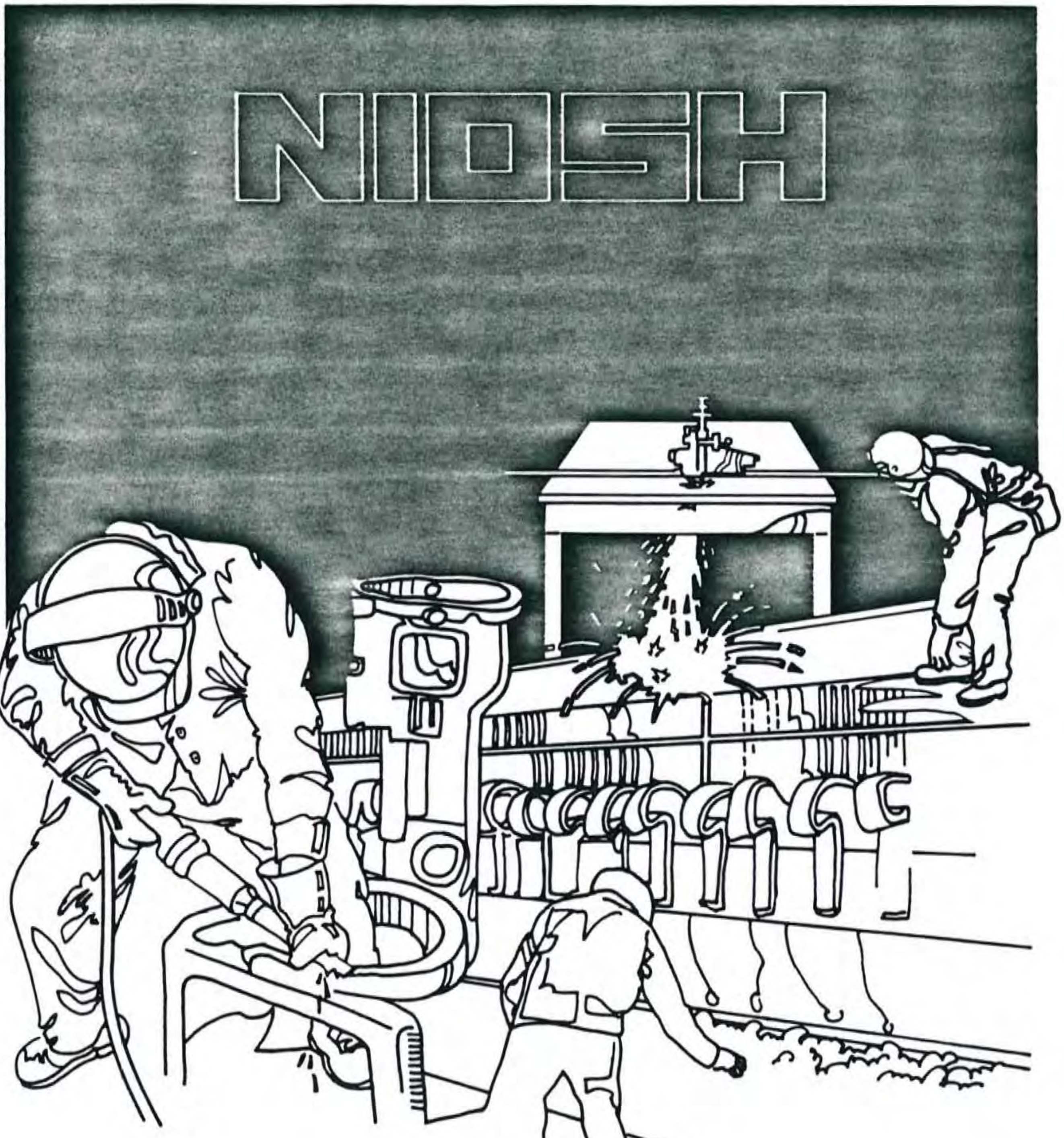
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 80-007-1520
GSA SWITCHGEAR SHOP
WASHINGTON, D.C.

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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I. SUMMARY

On November 1, 1979, NIOSH received a request from the National Capital Region of the General Services Administration to: 1) evaluate the health status of 43 employees who work with transformer fluid containing polychlorinated biphenyls (PCBs); 2) recommend appropriate work procedures and personal protective equipment; and 3) evaluate the working environment for airborne levels of PCBs.

On December 15-20, 1979, January 7-10, 1980, and May 14, 1980, NIOSH industrial hygienists collected personal air samples during four typical transformer maintenance and PCB cleanup operations. Nineteen (79%) of 24 PCB samples collected during maintenance and cleanup operations exceeded the NIOSH recommended standard of 1.0 ug/m^3 (range: nondetectable to 24 ug/m^3, 10-hour TWA). Exposures in excess of the OSHA standards - 0.5 mg/m^3 (chlorodiphenyl, 54%) and 1.0 mg/m^3 (chlorodiphenyl, 42%) - were not documented. Area air samples collected in the vault before, during, and after operations indicated a detectable background level (mean = 0.5 ug/m^3) rising to a mean of 15 ug/m^3 while work was in progress, and eventually declining to a mean of 0.8 ug/m^3. Wipe samples revealed wide-spread PCB contamination around the transformer vaults.

Analysis of one sample of transformer fluid showed 31 ppb 2,3,7,8-tetrachlorodibenzofuran present. No tetrachlorodibenzodioxins were detected.

A medical evaluation of 55 present and former GSA Switchgear Shop employees exposed to PCBs, and of a comparison group of 56 GSA operating engineers not exposed to PCBs, was conducted by the Center for Occupational and Environmental Health of the Johns Hopkins University. This medical evaluation included a detailed questionnaire and physical examination, pulmonary function testing, nerve conduction studies, neurobehavioral test battery, semen analysis, serum and fat PCB analyses, and a variety of clinical chemistry tests.

Serum PCB concentrations in the currently exposed workers ranged from 0 to 300 ppb (average 25 ppb) and were significantly higher than serum levels in the non-exposed comparison group. For current employees, both fat and serum PCB levels were significantly correlated with number of years worked in the Switchgear Shop, although not with time spent in specific job tasks.

No individuals in the study were observed with clinically diagnosable PCB poisoning. However, a number of differences on specific test results were found when comparing the PCB-exposed group with the non-exposed group. The exposed group reported a variety of symptoms more often than the comparison group, including eye irritation, increased tearing, and several non-specific central nervous system symptoms (headache, trouble sleeping, memory loss, and loss of appetite). Although the neurological examination revealed no significant differences in the prevalence of clinical peripheral neuropathy, one aspect of the nerve conduction testing (median nerve sensory distal latency) was significantly prolonged in the exposed group after excluding results in workers with other conditions known to affect this test. This finding may reflect early signs of nerve damage from PCB exposure, particularly in association with the effects of repetitive wrist motion changes (carpal tunnel syndrome).

Increased PCB levels were also associated with increased serum GGT (a liver function test) and with decreased urinary 17-hydroxy-cortico steroid concentrations. The changes are compatible with known or postulated biochemical actions of PCBs.

Although no clinically diagnosable cases of PCB poisoning were observed, NIOSH concludes that a potential health hazard to Switchgear workers from exposure to PCBs and related contaminants existed. Environmental levels of PCBs were in excess of the NIOSH recommended exposure limit, which was designed to minimize the potential for long-term health effects such as liver injury and carcinogenesis. Surface sampling indicated widespread PCB contamination in transformer vaults and on equipment associated with maintenance operations. Skin contact, although not quantitatively evaluated, would be expected to be a large contributor to overall PCB exposure.

Recommendations are presented in Section VII of this report, regarding alteration of work practices, protective clothing, and follow-up industrial hygiene and medical monitoring, to reduce this potential for contact with PCBs.

KEYWORDS: SIC code 3612 (power, distribution, and specialty transformers), PCB, dioxin, furan, transformer fluid, transformer maintenance, chloracne, health effects, neurological effects, hepatotoxicity.

II. BACKGROUND

On November 1, 1979, the Hazard Evaluation and Technical Assistance Branch of NIOSH received a request for technical assistance from the National Capital Region of the General Services Administration (GSA). NIOSH was asked to: 1) evaluate on the health status of approximately 43 GSA employees who work with transformer fluid containing polychlorinated biphenyls (PCB); 2) recommend appropriate PCB handling procedures, including personal protective equipment; and 3) evaluate the working environment for airborne levels of PCB and other chemical contaminants.

This request was necessitated by reports of skin rashes, headaches, loss of appetite, and possible sterility by various switchgear workers.

Three site visits for environmental sample collection were made (December 15-20, 1979, January 7-10, 1980, and May 14, 1980). Two interim reports were distributed (November 1979 and January 1980). In addition, a training course in the general concepts of personal protective equipment and chemical handling was conducted on August 26-28, 1980, for the benefit of switchgear personnel. The medical report was presented to GSA in late, 1983. The report presented here is a summary of a more extensive medical report submitted to NIOSH by Johns Hopkins.

III. PROCESS DESCRIPTION

The buildings containing the transformer vaults were large, multistoried federal government offices located in Washington, D.C. Vault sizes depended on the number of transformers contained within; vaults in this study varied from 26.5 to 62.7 m^2 (285 to 675 ft^2) with a ceiling height of 3.7 to 6.1 m (12 to 20 ft) [average 4.6 m (15 ft)], and contained from two to four transformers with approximately 1230 liters (320 gal) of askarel (a generic term for a broad class of synthetic chlorinated hydrocarbon insulating fluids) each.

In addition to other, non-askarel associated duties, GSA maintenance electricians are periodically required to field-service these PCB-filled transformers. Prior to the public interest in PCB transformers and potential PCB contamination of the environment, it was estimated that actual work with askarel amounted to only two hours out of a 40-hour work week. However, due to the recent emphasis on repairing the leaking transformers, exposure time has been considerably in excess of two hours per week. Usually, the work involves yearly inspection of each transformer and testing of the dielectric strength of the askarel. Askarel in transformer applications is generally a mixture of chlorinated (primarily tri- and tetra-) benzenes and PCB. PCBs are usually Aroclor® 1242, 1254, or 1260, representing 42, 54, and 60% chlorination, respectively. Aroclor 1016, a mixture of tri- and tetra-chlorinated biphenyls, has been used as a substitute in some cases. The dielectric strength (a measure of insulating ability) may decrease due to the electrically induced breakdown of the askarel during use, or by the accumulation of moisture or debris. Filtering removes the contamination and restores the dielectric strength. If any leaks are noticed during inspection, these are repaired.

Transformer repair can be broken down into four main components:

1. Draining the transformer. In order to gain access to the leak, the transformer is gravity drained (via a hose through the oil drain plug located at the bottom) into 55-gallon drums. The location of the leak determines how much askarel is removed because the fluid level must be brought below the leak.

2. Actual transformer repair. This phase could involve partial disassembly of the transformer to gain access to the leak, as in a secondary oil leak, or simply removing the sight gauge cover to replace the gasket. If it is a leak in a metal seam, it may be welded or hammered shut. The extent of this phase, and hence the time it takes to complete it, represents the primary difference between maintenance procedures.

3. Refilling the transformer. The askarel is forced back into the transformer by pressurizing the 55-gallon drum with nitrogen from a compressed gas cylinder.

4. Cleanup. Prior to draining the transformer, any askarel on the transformer or vault floor is dissolved with an organic solvent. Vermiculite is then spread on the solution. It is not picked up at this time, however. Cleanup is left until last. The PCB-soaked vermiculite is shovelled into a 55-gallon drum, and the area and repair equipment are wiped down with solvent-soaked rags. Depending on the location and complexity of the leak, the operation may take from two to ten hours to complete.

The workforce consisted of 43 male electricians. There are two shifts: 7:15a-5:45p and 4:30p - 7:30a. However, the number of workers required for a single transformer repair operation was only 3 to 5, in addition to a supervisor.

During this evaluation, workers were provided with certain personal protective equipment. Items included rubberized "rain" suits, rubber gloves, eye shields, respirators (half-face chemical cartridge-type or airline respirators, at the discretion of the individual worker), and occasionally rubberized forearm coverings. Shoe coverings were not provided.

IV. STUDY DESIGN

A. Environmental

Since it was not known to what levels of PCBs the electricians would be exposed, and whether or not the background levels of PCBs would constitute a significant portion of this exposure, before the study of the actual maintenance operation was undertaken a preliminary ambient air sampling survey of the transformer vault and surrounding environment was conducted. It was thought useful to determine the post-repair background PCB levels to see if repair operations added substantially to pre-repair levels. The study also was designed to categorize the potential PCB exposure to building residents.

An independent consulting firm had determined that over 200 to 1100 transformers subject to service by the GSA electricians required some type of repair, and an additional 200 had minor leaks which would require some decontamination. It was expected that an intensive cleanup operation would be mounted to avoid the spread of the PCBs into the environment. Accordingly, the study was expanded to include the evaluation of an operation that consisted of vault cleanup only.

All air samples were taken at a breathing-zone height of 1.2 to 1.8 m (4 to 6 ft). For reporting and comparison purposes, the sampling locations were grouped in three categories: those taken within the confines of the vault; those taken in public areas outside the vault, but no further than five feet from the vault entrance; and those taken in public areas further than five feet from the vault entrance. Sampling times for pre- and post-maintenance area samples were generally in excess of 10 hours, which is a reasonable estimate of the maximum time a worker would spend in the building each workday. Sampling times for area and personal samples taken during the repair operation were for the duration of the procedure (1.5 to 6.5 hrs).

Area and personal air samples were collected with Dupont® P-4000 personal portable sampling pumps operating at a 1.0 Lpm flowrate. Deactivated Florisil® (30-40 mesh) solid sorbent tubes were used as the collection medium. These were standard 7-mm (4-mm I.D.) tubes with a 100-mg front section preceeded by glass wool and separated from the 50-mg backup section by a polyurethane foam plug. The air samples were prepared for analysis by placing the glass wool and front section of Florisil in a glass crimp-top desorption vial. The backup section and retaining polyurethane plugs were placed in a second vial. Each section of Florisil was then separately desorbed with 2 mL of pesticide-grade toluene and analyzed by gas chromatography. A Tracor Model 560 gas chromatograph equipped with an electron capture detector was used for the analyses. A 1.8-m x 6.4 mm glass column packed with 3% OV-101 on 80/100 mesh Supelcoport was used isothermally at 230°C. The chromatograms obtained from the air samples confirmed the presence of Aroclor 1260, 1254, and 1242, based on major isomer retention times when compared to standards of Aroclor 1260, 1254, and 1242. The Aroclors were quantitated by comparison of peak areas of major isomers with peak areas of corresponding major isomers in standards. Aroclor standards were prepared on Florisil sampling tubes in order to obtain a recovery efficiency along with the calibration. The limit of detection for the Aroclors was 0.1 ug/sample for each.

Several bulk samples of askarel from each transformer location were initially screened qualitatively to determine the actual PCB in use. Since it was not known if a single PCB or several PCB mixtures were involved, this characterization of the bulk askarel was necessary. Information gained from the bulk samples then allowed a more accurate determination of PCB materials in airborne samples.

A sample of each askarel collected was weighed, dissolved in hexane, and diluted to a known volume. An aliquot of each sample solution was then analyzed by gas chromatography (GC). A Tracor Model 560 GC equipped with an electron capture detector (^{63}Ni foil) was used for the initial characterization.

Separation of the PCB mixture into its major isomer groupings was accomplished with a 6-foot by 1/4-inch glass column packed with 3% OV-210 on 100/200 mesh Chromosorb W-MP. The column was used isothermally at 200°C with nitrogen as the carrier gas at a flow rate of 90 mL/min. These instrument conditions allowed adequate resolution of the askarel sample components for a qualitative analysis. The amount of Aroclor 1260 or 1254 in each sample was then determined by a comparison of major isomer peak areas of each sample to corresponding peaks obtained from a series of standards containing known weights of the Aroclors. The limit of detection for both Aroclors in the askarel mixture was 0.0003% (wt/wt).

Earlier literature indicated the presence of dibenzodioxin and dibenzofuran compounds and theorized that they were wholly, or in part, responsible for the health effects seen in PCB exposures. Futher, it has been reported that polychlorinated dibenzofurans (PCDF) have been formed by heating Aroclor 1248 to 300°C in an oxygen atmosphere.[21] Therefore, selected samples, both bulk askarel and air, from each vault were also analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran TCDF).

The bulk askarels were initially screened for TCDD and TCDF by gas chromatography/mass spectrometry (CG/MS). A Hewlett-Packard (HP) 5985A GC/MS was used in this initial screening. The GC interfaced to the MS was an HP5840 using a 1.8-m x 2-mm glass column packed with 3% Dexsil 400 on Chromosorb W-MP. This analysis allowed the identification of any TCDD or TCDF in the samples or gross tetrachloro isomers. The indicated presence of either compound would lead to further work by high resolution GC/MS (HRGC/MS).

An aliquot of each bulk askarel was weighed, dissolved in petroleum ether, acid- and base-washed, and given a final cleanup on an alumina microcolumn. In the GC/MS analysis, only ions characteristic of TCDD or TCDF were monitored, and quantitation was based on retention time of the samples compared to authentic TCDD and TCDF. The limit of detection for TCDD was 1 ng/g (ppb), and 2.5 ng/g (2.5 ppb) for TCDF. Samples for chlorinated benzenes, the usual solvent used to thin PCBs for transformer use, and 1,1,1-trichloroethane, a solvent used in cleanup, were not collected.

In order to obtain a qualitative estimate of the extent of PCB contamination in and around the areas where Switchgear employees worked, wipe samples, using Whatman #40 tab filters either dry or wetted with xylene, were collected. No attempt was made to quantitate the levels by wiping a known area of surface or by employing a standardized wipe procedure. The samples were analyzed by CG/EC after desorption in 5 mL toluene for 1 hour. Separation was accomplished on a 6' x 1/4 mm ID glass column packed with 3% OV-101 on 80/100 mesh Supelcoport isothermally at 230°C. The limit of detection was 0.3 ug/sample each for 1254 and 1260.

B. Medical

1. Study Participants

The initial study group consisted of all 72 persons employed in the Switchgear shop since it opened in 1971. Of this group, 55 employees (38 currently and 17 former employees) agreed to participate in the study. The comparison group consisted of male operating engineers working at GSA who had never had jobs involving exposure to PCBs. Of the 144 eligible operating engineers, 56 were chosen to participate in the study, selected to approximate the age and race distribution of the Switchgear shop employees.

2. Examination Methods

Participation was voluntary. After signing a written informed consent statement, each employee was hospitalized for 24 hours at the USPHS Hospital, Baltimore, Maryland. All medical procedures were performed during this time.

A questionnaire, administered to each participant by a trained interviewer, elicted demographic data, occupational history, PCB exposure history, medical history, and a review of past and current symptoms. At the end of the questionnaire the exposed group was asked about specific work practices. With the exception of the interviewers, all physicians and technicians were blinded with respect to the jobs held by participants.

A detailed physical examination was performed. Items systematically recorded included height, weight, blood pressure, presence or absence of nasal discharge or edema, oral pigmentation, and the percentage of occlusion of each ear by cerumen. Skinfold thickness was measured to the nearest millimeter with a Holtain skinfold caliper at three sites: triceps, suprailiac, and subscapular.

Fundoscopy was performed; changes from normal were classified and recorded. Abnormalities of the thyroid, cervical, supraclavicular, axillary, inguinal or other lymph nodes, were noted.

The presence and type or absence of abnormalities on examination of the chest or cardiovascular system, the abdomen and extremities, was recorded. Liver size was determined by percussion on each subject. The size and consistency of the testes, presence of hydrocoele, variocele, and any epididymal abnormalities was recorded. A rectal examination was performed, prostatic size noted, and feces examined for blood using a hemoccult test.

Each subject underwent a thorough skin examination, performed by the same dermatologist under the same conditions. For each body region the following were systematically recorded: the presence and degree or absence of erythema, scaling, hyperpigmentation, and elastosis; and the number of closed comedones, open comedones, inflammatory papules, pustules, cysts, and milial cysts. In addition, for the facial region the presence of hypertrichosis, atrophic scarring, xanthalesma, scleral abnormalities, conjunctival abnormalities including hyperemia, meibomian gland secretion, palpable meibomian gland, lid margin or palpebral changes, superficial corneal pigmentation, oily precorneal film and arcus senilus; and for the oral cavity, oral pigmentation or other changes were recorded. A final dermatologic diagnosis based on clinical findings was made for each subject.

Each subject underwent a complete neurologic examination by a neurologist. A standardized neurologic examination was performed and recorded systematically, including an examination of mental status and a detailed examination of cranial nerves, motor function, deep tendon reflexes, coordination, sensory function, and gait.

3. Laboratory Tests as Procedures

After admission to the hospital, a number of tests and procedures were done. These included:

a) fasting blood samples for glucose, calcium, creatinine, uric acid, total protein, albumin, bilirubin, alkaline phosphatase, LDH, SGOT, SGPT, GGTP, T_3, T_4, a complete blood count, and lipid profile;
b) 24-hour urine specimen for excretion levels of creatinine, delta-amino levulinic acid, 17-keto steroids, and 17-hydroxy-cortico steroids, uroporphyrins, and coproporphyrins;
c) semen sample (after 48 hours abstinence) for sperm density and morphology;
d) PCB levels for serum and fat (obtained by needle biopsy). Samples were analyzed by packed column gas chromatography-electron capture detection and reported as total PCBs;
e) Anergy test battery by evaluating dermal reactions to mumps and trichophyton;
f) spirometry;
g) antipyrine half life: in order to determine the degree of induction of hepatic microsomal enzymes, plasma antipyrine levels were determined before administration of 18 mg/kg antipyrine and at 4, 8, and 12 hours afterward;
h) percent body fat estimation;
i) nerve conduction studies including motor conduction velocities of the ulnar, peroneal and posterior tibial nerves; sensory distal latencies in the median ulnar, peroneal, and sural nerves; and the conduction velocity of the slow fibers of the ulnar nerve; and
j) neurobehavioral testing, including specific tests of memory and learning ability; visual, perceptual, and visuomotor ability; manual dexterity; and reaction time.

4. Data Analysis

Standard data handling and statistical analysis techniques were used. For PCB levels and continuous variables on which PCB could have an impact, the distribution of each variable and its natural logarithmn mictransformation were examined. Either the original data or the transformed data, whichever yielded the distribution more closely resembling that of a normal random variable, were used in all further analyses. All PCB concentrations were log-transformed after adding 0.01 ppm to adipose concentrations and 0.1 ppb to serum concentrations to eliminate zero values.

V. EVALUATION CRITERIA

A. Environmental Criteria

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 exposures, 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 often not 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 Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, 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 exposures 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 legally required 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.

B. Specific Substances

1. Polychlorinated biphenyls[1]

Polychlorinated biphenyls (PCBs) are chlorinated aromatic hydrocarbons, manufactured in the U.S. from 1929 to 1977, and marketed under the tradename Aroclor.[2] They have been used commercially for a wide variety of purposes, including dielectric fluids for electrical equipment, hydraulic fluids, heat transfer fluids, lubricants, plasticizers, and components of surface coatings and inks. Since PCBs' manufacture and use in the U.S. was banned by the Toxic Substances Control Act (P.L. 94-469), occupational exposure to PCBs has been limited almost exclusively to servicing and repair of transformers and mining machinery that contain PCBs, and to activities relating to the disposal of PCB contaminated equipment and waste material.

PCB residues are detectable in various tissues of persons without known occupational exposure to PCBs. Mean whole blood PCB levels range from 1.1 to 8.3 ng/ml, while mean serum PCB levels range from 21. to 24.2 ng/ml[3]. Workplace PCB exposures have been documented in the published literature for industrial plants where PCB were used in the manufacturing, or encountered in the maintenance and repair[4,5], of PCB-containing electrical equipment.[6]

Mean serum PCB levels among workers in one capacitor manufacturing plant studied by NIOSH ranged from 111 to 546 ng/ml, or approximately 5 to 22 times the background level in the community.[4,7] Breathing-zone PCB air levels ranged from 31 to 154 ug/m^3 of air as 8 hour time-weighted averages.[5] Mean serum PCB levels among workers in transformer maintenance and repair typically range from 12 to 51 ng/ml, considerably lower than among workers at capacitor manufacturing plants.[7] Breathing-zone PCB air levels ranged from non-detectable to 215 ug/m^3 of air as 8 hour time-weighted averages.[8]

Burn-outs of fluorescent light ballasts manufactured prior to 1969 can release measurable amounts of PCBs into the ambient environment. Staiff et. al.[9] found approximately 0.1 ug/m^3 of Aroclor 1242 one meter below a fluorescent light ballast immediately after burn-out. MacLeod[10] demonstrated 5.74 ug/m^3 of PCBs as Aroclor 1242 and 5.86 ug/m^3 as Aroclor 1254 in laboratory air, immediately following a ballast burn-out. Kominsky et. al.[11] found 166 ug/m^3 of PCBs as Aroclor 1242 one meter below a ballast, and 10-20 ug/m^3 at six meters from the ballast, immediately after burn-out. Two human epidemics, "Yusho" and "Yu-cheng", from ingestion of cooking oil accidently contaminated by PCB heat-exchange fluids used in the oils' pasteurization, have been described in detail.[12,13] Although PCBs were initially regarded as the etiologic agent of Yusho, analyses of the offending cooking oil demonstrated high levels of polychlorinated dibenzofurans and polychlorinated terphenyls, as well as other unidentified chlorinated hydrocarbons, in addition to PCB.[14] Extrapolation of the "Yusho" and "Yu-cheng" experienced to occupational exposures, to impute human health consequences from such exposures, are best avoided.

The results of individual studies of PCB-exposed workers are remarkably consistent with each other. Among the cross-sectional studies of the occupationally exposed, a lack of clinically apparent illness in situations with high PCB exposure seems to be the rule. Chloracne was observed among recent studies of workers in Italy[15], but not among workers in Australia[16], Finland[17], or the U.S.[8,18,19,20] Nonetheless, there were weak correlations with SGOT[15,16,18,19], GGTP[8,15,19,20], and plasma triglycerides.[8,21,22]

Correlations with plasma triglycerides[4] and with GGTP[5] are also found among community residents with low-level PCB exposures. These studies were cross-sectional, and as such causality cannot necessarily be imputed to PCBs. Although it has been suggested that the simultaneous changes in SGOT, GGTP, and plasma triglycerides, with increasing serum PCB level, are indicative of an effect of PCB exposure on the liver[8], it has also been argued that the PCBs have merely partitioned into plasma triglycerides, the variation of which, within individuals, has nothing to do with PCB exposure.[21] PCBs are lipophilic, with a 128:1 PCB concentration gradient between blood lipids and whole blood.[7]

Two mortality studies, among workers at capacitor manufacturing plants in the U.S. and in Italy, are both equivocal in regard to an association between PCB exposure and malignant neoplasms. An excess of liver cancer at two plants in the U.S. was not statistically significant and occurred within 20 years of first PCB exposure; and a rectal cancer excess, although statistically significant, was observed only among females at one of the two plants.[23] The increased risk for neoplasms at an Italian plant was for all neoplasms among males. Various organ-specific neoplasms, although elevated in males and females, were not statistically significantly elevated. The risk for neoplasia was not analyzed by latency of exposures.[24]

The standard governing occupational exposure to PCBs in the United States is the 1968 American Conference of Governmental Industrial Hygiene (ACGIH) threshold limit value (TLV) for airborne contaminants, adopted in 1971 by the U.S. Occupational Safety and Health Administration.[25] Under this standard, occupational exposure to PCBs is limited to 1 mg/m^3 for 42% chlorinated biphenyl, and 0.5 mg/m^3 for 54% chlorinated biphenyl, as 8-hour time-weighted averages. The ACGIH TLV[26] is based upon studies which indicated liver injury, mild to moderate chloracne, and irritation of the respiratory passages. In 1977, the National Institute for Occupational Safety and Health (NIOSH) recommended that occupational exposure to PCBs be limited to 1 microgram per cubic meter (ug/m^3) as a time-weighted average, for up to a 10-hour workday, 40-hour work-week.[1] This limit was selected as the minimum reliable detectable level for PCBs for the recommended sampling method. It was "based on the findings of adverse reproductive effects (among experimental animals and among Yusho victims), on its (NIOSH's) conclusion (from animal carcinogenesis bioassays) that PCBs are potential carcinogens in humans and on its (NIOSH's) conclusion that occupational and animal studies have not demonstrated a level of exposure that will not subject the worker to possible liver injury..."

Listed below is the PCB exposure limit recommended in this report, and the current OSHA standards. The percent notation in each OSHA standard indicates percent chlorination. The NIOSH recommended exposure limit applies to all PCBs regardless of percent chlorination.

	Recommended Exposure Limit	OSHA Standard[25]
Time weighted average	1.0 ug/m^3 (10-hour)	1.0 mg/m^3 (8-hour) 42% 0.5 mg/m^3 (8-hour) 54%

VI. RESULTS AND DISCUSSION

A. Environmental

1. Bulk Askarel Analysis

Matching the major isomer patterns and retention times of major isomer peaks of samples to standards allowed a qualitative identification of Aroclor 1260 in four of five bulks, with the fifth bulk identified as Aroclor 1254. Aroclor 1242 was not found in any of the bulks obtained from transformers in which repair operations would be evaluated. However, Aroclor 1242 was found in a bulk liquid obtained from the electricians' shop, indicating that exposure to Aroclor 1242 was possible.

The amount of Aroclor 1260 in the oils ranged from 41 to 56%, and Aroclor 1254 was quantitated in the one oil at 54%.

An askarel supposedly not containing PCB was also analyzed. It was found to contain 75 ppm by weight Aroclor 1260. This finding suggests that cross contamination of non-PCB equipment with PCBs can occur.

TCDD was not detected in any of the bulk oils. TCDF was detected and ranged from 13 to 116 ppb by weight. Further analysis showed the TCDF to be 2,3,7,8-TCDF, at 31 ppb. At least 10 tetrachloro isomers were present in the sample. Therefore, the majority of TCDF contamination was due to isomers other than the 2,3,7,8-TCDF.

2. Ambient PCB Levels

Table 1 contains the ambient air PCB levels in the transformer vaults, adjacent areas, and areas some distance away from the indoor entrance to the vault. Results are presented as total ug PCBs/m^3. Values from the four operations evaluated have been grouped together according to location relative to the vault. Pre-maintenance PCB levels were all below the NIOSH-recommended exposure limit. In areas normally travelled by non-maintenance personnel [areas designated "immediately outside vault" - more than 1.5 m (5 ft) from the vault door] 55% (6/11) of the samples were nondetectable at the 0.1 ug/sample LOD. Using the Wilcoxon test[27] (a non-parametric statistical test of difference), there is no significant difference ($p \leq 0.05$) between pre-maintenance levels inside and those immediately outside the transformer vault. Although there is a difference indicated between vault levels and levels in generally occupied areas, the data in Table 1 shows that this is due to the low levels of the generally occupied area levels relative to vault levels.

A recent article[28] reported that urban outdoor airborne PCB levels range from 0.5-30 ng/m^3. It has also been reported[24] that PCBs contained in caulking material used in the general ventilation system of a chemistry laboratory contaminated the indoor air up to 0.3 ug/m^3. Pre-maintenance levels reported in this study do not differ greatly from these data.

Fifty-eight percent (7/12) of all post-maintenance PCB samples were below the limit of detection; 80% (4/5) of those taken in non-vault areas were below the LOD. The Wilcoxon Test suggests no statistical difference between levels in the three areas. By comparing the pre-maintenance and post-maintenance inside vault values, it appears that the repair operation contributes to the ambient environmental PCB burden. However, this difference is not statistically significant. Ambient PCB levels are greatly increased during repair operations in all areas; 65% are in excess of the NIOSH recommended exposure limit. The post-repair PCB levels indicate a decline to prerepair levels after a 4-month period of time (the time delay between repair and follow-up evaluation).

Considering these data, we conclude that there is minimal risk of building occupants being exposed to PCB. It is likely that with the use of exhaust ventilation during maintenance there will be no increase over normal background.

3. Personal Exposures

Personal sampling results are presented in Table II. Since the various duties necessary to complete the repair work were not individually, but collectively, performed, the data have been categorized by the type of repair rather than by individual job descriptions.

Personal exposure levels have been listed as exposure levels for the period sampled and converted to 10-hour time-weighted averages for comparison to the NIOSH criterion of 1 ug/m^3. Considered as a group, 79% (19/24) of the personal exposures exceeded the NIOSH criterion. Ten-hour TWAs ranged from 0.001 to 19.2 ug/m^3.

There are significant differences in degree of exposure between the various operations. For example, "oil drain plug repair and cleanup" and "sight gauge and oil drain plug repair and cleanup" show, on the average a 4-fold difference. (21 and 5.4 ug/m^3 TWA, respectively). However, the latter operation is somewhat more extensive.

Data concerning temperature variations from vault to vault, variations in vault size, ventilation rates, amounts of askarel transferred, and variations in team work practices were collected, but failed to reveal any consistent explanation. Further, individual work practices did not seem to be a factor. A more highly exposed individual on one operation would not necessarily be as highly exposed on another operation.

This variability may be due to the age of the leak (with a fresher leak or warmer fluid providing more PCB vapor) or to the amount of askarel which has leaked out, although no data were collected to substantiate these theories.

A representative number of air samples previously analyzed for PCB were also analyzed for TCDF. No TCDF was found in any of the samples (detection limit was 1 ng/sample).

4. Wipe Sample Data

The wipe samples were analyzed for 1254 and 1260. These data and a description of where they were obtained are in Table III. No conclusions have been drawn concerning the advantages of one method, wet or dry, over the other. The dry filter paper withstands wiping over a rough surface better than the wet paper, although rough surfaces do not lend themselves wipe sampling. Only the wet collection samples have been reported. This decision was purely arbitrary. The important information in these data are that PCB contamination is present on many objects associated with or located near transformer vault maintenance operations. Contamination on surfaces accessible to the public provides a mechanism for their contamination.

B. Medical

1. Clinical Overview

None of the examined individuals presented a classical syndrome (chloracne, jaundice, etc.) clinically recognizable as compatible with the descriptions of the PCB toxicity found in the older literature.

2. Demographic and Employment Characteristics of the Two Groups

The groups were almost identical in terms of mean age, racial composition, and marital status (Table IV). There was a slightly higher proportion of current smokers and alcohol drinkers in the Switchgear employees. The only statistically significant difference was in the number of employees who currently both drink alcohol and smoke. Evaluation of other past occupational exposures such as to lead, asbestos, use of solvents, were obtained by questionnaire. No significant differences were found between the two groups except for their exposure to askarels. All the exposed group, but none of the comparison group, gave a history of occupational exposure to PCBs. PCB exposure occurred as a result of working in the Switchgear shop. The distribution of length of exposure in this shop is seen in Table V. The shop had been in operation for nine years, so that this represented the maximum potential exposure with the present employer. The duration of work in this shop averaged 3.75 years, with a median of 2.

3. Serum and Adipose Tissue PCB Concentrations

A comparison of serum and adipose tissue PCB concentrations in workers currently exposed, previously exposed, and not exposed (comparison group) is shown in Table VI and VII. Concentrations in sera ranged from not detected (<1 ppb) to 300 ppb. Concentrations in adipose tissue ranged from not detected (<0.2 ppm) to 33 ppm. Serum PCB concentrations were below the quantifiable level for 1 currently exposed, 1 previously exposed, and 2 comparison group employees. Adipose tissue PCBs were below the quantifiable level for 1 currently exposed and 1 comparison group employee. Differences among the three groups were highly significant ($p < .01$) for both serum and adipose tissue PCB concentrations.

Duncan's Multiple range test at the .05 level showed that the mean PCB concentration in currently exposed workers is significantly higher than that in both those previously exposed and the comparison group, while the mean levels in the two latter groups do not differ significantly. For both serum and adipose tissue PCB, the mean PCB level in all exposed was significantly higher than the mean level in the comparison group at the $p=0.01$ level. Values for the previously exposed group of workers, while somewhat higher than those of the comparison group, were considerably below those seen in exposed workers.

Table VIII shows the Pearson correlation coefficients obtained between the serum and adipose tissue PCB concentrations and several historical measures of exposure for currently exposed workers, previously exposed workers, and the comparison group workers. For currently exposed workers, serum PCB concentration showed a significant association with age and number of years worked both at the Switchgear division and at GSA. Adipose tissue PCB concentration was significantly associated only with the number of years worked at the Switchgear division.

For previously exposed workers, age, years at GSA, and years worked in the Switchgear were not significantly associated with adipose tissue levels of PCB, while the association observed for the time spent (hrs./yr.) in the job functions of repair, storage, and filtering was significantly associated with adipose tissue concentration of PCBs. Other job activities gave borderline significant association (time spent in operation vs. serum PCB, and time spent in maintenance vs. adipose concentration of PCB). In the comparison subjects, neither age nor number of years worked at GSA were significantly associated with the adipose tissue levels of PCBs.

The correlation (Pearson's $r=0.319$) between serum and adipose tissue PCB concentration, though statistically significant ($p=0.001$), was relatively weak.

4. Questionnaire Results

A comparison of questionnaire responses to questions about symptoms currently or within the last year showed statistically significant differences between the exposed and comparison groups for eye irritation and increased tearing, chest pain on walking, wheezing, loss of appetite, frequent headaches, trouble sleeping, and memory trouble (Table IX). In each case, the abnormal response was more prevalent in the exposed group.

The association between the significantly different responses and PCB levels was explored. Only trouble sleeping and appetite loss were significantly associated with log PCB. Trouble sleeping had a significant association at $p=0.001$ with adipose tissue PCB and loss of appetite was significant at $p=0.02$ with serum PCB.

5. Physical Examination Findings

There were no statistically significant differences in physical examination findings between the groups apart from a greater suprailiac skin fold thickness in the exposed group.

There was no statistically significant difference between the exposed and comparison groups for hepatomegaly. One individual in the exposed group had a liver span greater than nine centimeters, as compared to six in the comparison group.

There were no differences in the distribution of facial lesions. The numbers of lesions elsewhere on the body were small, and there was no statistically significant difference between the groups for any observation except for the presence of comedones at any site on the body, which was higher in the exposed group (Table X).

6. Neurological Findings

Evidence of mild clinical peripheral neuropathy was found in 40% (22/54) of the exposed and 21% (12/56) of the comparison subjects. Differences between the groups in the prevalence of clincial peripheral neuropathy did not reach statistical significance. No significant intergroup differences were found in nerve conduction tests, except for the median sensory distal latency in individuals without overt carpal tunnel syndrome (Table XI). Moreover, the median sensory distal latency (again excluding individuals with carpal tunnel syndrome) was correlated with log serum PCB (r=0.383, p=0.0001). It was not correlated with adipose tissue PCB. Even after adjusting for age, alcohol consumption, smoking, and serum glucose, the correlation between the median sensory distal latency and log serum PCB remained significant (r=0.276, p=0.007).

Clinical peripheral neuropathy by physical examination was confirmed by electrodiagnostic testing in 23% (5/22) of the exposed workers and 0% (0/12) of the comparison group. The electrodiagnostic findings were present only in the lower extremities and consisted of an increase in the sural nerve distal latency or a decrease in the amplitude of the sural action potential.

The presence of an abnormal nerve conduction velocity with a normal physical examination was classified as a subclinical neuropathy, since it was not clinically apparent either to the worker or the examiner. Subclinical neuropathy was found in 5% (3/54) of exposed workers and 10% (5/50) of the comparison group. The electrodiagnostic findings again were limited to the lower extremities and consisted of an increased distal latency in the sural and peroneal sensory nerves and a decreased amplitude in the peroneal sensory action potential.

The results of neurobehavioral testing were also common (Table XII). A statistically significant difference was seen in manual dexterity in the non-dominant hand only, as determined by the Purdue Pegboard Test, with the comparison group being more dextrous.

7. Laboratory Testing and Spirometry (Tables XIII and XIV)

Statistically significant differences between the groups were found for serum albumin concentration, plasma T_4 concentration, calculated T_4 index and FEV_1 as a percentage of predicted value, all of which were lower in the exposed group and for serum lactic-dehydrogenase which was increased in the exposed workers. Differences of borderline significance were observed in serum total protein concentration, serum alkaline phosphatase, antipyrine half-life, and urinary 17-hydroxy-cortico steroid excretion. The differences in FEV_1 were not significant after adjusting for cigarette smoking.

After adjustment for potential confounding factors, the only variable which showed a significant association with adipose tissue PCB concentration was urinary 17-hydroxy-cortico steroids excretion (negative association). Serum PCB concentration was significantly associated with serum GGT activity (positive association).

8. Anergy Skin Testing

There was no significant difference between the numbers of positive responses in the exposed and comparison group for either of the antigens.

9. Reproductive Function

No statistically significant differences between the groups were observed either in sperm count (Table XIII) or in urinary 17-keto- steroid excretion (Table XIV).

VII. DISCUSSION

A. General

The medical study was performed on workers with a moderate level of current PCB exposure and some historic exposures, and there was partial overlap of tissue PCB concentrations between the exposed and the comparison groups, presumably reflecting some workers in the ostensibly exposed group who in fact had relatively minor or negligible occupational exposure. This possibility was supported by observations and records of work patterns. In this evaluation, PCB exposure was identified through the presence or absence of occupational exposure and by blood and adipose tissue total PCB concentrations, respectively. In most previous studies, only serum PCB concentrations have been measured. As PCBs are mixtures of homologues and isomers, the total PCB concentration is the sum of concentrations of several dozens of single compounds with different toxicological properties. Thus, there are still some limitations using the total PCB concentration to indicate biological exposure to toxic PCBs, even when both measures are used.

In light of these considerations, it is important that the results of the study are evaluated in terms of statistical significance and biological meaning and that results are compared with the results of experimental studies in animals and other clinical-epidemiologic studies in humans to determine consistency.

Both adipose and serum PCB levels were considerably higher in the occupationally exposed group when compared with the comparison group of operating engineers. The positive association between both serum and adipose PCB concentration and length of exposure in the Switchgear department in the currently exposed workers points out that occupational exposure at the Switchgear was important enough to produce an accumulation of PCBs over years well above that normally occurring in the population.

B. Neurotoxicity

Several non-specific central nervous system symptoms, namely, headache, trouble sleeping, memory trouble, and loss of appetite were significantly more prevalent in the exposed group. Only trouble sleeping and loss of appetite were significantly correlated with PCB concentrations. These may be components of the neurasthenic syndrome, which can represent early central nervous system dysfunction following exposure to a neurotoxic agents or a response to other stressors.

Neurologic examination revealed no significant difference in the prevalence of clinical peripheral neuropathy between the exposed and comparison groups. However, when the median sensory distal latency was examined without inclusion of individuals with carpal tunnel syndrome, it was found significantly prolonged in the exposed workers. The median sensory distal latency was significantly correlated with serum PCB. This correlation remained significant after adjustment for confounding variables. A possible interactive effect between PCB exposure and mechanical traction of the median nerve could explain this phenomenon.

C. Biochemical Effects

Statistically significant differences on examination and laboratory tests were observed between the groups for comedones anywhere on the body, serum albumin concentration, plasma T4 concentrations, calculated T7 index, FEV_1 as a percentage of predicted value and serum LDH. In each case, the more abnormal value was noted in the exposed group. After adjustment for potential confounding variables, the only statistically significant associations remaining were between log adipose PCB and decrease in log urinary 17-hydroxy-cortico steroid and log serum PCB and increased log serum GGT.

The associations of increased PCB levels with increased serum GGT and decreased urinary 17-hydroxy-cortico steroid concentrations are compatible with the known or postulated biochemical actions of PCBs. Although epidemiologically important, these biochemical changes were not of a degree which would be of immediate medical concern to the affected individuals.

D. The data in this and other studies does not allow us to establish serum or adipose levels at which workers should be withdrawn from all PCB exposure. The results of present and past PCB levels and of the monitoring examinations described above should be reviewed along with other pertinent medical information by a physician knowledgeable about the effects of PCBs. On the basis of this information and additional tests as necessary, the physician should assess whether the worker should continue to work exposure to PCBs. This assessment should be provided to both the worker and the GSA management. Whenever elevated body burdens of PCBs are found, a careful review of possible sources of PCB exposure should also be made and the need for careful hygienic practices reinforced.

VIII. RECOMMENDATIONS

1. Allow transformers to cool to ambient temperature before beginning any work.

2. Ventilate the vault to the outside if possible. All vaults should have a working ventilation system.

3. Clean up any spilled askarel before any maintenance work. This will minimize worker skin contact and may also reduce airborne PCB levels.

4. Be conscious of which tools and other equipment are potentially contaminated. Do not place contaminated articles outside the vaults where non-switchgear people may come in contact with them.

5. There is limited information on garment material suitable for PCB and associated solvents. One test[29] found Saranex-laminated Tyvek to exhibit the following breakthrough characteristics (time for liquid material permeate through one layer of garment): undiluted Aroclor 1254, 30 minutes; undiluted trichlorobenzene, no breakthrough after 15 minutes; 6:4:90 ratio of Aroclor 1254, trichlorobenzene, and mineral spirits, no breakthrough after 60 minutes. Saranex-laminated Tyvek exhibits adequate short-term protection; however, gross contact with askarel liquid is likely to render the garment useless in 15 minutes. In order to eliminate the debate over

whether gross contamination has occurred, we recommend that protective clothing be replaced as soon as possible if liquid askarel contact occurs. Of course, these garments should continue to be single-use items.

6. Use disposable boot coverings to prevent contamination of street shoes. Do not wear contaminated boot coverings out of the vault into public areas.

   Stampfer, et al[30], found that the glove materials nitrile rubber, viton, and viton SF rubber, had a breakthrough time greater than eight hours when tested with a mixture of 52% Aroclor 1254 and 48% trichlorobenzene. The authors note that these materials cannot be effectively decontaminated of Aroclor 1254 or Aroclor solutions and should be used only once. We suggest that efforts be made to use gloves made of these materials.

7. Replace the "wrench and drum" alarm system and nitrogen pressure method for filling and emptying transformers with a pumping system and a flowmeter. Pressurizing a 55-gallon drum is a dangerous method for filling a transformer.

8. Full-face respirators with organic vapor cartridges are sufficient for transformer maintenance under the conditions observed, except for one condition: air-supplied respirators should be used for any operation which requires the operator to put his head in the transformer or work over the open top of the transformer. This area holds the potential for even higher PCB levels than were measured (55 ug/m^3, 10-hour TWA). When supplied air is used, be sure to locate the compressor in an uncontaminated area. Cartridges should be changed daily or more frequently if odors are noticed during use. Because eye injury from splatter is a possibility, half-face respirators are not recommended. Safety eye wear and half-face respirators are difficult to use together.

9. Under no circumstances should an operator immerse his arms in askarel. Any askarel on the skin should be washed off immediately with soap and water.

10. Periodic air sampling and evaluation of work practices should be performed by the GSA industrial hygienist. This ongoing program can serve as an evaluative tool to gauge the effectiveness of control measures.

11. Continued monitoring of the health of PCB-exposed workers should be performed. The data from this study should serve as a baseline, and the results of future examinations should be

periodically reviewed to determine which examinations continue to prove necessary. The composition of the medical monitoring program has been detailed in a report by Johns Hopkins University dated September 1983.

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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. General Services Administration, National Capital Region, Washington, D.C.
2. International Brotherhood of Electrical Workers, Local 27
3. NIOSH, Region III
4. OSHA, Region III

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.

TABLE I

Environmental PCB Levels (ug/m^3) Determined by Long-Term (> 10-Hour) Air Sampling

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

	Pre-Maintenance	During Maintenance	Post-Maintenance
Breathing-Zone Level Inside Vault	0.9	55.0	1.9
	0.8	25.0	1.6
	0.7	17.9	1.1
	0.5	12.1	0.7
	0.2	2.8	0.1*
	0.1*	2.1	0.1*
		2.1	0.1*
		1.9	
Immediately Outside Vault	0.6	2.6	0.1*
	0.5	1.1	0.1*
	0.4	0.4	
	0.1*	0.3*	
	0.1*	0.2*	
Generally Occupied Areas	0.2	1.4	0.2
	0.2	0.5	0.1*
	0.1*	0.5	0.1*
	0.1*	0.3	
	0.1*		
	0.1*		

* Maximum estimation, extrapolated from LOD of 0.1 ug/sample. Conventionally reported as non-detectable.

TABLE II

Personal Breathing Zone Samples

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Sample Duration (Hours)	Concentration (ug/m^3)	10-Hour TWA Concentration (ug/m^3)
	Oil Drain Plug Repair and Cleanup	
3.2	60.0	19.2
3.2	55.7	17.8
3.1	43.1	13.4
	Sight Gauge and Oil Drain Plug Repair and Cleanup	
3.2	17.4	5.6
3.2	14.7	4.7
3.2	7.9	2.5
	Cleanup of PCB Leak Only	
1.0	3.1	0.3
1.0	3.1	0.3
1.0	0.1	>0.1
	Secondary Oil Leak Repair and Cleanup (2 Vaults)	
5.8	17.1	9.9
5.9	12.3	7.3
5.4	10.6	5.7
6.5	8.7	5.7
5.9	8.0	4.7
4.5	7.4	3.3
3.8	8.3	3.2
5.2	4.7	2.4
5.0	4.7	2.4
3.7	5.5	2.0
5.5	3.3	1.8
5.2	4.8	2.5
3.5	3.2	1.1
2.7	2.1	0.6
1.5	3.6	0.5

TABLE III

Environmental PCB Levels (ug) Determined by Wipe Sampling*

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Amount of Aroclor 1254	1260	Location
3.6	3.2	steering wheel. Switchgear truck used to transport PCBs and equipment
**	155	bannister of steps leading to vault
	5.5, 0.4	door knob of vault
	102	handle of compressor used to supply air to respirators
	1.1	inside airline respirator after use
	16	inside 1/2 face chemical cartridge mask
	2.5	inside chemical safety goggles
	54	crane used to remove network breaker protector
	26,6.5	switchgear employees' hands
	2	inside NIOSH investigator's respirator
3.6	ND	vault floor after spill cleanup
	0.4	visible handprint on vault door
	2.3	desktop lamp in office adjacent to vault

* Surface area variable.
** Blank data mean nondetectable (<0.3 ug/sample).

TABLE IV

Demographic and Employment Characteristics of the Two Groups

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

	Exposed Switchgear Electricians	Comparison Operating Engineers
Sample size	55	56
Males	55 (100%)	56 (100%)
White	45 (82%)	47 (84%)
Black	10 (18%)	9 (16%)
Age range (years)	24 - 60	24 - 64
Median age (years)	36	36
Mean age (years)	38	39
Currently smoke	33 (60%)	26 (46%)
Mean pack years (smokers and ex-smokers)	22.9 (n=48)	21.5 (n=43)
Currently drink alcohol	44 (80%)	40 (71%)
Currently drink moderate to high quantities of alcohol	13 (25%)	22 (39%)
Currently smoke and drink	29 (53%)	22 (39%)*
Mean years resident in urban setting	29	27

TABLE IV (Continued)

Demographic and Employment Characteristics of the Two Groups

	Exposed Switchgear Electricians	Comparison Operating Engineers
Employment		
Less than 5 years with current employer	18 (33%)	19 (34%)
More than 5 years with current employer	27 (67%)	27 (66%)
Mean years with current employer	7.0	9.5
Levels of Education		
No formal schooling	0 (0%)	0 (0%)
Less than or 6 grades	1 (2%)	1 (2%)
7 to 9th grade	1 (2%)	3 (5%)
High school, but not graduated	4 (7%)	3 (5%)
High school, not graduated + 1 yr. technical school	3 (5%)	0 (0%)
High school graduate	29 (53%)	21 (37%)
H.S. graduate + 1 yr. technical training	4 (7%)	13 (23%)
At least 1 yr. college but not graduate	13 (24%)	15 (27%)

None of the differences between the two groups were statistically significant at the 0.05 level using chi square or t-test as appropriate, except that which is noted as (*).

TABLE V

Years of Employment at Switchgear Shop of Exposed Group

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Years	Number of Employees	Percent
<1	2	3.6
1	8	14.5
2	18	32.7
3	3	5.5
4	6	10.9
5	3	3.6
6	6	10.9
7	1	1.8
8	1	1.8
9	7	12.7
	55	

mean years employed 3.7

TABLE VI

Serum PCB Concentrations for Current Exposed, Past Exposed, and Comparison Groups (ppb)

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Population	N	Range	Median	Geometric Mean	Group Comparisons Using Log Transformed Data		
					Mean	S.D.	P Value*
Current Exposed	(37)	ND[+] - 300	12	12.207	2.502	1.347	
Past Exposed	(17)	ND - 30	7	5.906	1.776	1.354	<0.01
Total Exposed	(54)	ND - 300	9	9.708	2.273	1.379	<0.01
Comparison	(54)	ND - 15	6	4.568	1.519	1.005	

* F-test or two-tailed t-test

+ The limit of detection was 1 ppb

TABLE VII

Adipose PCB Concentrations for Current Exposed, Past Exposed, and Comparison Groups (ppm)

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

					Group Comparisons Using Log Transformed Data		
Population	N	Range	Median	Geometric Mean	Mean	S.D.	P Value*
Current Exposed	(36)	ND[+] - 33	2.20	2.077	0.731	1.301	
Past Exposed	(16)	0.3 - 5.1	.75	0.826	-0.191	0.746	<0.01
Total Exposed	(52)	ND - 33	1.45	1.565	0.448	1.229	<0.01
Comparison	(53)	ND - 3.0	.60	0.603	-0.505	0.900	

* F-test or two-tailed t-test

+ The limit of detection was 0.2 ppm

TABLE VIII

Pearson Correlation Coefficients for Tissue Concentrations of PCB and Work Exposure Status

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Work Exposure Status	Log Serum PCB		Log Adipose PCB	
	R	P Value	R	P Value
Current Exposed				
Age	0.435	0.007	0.251	n.s.
Years worked with GSA	0.353	0.030	0.309	n.s.
Years worked at Switchgear	0.379	0.020	0.518	0.001
Hrs/Yr Spent in Maintenance	0.025	n.s.	-0.171	n.s.
Hrs/Yr Spent in Operations	0.131	n.s.	-0.009	n.s.
Hrs/Yr Spent in Repair	0.004	n.s.	0.025	n.s.
Hrs/Yr Spent in Storage & Filtering	-0.018	n.s.	0.042	n.s.
Past Exposed				
Age	0.390	n.s.	0.290	n.s.
Years worked with GSA	0.297	n.s.	0.224	n.s.
Years worked at Switchgear	-0.241	n.s.	0.068	n.s.
Hrs/Yr Spent in Maintenance	0.361	n.s.	0.416	n.s.
Hrs/Yr Spent in Operations	0.303	n.s.	0.284	n.s.
Hrs/Yr Spent in Repair	0.436	n.s.	0.646	0.007
Hrs/Yr Spent in Storage & Filtering	0.287	n.s.	0.621	0.010
Comparison Group				
Age	0.173	n.s.	0.044	n.s.
Years at GSA	0.229	n.s.	0.052	n.s.

n.s. - not significant at the 0.05 level

COMPARISON OF QUESTIONNAIRE RESPONSES

CURRENT AND PAST YEAR SYMPTOMATOLOGY - IN THE TWO GROUPS

	Exposed			Comparison			
SYMPTOMS	N	#	% Positive	N	#	% Positive	P Value
Eye irritation	55	(40)	73	56	(24)	43	.003
Increased tearing	55	(27)	49	56	(16)	29	.043
Blurred vision	55	(12)	22	56	(7)	12	(n.s.)
Nasal irritation	55	(24)	44	56	(18)	32	(n.s.)
Frequent colds	55	(13)	24	56	(13)	23	(n.s.)
Persistent sore throats	55	(12)	22	56	(10)	18	(n.s.)
Daily cough	55	(21)	38	56	(16)	29	(n.s.)
Phlegm production daily	55	(19)	34	56	(14)	25	(n.s.)
Hemoptysis	55	(0)	0	56	(1)	1	(n.s.)
Shortness of breath	54	(22)	41	55	(17)	31	(n.s.)
Chest pain on walking	55	(15)	27	56	(6)	11	.047
Wheezing	55	(22)	40	56	(11)	20	.032
Chest pain	55	(23)	42	55	(20)	36	(n.s.)
Cough-3 mos./yr.	53	(11)	21	55	(8)	14	(n.s.)
Heart palpitations	55	(17)	31	56	(11)	20	(n.s.)
Leg pain when walking	55	(12)	22	56	(8)	14	(n.s.)
Loss of appetite	55	(11)	20	55	(2)	4	.018
Loss of weight	55	(4)	7	56	(6)	11	(n.s.)
Frequent nausea	55	(4)	7	56	(5)	9	(n.s.)
Frequent or severe vomiting	55	(1)	2	56	(3)	5	(n.s.)

*corrected chi square with one degree of freedom or two tailed Fisher's exact test as appropriate.
n.s. - not significant at the 0.05 level

COMPARISON OF QUESTIONNAIRE RESPONSES

CURRENT AND PAST YEAR SYMPTOMATOLOGY - IN THE TWO GROUPS

	Exposed			Comparison			
SYMPTOMS	N	#	% Positive	N	#	% Positive	P Value*
Frequent heartburn	55	(24)	44	56	(23)	41	(n.s.)
Frequent stomach pains	55	(11)	20	56	(14)	25	(n.s.)
Jaundice	55	(2)	4	56	(0)	0	(n.s.)
Difficulty with urination	55	(3)	5	56	(9)	16	(n.s.)
Frequent diarrhea	55	(11)	20	56	(7)	12	(n.s.)
Constipation	55	(16)	29	56	(11)	20	(n.s.)
Frequent headaches	55	(29)	53	56	(17)	30	.0280
Trouble sleeping (insomnia)	55	(14)	25	56	(3)	5	.0070
Memory trouble	55	(15)	27	56	(6)	11	.0470
Lack of strength	55	(15)	27	56	(8)	4	(n.s.)
Lack of energy	55	(26)	47	56	(24)	43	(n.s.)
Vertigo	55	(13)	24	56	(6)	11	(n.s.)
Lightheadedness	55	(23)	42	56	(15)	27	(n.s.)
Blackouts	55	(5)	9	56	(6)	11	(n.s.)
Loss of smell	55	(3)	5	56	(3)	5	(n.s.)
Loss of balance	55	(11)	20	56	(7)	12	(n.s.)
Loss of taste	55	(1)	2	56	(3)	5	(n.s.)
Loss of vision	55	(7)	13	56	(9)	16	(n.s.)

*corrected chi square with one degree of freedom or two tailed Fisher's exact test as appropriate
n.s. - not significant at the 0.05 level

COMPARISON OF QUESTIONNAIRE RESPONSES

CURRENT AND PAST YEAR SYMPTOMATOLOGY - IN THE TWO GROUPS

	Exposed			Comparison			
SYMPTOMS	N	#	% Positive	N	#	% Positive	P Value*
Double vision	55	(4)	7	56	(3)	5	(n.s.)
Loss of hearing	55	(8)	14	56	(10)	18	(n.s.)
Seizures	55	(1)	2	56	(0)	0	(n.s.)
Numbness	55	(18)	33	56	(15)	27	(n.s.)
Trouble concentrating	54	(12)	22	55	(9)	16	(n.s.)
Frequent sleepiness	55	(18)	33	56	(16)	29	(n.s.)
Speech difficulty	55	(6)	11	56	(4)	7	(n.s.)
Difficulty swallowing	55	(5)	.9	56	(1)	2	(n.s.)
Tingling	55	(21)	38	56	(16)	29	(n.s.)
Pressure sensation	55	(5)	9	56	(4)	7	(n.s.)
Burning sensation	54	(4)	7	56	(7)	11	(n.s.)
Joint swelling	55	(13)	24	56	(7)	12	(n.s.)
Pains in limbs	54	(22)	41	56	(17)	30	(n.s.)
Joint pain	55	(25)	45	56	(21)	37	(n.s.)
Pain in back	55	(37)	67	56	(34)	61	(n.s.)
Pain in heels	54	(7)	13	56	(4)	7	(n.s.)
Tremor	54	(3)	6	55	(7)	13	(n.s.)
Nervousness	55	(25)	45	56	(22)	39	(n.s.)

*corrected chi square with one degree of freedom or two tailed Fisher's exact test as appropriate
n.s. - not significant at the 0.05 level

COMPARISON OF QUESTIONNAIRE RESPONSES

CURRENT AND PAST YEAR SYMPTOMATOLOGY - IN THE TWO GROUPS

SYMPTOMS	Exposed N	Exposed #	Exposed % Positive	Comparison N	Comparison #	Comparison % Positive	P Value*
Excessive worry	55	(19)	34	56	(15)	29	(n.s.)
Depression	55	(19)	34	56	(12)	21	(n.s.)
Crying spells	55	(1)	2	56	(5)	9	(n.s.)
Feelings of worthlessness	55	(10)	18	56	(6)	11	(n.s.)
Trouble getting along with people	55	(8)	14	56	(2)	4	(n.s.)
Personality change	54	(9)	17	56	(6)	11	(n.s.)
Hallucinations	55	(0)	0	56	(3)	5	(n.s.)
Mood swings	54	(13)	24	55	(8)	14	(n.s.)
Paralysis	54	(4)	7	56	(0)	0	(n.s.)
Frequent muscle cramps	55	(11)	20	56	(10)	18	(n.s.)
Frequent muscle twitching	55	(16)	29	56	(15)	27	(n.s.)
Rashes	55	(18)	33	56	(14)	25	(n.s.)
Acne	55	(26)	47	56	(17)	30	(n.s.)
Changes in body hair	55	(6)	11	56	(4)	7	(n.s.)
Darkening of the skin	53	(3)	6	56	(4)	7	(n.s.)
Discoloration of nails	55	(3)	5	56	(3)	5	(n.s.)
Thickening of the soles	55	(7)	13	56	(4)	7	(n.s.)
Itchy sensation	53	(24)	45	56	(20)	36	(n.s.)

*corrected chi square with one degree of freedom or two tailed Fisher's exact test as appropriate
n.s. - not significant at the 0.05 level

TABLE IX (Cont.)

COMPARISON OF QUESTIONNAIRE RESPONSES

CURRENT AND PAST YEAR SYMPTOMATOLOGY - IN THE TWO GROUPS

	Exposed			Control			
SYMPTOMS	N	#	% Positive	N	#	% Positive	P Val
Bruise easily	55	(8)	14	56	(4)	7	(n.s.)
Cysts, moles, knots	54	(24)	44	56	(18)	32	(n.s.)
Sores or cuts that heal slowly	54	(11)	20	56	(5)	9	(n.s.)
Blistering or excessive sunburn	55	(15)	27	56	(7)	12	(n.s.)
Incoordination	55	(3)	5	56	(1)	2	(n.s.)
Difficulty walking	55	(5)	9	56	(2)	4	(n.s.)
Difficulty writing	55	(3)	5	56	(1)	2	(n.s.)
Involuntary movements	55	(7)	13	56	(2)	4	(n.s.)
Swelling of limbs	55	(6)	11	56	(2)	4	(n.s.)
Decreased sexual desire	55	(8)	14	56	(3)	5	(n.s.)
Inability to have or sustain an erection	55	(7)	13	56	(4)	7	(n.s.)

*corrected cni square with one degree of freedom or two tailed Fisher's exact test as appropriate
n.s. - not significant at the 0.05 level

TABLE X

PREVALENCE OF DERMATOLOGIC FINDINGS - IN THE TWO GROUPS

	Exposed			Control			
	N	#	% Positive	N	#	% Positive	P Value*
Facial Erythema							
forehead	55	(1)	2	56	(0)	0	(n.s.)
malar area	55	(0)	0	56	(0)	0	(n.s.)
nose	55	(0)	0	56	(0)	0	(n.s.)
Facial Scaling							
forehead	55	(0)	0	56	(1)	2	(n.s.)
malar area	55	(1)	2	56	(0)	0	(n.s.)
nose	55	(0)	0	56	(0)	0	(n.s.)
Facial hyperpigmentation							
forehead	55	(2)	4	56	(1)	2	(n.s.)
malar area	55	(2)	4	56	(0)	0	(n.s.)
nose	55	(1)	2	56	(0)	0	(n.s.)
Facial elastosis							
forehead	55	(4)	7	56	(6)	11	(n.s.)
malar area	55	(3)	5	56	(5)	9	(n.s.)
nose	55	(1)	2	56	(4)	7	(n.s.)
Facial open comedones							
forehead	55	(3)	5	56	(3)	5	(n.s.)
malar area	55	(3)	5	56	(3)	5	(n.s.)
nose	55	(5)	9	56	(2)	4	(n.s.)

*corrected chi square with one degree of freedom or
Fischer's Exact Test
n.s. - not significant at the 0.05 level

TABLE X (Cont.)

PREVALENCE OF DERMATOLOGIC FINDINGS - IN THE TWO GROUPS

	Exposed			Comparison			
	N	#	% Positive	N	#	% Positive	P Value*
Facial closed comedones							
forehead	55	(0)	0	56	(1)	2	(n.s.)
malar area	55	(2)	4	56	(0)	0	(n.s.)
nose	55	(0)	0	56	(1)	2	(n.s.)
Facial inflammatory papules							
forehead	55	(3)	5	56	(0)	0	(n.s.)
malar	55	(3)	5	56	(0)	0	(n.s.)
nose	55	(0)	0	56	(1)	2	(n.s.)
Comedones anywhere on body	55	(18)	33	56	(8)	14	.038
Inflammatory papules anywhere on body	55	(21)	38	56	(16)	29	(n.s.)

*corrected chi square with one degree of freedom
or Fisher's exact test
n.s. - not significant at the 0.05 level

TABLE XI

COMPARISON OF NERVE CONDUCTION VELOCITIES - IN THE TWO GROUPS

	Exposed Group			Comparison Group			
<u>Conduction Test</u>	N	Mean	Standard Error	N	Mean	Standard Error	P Va
Peroneal Nerve Motor Conduction Velocity (m/sec)	55	47.16	1.04	56	48.14	0.49	(n.
Peroneal Nerve Motor Distal Latency (m/sec)	55	3.97	1.26	56	4.00	0.08	(n.
Tibial Nerve Motor Conduction Velocity (m/sec)	55	49.52	0.73	56	49.29	0.66	(n.
Tibial Nerve Motor Distal Latency (m/sec)	55	4.49	0.10	56	4.47	0.08	(n.
Ulnar Nerve Motor Conduction Velocity (m/sec)	55	57.34	0.07	56	56.98	0.59	(n.
Ulnar Nerve Sensory Distal Latency (m/sec)	55	2.69	0.04	56	2.75	0.03	(n.s
Ulnar Nerve Sensory Amplitude (uV)	55	15.95	0.94	56	16.23	0.99	(n.s

* pooled variance estimate t-test 2-tail probability
n.s. - not significant at the 0.05 level

COMPARISON OF NERVE CONDUCTION VELOCITIES - IN THE TWO GROUPS

Conduction Test	Exposed Group N	Exposed Group Mean	Exposed Group Standard Error	Comparison Group N	Comparison Group Mean	Comparison Group Standard Error	P Value*
Sural Nerve Sensory Distal Latency (m/sec)	55	3.71	0.09	56	3.69	0.05	(n.s.)
Peroneal Nerve Sensory Distal Latency (m/sec)	55	2.94	0.09	56	2.97	0.07	(n.s.)
Median Nerve Sensory Amplitude (uV)	55	18.13	0.96	56	20.28	1.33	(n.s.)
Median Nerve Sensory Distal Latency(m/sec)	55	3.13	0.061	56	3.05	0.065	(n.s.)
Median Nerve Sensory Distal Latency (m/sec) after removing subjects with Carpal Tunnel Syndrome	54	3.08	0.039	50	2.93	0.049	0.018

*pooled variance estimate t-test 2-tail probability
n.s. - not significant at the 0.05 level

TABLE XII

COMPARISON of NEUROBEHAVIORAL TEST RESULTS IN THE TWO GROUPS

	Exposed		Comparison		
Test	N	Mean	N	Mean	P Value *
Memory and Learning Ability:					
Digit Span ++ (scaled score)	55	10.2	55	10.1	(n.s.)
Immediate Recall - (Digit Symbol pairs - immediately (association+, association and free)	55	6.7	55	6.3	(n.s.)
Delayed Recall - (Digit Symbol pairs-after 30 min.) (association+, association and free)	55	6.3	55	5.8	(n.s.)
Paired Associate Learning ++	55	14.8	55	14.4	(n.s.)
Rey Auditory (trials 1-5)					
Verbal Learning (total for 5 trials)	55	46.4	55	44.4	(n.s.)
Verbal Fluency (total for 3-one min. trials)	55	36.3	55	35.7	(n.s.)
Visual Perceptual and Visuomotor Ability:					
+Visual Reproductions++	55	9.6	55	9.4	(n.s.)
Block Design++	55	11.0	55	11.4	(n.s.)
Digit Symbol++	55	9.4	55	9.3	(n.s.)
Trailmaking (time in seconds)	53	76.7	54	80.4	(n.s.)

* two-tailed t-test

\+ also a test of memory

++ standard scoring procedure per manual as described in references

n.s. - not significant at the 0.05 level

TABLE XII (Cont.)

COMPARISON OF NEUROBEHAVIORAL TEST RESULTS IN THE TWO GROUPS

Test	N	Mean	N	Mean	P Value *
Manual Dexterity:					
Finger Tapping-Dominant Hand	55	51.6	55	51.3	(n.s.)
Finger Tapping-Non Dominant	55	46.7	55	46.9	(n.s.)
Purdue Pegboard-Dominant Hand	55	44.0	55	45.3	(n.s.)
Purdue Pegboard-Non Dominant	55	42.4	55	44.8	0.013
Purdue Pegboard-Both Hands	55	34.9	55	35.9	(n.s.)
Reaction Time in m/sec:	55	237	55	233	(n.s.)
Perception Time in m/sec:	55	8	55	8	(n.s.)

* two-tailed t-test
n.s. - not significant at the 0.05 level

TABLE XIII

Laboratory Results in the Two Groups

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Test	Reference Values	N	Exposed Range	Mean	S.E.+	N	Range	Mean	Comparison	
									S.E.+	P Value*
				Variables with Normal Distribution						
Calcium mg/dL	(8.8 - 10.5)	55	(8.8 - 10.6)	9.48	0.050	56	(9.1 - 10.2)	9.57	0.039	n.s.
Uric Acid mg/dL	(3.0 - 8.0)	55	(3.3 - 7.4)	5.65	0.127	56	(3.00 - 8.7)	5.55	0.154	n.s.
T3 IU	(23 - 33)	55	(21.7 - 36.5)	27.64	0.381	56	(23.0 - 39.5)	28.26	0.427	n.s.
T4 IU	(4.5 - 12.5)	55	(4.8 - 10.4)	8.24	0.171	56	(4.7 - 13.4)	8.87	0.196	0.016
T7 (index calculated)		55		226.47	4.931	56		247.96	4.678	0.002
Cholesterol mg/dL	(age dependent)	55	(111 - 275)	191.38	5.17	56	(125 - 345)	197.27	6.017	n.s.
LDL mg/dL	(50 - 210)	55	(41 - 187)	120.56	4.558	56	(39 - 256)	126.68	5.820	n.s.
Hemoglobin gm %	(14 - 18)	55	(12.9 - 17.4)	15.30	0.132	56	(13.4 - 18.7)	15.47	0.121	n.s.
Total White Cell Count MC/L	$(3.9 - 10.4 \times 10^3)$	55	(3.9 - 13.1)	7.47	0.296	56	(3.5 - 14.4)	6.96	0.311	n.s.
Coproporphyrins ug/L	(50 - 200)	54	(4 - 224)	81.3519	5.077	51	(17 - 221)	89.0196	5.972	n.s.
Urine Creatinine gm/24 hour	(0.8 - 2.0)	54	(0.6 - 2.6)	1.60	0.062	50	(0.6 - 3.5)	1.63	0.076	n.s.
Delta ALA mg/24 hour	(1.3 - 7.0)	54	(0.487 - 4.68)	2.809	0.123	49	(0.176 - 4.970)	2.481	0.156	n.s.
17-Hydroxy-cortico steriods mg/24 hour	(2.0 - 10.0) (adult male)	53	(1.1 - 10.8)	6.428	0.302	51	(2.3 - 14.5)	7.41	0.409	0.055

S.E.+ - Standard Error
* Pooled variance estimate 't'-test 2-tail probability
n.s. - not significant at the 0.05 level. Borderline values are shown.

(continued)

TABLE XIII (Cont.)

Laboratory Results in the Two Groups

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

		Exposed					Comparison					
				Log Transformed Data					Log Transformed Data			
Test	Reference Values	N	Range	Geom. Mean	Mean	S.E.	N	Range	Geom. Mean	Mean	S.E.	P Value*
Variables with Log Normal Distribution												
Total Protein gm/dL	(6.2 - 8.3)	55	(6.5 - 8.4)	7.17	1.97	0.007	56	(6.7 - 8.3)	7.32	1.99	0.006	0.058
Albumin gm/dL	(3.9 - 5.4)	55	(3.9 - 5.2)	4.53	1.51	0.008	56	(4.1 - 5.1)	4.66	1.54	0.006	0.015
Total Bilirubin mg/dL	(0.0 - 1.1)	55	(0.3 - 1.5)	0.58	-0.55	0.045	56	(0.3 - 1.3)	0.62	-0.48	0.044	n.s.
Alkaline Phosphatase mu/mL	(28 - 98)	55	(34 - 570)	76.7	4.34	0.057	56	(41 - 126)	66.69	4.20	0.039	0.054
L.D.H. mu/mL	(102 - 228)	55	(108 - 361)	202.35	5.31	0.028	56	(138 - 265)	186.79	5.23	0.020	0.042
SGOT mu/mL	(7 - 40)	55	(12 - 82)	26.31	3.27	0.049	56	(15 - 70)	25.03	3.22	0.038	n.s.
GGT mu/mL	(0 - 36)	55	(0 - 202)	26.84	3.29	0.081	56	(9 - 159)	22.87	3.13	0.066	n.s.
SGPT mu/mL	(7 - 40)	55	(6 - 64)	23.34	3.15	0.103	56	(8 - 98)	26.05	3.26	0.064	n.s.
Triglycerides mg/dL	(10 - 90)	55	(32 - 320)	116.74	4.76	0.074	56	(40 - 450)	127.74	4.85	0.069	n.s.
HDL mg/dL	(30 - 85)	55	(27 - 98)	43.38	3.77	0.037	56	(15 - 81)	40.04	3.69	0.034	n.s.
VLDL mg/dL	(50 - 210)	55	(41 - 187)	23.10	3.14	0.075	56	(39 - 256)	25.28	3.23	0.070	n.s.
17 Keto Steroids	(9 - 22)	53	(2.6 - 23.5)	10.59	2.36	0.064	50	(2 - 22.9)	9.78	2.28	0.067	n.s.
Antipyrine half life t 1/2 hours		47	(4.9 - 19.2)	10.7	2.37	0.042	44	(5.1 - 53.4)	12.43	2.52	0.069	0.069

* Pooled variance estimate t-test 2 tail probability comparing log transformed means

n.s. - not significant at the 0.05 level. Borderline values are shown.

(continued)

TABLE XIII (Cont.)

Laboratory Results in the Two Groups

GSA Switchgear Shop
Washington, D.C.
HETA 80-7

Test	Reference Values	Exposed N	Exposed Range	Exposed Observed Score+ as % of Expected	Comparison N	Comparison Range	Comparison Observed Score+ as % of Expected	P Value*
Variables with Non-Normal Distribution								
Creatinine Sera mg/dL	(0.7 - 1.40)	55	(0.8 - 1.6)	103	56	(0.8 - 4.1)	97	n.s.
Glucose mg/dL	(63 - 110)	55	(75 - 121)	95	54	(78 - 173)	105	n.s.
Uroporphyrin ug/L	(10 - 50)	54	(1.75 - 29.45)	101	51	(0 - 24)	99	n.s.
Coproporphyrin ug/24	(50 - 200)	54	(7.2 - 142.5)	97	50	(5.5 - 246.6)	103	n.s.
FEV_1 (A/P)	**	54	(64 - 134)	89	47	(70 - 136)	111	0.046
FVC (A/P)	**	54	(63 - 132)	92	47	(68 - 140)	108	n.s.
FEV_1/FVC (A/P)	**	54	(52 - 90)	97	47	(60 - 97)	103	n.s.
Sperm Count in Millions/mL	(60 - 300)	38	(0 - 269)	100	31	(1.8 - 360)	100	n.s.

* Wilcoxon rank-sum test
** Dependent on age, race, ht/wt, sex
+ Scores as calculated in the Wilcoxon rank-sum test.
n.s. - not significant at the 0.05 level.