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

HEALTH HAZARD EVALUATION DETERMINATION REPORT NO. 72-50-117

CHEVROLET FLINT ASSEMBLY PLANT
FLINT, MICHIGAN
MARCH 1974

I. TOXICITY DETERMINATION

A. Paint Spray Booths

It has been determined that employee exposures to solvent vapors (xylene, toluene, butyl alcohol, and naphtha), are toxic at the concentrations found during the time of this evaluation (March, 1973) within the paint spray booth areas of this facility. This exposure has resulted in employee complaints of eye, nose, throat and in some cases chest and skin irritation. Considering all of the symptoms reported by the workers, 16 of 24(67%) Acrylic Booth workers, 11 of 13(85%) Tu-Tone Booth workers and 13 of 15(87%) Color Booth workers were symptomatic as determined by employee responses during medical interviewing. While such exposures have resulted in the problem of irritant toxicity, it has also been determined that no significant anesthetic toxicity has been revealed during this investigation. The latter determination is based on environmental air levels which were less than 20% of the "combined standard" for these vapors and a mean urinary total hippuric acid level of 1.62 grams per liter at the highest which indicates an exposure to both toluene and xylene of not more than 20 ppm on the average. The explanation for the finding of irritant toxicity in the absence of anesthetic toxicity may be related to short-term excursions in the individual and/or synergistic environmental levels of the vapors found in the various paint spray booths or to the solid components of the paint contained in the overspray which tended to adhere to the exposed skin of the employees.

B. Road Test Areas

It has been determined that employee exposures to carbon monoxide in the road test areas of this facility are not toxic at the concentrations as used or found. This determination is based on environmental air levels which averaged 35 ppm for all jobs and on finding an acceptable concentration of carboxyhemoglobin saturation (less than 4.2%) in the blood of non-smoking workers in the road test areas. It should be emphasized that both plant and office working smokers had an average carboxyhemoglobin level in excess of 5.0% before and after work. However, while such levels in smokers are considered to be a potential hazard (particularly for individuals who may have a predisposition for coronary heart disease), this finding in smokers and not in non-smokers strongly suggests that non-occupationally related factors(eg. cigarette smoking) have contributed to the excessive levels of carboxyhemoglobin in the blood of all workers who smoke cigarettes rather than the lesser contribution from in-plant sources of carbon monoxide. In-plant sources of carbon monoxide accounted for an average rise of 1.9% in the carboxyhemoglobin content in the blood of non-smokers; and with many of the non-smokers having post-work carboxyhemoglobin levels of 4.0 - 4.5%, any further rise in the plant sources of carbon monoxide would result in unsafe levels of blood carboxyhemoglobin for the non-smokers as well as the smokers.

C. Recommendations

In order to ameliorate the existing hazard of irritancy from exposure to solvent vapors, it is strongly recommended that workers in the paint spray booth areas of the plant be provided with and encouraged to utilize "supplied" air hoods during painting operations. Local exhaust ventilation systems for both the paint spray booth areas and the road test areas should receive proper periodic maintenance and should remain in operation throughout each entire work shift. In addition, periodic environmental and medical monitoring should be undertaken by management in order to assess the ongoing effectiveness of environmental (i.e. engineering) control systems.

Notwithstanding the absence of a significant hazard in the road test areas, recommendations have been offered to the management regarding both the environmental and medical standards of safe useage for carbon monoxide. Furthermore, it is strongly suggested that workers who use tobacco in these areas be encouraged to reduce or refrain from this practice while in the plant.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

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

a) Chevrolet Flint Assembly Plant, Flint, Michigan
b) Authorized Representative of Employees
c) U.S. Department of Labor - Region V
d) NIOSH - Region V

For the purposes of informing the approximately 170 "affected employees," the employer will promptly "post" the Determination Report in a prominent place(s) near 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, 29 U.S.C. 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 regarding personnel exposure to solvent vapors in three paint spray booths, as well as personnel exposure to carbon monoxide in the truck road test areas of the Chevrolet Flint Assembly Plant, Flint, Michigan. The request was initiated after a number of employees from each of the plant areas in question reported subjective complaints suggestive of a potential occupational health hazard.

IV. HEALTH HAZARD EVALUATION

A. Description of Process - Conditions of Use

The Chevrolet Flint Assembly Plant assembles Chevrolet and GMC pickup trucks, Chevrolet "Blazers," GMC "Jimmy" and Chevrolet Surburban vehicles. The request involved two areas in the plant. They are:

1. Three spray paint booths (#1 Acrylic Booth, #1 Tu-Tone Booth, and #2 Color Booth)

   The paint vapors the employees are exposed to in the booth are butyl alcohol, naphtha, toluene, and xylene. The booths are totally enclosed with the exception of the entrance and exits. The painters are responsible for manually spraying a particular portion of each unit as they are conveyed through the booths. There are also automated spray devices in the booths that are interspersed amongst the workers at various points along the line. The booths all utilize a down draft and water wash exhaust system. The workers are supplied with head caps, uniform, coveralls, gloves, shoes, and respirators, however, they are not used by every employee, especially respirators which have a low usage. There are approximately 25 employees in these booths per shift or 50 for both shifts.

2. Final assembly lines #1 and #2

   Employees are exposed to carbon monoxide at the end of the assembly lines. Each line consists of final assembly with engine start up and check, road test, toe-in adjust and a final repair area. There are lateral local exhaust ventilation systems at each point where the engines are normally run. The areas between the final assembly line to the road test and the toe-in adjust to the final repair line are not equipped with local exhaust systems. There are approximately 50 employees per shift (100 for two shifts) working directly in the areas where the engines are run and an unknown number working nearby.

B. Evaluation Design

Following a preliminary observational survey which facilitated recognition of the most probable health hazards (January 23, 1973), it was necessary to return to the plant to conduct more in-depth analyses of employee exposures to both the solvent vapors generated in the painting operations and the carbon monoxide emissions generated in the road testing process. Procedures used to assess the validity of the alleged hazards included: on site interviews with the management, a walk-through inspection of the work place, administration of brief medical questionnaires to all workers potentially exposed to plant contaminants as well as a selected group of workers from an area without such exposure, the collection of urine and blood samples for biochemical analyses, and extensive environmental air sampling to detect potentially toxic agents in the workroom atmosphere.

C. Evaluation Methods

1. Solvent Vapor Exposure:

(A) Medical Survey

Due to the dual nature of this investigation, each of the alleged problems (i.e. solvent vapors and carbon monoxide exposures) were evaluated separately.

Regarding the investigation of solvent vapor exposures, a total of 52 workers in the Paint Spray Booth Areas of the plant agreed to participate in the study. In addition, 12 workers from another area of the plant were randomly chosen as a control population (i.e. a group of workers not exposed to paint vapors). For statistical purposes, employees were grouped according to their work locations (i.e. Acrylic Booth, Tu-Tone Booth, Color Booth and Office Control Groups). All groups were treated in a similar manner.

On the day of the study each worker was instructed to refrain from urinating for three hours prior to the end of the work shift. The employees in exposed groups were in contact with paint vapors for a period of eight hours prior to the collection of urine samples. NIOSH medical personnel questioned each worker individually regarding their general health and any specific symptomatology that may have been present on the day of the study.

Urine samples were collected in a standard plastic container with a screw-top cap. A few crystals of thymol were added to each container to act as a preservative. All samples were maintained at a temperature of +4°C. for a period of 24 hours while in transport to the laboratory. The samples were then frozen and maintained at -20°C. for seven days prior to analysis for hippuric acid content. Specimens were thawed slowly at room temperature and total urinary hippuric acid concentration was determined by the direct method of Tomokuni and Ogata.[1] Comparison of the mean urinary hippuric acid levels for related (booth workers) and non-related (office workers) subjects was accomplished by using the Student t Test to test for significant differences between work groups.[2]

(B) Environmental Survey

Regarding the environmental sampling, employee exposures to solvent vapors were measured in the breathing zone via personal air sampling equipment and charcoal air sampling tubes. The charcoal tubes were analyzed by a gas chromatographic method.

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2. Carbon Monoxide Exposure:

(A) Medical Survey

In the evaluation of carbon monoxide exposures, a total of 28 workers employed in the Road Test Areas of the plant agreed to participate in the study. The control population consisted of 10 workers randomly chosen from the office area of the plant.

On the day of the study, prior to the work shift, employees were instructed to report to the plant dispensary. NIOSH medical personnel individually questionned each worker and recorded age, mode of transportation to the plant on the morning of the study, and the traveling time to the plant. A brief smoking history was obtained. Employees indicating that they were cigarette smokers were questioned as to the number of cigarettes they had smoked on the morning of the study before arriving at the plant dispensary. Each smoker was asked to count the number of cigarettes in their pack with NIOSH personnel looking on. This number was then recorded on the questionnaire form. At the end of the eight-hour work shift, all workers again reported to the plant dispensary. A repeat count of the number of cigarettes remaining in the pack enabled the interviewer to ascertain the total number of cigarettes that had been smoked during the exposure period. Furthermore, each worker was questioned as to any ill effects that may have been present.

Following the pre-work and post-work interviews a sample of venous blood was obtained from each subject. In all cases a volume of 10 milliliters was drawn from a vein in the anticubital fossa of the subject using standard Vacutainer collection apparatus(Becton-Dickinson). Blood was drawn directly into sterile, heparinized, lead-free Vacutainer tubes and maintained at +4°C. until the time they were received by the laboratory. Representative portions of these blood specimens were analyzed for carboxyhemoglobin(COHb) content by the procedure of Dubowski and Luke,[3] employing automated differential spectrophotometry with the Model 182 CO-Oximeter(Instrument Labs, Inc.). The total hemoglobin content was also measured on representative portions of each whole blood specimen by a standard spectrophotometric cyanmethemoglobin procedure.[4]

In order to isolate and evaluate the unique contribution of carbon monoxide from in-plant sources, all known potential causes for intersubject variation in blood COHb were considered. These causes included work location (plant vs office), line (line 1 vs line 2), shift (1st or second), age, travel time to work, smoking history (smokers vs non-smokers), the number of cigarettes smoked prior to work, and the number of cigarettes smoked during work. The statistical interpretation of this data was performed by using the method of analysis of covariance.[5]

The statistical analysis was performed in three phases. The first analysis was of pre-work COHb measurements. Independent variables were chosen for this analysis which were thought to be individually related to the variability of pre-work COHb levels among subjects. Line and Shift were not included since biological decay during off-work hours would be expected to obscure any small differences in the blood levels due to these two factors by the time the next day's pre-work COHb levels were measured. It was planned to add these two variables to the first analysis as a refinement if the first analysis were to indicate that there had been a residual effect of work olaction on pre-work COHb. The first phase of the analysis provided no information about the direct effects of plant exposures on end-of-workday increases in the COHb levels.

The second phase of the statistical analysis was of post-work COHb measurements. This analysis was performed mainly for the purpose of comparing post-work COHb levels for plant workers with post-work levels for the office-worker controls. The number of cigarettes smoked during the workday and the pre-work COHb levels were included as covariates in order to prevent bias. The three covariates used in the first analysis, namely age, travel time to work and the number of cigarettes smoked prior to arriving to the plant were replaced by a single covariate, the pre-work COHb level, in the second phase of the analysis. This substitution served to reflect the combined indirect effects of these three pre-work variables on the post-work COHb levels.

The third and last phase of the statistical analysis was of the difference between pre-work and post-work COHb levels. The protocol for this phase of the analysis was chosen a posteriori based upon the results from the first and second phases. This protocol presumes that paired differences between pre-work and post-work COHb levels(Δ) for the same worker were independent of the true pre-work level of COHb, as well as of shift and the number of cigarettes smoked during work. Since such independence is a crucial assumption for valid interpretation of the final results from the third phase of the analysis, an additional and more refined test for independence between Δ and the pre-work COHb was made is explained below.

The analysis of covariance was performed under the implicit assumption that pre-work COHb measurements contained no measurement errors. This assumption would be expected to yield a good approximation since variability in values of the dependent variable(post-work COHb) among subjects in the same category is mostly due to real biological variability of the true blood concentrations. Errors of measurement were probably small in comparison. Nevertheless, at this point in the analysis, a more exact test was made of the hypothesis that differences (Δ) are equal on the average at all levels of pre-work COHb. This was done by a method of regression analysis known as "analysis of linear functional relation."[6] For this analysis, it was assumed that errors of measurement in the pre-work and post-work COHb were independent and had equal variances.

It should be noted that three pipe-or-cigar smokers were not included among the 38 subjects in the study. Three of the six office-worker smokers were women but since there is no distinct biological variability in the response to carbon monoxide between men and women, the women were included in the study. Moreover, all workers are assumed to be random samples from hypothetical similar working populations which are (or could be) employed under the same working conditions.

(B) Environmental Survey

Concerning the environmental sampling, employee exposure to carbon monoxide was measured on January 22-24, 1973, by collecting air from the breathing zone in plastic bags and subsequent analysis by detector tubes. On March 28, 1973, the air samples collected in plastic bags were analyzed using a Wilks portable infrared analyzer. The area samples were measured using continuous monitoring carbon monoxide meters, which were calibrated hourly using a standard carbon monoxide calibrating gas, and recorded on strip chart recorders.

D. Evaluation Criteria

The Occupational Health Standards promulgated by the U.S. Department of Labor (Federal Register, October 18, 1972, Title 29, Chapter XVII, Subpart G, Tables G-1, G-2) applicable to the individual substances of this evaluation follows:

Substance	8-Hour Time Weighted Average	Acceptable Ceiling Concentration	Acceptable Maximum Peak Above The Acceptable Ceiling Concentration For An 8-Hour Shift	
			Concentration	Maximum Duration
Butyl Alcohol	100 ppm*	-	-	-
Carbon Monoxide	50 ppm	-	-	-
Naphtha(Stoddard Solvent)	100 ppm	-	-	-
Xylene	100 ppm	-	-	-
Toluene	200 ppm	300 ppm	500 ppm	10 minutes

*Parts of vapor or gas per million parts of contaminated air by volume at 25°C. and 760 millimeters mercury pressure.

Occupational Health Standards for individual substances are established at levels designed to protect workers occupationally exposed on an 8-hour per day, 40-hour per week basis over a normal working lifetime. An employee's exposure shall at no time exceed a designated "ceiling concentration" during the work day unless specific limits have been designated otherwise.

Additionally, the National Institute for Occupational Safety and Health (NIOSH) has published the "Criteria For A Recommended Standard....Occupational Exposure to Carbon Monoxide" and"...Occupational Exposure to Toluene." These authoritative limits are lower for both carbon monoxide and toluene than the Federal Standards. They are listed for the reason that the more restrictive limits may eventually be adopted as the Federal Standard.

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Substance	8-Hour Time Weighted Average	Acceptable Ceiling Concentration
Carbon Monoxide	35 ppm	200 ppm
Toluene	100 ppm	200 ppm

Biological criteria for the toxicity determination of carbon monoxide exposure is based on a blood level of carboxyhemoglobin in excess of five percent saturation.[7,8,9] The toxicity determination for combination toluene-xylene exposure is based on a total urinary hippuric acid concentration in excess of five grams per liter urine(corrected to a specific gravity of 1.024).[10,11]

E. Evaluation Results and Discussion

1. Solvent Vapor Exposure

All workers participating in the evaluation of solvent vapor exposures indicated that they were in good general health, however, on the day of the study a significant number of employees in all exposed groups reported adverse effects resulting from the paint spraying operations. There were no symptoms reported in the control group of office employees. A list of worker complaints is shown in Table I.

The most frequently reported symptom was that of eye irritation. Nine(38%) of the Acrylic Booth workers reported this symptom, whereas 6(46%) of the Tu-Tone Booth workers and 4(27%) of the Color Booth workers also complained of eye irritation. A high percentage of workers in all three booths reported nasal and throat irritation as burning and dryness of the effected structures. A lesser number of employees complained of chest irritation(burning, congestion, etc.), headache, nausea, dizziness and skin irritation(pruritis, burning, etc.). Considering all symptoms reported, 16 of the 24(67%) Acrylic Booth workers were symptomatic, 11 of the 13(85%) Tu-Tone Booth workers were symptomatic, and 13 of the 15(87%) Color Booth workers were symptomatic.

The results of the urinary hippuric acid analyses for paint booth workers are shown in Table II. An examination of the data by work shift revealed no statistically significant differences between the mean urinary hippuric acid levels of shift 1 and shift 2 workers in any of the three paint spray booth areas. However, after pooling work groups by shift it can be seen that the mean hippuric acid excretion for the Color Booth workers(1.62 grams per liter urine [g/l]) approaches a significantly higher value for the Tu-Tone Booth work group (p value = .063) and is significantly higher than that for the Acrylic Booth work group (p value = .006). This statistical relationship is similarly significant when Acrylic Booth and Color Booth work groups are combined and their urinary hippuric acid levels are compared with that of the Color Booth workers (p value = .006). [The Acrylic Booth and Tu-Tone Booth work groups had nearly identical mean hippuric acid excretions, thus enabling a pooled sample for comparative purposes.]

Although there were originally 12 workers chosen as the control group, three of the subjects were female and it was decided not to include them in the study. Ikeda and Ohtsuji[12] have shown that non-exposed females normally run higher levels of urinary hippuric acid than their male counterparts and this observation was confirmed in our control group where the mean level for females was 2.19 g/l as compared to a level of 0.84 g/l for the male subjects. The comparison of hippuric acid levels in the urine of exposed and non-exposed work groups is shown in Table III. There was a highly significant difference between means for the Color Booth workers and the Office workers (p value = .003).

Despite the fact that the workers in the Color Booth area of the plant have a significantly higher excretion of hippuric acid than both their employee peers in other booth areas and the Office working control population, a level of 1.62 g/l, according to the studies of Ikeda and Ohtsuji[10] and others,[13] corresponds to a combined hydrocarbon exposure(toluene-xylene) of no more than 20 ppm on the average.

The employees time weighted average exposure to paint solvent vapors(xylene, toluene, butyl alcohol, and naptha) at each job description in the #1 Acrylic Booth, the #1 Tu-Tone Booth, and the #2 Color Booth was less than 20% of the existing Federal standard. The exposures were evaluated using the following formula. "When two or more hazardous substances (several solvents) are present, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. That is, if the sum of the following fractions,

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots\ldots \frac{C_n}{T_n}$$

exceeds unity, then the threshold limit of the mixture should be considered as being exceeded."[14]

The average concentration for each solvent vapor expressed in parts of vapor per million parts of air (ppm) for each job description is shown in Table V. The average concentrations for toluene ranged from 1ppm-2ppm, xylene 1ppm-16ppm, butly alcohol 1ppm-2ppm, and naphtha was not detectable. Table VI shows the average exposure of all workers in each spray booth. The highest concentration measured occurred during a two and one-half hour sampling period while an employee was painting the cabs of the Suburban and Blazer vehicles in the line #2 Color Booth. The average xylene concentration during this period was 32 ppm. (6 of the 123 thirty minute samples were above 20% of the combined standard for the vapors present, and five of the six elevated values were encountered while sampling this one individual.) His counterpart in the night shift had an average xylene exposure of 13 ppm. This can be expected as their work habits may vary, thus varying the exposures.

2. Carbon Monoxide Exposure

None of the workers participating in the evaluation of carbon monoxide exposure indicated the presence of ill-effects on the day of the study. The results of the COHb measurements for all workers in presented in Table IV.

The numerical results from the analysis of covariance of pre-work COHb levels shows that there is a highly statistically significant difference(p value<0.01) between the mean COHb levels for smokers versus non-smokers after adjusting the means for differences in numbers of cigarettes smoked. There is also a significant regression(p value<0.05) of COHb on the number of cigarettes smoked before work.

The mathematical model underlying these results, as well as the equations for the model are depicted graphically in Figure 1. The model implies that a chronic smoker would have a pre-work COHb level about 2.3% higher on the average than a non-smoker even if the smoker were to abstain completely from smoking on the day of the study. (There was actually one subject who was a smoker but who did not smoke on the day of the study. His pre-work blood level agrees very closely with the value given by the model). The 95% confidence limits for this average difference are from 1.0% to 3.6%.

The model also shows that the average pre-work COHb level of smokers increase by an additional 0.5% COHb for every cigarette smoked before work(95% confidence limits = 0.1% to 0.9% per cigarette). This latter gradient effect would seem to be attributable entirely to pre-work cigarette smoking and not to a correlated "carry-over" effect of cigarettes smoked during-or-after work on the previous day. This interpretation is made because the correlation was found to be very weak between the number of cigarettes smoked during work and the number of cigarettes smoked before work (Figure 2).

There was no significant difference detected between adjusted average values of the pre-work COHb for plant workers versus office workers. Also, there were no significant effects for either of the other two covariates; i.e., neither the worker's age nor travel time to work could be related to the pre-work COHb level.

Results of the analysis of covariance of post-work COHb levels showed that the number of cigarettes smoked during work was not significantly correlated with the post-work COHb. A plot of post-work versus pre-work COHb for individual subjects along with the family of six parallel regression lines is shown in Figure 3. (Parallel regression lines were fitted after determining that slopes of six separate lines were statistically homogeneous.)

These lines were fitted by least squares and their slopes were slightly biased (negatively) because errors of measurement in pre-work COHb were ignored. The common slope for these regressions of post-work COHb on measured values of pre-work COHb(Figure 3) is 0.930 which is not significantly different from unity. For reasons discussed earlier, a supplementary exact test (based on the linear functional relation) was performed of the hypothesis that the slope of lines relating true values of post-work COHb to true values of pre-work COHb is unity.

The result from the exact test did not contradict the conclusion drawn above based on the approximate analysis that the slope is not significantly different from unity. The pooled regression slope(ignoring errors in pre-work COHb) of the family of 6 lines relating post-work to pre-work COHb was 0.930 whereas the unbiased estimate obtained under the assumption that errors in post-work and pre-work COHb were independent with equal variances was 1.07. Neither value approaches a significant difference from unity. The implication of this finding is that the differences(Δ) are independent of pre-work COHb. Thus, it was possible to perform comparisons among the six groups of workers of differences by means of a simple one-way analysis of variance of Δ-values.

The results of the third phase of this analysis indicated that office workers who were non-smokers had no significant changes in their COHb during the workday. Plant workers who were non-smokers had a significant average increase of 1.9% COHb. Plant workers on line 2 who were smokers showed no increase from their baseline levels but plant workers on line 1 who were smokers showed a significant average increase of 1.3% COHb. Office workers who were smokers also increased their levels by 1.3% COHb(Figure 4).

It was at first disturbing to find that plant smokers on line 2 showed no increase in COHb during the workday whereas office smokers did show an increase. However, this is probably due to the larger numbers of cigarettes smoked by office smokers. The average number of cigarettes smoked by office smokers during the workday was 13(range 10 - 18) compared to an average of 6(range 0 - 12) for line 2 smokers. Thus, office workers smoked about twice as many cigarettes during work as plant workers.

The net result of the various types of effects described above is that all three groups of smokers, whether plant workers or office workers, had an average COHb level in excess of 5.0% both before work and after work. On the other hand, average levels for non-smokers did not exceed 5.0% even though substantial increases occurred during the workday for plant workers. This strongly suggests that non-occupationally related factors(i.e. cigarette smoking) have contributed to excessive levels of COHb in the blood of all workers who smoke cigarettes rather than the lesser contribution from in-plant sources of carbon monoxide.

All the time-weighted average carbon monoxide exposures were below the 50 ppm federal standard, however, the NIOSH recommended time-weighted average of 35 ppm was exceeded at several locations.

Seventy breathing zone samples collected indicate that the time weighted averages at the various jobs in the road test area ranged from 20 ppm to 41 ppm. (See Table VII.) The average for all jobs was 35 ppm. The individual samples from which the averages were determined ranged from 15 to 50 ppm.

Of these samples one was less than 20 ppm, 37 were between 20 and 35 ppm and 32 were between 35 and 50 ppm. None exceeded 50 ppm.

The average carbon monoxide levels measured continuously at three locations in the road test area on March 28, 1973 were approximately 30 ppm. During the 26 hours of recorded measurements, the CO levels would occasionally peak above 50 ppm for 15 to 30 seconds. There were 62 such peaks recorded with 45 of these between 50 and 100 ppm, 15 between 100 and 200 ppm and two were approximately 225 ppm.

3. Discussion

In first considering the findings of this study which relate to solvent vapor exposures for workers in the paint spray booth areas of the plant, the environmental data, as well as the medical data indicates that exposure to organic hydrocarbon vapors have been minimal. The airborne concentrations of all potential atmospheric contaminants(toluene, xylene, butyl alcohol and naphtha) were well below both the current Federal Standards and the more restrictive Standards proposed by the National Institute for Occupational Safety and Health. Furthermore, the additive-concentration-ratio determined for all measurable contaminants was less than 1, lending further support to the conclusion that even the combined environmental exposures to these substances were within safe limits. It should be pointed out, however, that the environmental concentrations of these solvent vapors may vary, depending on the operation of the spray gun and its intermittence as well as the efficiency of the exhaust systems. Therefore, it is reassuring to note that the more sensitive biological index of total exposures to toluene and xylene (i.e. urinary hippuric acid excretion) was quite consistent with the environmental findings.

In general, the acute toxic effects of the organic hydrocarbons may be that of irritation to the eyes, nose, throat and lower respiratory tract structures or anesthetic in nature leading to headaches, dizziness, nausea, mental confusion and loss of motor coordination.[15] Interviews with the employees who participated in the study of solvent vapor exposures essentially ruled out the possibility that significant anesthetic toxicity had resulted from such exposures. On the other hand, more than sixty per cent of the work force employed in each of the paint spray booth areas reported symptoms consistent with the direct irritant effects of the substances under investigation. The explanation for this irritant toxicity in the absence of anesthetic toxicity may be related to short-term excursions in the individual and/or synergistic environmental levels of the vapors found in the various paint spray booths or to the solid components of the paint contained in the overspray which tended to adhere to the exposed skin of the employees.

In next considering the carbon monoxide exposure for the workers employed in the road test areas of this plant, it has been shown that the environmental levels of the gas were generally well below the current Federal Standard and with few exceptions also below the more restrictive Standard proposed by the National Institute for Occupational Safety and Health. Moreover, using the Coburn equation to predict the expected COHb levels in workers exposed to the environmental concentrations of carbon monoxide measured in this study,[16] the COHb levels for non-smoking plant workers (after an 8 hour period of exposure) were indicative of carbon monoxide exposures below 30 ppm on the average. At an average carbon monoxide exposure of 30 ppm for an 8 hour period of moderate work the expected COHb level in a non-smoker would be predicted at 6.2 per cent saturation. The average COHb level in the non-smoking road test workers in this plant was 4.2 per cent saturation at the highest and thus consistent with the environmental concentrations of carbon monoxide as measured below 35 ppm on the average for this plant.

The statistical analysis of the COHb data showed the plant and office working smokers to have levels in excess of five per cent saturation, before and after work. While these COHb levels are considered a potential hazard, particularly for individuals who may have a predisposition for coronary heart disease, the development of these unsafe COHb levels have not resulted from in-plant exposures to carbon monoxide. Rather, the development of COHb levels in excess of five percent saturation is directly related to the use of tobacco for the workers in this plant. Nonetheless, in-plant sources of carbon monoxide did account for an average rise of 1.9% carboxyhemoglobin content in the blood of non-smokers; and, with many of the non-smokers having post-work carboxyhemoglobin levels of 4.0 - 4.5%, any further rise in the plant sources of carbon monoxide would result in unsafe levels of blood COHb for the non-smokers as well as the smokers.

In summarizing the findings of this evaluation, firstly regarding the solvent vapor exposures, it has been determined that employee exposures to solvent vapors (xylene, toluene, butyl alcohol, and naphtha), are toxic at the concentrations found during the time of this evaluation within the paint spray booth areas of this facility. This exposure has resulted in eye, nose, throat and chest irritation among a majority of the exposed workers. However, while such exposures have resulted in the problem of irritant toxicity, it has also been determined that no significant anesthetic toxicity has been revealed during this investigation.

In order to ameliorate the existing hazard of irritantcy from these organic hydrocarbon vapors, it is strongly recommended that workers in the paint spray booth areas of the plant be provided with and encouraged to utilize "supplied" air hoods during painting operations. Local exhaust ventilation systems for the paint spray booth areas should receive proper periodic maintenance and should remain in operation throughout each entire work shift. Also, the recommendations offered in the NIOSH "Criteria Document"[18] regarding both the environmental and medical standards of safe usage for toluene....should be implemented by management.

In summarizing the findings of the evaluation pertaining to the carbon monoxide exposure in the road test areas of the plant, it has been determined that environmental levels of this substance as measured during normal operating conditions present no hazard. This determination is based on environmental air levels which averaged 35 ppm for all jobs and on finding an acceptable concentration of carboxyhemoglobin saturation (less than 4.2%) in the blood of non-smoking workers in the road test areas. It should be emphasized that both plant and office working smokers had average carboxyhemoglobin levels in excess of 5.0% before and after work. However, while such levels in smokers are considered to be a potential hazard (particularly for individuals who may have a predisposition for coronary heart disease), this finding in smokers and not in non-smokers strongly suggests that non-occupationally related factors (eg. cigarette smoking) have contributed to the excessive levels of carboxyhemoglobin in the blood of all workers who smoke cigarettes rather than the lesser contribution from in-plant sources of carbon monoxide. In-plant sources of carbon monoxide accounted for an average rise of 1.9% in the carboxyhemoglobin content in the blood of non-smokers; and with many of the non-smokers having post-work carboxyhemoglobin levels of 4.0 - 4.5%, any further rise in the plant sources of carbon monoxide would result in unsafe levels of blood carboxyhemoglobin for the non-smokers as well as the smokers.

Notwithstanding the absence of a significant hazard in the road test areas, the recommendations offered in the NIOSH "Criteria Document"[19] regarding both the environmental and medical standards of safe usage for carbon monoxide should be undertaken by the management. It is strongly suggested that workers who use tobacco in these areas be encouraged to reduce or refrain from this practice while in the plant.

The application of the recommendations pertaining to both aspects of this evaluation are needed in this facility, specifically those relating to environmental and medical monitoring and employee "awareness" education. The institution of such measures should obviate employee dependence on Federal Occupational Safety and Health Services to answer questions that can be more adequately handled by an ongoing occupational health program within the plant itself. A complete discussion of the "In-Plant Occupational Health Program" has been reviewed elsewhere by Cohen.[20]

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TABLE I

SYMPTOMS REPORTED FROM 52 PAINT SPRAY BOOTH WORKERS

ON AN AUTOMOBILE-TRUCK ASSEMBLY-LINE

Symptom	Total #Workers Reporting Symptom(%)		
	Acrylic Booth (n=24)	Tu-Tone Booth (n=13)	Color Booth (n=15)
Eye Irritation	9(38)	6(46)	4(27)
Nasal Irritation	6(25)	4(31)	4(27)
Throat Irritation	4(17)	1(8)	4(27)
Chest Irritation	2(8)	1(8)	5(33)
Headache	0(0)	1(8)	0(0)
Nausea	2(8)	0(0)	0(0)
Skin Irritation	0(0)	2(15)	0(0)
No Symptoms Reported	8(33)	2(15)	2(13)

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No Symptoms Reported	8(33)	2(15)	2(13)

TABLE II

SUMMARY OF MEAN
TOTAL URINARY HIPPURIC ACID LEVELS IN 52 PAINT BOOTH WORKERS
EXPOSED TO VAPORS OF TOLUENE AND XYLENE

Group	No.	Total Urinary Hippuric Acid (g/l)*			
		Range	Mean	S.C.	Significance
Acrylic Booth Workers					
Shift 1	12	0.47-2.46	1.10	0.54	p value = 0.78
Shift 2	12	0.50-2.34	1.04	0.50	
Tu-Tone Booth Workers					
Shift 1	6	0.59-2.59	1.11	0.75	p value = 0.94
Shift 2	7	0.43-2.18	1.14	0.73	
Color Booth Workers					
Shift 1	7	1.11-2.26	1.55	0.46	p value = 0.72
Shift 2	8	0.54-2.70	1.68	0.83	
All Acrylic Booth Workers	24	0.47-2.46	1.07	0.51	p value = 0.006**
All Color Booth Workers	15	0.54-2.70	1.62	0.65	
All Tu -Tone Booth Workers	13	0.43-2.59	1.12	0.71	p value = 0.063
All Color Booth Workers	15	0.54-2.70	1.62	0.65	
All Acrylic Booth Workers	24	0.47-2.46	1.07	0.51	p value = 0.81
All Tu-Tone Booth Workers	13	0.43-2.59	1.12	0.71	
All Acrylic + Two-Tone	37	0.43-2.59	1.09	0.58	p value = 0.006**
All Color Booth Workers	15	0.54-2.70	1.62	0.65	

* Total hippuric acid is expressed as grams of hippuric acid per liter of urine corrected to a specific gravity of 1.024.

**Value considered statistically significant.

TABLE III

COMPARISON OF TOTAL URINARY HIPPURIC ACID LEVELS IN PAINT BOOTH WORKERS EXPOSED TO VAPORS OF TOLUENE AND XYLENE AND NON-EXPOSED OFFICE WORKERS

Group	No.	Total Urinary Hippuric Acid (g/l)*			
		Range	Mean	S.D.	Significance
All Acrylic Booth Workers	24	0.47-2.46	1.07	.51	p value = 0.22
Male Office Workers	9	0.47-1.36	0.84	.33	
All Tu-Tone Booth Workers	13	0.43-2.59	1.12	.71	p value = 0.29
Male Office Workers	9	0.47-1.36	0.84	.33	
All Color Booth Workers	15	0.54-2.70	1.62	.65	p value = 0.003**
Male Office Workers	9	0.47-1.36	0.84	.33	

*Total hippuric acid is expressed as grams of hippuric acid per liter of urine corrected to a specific gravity of 1.024.

**Value considered statistically significant.

TABLE IV

AVERAGE SOLVENT VAPORS CONCENTRATIONS FOR EACH JOB IN 3 SPRAY PAINT BOOTHS

JOB DESCRIPTIONS	# OF SAMPLES	TOLUENE PPM TWA	TOLUENE RANGE PPM	XYLENE PPM TWA	XYLENE RANGE PPM	BUTYL ALCOHOL PPM TWA	BUTYL ALCOHOL RANGE PPM
Line # 1 Acrylic Booth							
Inner door sprayer	10	1	<1 - 1	9	7 - 13	2	1 - 3
Pick up paint on left or right side	9	1	all <1	4	2 - 6	1	all <1
Sprays front of cowl, box rail, and front of box	9	2	1 - 2	12	6 - 16	2	ND - 3
Sprays inner cab	10	<1	all <1	5	3 - 9	1	ND - 2
Sprays inner box	10	2	1 - 4	9	2 - 22	1	ND - <1
Color Selector	10	<1	all <1	<1	<1 - 3	<1	ND - <1
Line # 1 Tu-Tone Booth							
Top sprayer	8	<1	ND - <1	1	ND - <1	1	ND - <1
Sprays inside and outside of box	10	<1	1 - 1	2	<1 - 4	1	ND - 2
Sprays inner box	10	<1	1 - 2	3	<1 - 8	1	ND - <1
Line # 2 Color Booth							
Front of windshield post, wheel well opening, tailgate, etc.	9	<1	ND - 1	2	<1 - 7	1	ND - <1
Inside of box and subinterior	5	<1	all <1	5	2 - 10	1	<1 - 2
Inside of cab and blazer	15	<1	ND - <1	16	1 - 40	2	ND - 2
Front fire wall, door inside and exterior tailgate, etc.	8	<1	ND - <1	3	1 - 7	<1	ND - <1

NOTE: Naptha was not detected on the samples

TABLE V

AVERAGE SOLVENT VAPOR CONCENTRATIONS IN 3 SPRAY PAINT BOOTHS

	# OF SAMPLES	TOLUENE PPM TWA	TOLUENE RANGE PPM	XYLENE PPM TWA	XYLENE RANGE PPM	BUTYL ALCOHOL PPM TWA	BUTYL ALCOHOL RANGE PPM
.ine #1 Acrylic Booth							
Shift #1	28	1.5	<1 - 5	6	<1 - 22	<1	ND - 2
Shift #2	30	1	<1 - 2	7	2 - 16	1	ND - 3
.ine #1 Tu-Tone Booth							
Shift #1	13	<1	<1 - 1	2	<1 - 4	<1	ND - 1
Shift #2	15	<1	<1 - 2	2	<1 - 8	<1	ND - 2
.ine #2 Color Booth							
Shift #1	20	<1	<1 - 1	11	1 - 40	2	ND - 7
Shift #2	17	<1	<1 - 1	6	1 - 17	<1	ND - 2

TABLE VI

RESULTS OF CARBOXYHEMOGLOBIN BLOOD LEVELS FOR CARBON MONOXIDE AUTOMOBILE-TRUCK ASSEMBLY-LINE WORKERS AND NON-EXPOSED WORKER CONTROLS

Work Location	Line	Smoker	#Workers	Blood Carboxyhemoglobin Levels Pre-Work %	Post-Work %	Δ
Office	-	Yes	6	5.1	6.4	1.3
Office	-	No	4	1.2	1.4	0.2
Plant	1	Yes	7	5.1	6.4	1.3
Plant	2	Yes	5	5.8	5.7	-0.1
Plant	1	No	10	1.8	3.6	1.7
Plant	2	No	6	2.1	4.2	2.1

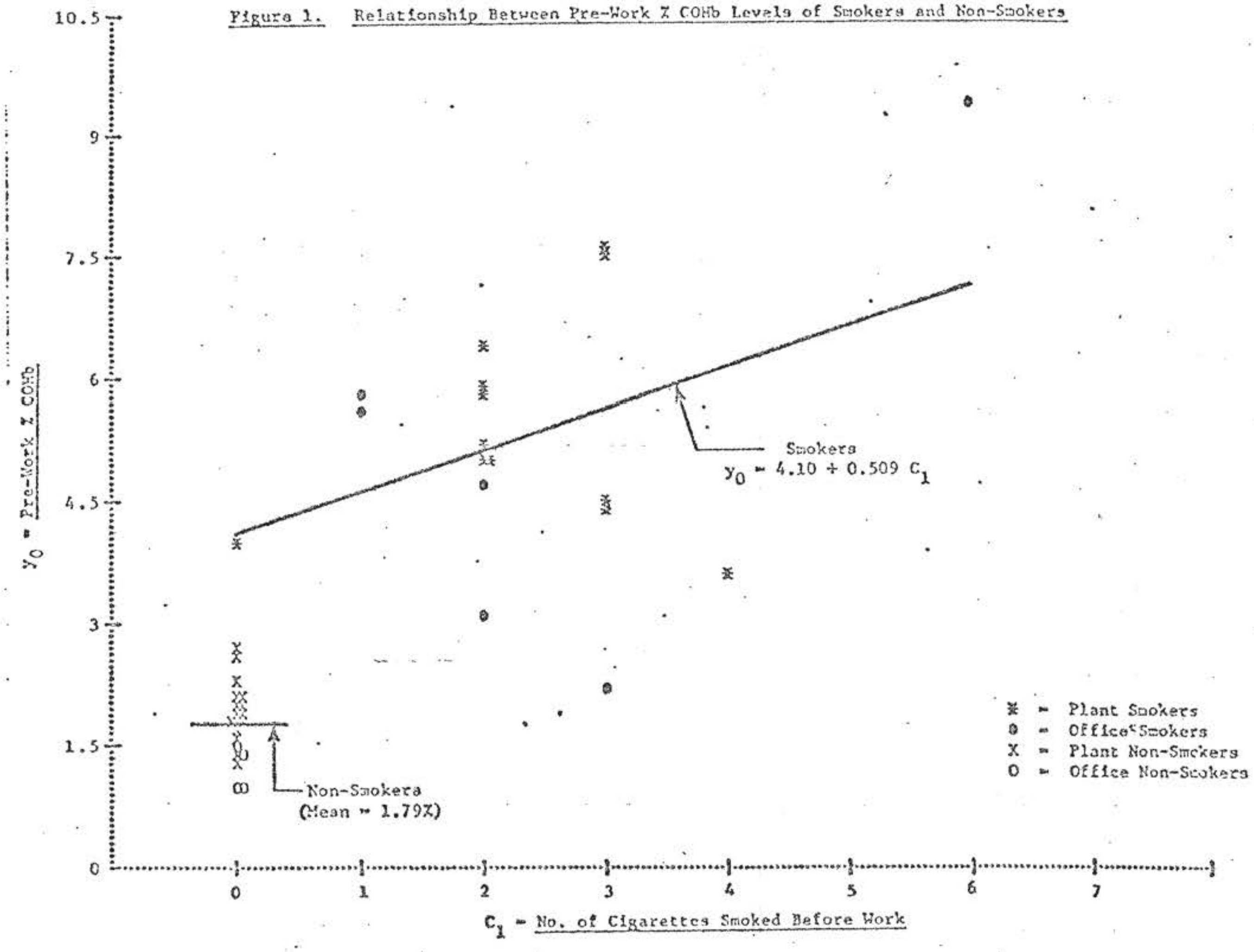
TABLE VII

CARBON MONOXIDE CONCENTRATIONS AT THE ROAD TEST AREA

OF THE TRUCK ASSEMBLY LINES

LINE #	SHIFT	JOB	CARBON MONOXIDE PPM TWA	RANGE PPM
1	1st	Inspector and driver Breathing Zone Sampling (BZ)	34	29 - 43
	2nd	"	38	29 - 50
1	1st	Toe-in pit operators (BZ)	29	22 - 36
	2nd	"	34	29 - 40
1	1st	Headlight adjust (BZ)	33	32 - 34
	2nd	"	39	32 - 45
2	1st	Road test drivers (BZ)	35	25 - 41
	2nd	"	39	31 - 50
2	1st	Inspectors (BZ)	24	31 - 40
	2nd	"	41	32 - 45
2	1st	Toe-in pit operators (BZ)	20	15 - 25
	2nd	"	36	34 - 37
2	2nd	Headlight adjust (BZ)	40	36 - 45
1	1st	Column U - 45 Area Sample	25	
	2nd	"	30	
1	1st	Column U - 49 Area sample	30	
	2nd	"	35	
2	1st	Column X - 47 Area sample	25	
	2nd	"	30	

Figure 1. Relationship Between Pre-Work % COHb Levels of Smokers and Non-Smokers



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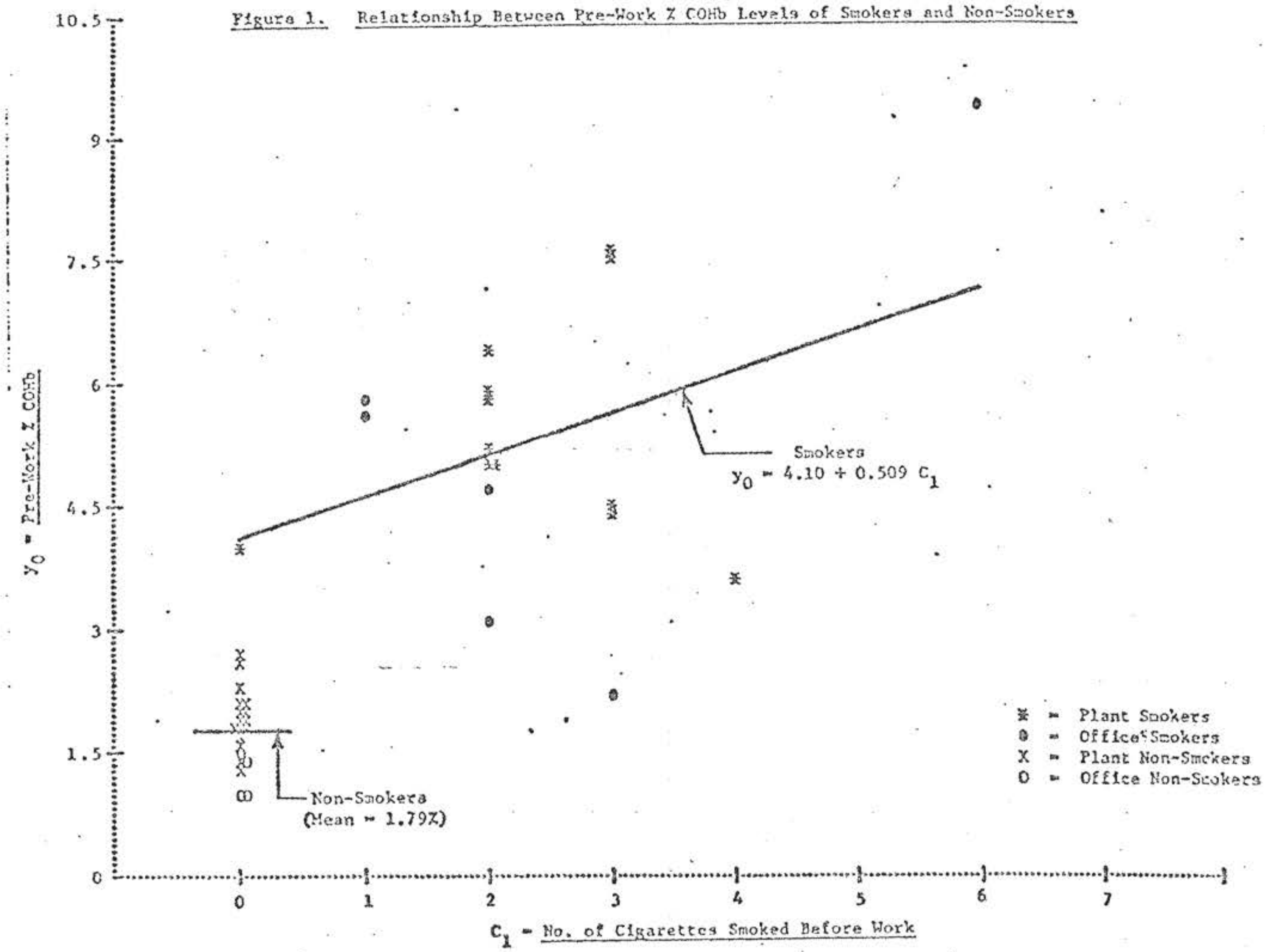

Figure 2. Relationship Between Numbers of Cigarettes Smoked Before Work and During Work by 12 Plant Workers and 6 Office Workers

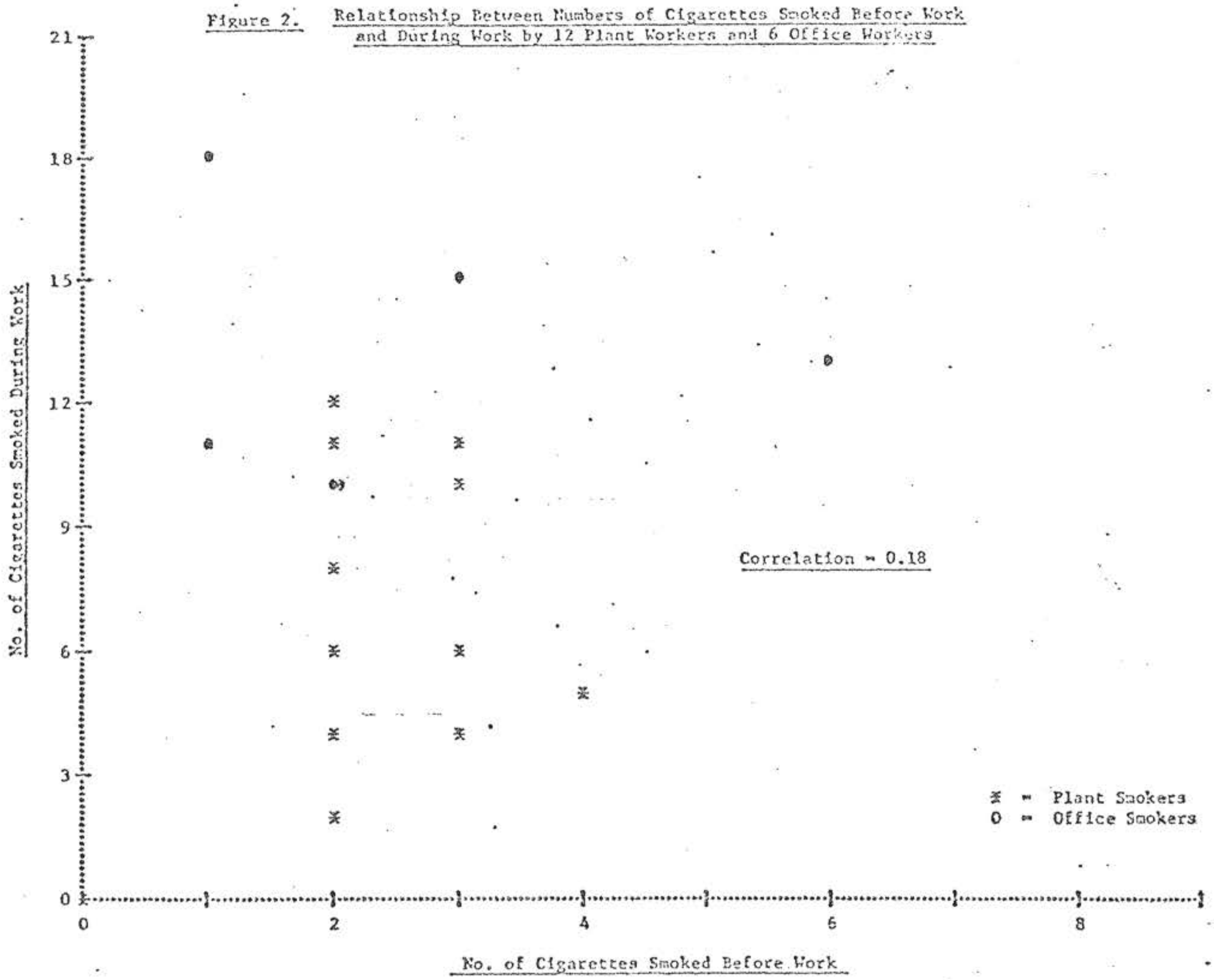

Figure 3. Relationship Between Post-Work and Pre-Work % COHb Levels in Six Groups of Workers

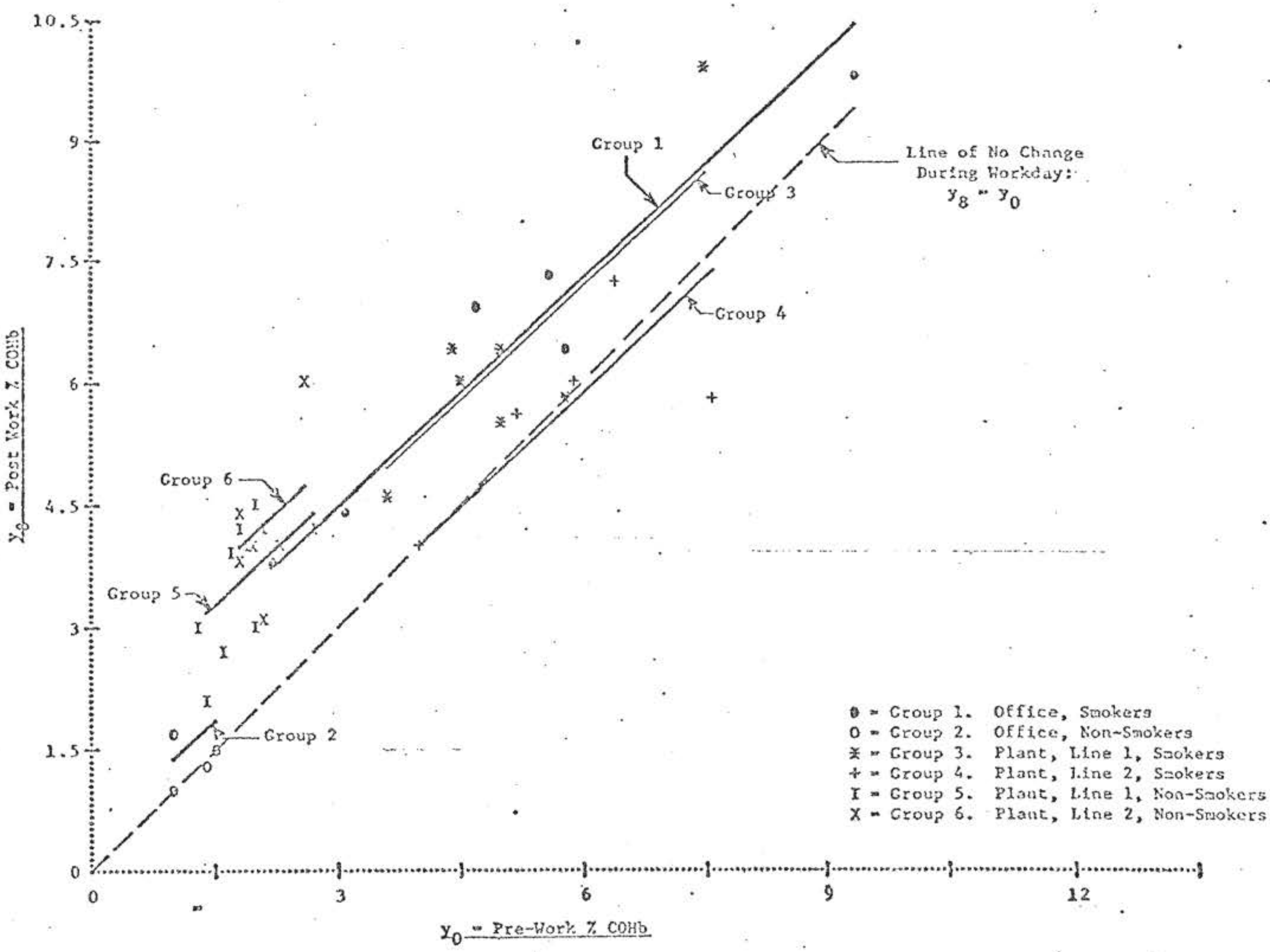

Figure 4. Graph Depicting Model for Statistical Estimation of Average Increases in % COHb Levels of Four Groups of Workers During an 8-Hour Workday