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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45202

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 73-185-256

ELECTROMOTIVE-DIVISION GMC (Plant 2)
CHICAGO, ILLINOIS

JANUARY 1976

I. TOXICITY DETERMINATION

Based upon a sample of workers, chosen on a statistically random basis from a population defined from the eight departments pertaining to this evaluation, it has been determined that the MIG welders in at least three of the eight departments and the STIK welders in one of the eight departments were exposed to concentrations of iron oxide fume in excess of levels permitted by the Permissible Excursion Value of the Threshold Limit Value for iron oxide fume, at the time of this evaluation; and therefore, workers are exposed to toxic concentrations of fumes and vapors. This determination is based on environmental measurements and medical observation of acute irritation symptomatology among significant numbers of workers.

It has also been determined that exposure of the STIK and the MIG welders to Carbon Monoxide, Ozone, and Nitrogen Dioxide gases would not be expected to cause toxic effects at the concentrations measured during this evaluation.

A medical evaluation was also performed on the same population of workers. It was found that there was a statistically significant difference between pre- and post-shift observations for eye, nose, and throat symptomatology (throat redness) at the time of this evaluation. The development of adverse symptomatology with respect to eyes, nose, and throat, indicates an irritant exposure taking place over the shift for employees in the eight departments working the day and evening shift.

In conjunction with particulates (welding fume) it is possible the synergistic effects develop from the combination of irritant gases and particulates. A potentially toxic exposure to carbon monoxide in one area was measured, that may have caused the excessive reporting of headaches as a common symptom among workers.

This determination is based on pre- and post-shift medical questionnaires and physical exam findings as well as environmental measurements made on welders chosen in a randomly selected manner from the department populations in question.

No evidence of systemic toxicity was observed.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are available upon request from the Hazard Evaluation Services Branch, NIOSH, U.S. Post Office Building, Room 508, 5th and Walnut Streets, Cincinnati, Ohio 45202. Copies have been sent to:

1. Electro-Motive Division, GMC, 103rd Street, Chicago, Illinois.
2. Authorized representative of employees.
3. U.S. Department of Labor, Region V, Chicago, Illinois.
4. Regional Consultant for Occupational Safety and Health, Region V, Chicago, Illinois.

For the purpose of informing the approximately 237 "affected employees" (see Appendix I), the employer will promptly "post" the Determination Report in prominent places where affected employees work for a period of 30 calendar days.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, CFR 29, U.S. Code 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by 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 National Institute for Occupational Safety and Health (NIOSH) received such a request from an authorized representative of employees of Electro-Motive Division, GMC, Plant 2, Chicago, Illinois regarding exposure to welding fumes in departments throughout Plant 2.

The request was prompted by employee concern over the lack of ventilation in the welding areas, which allegedly did not remove welding fumes.

IV. HEALTH HAZARD EVALUATION

A. Plant Process-Conditions of Use

Approximately 1000 production employees and 100 administrative employees are employed at Electro-Motive Division, GMC, Plant 2. The plant is engaged in production activities over two shifts, with a skeleton crew (primarily maintenance) on the night shift.

Plant 2 fabricates fuel tanks, exhaust manifolds, crankcases, and traction motor housings, all of which are integral parts in the construction of diesel locomotives, which are assembled at Plant 1, LaGrange, Illinois.

Fabrication of the above locomotive components at Plant 2 is accomplished primarily through several welding processes, the most prevalent being shielded metal arc welding (Stik welding) and gas metal arc welding or metal inert gas welding (MIG welding). Some submerged arc welding is also done. In addition to the above welding processes, flame-cutting and arc-gouging are also used in fabrication.

B. Evaluation Progress

1. Initial Plant Visit

On February 27, 1974, NIOSH representatives, which included two industrial hygienists and a physician met with representatives of labor and management to discuss the purpose of the evaluation. Background information regarding processes, materials and occupational health problems was obtained after which a walk-through survey of the area specified in the request was made.

The production area of Plant 2 is divided into four bays, which are involved in the fabrication of the following:

Bay 1: Production of miscellaneous heavy weldments -- undercarriage components, generator housings, commutator housings, and traction motor housings.

Bay 2: Crankcase and oilpan.

Bay 3: Exhaust manifolds.

Bay 4: Fuel tanks.

The health hazard evaluation request specified "critical" areas as, throughout Bay 1 (no department specified), east end of Bay 4 (Departments 7182, 7024), west end of Bay 3 (Department 7031), and in Bay 2 (no department specified).

A walk-through survey was conducted in the aforementioned areas. A lack of effective ventilation was readily apparent in Bay 1, especially at the traction motor housing area. Several welders were seen to be welding in severely enclosed areas (inside the traction motor housing). A snorkel ventilation "tube" was available for use in this operation, however, it did not appear to be removing welding effluent.

A visual observation of Bay 2 also showed a lack of effective ventilation. In Bay 2 (and in Bay 1) a thick haze was seen to have settled over the welding areas. The haze considerably reduced the visibility from one end of the plant to the other.

A visual observation of Department 7031 showed welding fumes to be entering the breathing zone of the welders. Although the welders' helmet afforded some protection by diverting the fume stream, welding fumes were observed to be entering the underside of the helmet.

A visual observation of Departments 7182 and 7024 showed similar welding fume characteristics.

A lack of ventilation throughout the plant, and more important, an indicator of the particulate matter in the air, was shown by the thick deposits of particulate on ceiling windows due to thermal precipitation. This deposit all but blocked out the light coming through the windows.

During the walk-through survey of the aforementioned areas, detector tube measurements were made on welders, chosen at random at the various locations specified in the request for Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Ozone (O_3). Measurements were made outside the welders helmet, which is an indication of maximum possible exposure. Carbon Monoxide measurements indicated concentrations of 10 parts per million in Departments 7102, 7146, 7086, and 7182. In Department 7144, one stik welder showed a concentration of 50 ppm. In Department 7031, a MIG welder showed a concentration of 50 ppm. Concentrations of Ozone and Nitrogen Dioxide in the aforementioned departments were not detected. It should be noted that these measurements are grab samples and should not be construed as an 8-hour Time Weighted Average (TWA). No measurements were made for welding fume-total particulate in this initial survey.

Interviews, conducted by a NIOSH physician, were held with eighteen affected employees throughout the plant regarding health effects due to employment. Symptoms due to employment reported during the interviews included black sputum production with cough, black mucous discharge from the nose, occasional dry or sore throat, watery or blurring eyes, fatigue or tiredness, shortness of breath, dizziness, and headache.

a. Initial Survey Conclusions

A review of initial survey findings indicated that a large number of individuals were experiencing adverse effects despite low levels of measured welding gases. An expanded environmental-biomedical evaluation was deemed necessary to determine quantitatively and qualitatively the cause and effect relationship.

2. Expanded Evaluation

On May 16, 1974, NIOSH representatives met with representatives of management and labor to discuss the protocol for the expanded evaluation. The basic evaluation design was to select a number of various types of welders chosen in a statistically random manner--and conduct the environmental/medical evaluation on this group.

The environmental evaluation consisted of two phases:

1. A preliminary evaluation which would examine a selected group of workers' exposure to Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Ozone (O_3).

2. An expanded evaluation which would examine selected group of workers' exposure to welding fume particulate matter.

The medical evaluation would consist of medical interview and physical examination of selected group welders. (At the conclusion of this medical evaluation, it was further deemed appropriate to conduct pulmonary function tests on a random sample taken from the selected group.)

a. Statistical Methods

To obtain the sample for the study, a random selection was made from the populations of Stik welders and MIG welders in the departments included in the request. The population was first divided into subgroups (strata) as shown in Table I. (See Appendix I) A random sample was then drawn from each subgroup (strata). A total of 128 welders would constitute the sample size:

i. Phase I - Statistical Method-Environmental

From each of the sample sizes listed for the strata in Table I, a random sample of welders was drawn. Consideration was given to the number of welders in a particular strata in determining the sample size for each strata. Availability of time and manpower were also considered.

ii. Phase II - Statistical Method-Environmental

Again from each of the sample sizes listed for the strata in Table I, a random sample of welders was drawn. Number of welders in a particular strata, time, and available manpower were used in determining the number of welders from each strata.

iii. Phase II - Statistical Method-Medical

All welders in the sample sizes from all strata were examined medically. Phase II Medical included pre- and post-shift interviews and some physical examination.

iv. Phase III - Statistical Method-Medical

Criteria used in selecting the welders for the Pulmonary Function Test were narrowly defined so that welders with a considerable length of exposure ($\geq$5 years) as well as those with the great majority of their welding at GMC ($\geq$75%) could be evaluated. Thirty-two of fifty-three (60%) individuals who met these criteria were tested.

b. Phase I - Environmental - June 25, 1975

Seventeen welders taken from the various stratas were included in this phase of the environmental evaluation. Detector tube measurements were made for Carbon Monoxide (CO), Ozone (O_3), and Nitrogen Dioxide (NO_2) - near the "breathing zone", outside the welding helmet. (Initially measurements were taken outside the helmet for each of the above gases to detect the presence of the substance. If these measurements indicated a "considerable" presence of the above gases measurement of that substance was made inside the welding helmet to better quantify the welders exposure.) The detector tubes used are designed to measure levels of Ozone between .05-1.4 parts per million (ppm); of Nitrogen Dioxide from .5-10 ppm; and of Carbon Monoxide from 10-3000 ppm.

i. Evaluation Criteria - Environmental - Phase I

Criteria used in determining the basis for toxicity of substances identified in this phase of the environmental evaluation are the Threshold Limit Values (TLV) as issued by the American Conference of Governmental Industrial Hygienists (ACGIH) as documented in the Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment - with Intended Changes for 1974.

Substance	TLV ppm[1]
CO	50
NO_2	5[2]
O_3	0.1

1 Parts of vapor or gas per million parts of contaminated air by volume at 25° C. and 760 mm. Hg. pressure.

2 This value represents a ceiling Value and should not be exceeded at any time.

c. Phase II - Environmental - July 15-18, 1974

Thirty nine welders taken from the various strata were included in this phase of the environmental evaluation. This phase examined worker exposure to welding fumes.

The environment sampling train consisted of a "modified" welders helmet, with a fitted cassette attached to the front of the helmet just below the glass, and a MSA model G pump. The sample flow rate was set at 1.5 l/min. The filter used in the cassette was Type AA, .8μ pore size.

i. Evaluation Criteria-Environmental-Phase II

Criteria used in determining the basis for toxicity of substances identified in this phase of the environmental evaluation are the Threshold Limit Values (TLV) as issued by the ACGIH as documented in the Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment - with Intended Changes for 1975.

Substance	TLV (mg/M^3)[1]
Iron Oxide	5

1 Approximate milligrams of substance per cubic meter of air.

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect.

A second criteria used in determining the presence or absence of excessive exposure of a substance to the worker is the Excursion TLV Factor as documented in Threshold Limit Values for Chemical Substances and Physical

Agents in the Workroom Environment - with Intended Changes for 1975. This factor defines the magnitude of the permissible excursion above the limit for those substances, not given a "C" designation, i.e. the TWA Limits. These excursion factors are to be considered to provide a "rule-of-thumb" guidance for listed substances generally, and may not provide the most appropriate excursion for a particular substance.

A table of Excursion Factors is presented below:

Range	Excursion Factor
0 < TLV < 1 (ppm or mg/M^3)	3
1 < TLV < 10 " "	2
10 < TLV < 100 " "	1.5
101 < TLV <1001 " "	1.25

d. Phase II - Medical Evaluation - July 16-18, 1974

This phase of the medical evaluation was conducted to ascertain the presence or absence of acute adverse effects which developed over the shift in the randomly selected population of welders. This included pre- and post-shift questionnaire and physical examination. To identify chronic respiratory effects, a detailed questionnaire was administered to the randomly selected population.

i. Medical Analytical Methods

a. Pre- and Post-shift

The determination of whether there was a statistically significant difference between the number of persons observed to have a particular sign or symptom on the pre- and post-shift testing was made using the Chi square statistic with Yates correction for continuity for 2 by 2 tables.

b. Respiratory Questionnaire

A modified version of the Medical Research Council's Questionnaire on Respiratory Symptoms (MRCQ) was used to assess the prevalence of chronic respiratory disease. Using the Chi square Goodness of Fit test, the data from several studies were compared to the observed GMC data.

ii. Evaluation Criteria - Medical Evaluation

a. Pre- and Post-shift

The medical criteria used to determine a toxic response to the substances under investigation consists of symptoms and signs which each substance produces when toxic exposure occurs. A brief review of the substances of primary concern follows:

A statistically significant difference between pre- and post-shift findings was recorded if the prevalence of a symptom or sign exceeded what one would expect on the basis of chance or randomness. The probability that such significant symptoms or signs could have developed by chance over the shift was 5% or less (i.e. $p \leq 0.05$).

Breathing excessive amounts of fumes from metals such as zinc, manganese, copper, nickel, magnesium, and chromium can bring about "metal fume fever". The symptoms of metal fume fever include chills and fever (which rarely exceeds 102° F.) upset stomach and vomiting, dryness of the throat, weakness, and aching of the head and body. They often occur some hours after exposure to welding fumes and usually last only a day or less.

Iron Oxide ($Fe_2 O_3$)

Prolonged, excessive exposure to this agent gives rise to "iron pigmentation" of the lungs, known as siderosis, which is generally considered a benign pheumoconiosis. This type of dust or fume is found in a number of jobs (welding, iron ore mining, foundry and fettling operations, and others). Regarding the systemic absorption of iron from iron oxide inhalation, no evidence of impairment has been noted.

With regard to local effects, upper respiratory and sinus irritation and congestion have been known to occur with excessive exposure to the dust or fume.

Ozone (O_3)

When exposed to very low concentrations of ozone for even brief periods of time, an individual may notice a pungent, sharp odor. As the concentration of ozone increases, the odor often seems to lessen. One then may experience irritation to the eyes, dryness of the nose and throat, and cough. If the ozone concentration continues to rise more severe symptoms may develop. These include headache, upset stomach or vomiting, pain or tightness in the chest, shortness of breath, tiredness, or weight loss which may last for several days to weeks. Finally, with higher levels of exposure lung edema and hemorrhage, and ultimately death, may take place if the individual continues his exposure.

Carbon Monoxide (CO)

The acute effects resulting from exposure to increasing concentrations of CO are well defined. Because CO is an odorless gas, the sense of smell does not help in detecting its presence. Early symptoms include tightness across the forehead and slight headache. As the concentration increases, throbbing bitemporal headache ensues followed by weakness, dizziness, dimness of vision, nausea and vomiting. Finally, collapse, coma and death may occur if high levels of exposure continue. Also, the effect of chronic low level exposure has been associated with deleterious effects on the heart circulation and mild adverse behavioral effects as noted by psychological testing.

Nitrogen Dioxide

The pungent odor of NO_2 is detected at conditions as low as 5 ppm. As concentrations increase (10-20 ppm), the gas becomes mildly irritating to the eyes, nose, and upper respiratory mucosa. Very high concentrations (100 ppm) of the gas appear to have a red-brown tint and exposure to them can lead to serious pulmonary effects.

A statistically significant difference between pre- and post-shift findings was recorded if the prevalence of a symptom or sign exceeded what one would expect on the basis of chance or randomness. The probability that such significant symptoms or signs could have developed by chance over the shift was 5% or less (i.e. $p \leq 0.05$).

b. Respiratory Questionnaire (MRCQ)

Work exposure is only one of many factors which can significantly influence an individual's respiratory health. Other factors such as infection, smoking history, family history, air pollution, etc. may play major roles as well. For this reason, it is often difficult to compare questionnaire responses of groups of workers from various localities and to attempt to draw conclusions about how their work environment influences their respiratory health. Recognizing these limitations, the responses of the GMC welders were compared with the following studies:

(1) Fogh et al. evaluation of respiratory symptoms in Danish welders and controls.[1]

(2) Sharp et al. evaluation of chronic bronchitis in an American male urban industrial population.[2]

(3) Ferris et al. evaluation of chronic respiratory disease in a New Hampshire town.[3]

Differences between the GMC responses and the comparison studies were considered significant at the $p \leq 0.05$ level.

e. Phase III - Medical Evaluation - October 15-16, 1974

This phase of the medical evaluation was conducted to ascertain whether the pulmonary function of the welders was being affected by their working environment.

Pulmonary function tests were administered to a specifically defined group of welders. - This group included all individuals who had welded at GMC for 5 years or more with at least 75% of the individual's welding experience at GMC. Individuals who met the above definition but had worked prior to GMC in a "dusty trade" for 5 years or more were not given pulmonary function tests. A "dusty trade" was defined as an occupation in which agents are present that are known - or suspected to affect an individual's respiratory tract when excessive exposure occurs.

i. Medical Analytical Methods

In order to assess whether the pulmonary function of the welders was being affected by their working environment, it was necessary to compare each individual's actual values with predicted values. Predictions depend upon race, sex, height, and age. Other factors such as smoking history and degree of air pollution may have considerable influence as well.

The "t" test was used in comparing the pulmonary function test results of the GMC welders with their predicted values, both individually and for mean values. The GMC welders' pulmonary function test values were considered significantly low if they fell more than twice the standard error of the estimate (SEE) below the predicted value ($p < 0.05$). This follows the suggestion of Sobol and Weinheimer.[4] Three sets of formulae for predicting Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1) were used:

(1) Oscherwitz et al.[5] for black male workers
(2) Kory et al.[6] for white male workers
(3) Morris et al.[7] for female workers.

C. Expanded Environmental Results

1. Phase I

A summary of results of environmental measurements made for CO, O_3, and NO_2 are shown in Tables II and III (See Appendices II and III). Table II summarizes MIG welder exposure, and Table III summarizes STIK welder exposure. As mentioned previously , all measurements were taken in the "breathing zone" outside of the welders helmet. For purposes of discussion pertaining to Phase I, except where noted, these measurements will constitute the exposure level.

A review of the data depicted in Table II indicates that measurements taken of MIG welders, selected in a random manner from the populations of the MIG welders in the areas in question were well below defined levels of toxicity. When considered in light of the "grab" sample nature of the measurements, the intermittance of the welding operations, and the diversion of welding gases around the welders' helmet, actual exposure of welders (inside the helmet) are reduced further, so that the 8-hour TWA actual exposures are well below defined levels of toxicity -- at the time of this evaluation.

An exception to the above conclusion occurred in Department 7144. The initial sample taken of the welder indicated an excessive exposure to carbon monoxide. This welder was welding in a semi-enclosed area with limited cross drafts available. During the initial sample measurement, the welder was observed to be welding approximately one foot from the arc. (Helmet was one foot from the arc.)

To clarify the magnitude of this exposure, two additional measurements for CO were taken. One measurement was taken as the welder welded approximately 1.5 feet from the arc. The other measurement was taken as the welder welded approximately 2.5 feet from the arc.

As can be seen from Table II, the exposure level decreased considerably, as the distance from the arc increased. The reason for the excessive level of CO in the area of the arc (within 2 feet) is that in the presence of the intense heat generated by the arc, carbon dioxide will dissociate to CO. CO levels of 100 ppm have been measured as far as 2 feet from the arc by several investigators.[8]

Other STIK welders, working in close proximity to this welder were observed with regard to welding technique and access to available cross drafts. Definite differences in welding technique and available cross drafts were noted between the sample welder and the Department 7144 population.

After consideration of differences of welding technique and cross draft access between the sample welder and the other welders in the Department 7144 population, it was evident that the sample welder was not a true indicator of the exposure at MIG welders to CO in Department 7144.

However, when we consider the reduced exposure of the sample welder to CO at a distance of 3 feet, and his semi-enclosed welding area, it is a reasonable assumption that, given access to cross drafts and utilization of good welding technique, the sample welder would have had further reductions in exposure to CO. If the intermittance of the welding operation, the diversion of welding gases around the welders' helmet along with welding technique, and cross draft access are taken into account, actual exposure of welders chosen in a random manner in Department 7144 would probably not have exceeded defined levels of toxicity, . . . although this judgment was not conclusively proven by our sampling strategy!

2. Phase II

A summary of results of environmental measurements made for iron oxide (FE_2O_3) fume is shown in Tables IV and V. A more informative display of Table IV is shown as a bar graph Figure I (See Appendix VI). The values shown represent the TWA for the sampling period. For the majority of sample periods, the time ranged between 40 to 50 minutes.

It is imperative to state again that the values obtained represent exposure of welders, selected in a random manner from the specified department populations, to iron oxide fume.

An examination of Table IV - MIG welders reveals that the Permissible Excursion Values (PEV) for iron oxide fume (10 mg/M^3) was exceeded in three departments - 7144, 7111 and 7024. Whether the high value represents the true or maximum value of exposure of the welders in the above three departments for the sampling period is of secondary importance. Of primary importance is that a welder selected in a random manner from the department was found to have an exposure exceeding the PEV. Since any subsequent control mechanisms would probably address an entire department rather than a particular operation, the random finding takes on additional importance.

The high values and Permissible Excursion Value can be examined in a different manner. The welding sample period can be separated into two components: The period of actual arc time, and the period of "down" time (set-up, adjust equipment, etc.). It follows that the TWA for a sample period is composed of two elements: the concentration during the actual arc time and the concentration during the "down" time (which is zero, if we ignore exposure from area welders).

Stated mathematically:

$$\text{TWA}_{\text{Sample Period}} = \frac{C(\text{arc}) \times \text{Time}(\text{arc}) + C(\text{down}) \times \text{Time}(\text{down})}{\text{Total Sample Period Time}}$$

C = concentration

It is seen that the entire fume exposure is obtained during the arc time with the "down" time "acting" to reduce the TWA. If we consider this fact in the analysis of Table IV MIG welders, it is apparent that concentrations during the arc time exceeded the high values. Since the PEV does not have a minimum time requirement but rather addresses the concentration at any time, the PEV was exceeded by even a higher degree in three departments. Using the mathematical relation the PEV may have been exceeded in departments 7102, 7031, and 7182.

An examination of Table IV - STIK welders shows that no concentration exceeded the PEV. However, if we use the mathematical relation, it appears that exposures in department 7144 are likely to exceed the PEV.

Table V depicts results obtained from welders selected in a non-random manner. During the environmental evaluation, several cases arose where the welder, who was on the random sample list, was not available for sampling. In another case, the random sample process omitted all welders in a critical welding operation, which was alleged to induce excessive concentrations of fumes. In the interest of obtaining information, samples were collected from welders (chosen non-randomly) welding at the above operations. However, the results from these samples were not incorporated into Table IV since the welders were not chosen on a random basis.

The areas of concern, as seen in Table V, is Department 7146, the Traction Motor "merry-go-round." Much of the welding done in this area is done inside of the traction motor housing. Thus, the exposures are apt to be concentrated and excessive. "Elephant trunk" exhausts are available as a local exhaust ventilation mechanism. Based upon the magnitude of the exposures and the mathematical relation, there is a strong indication that the PEV was exceeded, and also possibly the Time Weighted Average (8-hour day) TLV may have been exceeded.

One should not attempt to interpret the values reported in Tables IV and V as an eight-hour TWA. The intermittance of the welding operation itself and the variable work schedule make it difficult to determine an eight-hour TWA.

It should be evident that iron oxide fume does not constitute the total species in the total fume. Fumes for the welding rod constituents as well as fumes from base metal alloys are present. However, several studies have shown that iron oxide fume constitutes roughly 50% (by weight) of the total fume content.[9] Thus it can be used an indicator of total fume exposure. A TLV has been established for iron oxide, adding a "quantitativeness" to the indicator.

3. Phase III - Medical Evaluation

a. Pre- and Post-shift

Referring to Table VI (see Appendix VII), the following symptoms and signs showed a statistically significant difference between pre- and post-shift observations in the day and evening shift workers:

(1) Stuffy nose
(2) Sore throat with medical confirmation that the oropharynx was reddened
(3) Hyperemic conjuctival vessels (i.e. reddened eyes)

The complaint of sore throat was confirmed by physical exam findings. The presence of the above symptoms and signs is evidence of an irritant exposure taking place over the shift for individuals working the day and evening shifts. The smoking habits of the welders did not correlate with the observed effects.

b. Respiratory Questionnaire (MRCQ)

Comparisons were made between the GMC welders and several published studies. A summary of the pertinent findings follows:

(1) Persistent cough**, persistent expectoration**, chronic brochitis** -

Non-conclusive results were noted in comparing the prevalence of the above symptoms in the GMC welders with the studies by Sharp, Ferris, and Fogh. The first two studies showed a higher prevalence of cough and expectoration than the GMC prevalence of these symptoms, while the Fogh study showed a lower prevalence of chronic bronchitis than the corresponding GMC prevalence.

** For definition see Appendix VIII

(2) Chest illness in the last three years**

For men ages 40-60 there was a significant difference between the observed prevalence in the GMC welders and the expected prevalence based upon (a) Sharp's study and (b) Ferris' study. In both cases, the observed frequencies were higher than expected.

(3) Shortness of Breath**

For men ages 40-60 the comparisons between the observed prevalence in the GMC welders and the expected based on (a) Sharp's study and (b) Ferris' study indicated significant differences. In both cases there was greater frequency for the observed than the expected.

It is however, difficult to draw definite conclusions from the comparisons made between GMC welders and the various study groups. This is because of several major variables in the different groups which could not be controlled in many instances - i.e. geographic location, air pollution, race, smoking history, and different groups of interviewers. For this reason, it is best to draw no definite conclusions from the data and simply state that more investigation may be warranted to determine the extent of chronic respiratory effect, if any, from welding exposure.

(c) <u>Pulmonary Function Testing (PFT)</u>

Fifty-three individuals met the necessary criteria to undergo PFT (for criteria page 20). However, only 33 individuals were present to receive the PFT. For purposes of analysis, the group of welders was divided into five groups: females, black male smokers, black male non-smokers, white male smokers, and white male non-smokers. The three best trials of each subject were used to determine his mean value for (1) forced vital capacity (FVC) and (2) forced expiratory volume in one second ($FEV_{1.0}$). None of the observed values from any of the five groups differed significantly (i.e. p._0.05) from its corresponding predicted value. Several studies for comparison were reviewed and the studies by Osherwitz, Kory, and Morris were chosen. A summary of those results appears in Table 7 (Appendix IX).

Additionally, the PFT of the 33 welders was analyzed to see if there was an association between years of welding and decrement in pulmonary function comparing the observed and predicted values - i.e., does a welder's pulmonary function worsen progressively the longer he welds?

** For definition see Appendix VIII

It was found that there was no association between duration of welding experience at GMC and the difference between observed and predicted for both FEV_1 and FVC. The correlation coefficients were:

for FEV	r =	0.1606
for FVC	r =	0.1791

The PFT showed no significant differences between values of the five groups of welders and their corresponding predicted values. Furthermore, there was no association between worsening PFT and length of years welding at GMC. This suggests that the workers' welding exposure has not been detrimental to their pulmonary function. However, these findings are only suggestive and not definitive because of the inherent limitations in comparing an individual's observed value with an arbitrary predicted value. Secondly, although statistical comparisons were made for PFT results, the numbers of individuals in each of the groups evaluated was quite small. Therefore, markedly abnormal value in the GMC welders' PFT would have to be present in order to show "a statistically significant difference." Differences which are less in degree could be present, but a much more extensive evaluation would be necessary in order to demonstrate them. Thirdly, determinations of forced vital capacity (FVC) and forced expiration volume in one second ($FEV_{1.0}$)are generally abnormal only after significant airways disease has taken place. More refined measurements (e.g., expiratory flow rates - $MMEF_{25-75}$, $FEF_{2.-1.2}$), could be made but should be followed over a period of years to determine if development of airway disease occurs. In view of these limitations, the present investigators conclude only that gross abnormalities in PFT were not noted in the small group of welders tested. These findings do not negate the possiblity that pulmonary function abnormalities may arise from chronic exposure to welding fumes. Further evaluation in this matter seems warranted but lies outside the scope of the Health Hazard Evaluation. Three workers were referred to their own physician for further evaluation of their pulmonary function as both FVC and FEV_1 were less than 80% of their predicted values.

D. Conclusions and Recommendation

As is evidenced by the development of irritant symptoms and signs over the workshift, and the Permissible Excursion Value being exceeded in three and possibly as many as six departments for MIG welders, and at least one department for the STIK welders, the problem is indicative of an acute exposure as well as a chronic exposure - for the population of welders studied. Since this population does not include representatives from all welding departments, some extrapolation of results is necessary.

Although systemic toxicity was not indicated by the medical evaluation and corroborating environmental evaluation, it is recommended that worker exposures be reduced to levels of air contaminants previously used in this report for criteria.

V. REFERENCES

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TABLE I
STUDY POPULATION

Stratum	Area	Type Welding	Shift	Population	Sample
A	Bay 1	-Stick	- Day	70	36
B	Bay 1	-Stick	- Evening	44	25
C	Bay 1	-MIG	- Day	9	5
D	Bay 1	-MIG	- Evening	10	6
E	Dept 718-2	-Stick	- Day	6	3
F	Dept 718-2	-Stick	- Evening	7	4
G	Dept 718-2	-MIG	- Day	16	9
H	Dept 718-2	-MIG	- Evening	17	9
I	Dept 703-1	-Stick	- Day	13	7
J	Dept 703-1	-Stick	- Evening	6	3
K	Dept 703-1	-MIG	- Day	11	6
L	Dept 703-1	-MIG	- Evening	11	6
M	Dept 702-4	-Stick	- Day	3	2
N	Dept 702-4	-Stick	- Evening	0	0
O	Dept 702-4	-MIG	- Day	8	4
P	Dept 702-4	-MIG	- Evening	6	3

	Population	Sample
A+B+C+D = Bay 1	133	72
E+F+G+H = Dept 718-2	46	25
I+J+K+L = Dept 703-1	41	22
M+N+O+P = Dept 702-4	17	9
A+B+E+F+I+J+M+N = Stick	149	80
C+D+G+H+K+L+O+P = MIG	88	48
A+C+E+G+I+K+M+O = Day	136	72
B+D+F+H+J+L+N+P = Evening	101	56
A - P = Total	237	128

TABLE II

SUMMARY - MIG WELDER EXPOSURE TO WELDING GASES

CARBON MONOXIDE (CO)

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High ppm	Low ppm
7144	Traction M. Housing	3	1	150[1]	35[2]
7182	Fuel Tank	2	2	8	5
7024	Draft Gear	2	2	12	5
7031	Exhaust Manifold	2	2	3	1
7102	Generator Housing	1	1	5	-

OZONE (O_3)

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High ppm	Low ppm
7144	Traction M. Housing	1	1	N.D.[3]	-
7182	Fuel Tank	3	2	N.D.	
7024	Draft Gear	2	2	N.D.	-
7031	Exhaust Manifold	2	2	N.D.	
7102	Generator Housings	1	1	N.D.	-

NITROGEN DIOXIDE (NO_2)

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High ppm	Low ppm
7144	Traction M. Housing	1	1	N.D.	-
7182	Fuel Tank	2	2	N.D.	-
7024	Draft Gear	2	2	N.D.	-
7031	Exhaust Manifold	2	2	N.D.	-
7102	Generator Housings	1	1	N.D.	-

[1] Sample taken in breathing zone, outside helmet approximately one foot from arc

[2] Sample taken in breathing zone, outside helmet approximately 2 1/2 feet from arc

[3] Non-Detectable

TABLE III

SUMMARY - STIK WELDER EXPOSURE TO WELDING GASES

CARBON MONOXIDE (CO)

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High ppm	Low ppm
7144	Traction M. Housing	3	3	20	3
7172	Traction M. Housing	1	1	4	-
7182	Fuel Tank	2	2	25	2
7024	Draft Gear	1	1	5	-
7031	Exhaust Manifold	2	2	5	3

OZONE (O_3)

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High ppm	Low ppm
7144	Traction M. Housing	3	3	N.D.[1]	-
7172	Traction M. Housing	1	1	N.D.	-
7182	Fuel Tank	2	2	N.D.	-
7024	Draft Gear	2	2	N.D.	-
7031	Exhaust Manifold	1	1	N.D.	-

NITROGEN DIOXIDE (NO_2)

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High ppm	Low ppm
7144	Traction M. Housing	3	3	N.D.	-
7172	Traction M. Housing	1	1	N.D.	-
7182	Fuel Tank	2	2	N.D.	-
7024	Draft Gear	1	1	N.D.	-
7031	Exhaust Manifold	2	2	N.D.	-

[1] Non-Detectable

APPENDIX IV

TABLE IV

SUMMARY - IRON OXIDE ($Fe_2 O_3$) FUME EXPOSURE

MIG WELDERS

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High mg/M^3	Low mg/M^3	Average mg/M^3
7144	Traction M. Housing	1	1	-	-	10.70
7102	Gen. End Housing	3	1	6.20	1.50	3.61
7111	Gen. Rings	4	3	10.79	0.79	4.43
7031	Exhaust Manifold	4	4	5.35	0.91	3.19
7024	Draft Gear	6	6	11.44	1.10	3.80
7182	Fuel Tank	7	5	5.04	1.54	3.04

STIK WELDERS

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High mg/M^3	Low mg/M^3	Average mg/M^3
7144	Traction M. Housing	2	2	7.85	7.49	7.67
7146	Traction M. Housing	2	2	1.39	1.33	1.36
7172	Stainless Steel	1	1	1.61	-	-
7031	Exhaust Manifold	6	3	3.26	0.52	1.77
7182	Fuel Tank	5	5	2.45	0.21	0.98

APPENDIX V

TABLE V

SUMMARY - IRON OXIDE ($Fe_2 O_3$) FUME EXPOSURE

NON-RANDOM SELECTION

MIG WELDERS

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High mg/M3	Low mg/M3	Average mg/M3
7031	Exhaust Manifold	3	3	5.268	2.486	3.62
7024	Draft Gear	1	1	4.033	-	-

STIK WELDERS

Dept.	Job Description	No. of Samples	No. of Welders Sampled	High mg/M3	Low mg/M3	Average mg/M3
7146	Merry-Go-Round	2	2	30.166	7.004	18.58

APPENDIX VI

FIGURE I - CONCENTRATION-IRON OXIDE FUME IN SELECTED DEPARTMENTS

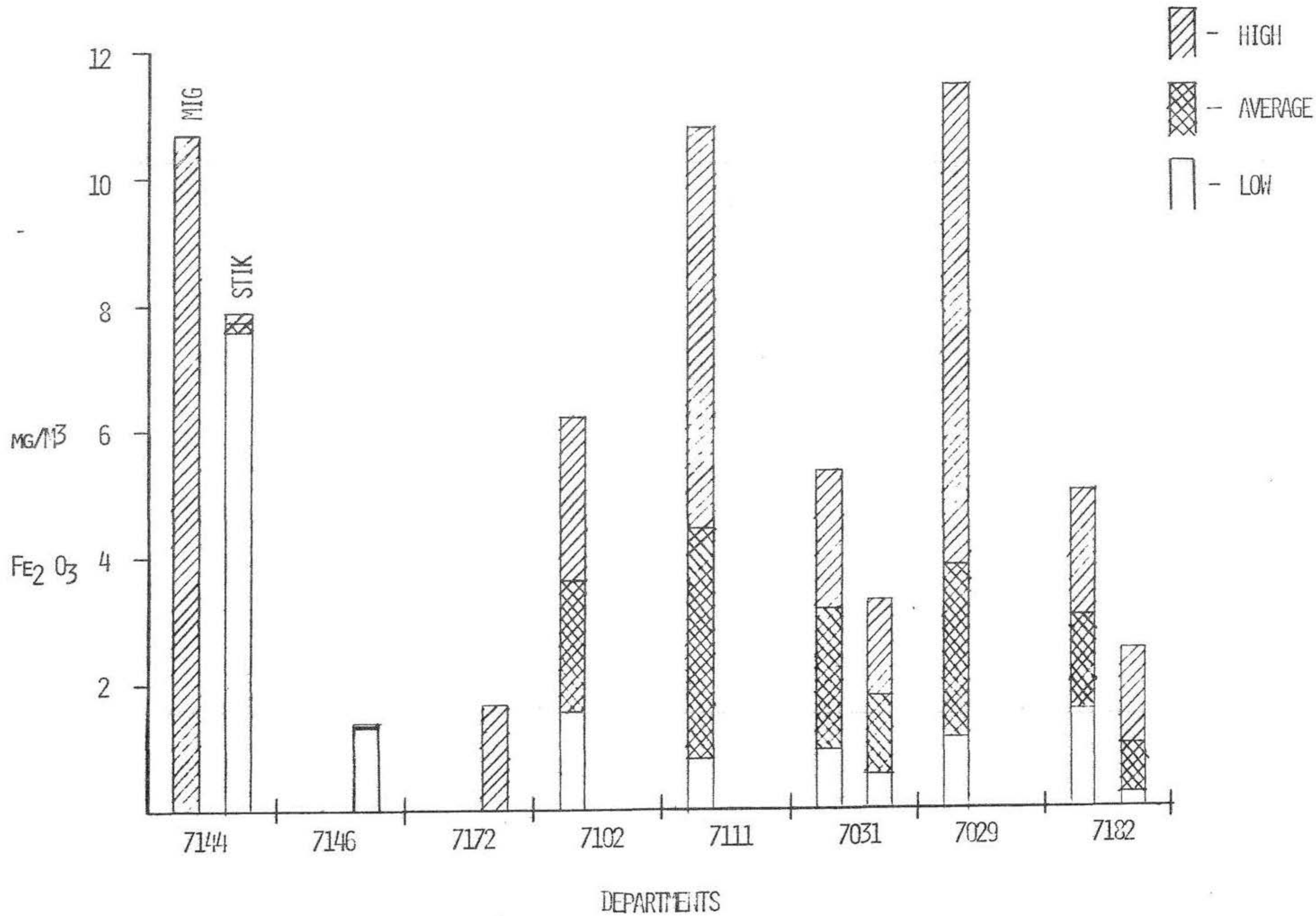

TABLE VI

MEDICAL EVALUATION

PRE SHIFT VS POST SHIFT

Item	x^2	Probability	Comment
Combined Day & Swing Shift			
Stuffy nose	4.3.20	0.0378	Sign. diff.
Sore throat	3.2925	0.0696	Near sign. diff.
Chest pain	1.3562	0.2442	No sign. diff.
Burning eyes	1.0056	0.3159	No sign. diff.
Nervousness	1.2557	0.2625	No sign. diff.
Phlegm	1.2257	0.2625	No sign. diff.
Headache	2.3017	0.1292	No sign. diff.
Abnormal breathing	2.3017	0.1292	No sign. diff.
Red eyes	16.6489	0.00004	Very sign. diff.
Red throat	16.6489	0.00004	Very sign. diff.

The following definitions were used for persistent cough, persistent expectoration, chronic bronchitis, shortness of breath, and chest illness:

PERSISTENT COUGH (= "Yes" response to questions 1&3 or 2&3)

1. Do you usually cough first thing in the morning (on getting up) in the winter?
   Yes___ No___

2. Do you usually cough during the day (or at night) in the winter?
   Yes___ No___

3. Do you cough like this on most days (or nights) for as much as three months each year? Yes___ No___ NA___

PERSISTENT EXPECTORATION (="Yes" response to questions 4&6 or 5&6)

4. Do you usually bring up any phlegm from your chest first thing in the morning (on getting up) in the winter? Yes___ No___

5. Do you usually bring up any phlegm from your chest during the day (or at night) in the winter? Yes___ No___

6. Do you bring up phlegm like this on most days (or nights) for as much as three months each year? Yes___ No___ NA___

CHRONIC BRONCHITIS (="Yes" response to question 3 or 6)

SHORTNESS OF BREATH (= "Yes" response to questions 11&12 or 11, 12, &13)

11. Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill? Yes___ No___ Disabled___

12. Do you get short of breath walking with other people of your own age on level ground? Yes___ No___ NA___

13. Do you have to stop for breath when walking at your own pace on level ground?
    Yes___ No___

CHEST ILLNESS (= "Yes" response to question 24)

24. During the past three years have you had any chest illness which has kept you from your usual activities for as much as a week? Yes___ No___

APPENDIX IX

TABLE VII

PULMONARY FUNCTION RESULTS
mean FVC value (liters)

Group	n	Actual Value	Predicted Value		
			Oscherwitz	Kory	Morris
Black Male Smokers	10	3.70	3.78	NA	NA
Black Male Non-smokers	9	4.00	3.74	NA	NA
White Male Smokers	5	3.62	NA	3.94	NA
White Male Non-smokers	5	3.94	NA	4.41	NA
Females	4	2.77	NA	NA	2.97

mean $FEV_{1.0}$ value (liters)

Group	n	Actual Value	Oscherwitz	Kory	Morris
Black Male Smokers	10	2.85	2.94	NA	NA
Black Male Non-smokers	9	3.06	2.90	NA	NA
White Male Smokers	5	2.79	NA	3.08	NA
White Male Non-smokers	5	3.25	NA	3.44	NA
Females	4	2.27	NA	NA	2.39