Ordering Information

Catalog numbers

449646	Ultravue Welders Adapter, complete with cover lens, less filter plate
471180	Clearvue Welders Adapter, complete with cover lens, less filter plate
38346	Rayfoe Filter Plate, shade 6, heat-treated
38347	Rayfoe Filter Plate, shade 10, heat-treated
38277	Rayfoe Filter Plate, shade 12, heat-treated
38348	Rayfoe Filter Plate, shade 14, heat-treated
88379	Cover Lens
87408	Welders Hood, chrome leather
34337	Cleaner-Sanitizer, 25 1-oz pkgs

Note: This Data Sheet contains only a general description of the MSA Welders Adapter. While uses and performance capabilities are described, under no circumstances should the product be used except by qualified, trained personnel and not until the instructions, labels, or other literature accompanying it have been carefully read and understood and the precautions therein set forth followed. Only they contain the complete and detailed information concerning this product.



Application

MSA® Welders Adapter affords a means of combining vision protection with a wide choice of respiratory protection for welders subject to toxic hazards. Models are available to adapt both Ultravue® and Clearvue® Facepieces, making the whole line of MSA full-facepiece respiratory protection devices suitable for welding operations.

Description

The Welders Adapter is molded of polycarbonate plastic, which has high resistance to impact, heat, and welding splatter, and retains its strength at temperatures from −100° to 270°F. Adapter is attached to Ultravue or Clearvue Facepiece by spring retainers, and has a light-tight, fire-retardant polyurethane foam gasket. A large vision area— 4½ x 5¼ in.— provides an unobstructed view of work.

The Welders Adapter is supplied with an impact-resistant cover lens; desired filter plate is ordered separately. Rayfoe™ Filter Plates are available in four standard shades—6,10,12, and 14. Intermediate shades are also available on request.

Operation

With Welders Adapter attached, the Ultravue or Clearvue Facepiece is worn normally. Filter plate and cover lens slide easily into place and are held securely by retaining springs. The lift-front, which contains the lenses, swings up easily to allow a clear view for preparatory work. It is returned to welding position with a downward snap of the head, leaving the welder's hands free for work.

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