

INDUSTRIAL HYGIENE SUMMARY REPORT
OCCUPATIONAL EXPOSURE TO POLYCHLORINATED BIPHENYLS AT
SIX COMMERCIAL FACILITIES

1976-1977

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16. Abstract (Limit 200 words) A survey of occupational exposure to polychlorinated biphenyls (PCBs) was conducted. Personal and area samples were analyzed for PCBs at six facilities: a producer of PCBs, an electrical transformer manufacturer, a renovator of transformers, and three electrical capacitor manufacturers. Average personal exposures ranged from 30.5 to 640 micrograms per cubic meter (microg/m ³), the highest exposure occurring at a manufacturer of large and small capacitors utilizing Arochlor-1016 (12674112). The OSHA standard for PCBs containing 42 percent chlorine is 1 milligram/r ³ . The NIOSH recommended standard is 1microg/m ³ . Average area exposures ranged from 34 to 237microg/m ³ . The facilities with the highest average exposures tended to have a greater number of PCB handling operators. The author concludes that airborne PCB exposures at the facilities were generally below the OSHA standards, but exceeded the NIOSH standard. Recommendations include supplying workers handling PCBs daily with clean work clothes from the skin out, requiring all workers to shower at the end of a shift, and prohibiting eating in work areas.				
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DISCLAIMER

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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ABSTRACT

Researchers for the National Institute for Occupational Safety and Health evaluated worker exposure to airborne concentrations of polychlorinated biphenyls (PCBs) at six facilities: a producer of PCBs, a manufacturer of electrical transformers, a renovator of transformers, and three manufacturers of electrical capacitors.

This report presents the results of measurements of worker exposure to airborne concentrations of polychlorinated biphenyls (PCBs) at these facilities. Measurements at one facility -- a small capacitor manufacturer -- indicated that PCB air concentrations would probably exceed the OSHA Permissible Exposure Level of 1 mg/m^3 (for chlorodiphenyl--42% CL) and measurements taken at all facilities suggest that air levels exceeding the NIOSH recommended exposure limit of 1 ug/m^3 . (This recommended limit applies to all commercial preparation of PCBs.) Average personal exposures to PCBs by industry visited were as follows: PCB production-- 50 ug/m^3 ; transformer manufacturer-- 30.5 ug/m^3 ; transformer repair-- 140 ug/m^3 ; electrical capacitor manufacturer (three facilities)-- 91 ug/m^3 (large capacitors), 143 ug/m^3 (large and small capacitors), 640 ug/m^3 (large and small capacitors). Measurements of non-PCB substances incident to the PCB exposure scenarios are also presented.

INTRODUCTION

Researchers for the National Institute for Occupational Safety and Health conducted industrial hygiene surveys at six commercial facilities in 1976-77 to document occupational exposure to polychlorinated biphenyls (PCBs). This industrial hygiene characterization study was prompted by the increased awareness, since the mid-1960's, that PCBs exhibit a variety of adverse human health effects, and are highly resistant to biodegradation, the latter resulting in long-term accumulation in the biosphere.¹

Growing public concern over environmental accumulation of PCBs, as well as several industrial accidents resulting in PCB contamination of human and animal food sources^{2,3} led to federal regulations concerning PCB use, manufacture, and disposal.⁴ The Federal regulation governing PCB use, manufacturing, and disposal (40 CFR Part 761) which was published May 31, 1979 was subsequently amended as described in the Federal Register, Volume 50: 29170-29201, July 17, 1985. This final rule amends portions of the existing rule--40 CFR Part 761--by placing additional restrictions and conditions on the use of PCB transformers (those containing 500 parts per million or greater PCBs).⁴ Because of this legislation, which includes a prohibition of PCB use after January 1, 1978 with but two exceptions, current potential occupational exposure to PCBs has been limited to servicing of PCB containing transformers, mining machinery, and hydraulic and heat transfer systems manufactured prior to the control legislation; and to fire, explosions and hazardous waste cleanups.

This report presents the results of measurements of worker exposure to airborne PCBs at six facilities: a producer of PCBs, a manufacturer of electrical transformers, a renovator of transformers, and three manufacturers of electrical capacitors. Results of measurements for non-PCB substances are also included in the report.

USES

PCBs are a class of chlorinated aromatic compounds that possess several physical and chemical properties which make them attractive for many industrial applications. For example, PCB properties such as thermal stability, inertness, and dielectric strength have been exploited commercially for use as non flammable insulating liquids in electric transformers and capacitors, as lubricating fluids for hydraulic systems, gas turbines and vacuum pumps, in fire retardants for heat transfer applications, plasticizers for adhesives, textiles, surface coatings and sealants, for microencapsulation of dyes for carbonless "carbon paper", and as extenders for pesticides and waxes. Production of PCBs in the U.S. began in 1929 and 85 million pounds were produced under the trade name Arochlor[®] in 1970.⁵ Since 1970 production has decreased considerably; in 1976, annual production was around 40 million pounds. By 1977, industrial use and manufacture of PCBs had ended in the United States. As alluded to previously, Section 6(e) of the Toxic Substances and Control Act (TSCA) generally prohibits the use of PCBs after January 1, 1978. The Environmental Protection Agency (EPA) was given the authority to allow particular uses of PCBs under specific conditions.⁴

CHEMISTRY/NOMENCLATURE

Biphenyl, the chemical foundation structure for PCBs, is shown in Figure 1. This structure, (C₁₂H₁₀), can be chlorinated by replacing any or all of its hydrogen atoms with chlorine.⁵

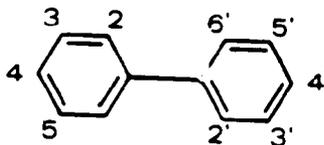


FIGURE 1: BIPHENYL MOLECULE AND RING NUMBERING SYSTEM

The specific chlorobiphenyl compounds formed by chlorination are designated by the position of the chlorine atoms with respect to the biphenyl numbering scheme. The lowest possible numbers are assigned, and the phenyl moiety having the fewest chlorine atoms is numbered as prime (see Figure 2)^{5,6}. There are 209 possible chlorobiphenyls.



FIGURE 2: EXAMPLES OF NOMENCLATURE SYSTEM OF CHLOROBIPHENYL COMPOUNDS

Commercial synthesis of chlorobiphenyl involves chlorination of biphenyl with anhydrous chlorine, utilizing iron filings or ferric chloride as a catalyst.⁵ The commercial products are isomeric mixtures commonly called PCBs. The chlorine content (weight percent) of the commercial mixtures has generally varied between 21 and 68% and is used to designate the grades of commercial products. Most of the PCBs used in the U.S. were manufactured in the U.S., Great Britain, and Japan and marketed under the trade names Arochlor^{5,7} and Kanechlor.⁸ The approximate chlorine content of PCB mixtures is as follows: Arochlors, 1221 (21 percent), 1016 (42 percent), 1242 (42 percent), 1254 (54 percent), and 1260 (60 percent); Kanechlors, 300 (43 percent), 400 (48 percent), 500 (53 percent), and 600 (60 percent).⁸

HEALTH EFFECTS

Current knowledge regarding human health effects from chronic low-level exposure to PCBs and their mechanisms of toxic action is very limited. Significant acute exposure to PCBs by inhalation, swallowing, or contact with skin or eyes is known to cause adverse health effects. The eyes, nose, and throat can become irritated, chloracne skin rashes followed by jaundice can develop, hyperpigmentation, gastrointestinal disturbances, elevated serum

enzyme and triglyceride levels, numbness of the extremities, and fatigue can occur. Also, liver injuries may occur which can result in dark urine, and cirrhosis^{9,10}. Since PCBs are absorbed thru the skin, adverse health effects could arise due to this exposure mechanism. Animal studies have shown that ingestion of PCBs causes production of liver tumors and adverse reproductive effects.¹¹

There are two relatively recent occupational exposure studies of the workforce discussed in this document reported in the literature: Brown and Jones (NIOSH), published a retrospective cohort mortality study pertaining to Facilities E and F;¹² Smith, et. al. (NIOSH) reported the results of an evaluation of serum PCB concentrations pertaining to Facility D.¹³ The metabolism of PCBs in man has not been studied extensively. However, clinical reports have shown that certain PCB isomers, which are believed to be difficult for humans to metabolize, became concentrated in tissues and were found in the hair, blood, and milk of persons who had ingested, or were occupationally exposed to PCBs. These reports suggested that human metabolism and excretion are similar to those of animals studied.¹⁴

In general PCBs are easily absorbed from the gastroenteric tract, the degree of which is dependent on their chemical composition. Vapors are readily absorbed by the lungs. Skin absorption may result in systemic toxicity and mild local effects, depending on the composition of the PCBs and the duration of contact.¹⁵

Animal toxicity studies have indicated that the major excretory route of PCBs is via the feces, and the position of the chlorines governs the rate of elimination, probably by affecting the rate of metabolism.¹⁵

ESTABLISHED EXPOSURE LIMITS

There are currently two PCBs for which Occupational Safety and Health Administration (OSHA) Permissible Exposure Levels (PELs) have been established: 1 mg/m³ for chlorodiphenyl (synonymous with chlorobiphenyl) with a 42% chlorine content, and 0.5 mg/m³ for chlorodiphenyl with a 54% chlorine content. These PELs are based on an 8-hour time weighted average (TWA) exposure.¹⁶ The American Conference of Governmental Industrial Hygienists (ACGIH) presently recommends these same levels as Threshold Limit Values (TLV).¹⁷ To reduce any risk of reproductive, tumorigenic, and other possible adverse health effects from exposure in the workplace, NIOSH recommended an exposure limit of 1 ug/m³. NIOSH limits are based on a TWA of up to 10 hours per day averaged over a 40 hour week. This limit is applicable to commercial preparations of chlorinated biphenyl compounds, including the aforementioned PCBs.¹⁴

SAMPLING AND ANALYTICAL METHODS

Personal and general area air samples were collected at each of the six facilities to evaluate worker exposure to airborne levels of PCBs. A glass tube containing a magnesium-silicate sorbent, Florosil[®], was used as the

sampling media. The sorbent tubes were divided into two sections (primary and back-up) by a glass-wool plug, and heat sealed at the ends. The primary section contained 100 mg of florosil and the back-up section 50 mg.

For personal sampling the Florosil tube was positioned in the breathing zone by fastening to the worker's collar/lapel. Air was drawn through the tube at a flow rate of 100 to 200 cc/minute using a Sipin Model SP1 pump attached to the workers belt and connected to the sample tube with plastic tubing. General area samples were collected using the same sampling train, but the sampling train was fixed in specific areas of the facilities. The sample tubes were subsequently analyzed for PCBs by NIOSH Method P&CAM 244.18 In brief, the samples were desorbed with cyclohexane and the eluent was analyzed by a gas chromatograph equipped with an electron capture detector. The reported analytical limit of quantitation (point at which the range of possible instrument response values are within statistically acceptable limits) for PCBs was 0.1 ug per sample.

DESCRIPTION OF FACILITIES AND SURVEYS

A. General Information

1. Facility Identification

Each of the six facilities evaluated was engaged in PCB using operations: one facility was engaged in the production of PCBs; one facility manufactured PCB containing transformers; one facility refurbished PCB containing transformers; and three facilities produced large and small PCB filled capacitors. The plants are coded as follows:

- Facility A - Polychlorinated Biphenyl Production
- Facility B - Transformer Manufacturing
- Facility C - Transformer Repair
- Facility D - Manufacture of Large Capacitors
- Facility E - Manufacture of Large and Small Capacitors
- Facility F - Manufacture of Large and Small Capacitors

2. Description of Medical, Industrial Hygiene and Safety Programs

For purposes of report brevity, an overview of available information concerning the medical, industrial hygiene, and safety programs for the six facilities surveyed is presented.

All facilities required pre-employment physicals; several facilities also offered annual physicals. All facilities had on-site medical personnel available during the workshift. Nurses were employed at all facilities; physicians were employed or on call at three of the facilities. One facility had an arrangement with a local hospital in case of an emergency.

Details regarding the programmatic aspects of industrial hygiene and safety programs were not made available during the surveys. All facilities required the use of safety glasses, safety shoes, impervious (to PCBs) clothing including gloves, and respiratory protective equipment where appropriate. Several facilities reported formal arrangements for disposal of PCB contaminated clothing. One facility carried out bi-weekly analysis of plant wastewater for PCB content.

B. Data Presentation

Results of personal and area measurements made for airborne PCBs in the six facilities are presented in Appendices A-F. In addition, these appendices also contain results of measurements of exposure (personal and area) to agents resulting from operations incidental to the PCB process, such as painting, welding, and soldering.

A general summary of PCB air sampling results for the six facilities is shown in Table 1, page 13.

C. Exposure Reference to Standards

All PCB/non-PCB concentration data reported in Appendices A to F and Table 1 refers to that measured during the sample period; 8-TWAs were not calculated. Subjective assessments, taking into account the exposure scenario and the job activity were made at the time of measurement concerning the relationship between concentration and PEL/TLV. Based on these assessments, it was believed that for the most part, concentration data (with the exception of the short-term samples) were representative of the 8-TWA--thus allowing direct comparison with the appropriate PEL/TLV and NIOSH recommended standards. Therefore, the reader should consider all reported concentration data (with the exception noted previously) as being representative of the 8-TWA.

D. Facility Discussion

1. Facility A

a. Description

Most of the polychlorinated biphenyls that have been manufactured in the United States were produced at this facility. Production began at this plant in 1929 and reached a peak of about 85 million pounds in 1970. The PCBs produced at this facility were either of 42 or 54 percent chlorine content. A number of different mixtures of these two PCBs were produced in the past under the trade name Arochlor^R. During this survey only Arochlor^R 1016 (42% Cl) was being manufactured. However, Arochlor^R 1242 and 1254 (42 and 54% Cl, respectively) had been produced just prior to the survey at this location. Presently (1985), no Arochlors are manufactured at this or any plant in the United States.

The entire workforce at the facility numbered approximately 1300, of which about 835 were hourly workers involved in some phase of PCB production. Production of PCBs was carried out using a combination of a continuous and a batch process involving about 25 workers over three shifts. Biphenyl was brought into the plant by tank car and pumped into storage tanks. Chlorine was piped in from another part of the plant. Both chlorine and biphenyl were fed into a chlorinator where, in the presence of an iron chloride catalyst, they reacted to produce PCBs. After chlorination the product was washed to remove hydrogen chloride, distilled into various boiling range fractions, and then filtered to remove iron catalyst and other solid impurities before being blended to customer specification.

b. Measurement Results

PCB

During PCB sample collection, Arochlor 1016 (42% Cl) was being produced. Eleven personal PCB samples for PCB process operators were collected. PCB exposure levels ranged from 20 ug/m³ to 86 ug/m³, with an average exposure of 50 ug/m³. The OSHA PEL and ACGIH TLV for this PCB was 1000 ug/m³. Nine area air samples collected at this plant showed PCB levels ranging from 0.3 ug/m³ to 55 ug/m³ with an average concentration of 34 ug/m³. The company had collected a few air samples (the type was not reported) in the past and reportedly showed PCB concentration ranging from 60 ug/m³ to 338 ug/m³. See Appendix A for further air sampling data.

Non-PCB

Two air samples were also collected for analysis of iron chloride and chlorine, and a bulk sample for diatomaceous earth was obtained. One of the two three-minute area air samples for iron/iron chloride indicated a non-detectable level while the other had a concentration of 8.1 mg/m³ of iron and 18.4 mg/m³ of iron chloride. The 8-hour time weighted average (TWA) exposure for this sample would be well below the ACGIH TLV of 1 mg/m³ for iron salts since employees were only exposed for three minutes per shift. The detector tube area sample collected for chlorine did not detect the presence of chlorine. The diatomaceous earth bulk sample analysis indicated a free silica content of 9.8%. This material was only handled about once a week. See Appendix A for further non-PCB air sampling data.

2. Facility B

a. Description

Transformers of many sizes and types were manufactured at this facility starting in 1923. Those to be filled with PCB were manufactured starting in 1938 and represented less than 1% of the total transformer production. Production levels were based on "per order" requirements, and the PCB filling operation was only utilized when specific orders for transformers were received. Consequently, about 20 employees were involved intermittently in producing transformers which were filled with PCB, usually Arochlor 1242 (42% chlorine). The total work population was approximately 3100 with about 2300 being hourly workers.

The manufacturing process began by winding coils of metal (e.g., copper, aluminum) within a magnetic core, placing the cores in a metal case, and sealing the case by welding the top. The assembled transformer was then prepared for performance testing by filling with mineral oil. After passing inspection, the mineral oil was drained and Arochlor 1242 was pumped into the transformer. A cover was bolted on, and the transformer was prepared for shipment to the customer.

b. Measurement Results

PCB

Nineteen personal air samples for airborne PCB exposure were collected. The PCB levels ranged from 9.5 ug/m³ to 69.7 ug/m³ with an average concentration of 30.5 ug/m³. Five area samples (General Process) collected for airborne PCBs ranged from 26.1 ug/m³ to 100.6 ug/m³ with an average concentration of 66.3 ug/m³. The PEL and TLV for Arochlor 1242 used here was 1 mg/m³

(1000 ug/m³) based on a chlorine content of 42%. See Appendix B for further PCB air sampling results.

Non-PCB

Two personal air samples for organic solvents utilized in the manufacturing process were also collected. Solvents monitored included methyl ethyl ketone, toluene, benzene, xylene, butyl acetate, and ethyl acetate. Benzene, butyl acetate, ethyl acetate and methyl ethyl ketone were not detected in either sample. One sample had a xylene concentration of 0.17 ppm (OSHA PEL: 100 ppm) and a toluene level 77.7 ppm (OSHA PEL: 200 ppm). See Appendix B for further non-PCB air sampling results.

3. Facility C

a. Description

This facility began operation in 1947 employing approximately 1450 employees, of which about 650 were hourly workers. Transformers filled with a mixture of Arochlor 1260 (60% chlorine) and trichlorobenzene were refurbished at this facility. Sixteen workers repaired, rebuilt, and thoroughly overhauled transformers as needed. This involved removing the transformer from its case and transporting it to a repair shop, where the PCB fluid was drained and all parts of the transformer were cleaned with shop cloths. At this facility it usually took a month or more, depending on the extent of repairs necessary, to completely overhaul a transformer. It was estimated that only two or three transformers per year were serviced at this facility.

Transformers that only required switch gear (protector and primary switch) repair were serviced without removing them from their vaults. The PCB contained in the primary switch was pumped out into a drum, sent through a filtration purification process, and returned to the primary switch. The removal, filtration, and purification, along with the wiping of the switch with shop cloths, constituted the operations with greatest potential for worker exposure to PCB. Since Arochlor 1260 was usually processed and returned for use in the rebuilt transformer, the problem of PCB disposal was minimized. Contaminated shop cloths and other PCB-contaminated materials were drummed and disposed of at an authorized land fill.

b. Measurement Results

PCB

Twenty-three personal airborne PCB samples were collected over two separate visits. Worker exposures ranged from 51 ug/m³ to 311 ug/m³ with an average of 140 ug/m³. Sixteen area samples collected had PCB concentrations ranging from 8 ug/m³ to 535 ug/m³ with an average level of 202 ug/m³. Air samples have been collected in the past by the company. These ranged in concentration from 99 ug/m³ to 355 ug/m³ for PCB. There is, presently, no PEL/TLV assigned to PCBs with a 60% chlorine content. See Appendix C for further PCB air sampling data.

Non-PCB

Ten personal air samples were also collected for trichlorobenzene. Trichlorobenzene was only detected on two samples at levels of 0.1 and 0.2 ppm. See Appendix C for further non-PCB air sampling data.

4. Facility D

a. Description

The plant began operation in 1958. The main products of the plant were shunt capacitors, series capacitors, lightning arresters, reclosers and breakers, switches, potential devices and line traps. Production of PCB-filled capacitors also started in 1958. The PCB used was Aroclor 1016 at the time of the survey, but from 1958 to 1971 Aroclor 1242 was used. There were approximately 745 employees at the facility of which approximately 445 were hourly employees.

PCB-filled capacitors were being worked on by twenty people at the time of this survey. These capacitors were made in a dust free room by winding together bales of foil, paper and plastic film. The size of the bale depended upon the size of the capacitor being made. A predetermined number of bales were then placed into a metal capacitor box and the top of the capacitor along with connector bushings were put in place. The capacitors were grouped, banded together, and conveyed into a chamber for desiccation by heating and evacuation. The chamber was then flooded with PCB until the capacitors were filled. Residual PCB was pumped out, filtered, and recycled. The capacitors were removed from the chamber via the conveyor system. Absorbent material was placed under the conveyor system to absorb any excess PCB which might spill on the floor. The capacitors were subsequently sealed by soldering, then degreased, and finally spray painted. The PCB contaminated absorbent material along with other PCB contaminated materials, such as clothing, was drummed and shipped to a licensed disposal firm.

b. Measurement Results

PCB

Thirty-seven personal air samples for PCB were collected during the survey. Personal exposures ranged from 8 ug/m³ to 264 ug/m³ with an average level of 91 ug/m³. (PEL/TLV for Arochlor 1242 is 1000 ug/m³). Sixteen area samples were also collected and PCB concentrations ranged from 5 ug/m³ to 146 ug/m³ and averaged 55 ug/m³. See Appendix D for further PCB air sampling data.

Non-PCB

Samples were also collected for iron and aluminum during welding; toluene, xylene, methyl ethyl ketone and trichloroethylene during painting; and for trichloroethylene during cleaning/degreasing. The welders range of exposure to aluminum and iron were from non-detectable (N.D.) to 0.82 mg/m³ and N.D. to 5.00 mg/m³ respectively. The painters exposure to toluene and xylene ranged from N.D. to 4.0 ppm and N.D. to 9.1 ppm respectively; methyl ethyl ketone was N.D.; trichloroethylene exposures ranged from 61.8 to 289.6 ppm (PEL:100 ppm; TLV 50 ppm). See Appendix D for further non-PCB air sampling data.

5. Facility E

a. Description

Facility E manufacturing operations were located in two buildings, one for large capacitor manufacture, and another about a mile away for small capacitors (containing less than 3 pounds of dielectric fluid). Large capacitor production began in 1951. These capacitors were used primarily in electric power plants or distribution facilities. Small capacitor production began in 1946. These capacitors were generally used in lighting, air conditioning, and other small electrical equipment. At the time of this survey Arochlor 1016 (42% Cl) was the principal PCB used.

The large capacitors were manufactured basically the same as those described for Facility D. Bales of paper, film, and foil were rolled together automatically. Prior to assembly the rolls were covered with cardboard, bound together, and tested. After testing the rolls were inserted in a metal box, the box was filled with PCB, and the fill holes were soldered to seal the capacitor. The capacitor assembly was heat soaked for several hours to aid in the penetration of the dielectric fluid, and then leak tested, spray painted, and packed for shipment.

The small capacitors were manufactured in a similar manner but were sealed by crimping instead of soldering.

The workforce was predominately white and approximately 50% female. The company estimated that 137 of its 1,030 workers were exposed to PCB.

b. Measurement Results

PCB

At the large capacitor plant, 12 personal and 8 area samples were collected. The personal employee exposures ranged from 50 ug/m³ to 396 ug/m³, with an average exposure level of 143 ug/m³. The area sample concentrations ranged from 3 ug/m³ to 52 ug/m³, with an average level of 27 ug/m³ (the PEL/TLV for Arochlor 1016 is 1000 ug/m³).

There were 19 personal and 13 area samples collected at the small capacitor plant. Employee exposures ranged from 116 ug/m³ to 396 ug/m³, with an average exposure concentration of 209 ug/m³. The area samples ranged from 3 ug/m³ to 564 ug/m³, with an average concentration of 132 ug/m³. See Appendix E for tabulation of sampling data results.

Non-PCB

Samples were also collected for trichloroethylene in degreasing areas and personal monitoring was conducted for toluene and methyl isobutyl ketone (MIBK) during painting, packing, and labeling operations. Lead, zinc, and tin area samples were taken during soldering, and iron and aluminum area samples were taken during welding. The trichloroethylene exposures in the degreasing area ranged from N.D. to 5.9 ppm. Toluene and MIBK personal exposure levels in the painting operation ranged from N.D. to 5.7 ppm and N.D. to 5.0 ppm respectively, and both compounds were N.D. during the labeling/packing operation. Area exposure levels to lead and zinc during soldering ranged from N.D. to 12 ug/m³ and N.D. to 24 ug/m³ respectively, while tin was N.D. The personal exposures to iron and aluminum during welding ranged from 47 to 123 ug/m³ and N.D. to 233 ug/m³ respectively. See Appendix E for further non-PCB sampling results.

6. Facility F

a. Description

Facility F manufactured capacitors at the same site since 1938. It had used mostly PCB as the dielectric since start up. The

manufacturing area consisted of approximately 420,000 square feet, and on the day of the survey the company had approximately 380 employees with 300 in production, of which two-thirds were female. About half of the production employees had direct contact with PCB.

This facility produced mainly small capacitors, which contained the PCB Arochlor 1016 (42% Cl). The few large capacitors manufactured at this plant contained non-FCB dielectrics such as mineral oils and dioctyl phthalates.

The small capacitors (containing less than three pounds of dielectric) were produced as follows: first a foil and paper bale were (manually) wound, then electrical connectors were inserted into the wound bale automatically. The connectors were then welded to terminals at the top of the capacitor. Next the assembled bale was placed into the capacitor can which was transferred to a chamber and desiccated at 150°C under vacuum. PCB was pumped into the heated chamber to fill the capacitors which were then stored under heat to remove excess PCB, and then sealed by soldering. Finally, the capacitors went through a trichloroethylene degreaser to remove any excess oils, and were again heated to test for leaks.

b. Measurement Results

PCB

Twenty-nine personal and 26 general area samples for PCB were collected at this plant. Personal exposures ranged from 140 ug/m³ to 1,260 ug/m³ and averaged 640 ug/m³. (The PEL/TLV for this PCB is 1000 ug/m³). The area sample concentrations ranged from 30 ug/m³ to 1,010 ug/m³ with an average level of 237 ug/m³. See Appendix F for tabulation of the air sampling data.

Non-PCB

Samples were also collected for trichloroethylene in the degreaser area, and in the soldering area for lead, tin, and zinc. The trichloroethylene exposure levels in the degreaser area ranged from 53.4 to 77.5 ppm. The soldering area exposures to lead and zinc ranged from N.D. to 41.2 ug/m³ and N.D. to 94.1 ug/m³ respectively. Tin levels were N.D. See Appendix F for further non-PCB sampling results.

SUMMARY DISCUSSION OF RESULTS OF MONITORING FOR AIRBORNE PCBs

Table 1 presents the ranges and averages for personal and area samples collected at the six facilities monitored.

Table 1 shows that the OSHA PEL for airborne PCB was exceeded at Facility F (which used Arochlor 1016-42% chlorine; TLV/PEL-1.0 mg/m³). Reference to

TABLE 1 - SUMMARY OF PCB AIR SAMPLING RESULTS

Type of Facility	Facility Code	PERSONAL			AREA		
		# of Samples	Range of Exposures ug/m ³	Average Exposure ug/m ³	# of Samples	Range of Conc. ug/m ³	Average Exposure ug/m ³
PCB Production (Arochlor 1016-42% chlorine)	A	11	20-86	50	9	0.3- 55	34
Transformer Mfg. (Arochlor 1242-42% chlorine)	B	19	9.5-69.7	30.5	5	26.1-100.6	66.3
Transformer Repair (Arochlor 1260-60% chlorine)	C	23	51-311	140	16	8-552	202
Manufacture of Large Capacitors (Arochlor 1242-42% chlorine)	D	37	8-264	91	16	5-146	55
Manufacture of Large & Small Capacitors ^{1,2} (Arochlor 1016-42% chlorine)	E	31	50-396	143	21	3-564	132
Manufacture of Large & Small Capacitors (Arochlor 1016-42% chlorine)	F	29	140-1,260	640	26	30-1,010	237

NOTES

- 1 Small capacitors contain less than 3 pounds of dielectric fluid
- 2 Summary data represents combined results from large and small capacitor production.

Appendix F shows that seven of the 29 personal samples exceeded the TLV/PEL, as well as one of the 26 area samples. The excessive airborne levels of PCB at this facility were most likely generated by the soldering operations. The high temperature used for soldering probably increased the volatilization of the PCB residue on the soldering surface.

The personal PCB exposure levels for the other five facilities were below the OSHA PEL, however an area concentration (1010 ug/m³) at Facility C (which used Arochlor 1016--containing 41% chlorine) exceeded the PEL of 1 mg/m³ assigned to PCBs containing 42% chlorine.

All personal exposures and all but one of the area samples significantly exceeded the NIOSH recommended exposure standard of 1 ug/m³ of PCB.

CONCLUSIONS

1. Airborne concentrations of PCBs, in general, with the exception of one plant manufacturing small capacitors, were below the appropriate OSHA PELs and ACGIH TLVs (as predicated on the respective chlorine contents).
2. Airborne PCB levels measured at all facilities exceeded the NIOSH recommended exposure limit.
3. Average PCB personal exposures by industry visited are as follows: 50 ug/m³ in PCB production (facility A); 30.5 ug/m³ in the transformer manufacturing industry (facility B); 140 ug/m³ for transformer repair operations (facility C); and a range of 91 to 640 ug/m³ in the capacitor manufacturing industry (facilities D,E,F). The facilities with the highest average exposures (C,D,E,F) tended to have a greater number of PCB handling operations.

RECOMMENDATIONS

Although EPA has generally banned the use of PCBs (after January 1, 1978), EPA may still allow PCBs to be used in a "totally enclosed manner." EPA may also authorize use of PCBs in a manner other than a totally enclosed manner if the Agency finds that such use "will not present an unreasonable risk of injury to health or the environment."⁴ Accordingly, it seems reasonably clear that, in all probability, many devices (transformers, capacitors, electromagnets) containing this material will be in service for years. Employee exposure may occur during repair or in accidents involving these types of electrical equipment.

Since skin absorption (by direct contact or by contact with contaminated surfaces, clothing, and equipment) constitutes a major PCB exposure concentration, the following recommendations are offered in the interest of reducing overall potential skin exposure to PCBs.

1. All workers assigned to handle PCBs should be supplied each day with clean

work clothes from the skin out. Showering at the end of the shift should be mandatory. The clothing which the worker discards each day should be laundered or dry cleaned in-house or discarded.

2. When actually handling PCBs, workers should wear appropriate impervious clothing in addition to the work clothing supplied each day. Recommendations on the use of impervious clothing for protection against PCBs have been documented by NIOSH.¹⁹
3. Used impervious clothing to be discarded should be drummed and sent to an authorized disposal site.
4. A lunch room separate from the work area should be supplied, and eating in work areas should be prohibited.

REFERENCES

1. Risebrough, R.W., Reiche, P., Peakall, D.B., Herman, S.G., Kirven, M.N.: Polychlorinated Biphenyls in the Global Ecosystem. *Nature* 1968: 220:1098-1102.
2. Higuchi, K., Ed.: *PCB Poisoning & Pollution*, Academic Press, New York, (1976).
3. Spauling, J.E., Wessel, J.R., Occurrence & Sources of PCBs in Food. In: Interdepartment Task Force on PCBs. *Polychlorinated Biphenyls and the Environment*, Washington, D.C. (1972).
4. Environmental Protection Agency. *Polychlorinated Biphenyls (PCBs): Manufacturing, Processing, Distribution in Commerce and Use Prohibitions*. Fed. Reg. 1979 44: 31542-31568 (40CFR Part 761).
5. Hutzinger, O., Safe, S.H., Zitko, V.: *The Chemistry of PCBs*. P.7 CRC Press, Inc., Boca Rotan, Florida (1979).
6. Miere JP, Hicks O, Kaley RG, Saeger VW: Characterization of Polychlorinated Biphenyls, in *Proceedings of the National Conference on Polychlorinated Biphenyls*, November 19-21, 1975, Chicago, EPA-560/6-75-004. U.S. Environmental Protection Agency, Office of Toxic Substances, 1976, pp 84-93.
7. Kuratsune M (ed): *Environmental Health Criteria for Polychlorinated Bi- and Terphenyls--WHO Environmental Health Criteria Programme (Japanese document to World Health Organization)*. Fukuoka, Japan, Public Health Association, Japan Environmental Agency, 1974, 159 pp.
8. Uğawa M, Nakamura A, Kashimoto T: *Studies on a Calculation Method for Polychlorinated Biphenyl Isomers (PCBs)*. In: *New Methods in Environmental Chemistry and Toxicology--A Collection of Papers Presented at the Research Conference on New Methodology in Ecological Chemistry*, Susono, Japan, November 23, 24, 25, 1973. Tokyo, International Academic Printing Co Ltd, 1973, pp 253-67.
9. Schwartz L: *Dermatitis from Synthetic Resins and Waxes*. *Am J Public Health* 26:586-92, (1936).
10. Drinker, CK, Warren MF, Bennett GA: *The Problem of Possible Systemic Effects from Certain Chlorinated Hydrocarbons*. *J Ind. Hyg. Toxicol.* 19:283-99, (1937).
11. NIOSH: *Criteria for a Recommended Standard--Occupational Exposure to Polychlorinated Biphenyls (PCBs) DHEW (NIOSH) Publ. #77-225, p. 66. (September 1977)*.

12. Brown, D.P., Jones, M.: Mortality and Industrial Hygiene Study of Workers Exposed to Polychlorinated Biphenyls, Archives of Environmental Health 36, No.3: 120-129.
13. Smith, A.B., et. al.: Metabolic and Health Consequences of Occupational Exposure to Polychlorinated Biphenyls. British Journal of Industrial Medicine, 1982; 39: 361-369.
14. NIOSH: Criteria for a Recommended Standard-Occupational Exposure to Polychlorinated Biphenyls (PCBs) DHEW (NIOSH) Publ. #77-225, p. 106 (September 1977).
15. Patty's Industrial Hygiene and Toxicology - Third Edition, Volume IIB, Toxicology, 3645-3669, 1981.
16. Occupational Safety and Health Administration. General Industry OSHA Safety and Health Standards (29 CFR 1910.1000, Subpart Z), OSHA Publication No. 2206, revised, Washington, D.C. p. 600 (March 1983).
17. TLVs Threshold Limit Values and Biological Exposure Indices for 1985-86, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio (1985).
18. NIOSH Manual of Analytical Methods - Vol. I - 2nd Edition, DHEW (NIOSH) Publication No. 77-157A - p. 244-1.
19. NIOSH Technical Report: Permeation of Protective Garment Material by Liquid Halogenated Ethanes and Polychlorinated Biphenyls, DHHS (NIOSH) Publ. No. 81-110.

APPENDICES
AIR SAMPLING RESULTS

APPENDIX A

AIR SAMPLING RESULTS: FACILITY A

SURVEY DATE: July 21-22, 1976

FACILITY A

POLYCHLORINATED BIPHENYLS PRODUCTION
SURVEY DATES: JULY 21-22, 1976

PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1016
001	Premium Operator	7/21/76	436	91.0	47
002	Premium Operator	7/22/76	451	97.8	20
003	Second Operator	7/21/76	432	80.0	46
004	Second Operator	7/22/76	448	95.3	43
005	Column Operator	7/22/76	446	85.7	51
006	Still Operator	7/21/76	432	94.6	40
007	Still Operator	7/22/76	444	67.6	86
008	Standard Operator	7/22/76	445	96.1	61
009	Standard Operator	7/21/76	430	97.6	61
010	Distrib. Oper.	7/21/76	413	88.3	54
011	Distrib. Oper.	7/22/76	419	91.3	36

AREA SAMPLES

001	Drumming	7/21/76	418	89.1	45
002	Drumming	7/22/76	418	87.6	51
003	Temperature Test.	7/21/76	417	201.6	25
004	Temperature Test.	7/22/76	455	105.4	52
005	Chlorinator	7/21/76	419	89.0	55
006	Chlorinator	7/22/76	459	70.3	36
007	Chlorinator (top level)	7/22/76	453	97.1	0.3
008	Incinerator Burner	7/21/76	409	81.6	16
009	Temperature & Gravity Test	7/21/76	417	201.6	25

FACILITY A

NON-PCB AIR SAMPLING RESULTS

GENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION	P&CAM NUMBER
Iron	1	7/21/76	Reactor Vessel	Area	3	5.1	ND ¹	173
Iron Chloride	1	7/21/76	Reactor Vessel	Area	3	5.1	ND ¹	173
Iron	2	7/22/76	Reactor Vessel	Area	3	5.1	8.1 mg/m ³	173
Iron Chloride	2	7/22/76	Reactor Vessel	Area	3	5.1	18.4 mg/m ³	173
Free Silica	3	7/22/76	Reactor Vessel	bulk	NA ²	NA	9.8%	106
Chlorine	4	7/22-23/76	PCB Production	Area	1	0.1	ND	*

N.D. = Not Detected

N.A. = Not Available

Detector Tube Sample

APPENDIX B

AIR SAMPLING RESULTS: FACILITY B

SURVEY DATES: OCTOBER 27, 1976; JANUARY 5-6, 1976

FACILITY B

TRANSFORMER MANUFACTURE
 SURVEY DATES: OCTOBER 27, 1976; JANUARY 5-6, 1977

PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1242
001	Fit Tester	1/6/77	319	53.4	26.8
002	Fit Tester	1/5/77	418	81.4	21.0
003	Fit Tester	1/5/77	419	40.5	25.4
004	Group Leader	1/5/77	404	86.6	31.9
005	Group Leader	1/6/77	300	60.0	50.0
006	Mounter	1/5/77	425	83.9	26.7
007	Mounter	1/6/77	303	61.2	22.1
008	Painter	1/5/77	406	81.8	18.9
009	Painter	1/6/77	246	59.5	24.0
010	Shipper	1/5/77	408	83.0	26.6
010	Shipper	1/6/77	306	57.6	48.6
012	Packer	1/5/77	407	79.4	20.7
013	Packer	1/5/77	410	81.5	11.8
014	Packer	1/5/77	413	73.3	13.1
015	Packer	1/6/77	304	56.9	14.9
016	Packer	1/6/77	305	58.8	16.3
017	Dismantler	1/6/77	299	33.0	69.7
018	Craneman	1/5/77	415	91.8	9.5
019	Craneman	1/5/77	409	82.4	13.1

AREA SAMPLES

001	General Process	10/27/76	181	35.4	61.4
002	General Process	10/27/76	186	37.2	100.6
003	General Process	10/27/76	182	36.4	26.1
004	General Process	10/27/76	185	33.2	82.2
005	General Process	10/27/76	180	38.2	61.3

Filling Chamber

001	Left Side	1/5/77	385	72.8	56.7
002	Left Side	1/6/77	282	61.4	47.2
003	Front	1/5/77	381	76.7	46.7
004	Front	1/6/77	282	56.6	39.8
005	Right Side	1/5/77	383	59.3	30.9
006	Right Side	1/6/77	283	55.2	28.4

FACILITY B

NON-PCB AIR SAMPLING RESULTS

AGENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION (PPM)	P&CAM NUMBER
Methyl Ethyl Ketone (MEK)	1	1/6/77	Painter/Transform Mfg. Process	Personal	248	67.6	N.D.*	127
Toluene	1	1/6/77	Painter/Transform Mfg. Process	Personal	248	67.6	0.6	127
Benzene	1	1/6/77	Painter/Transform Mfg. Process	Personal	248	67.6	N.D.*	127
Xylene	1	1/6/77	Painter/Transform Mfg. Process	Personal	248	67.6	0.17	127
Butyl Acetate	1	1/6/77	Painter/Transform Mfg. Process	Personal	248	67.6	N.D.*	127
Methyl Acetate	1	1/6/77	Painter/Transform Mfg. Process	Personal	248	67.6	N.D.*	127
MEK	2	1/6/77	Shipping Fitter	Personal	305	68.7	N.D.*	127
Toluene	2	1/6/77	Shipping Fitter	Personal	305	68.7	77.7	127
Benzene	2	1/6/77	Shipping Fitter	Personal	305	68.7	N.D.*	127
Xylene	2	1/6/77	Shipping Fitter	Personal	305	68.7	0.01	127
Butyl Acetate	2	1/6/77	Shipping Fitter	Personal	305	68.7	N.D.*	127
Methyl Acetate	2	1/6/77	Shipping Fitter	Personal	305	68.7	N.D.*	127

*N.D. = Not Detected (limit of detection 0.01 mg/sample).

APPENDIX C

AIR SAMPLING RESULT: FACILITY C

SURVEY DATES: NOVEMBER 17, 1976; AUGUST 2-4, 1977

FACILITY C

TRANSFORMER REPAIR OPERATION
SURVEY DATES: NOVEMBER 17, 1976; AUGUST 2-4, 1977

PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1260
001	Electrical Mechanic	8/2/77	357	71.8	279
002	Electrical Mechanic	8/3/77	355	69.2	275
003	Electrical Mechanic	8/4/77	336	64.7	232
004	Electrical Mechanic	8/3/77	349	59.1	68
005	Electrical Mechanic	8/4/77	347	76.3	66
006	Electrical Mechanic	8/2/77	352	80.3	311
007	Electrical Mechanic	8/3/77	351	61.7	243
008	Electrical Mechanic	8/2/77	354	70.1	185
009	Electrical Mechanic	8/4/77	376	80.6	99
010	Electrical Mechanic	8/4/77	336	63.6	63
011	Electrical Mechanic	8/3/77	362	72.6	234
012	Electrical Mechanic	8/3/77	358	87.8	91
013	Electrician	11/17/76	90	18	55.6
014	Utility Helper	11/17/76	98	19.6	51.0
015	Apprentice Elect.	11/17/76	96	19.2	52.1
016	Utility Helper	11/17/76	95	19	52.6
017	Utility Helper	11/17/76	79	15.8	63.3
018	Apprentice Elect.	11/17/76	89	17.8	56.2
019	Apprentice Elect.	11/17/76	92	18.4	54.3
020	Electrician	11/17/76	75	15.0	66.7
021	Apprentice Elect.	11/17/76	95	19.0	526
022	Apprentice Elect.	11/17/76	100	20.0	50.0
023	Apprentice Elect.	11/17/76	95	19.0	52.6

FACILITY C (CONT.)

TRANSFORMER REPAIR OPERATION
 SURVEY DATES: NOVEMBER 17, 1976; AUGUST 2-4, 1977

AREA SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1260
<u>Primary Switch</u>					
001	Top	8/3/77	331	54.5	535
002	Top	8/2/77	313	63.4	552
003	Front	8/4/77	363	64.5	411
004	Bottom	8/4/77	355	62.9	429
<u>Top of Transformer</u>					
005	Primary Switch	8/2/77	355	604	8
006	Bottom	8/3/77	330	361	22
007	Top	8/2/77	313	532	13
008	Top	8/4/77	363	617	11
009	Front	8/3/77	333	566	14
010	Side	8/2/77	304	516	8
<u>Top of Transformer</u>					
<u>Primary Switch</u>					
011	Bottom	8/4/77	355	355	107
012	Top	8/2/77	331	331	184
013	Top	8/2/77	331	331	130
014	Front	8/4/77	363	363	317
015	Side	8/3/77	334	334	353
016	Top of Transformer	8/2/77	304	304	135

FACILITY C

NON-PCB AIR SAMPLING RESULTS

AGENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION (FPM)	P&CAM NUMBER
Trichlorobenzene	1	11/17/76	Apprent. Elec.	Personal	96	8.7	N.D.*	S-133
Trichlorobenzene	2	11/17/76	Apprent. Elec.	Personal	94	8.4	N.D.	S-133
Trichlorobenzene	3	11/17/76	Apprent. Elec.	Personal	94	11.8	N.D.	S-133
Trichlorobenzene	4	11/17/76	Apprent. Elec.	Personal	96	12.0	N.D.	S-133
Trichlorobenzene	5	11/17/76	Apprent. Elec.	Personal	89	10.9	N.D.	S-133
Trichlorobenzene	6	11/17/76	Apprent. Elec.	Personal	93	11.6	N.D.	S-133
Trichlorobenzene	7	11/17/76	Electrician	Personal	83	11.5	0.1	S-133
Trichlorobenzene	8	11/17/76	Electrician	Personal	90	13.3	N.D.	S-133
Trichlorobenzene	9	11/17/76	Utility Helper	Personal	98	11.6	0.1	S-133
Trichlorobenzene	10	11/17/76	Utility Helper	Personal	94	11.0	N.D.	S-133

*N.D. = Not Detected (limit of detection 1.0 ug/sample).

APPENDIX D

AIR SAMPLING RESULTS: FACILITY D

SURVEY DATES: APRIL 19-21, 1977

FACILITY D

ELECTRIC CAPACITOR MANUFACTURER
SURVEY DATES: APRIL 19-21, 1977
PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE VOLUME (LITERS)	SAMPLE TIME (MIN.)	CONCENTRATION (ug/m ³) Arochlor 1242
001	Process Operator	4/21/77	87.9	451	100
002	Process Operator	4/20/77	89.0	462	34
003	Boilerhouse Oper.	4/19/77	83.1	388	8
004	Heaterman	4/20/77	78.7	393	42
005	Heaterman	4/19/77	80.8	418	74
006	Heaterman	4/21/77	76.3	437	61
007	Power Test Operator	4/20/77	90.5	444	48
008	Power Test Operator	4/21/77	82.9	446	82
009	Power Test Operator	4/20/77	69.2	346	51
010	Power Test Operator	4/21/77	86.2	431	98
011	Final Assembly	4/21/77	91.5	449	46
012	Final Assembly	4/19/77	90.9	436	19
013	Final Assembly	4/20/77	86.8	438	34
014	Solder	4/20/77	83.0	387	132
015	Solder	4/19/77	84.1	445	69
016	Solder	4/19/77	90.7	458	125
017	Hanger	4/21/77	84.9	473	216
018	Solder/Hanger	4/21/77	93.4	478	170
019	Solder	4/19/77	88.9	452	122
020	Solder	4/21/77	94.8	477	222
021	Misc. Assembly	4/20/77	86.3	461	171
022	Misc. Assembly	4/19/77	92.1	440	88
023	Misc. Assembly	4/21/77	85.7	474	136
024	Misc. Assembly	4/19/77	92.9	443	61
025	Leak Test Operator	4/20/77	81.0	458	50
026	Leak Test Operator	4/19/77	90.4	467	28
027	Painter	4/20/77	85.5	453	72
028	Painter	4/19/77	100.5	460	18
029	Painter	4/19/77	53.7	269	27
030	Painter	4/21/77	89.0	460	82
031	Capacitor Repairman	4/20/77	89.0	478	247
032	Capacitor Repairman	4/21/77	96.2	462	264
033	Capacitor Repairman	4/21/77	68.8	460	142
034	Capacitor Repairman	4/20/77	86.1	462	133
035	Capacitor Repairman	4/19/77	92.4	460	80
036	Capacitor Repairman	4/19/77	64.2	321	69
037	Capacitor Repairman	4/20/77	84.8	462	168

FACILITY D (CONT.)

ELECTRIC CAPACITOR MANUFACTURER
 SURVEY DATES: APRIL 19-21, 1977
 AERA SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE VOLUME (LITERS)	SAMPLE TIME (MIN.)	CONCENTRATION (ug/m ³) Arochlor 1242
001	Winding F-18	4/21/77	77.8	362	47
002	Office Area	4/22/77	84.6	454	26
003	A-20	4/21/77	74.6	338	27
004	A-35	4/21/77	76.6	353	5
005	G-44	4/21/77	72.0	356	26
006	F-41	4/21/77	71.4	360	52
007	E-50	4/21/77	75.6	368	71
008	D-40 (Arresters)	4/22/77	85.6	435	78
009	D-20	4/22/77	79.3	408	20
010	F-40	4/22/77	77.9	431	146
011	B-44	4/22/77	79.0	436	65
012	D-11	4/22/77	82.9	453	60
013	B-11	4/22/77	75.3	450	50
014	A-40	4/22/77	92.1	439	53
015	B-30	4/22/77	88.2	430	77
016	B-20	4/22/77	83.9	448	78

FACILITY D

NON-PCB AIR SAMPLING RESULTS

GENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION (PPM)	P&CAM NUMBER
luminum	1	4/22/77	Welder	Personal	187	280.5	0.57 mg/m ³	173
luminum	2	4/22/77	Welder	Personal	237	355.5	0.82 mg/m ³	173
luminum	3	4/21/77	Welder	Personal	173	259.5	0.62 mg/m ³	173
luminum	4	4/21/77	Welder	Personal	209	313.5	0.64 mg/m ³	173
luminum	5	4/20/77	Welder	Personal	201	301.5	0.70 mg/m ³	173
luminum	6	4/20/77	Welder	Personal	147	220.5	0.30 mg/m ³	173
luminum	7	4/20/77	Welder	Personal	191	286.5	0.21 mg/m ³	173
ron	8	4/22/77	Welder	Personal	147	220.5	0.22 mg/m ³	173
ron	9	4/22/77	Welder	Personal	191	286.5	0.12 mg/m ³	173
ron	10	4/21/77	Welder	Personal	164	246.0	3.25 mg/m ³	173
ron	11	4/19/77	Welder	Personal	149	223.5	3.49 mg/m ³	173
ron	12	4/22/77	Welder	Personal	256	384.5	1.28 mg/m ³	173
ron	13	4/20/77	Welder	Personal	200	300.0	5.00 mg/m ³	173
ron	14	4/20/77	Welder	Personal	155	232.5	1.76 mg/m ³	173
ron	15	4/19/77	Welder	Personal	180	270.0	N.D.+	173
oluene	16	4/20/77	Painter	Personal	358	40.5	3.3 ppm	127
oluene	17	4/21/77	Painter	Personal	157	8.5	2.6 ppm	127
oluene	18	4/22/77	Painter	Personal	248	12.0	0.9 ppm	127
oluene	19	4/22/77	Painter	Personal	191	9.2	4.0 ppm	127
oluene	20	4/22/77	Painter	Personal	238	10.3	N.D.*	127
oluene	21	4/22/77	Painter	Personal	169	6.0	N.D.*	127
oluene	22	4/22/77	Painter	Personal	248	12.0	0.7 ppm	127
oluene	23	4/22/77	Set-up Painter	Personal	179	7.8	0.7 ppm	127
oluene	24	4/22/77	Set-up Painter	Personal	249	12.4	0.4 ppm	127
ylene	25	4/20/77	Painter	Personal	358	40.5	2.6 ppm	127
ylene	26	4/21/77	Painter	Personal	157	8.2	0.3 ppm	127
ylene	27	4/22/77	Painter	Personal	248	12.0	0.9 ppm	127
ylene	28	4/22/77	Painter	Personal	191	9.2	1.7 ppm	127
ylene	29	4/22/77	Painter	Personal	238	10.3	4.5 ppm	127
ylene	30	4/22/77	Painter	Personal	169	6.0	N.D.*	127
ylene	31	4/22/77	Painter	Personal	248	12.0	0.4 ppm	127
ylene	32	4/22/77	Set-up Painter	Personal	179	7.8	9.1 ppm	127
ylene	33	4/22/77	Set-up Painter	Personal	249	12.4	2.6 ppm	127

N.D.+ = Not Detected (limit of detection 2.0 ug./sample)

N.D.* = Not Detected (limit of detection 10 ug/sample)

FACILITY D (CONT.)

NON-PCB AIR SAMPLING RESULTS

GENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION (PPM)	P&CAM NUMBER
richloro-ethylene	34	4/20/77	Degreaser-Plating	Area	201	46.1	145.0	127
richloro-ethylene	35	4/19/77	Degreaser-Plating	Area	176	16.0	289.6	127
richloro-ethylene	36	4/22/77	Degreaser-Plating	Area	255	13.9	140.3	127
richloro-ethylene	37	4/22/77	Degreaser-Plating	Area	191	10.5	61.8	127
richloro-ethylene	38	4/21/77	Casting Assembly	Area	190	11.3	12.4	127
richloro-ethylene	39	4/19/77	F-30 Degreaser	Area	129	16.5	339.3	127
richloro-ethylene	40	4/22/77	F-30 Degreaser	Area	94	5.0	8.1	127
richloro-ethylene	41	4/22/77	F-30 Degreaser	Area	233	12.8	6.7	127

APPENDIX E

AIR SAMPLING RESULTS: FACILITY E

SURVEY DATES: JUNE 21-23, 1976; APRIL 27-28, 1977

FACILITY E

MANUFACTURE OF LARGE & SMALL CAPACITORS
 SURVEY DATES: JUNE 21-28, 1976; APRIL 27-28, 1977

PLANT A (Large Capacitor)
 PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1016
001	Treat Operator	4/27/77	427	82.3	55
002	Treat Operator	4/28/77	304	56.2	81
003	Treat Helper	4/27/77	426	67.0	75
004	Treat Helper	4/28/77	441	95.1	84
005	Recovery & Repair	4/27/77	422	84.5	281
006	Recovery & Repair	4/28/77	418	80.9	316
007	Repair & Seal	4/27/77	119	23.8	201
008	Repair & Seal	4/28/77	254	50.9	136
009	EMF Operator	4/28/77	431	65.3	115
010	EMF Operator	4/28/77	176	35.2	171
011	Repair	4/27/77	422	89.0	50
012	Salvage Operator	4/28/77	426	31.0	155

AREA AIR SAMPLES

001	Winding	4/27/77	195	38.9	43
002	Winding	4/28/77	420	62.9	3
003	Test & Paint	4/27/77	423	75.1	52
004	Test & Paint	4/28/77	417	84.7	30
005	Assembly	4/27/77	426	84.1	33
006	Assembly	4/28/77	425	86.2	24
007	Storage	4/28/77	427	85.2	14
008	Shipping	4/27/77	426	82.7	16

FACILITY E (CONT.)

MANUFACTURE OF LARGE & SMALL CAPACITORS
 SURVEY DATES: JUNE 21-28, 1976; APRIL 27-28, 1977

PLANT B (Small Capacitor)
 PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1016
001	Treat Operator	4/27/77	414	100.4	116
002	Treat Operator	4/28/77	431	28.1	203
003	Maintenance	4/27/77	404	82.1	150
004	Tester	4/28/77	440	63.8	264
005	Tester	4/27/77	427	83.6	226
006	Tester	4/27/77	423	83.5	161
007	Packer	4/28/77	434	57.1	256
008	Packer	4/27/77	428	81.9	166
009	Packer	4/27/77	425	69.3	175
010	Rework & Final Assem.	4/27/77	411	84.3	130
011	Rework & Final Assem.	4/27/77	413	79.5	174
012	Rework & Packer	4/28/77	435	60.9	132
013	Rework & Tester	4/28/77	433	53.1	140
014	Rework & Tester Solder	4/28/77	271	38.7	241
015	Moveman (Testing & Solder)	4/28/77	439	56.6	303
016	Moveman (Testing & Solder)	4/27/77	415	84.7	173
017	Moveman (Testing & Solder)	4/28/77	452	24.5	183
018	Moveman (Sealing)	4/28/77	432	24.3	396
019	Moveman (Sealing)	4/27/77	257	51.5	389

AREA AIR SAMPLES

001	Final Assembly	4/28/77	423	83.9	111
002	Final Assembly	4/28/77	410	82.0	134
003	Final Assembly	4/27/77	404	82.2	119
004	Soldering	4/28/77	398	58.2	392
005	Soldering	4/27/77	384	53.9	564
006	Winding	4/28/77	441	83.8	54
007	Winding	4/27/77	387	75.1	53
008	Shipping	4/28/77	428	61.6	101
009	Shipping	4/28/77	410	81.1	9
010	Can Manufacturing	4/28/77	437	78.7	36
011	Can Manufacturing	4/27/77	399	82.3	67
012	Cover Manufacturing	4/28/77	442	72.6	62
013	Cover Manufacturing	4/27/77	392	75.1	25

FACILITY E

NON-PCB AIR SAMPLING RESULTS

AGENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION (PPM)	P&CAM NUMBER
Trichloro-ethylene	1	4/27/77	Degreaser-Soldering Area		154	7.4	4.9	127
Trichloro-ethylene	2	4/2/777	Degreaser-Soldering Area		171	8.3	0.76	127
Trichloro-ethylene	3	4/28/77	Degreaser-Soldering Area		149	7.3	0.25	127
Trichloro-ethylene	4	4/28/77	Degreaser-Soldering Area		174	11.4	0.25	127
Trichloro-ethylene	5	4/27/77	Degreaser-3rd Floor Area		185	9.4	0.48	127
Trichloro-ethylene	6	4/27/77	Degreaser-3rd Floor Area		214	10.6	0.12	127
Trichloro-ethylene	7	4/28/77	Degreaser-3rd Floor Area		210	10.8	0.10	127
Trichloro-ethylene	8	4/28/77	Degreaser-3rd Floor Area		196	10.2	0.75	127
Trichloro-ethylene	9	4/28/77	Degreaser-1st Floor Area		189	9.6	0.04	127
Trichloro-ethylene	10	4/28/77	Degreaser-1st Floor Area		190	10.2	5.9	127
Trichloro-ethylene	11	4/27/77	Degreaser-1st Floor Area		185	9.9	N.D.1	127
Toluene	12	4/28/77	Painter	Personal	144	7.7	2.8	127
MIBK	12	4/28/77	Painter	Personal	144	7.7	2.2	S-18
Toluene	13	4/28/77	Painter	Personal	234	12.2	5.6	127
MIBK	13	4/28/77	Painter	Personal	234	12.2	5.0	S-18
Toluene	14	4/27/77	Painter	Personal	153	6.0	5.7	127
MIBK	14	4/27/77	Painter	Personal	153	6.0	4.9	S-18
Toluene	15	4/27/77	Painter	Personal	163	3.3	4.9	127
MIBK	15	4/27/77	Painter	Personal	163	3.3	5.2	S-18
Toluene	16	4/27/77	Painter	Personal	199	9.8	N.D.1	127
MIBK	16	4/27/77	Painter	Personal	199	9.8	N.D.1	S-18
Toluene	17	4/28/77	Painter	Personal	189	11.0	N.D.1	127
MIBK	17	4/28/77	Painter	Personal	189	11.0	N.D.1	S-18
Toluene	18	4/28/77	Painter	Personal	215	11.0	0.48	127
MIBK	18	4/27/77	Painter	Personal	215	11.0	N.D.1	S-18
Toluene	19	4/27/77	Painter	Personal	206	10.0	0.53	127
MIBK	19	4/27/77	Painter	Personal	206	10.0	N.D.1	S-18
Toluene	20	4/28/77	Label/Packer	Personal	258	12.7	N.D.1	127
MIBK	20	4/28/77	Label/Packer	Personal	258	12.7	N.D.1	S-18
Toluene	21	4/28/77	Label/Packer	Personal	145	7.1	N.D.1	127
MIBK	21	4/28/77	Label/Packer	Personal	145	7.1	N.D.1	S-18
Toluene	22	4/27/77	Label/Packer	Personal	204	11.0	N.D.1	127
MIBK	22	4/27/77	Label/Packer	Personal	204	11.0	N.D.1	S-18
Toluene	23	4/27/77	Label/Packer	Personal	199	10.9	N.D.1	127
MIBK	23	4/27/77	Label/Packer	Personal	199	10.9	N.D.1	S-18

FACILITY E (CONT.)

NON-PCB AIR SAMPLING RESULTS

AGENT	SAMPLE NO.	DATE	JOB/OPERATION TITLE	SAMPLE TYPE	SAMPLE TIME (MIN.)	VOLUME (L)	CONCENTRATION ug/m ³	P&CAM NUMBER
Zinc	36	4/27/77	Soldering	Area	185	277.5	N.D. ²	173
Lead	37	4/27/77	Soldering	Area	185	277.5	N.D. ³	173
Zinc	38	4/28/77	Soldering	Area	167	250.5	8	173
Lead	39	4/28/77	Soldering	Area	167	250.5	N.D. ²	173
Zinc	40	4/27/77	Soldering	Area	164	246.0	N.D. ²	173
Lead	41	4/27/77	Soldering	Area	164	246.0	N.D. ³	173
Zinc	42	4/28/77	Soldering	Area	166	249.0	24	173
Lead	43	4/28/77	Soldering	Area	166	249.0	N.D. ³	173
Aluminum	44	4/28/77	Welding	Personal	128	180.0	233	173
Aluminum	45	4/28/77	Welding	Personal	191	286.0	112	173
Aluminum	46	4/27/77	Welding	Personal	133	199.5	N.D. ⁴	173
Iron	47	4/27/77	Welding	Personal	131	196.5	47	173
Iron	48	4/28/77	Welding	Personal	190	285.0	123	173
Iron	49	4/28/77	Welding	Personal	181	271.5	52	173
Iron	50	4/27/77	Welding	Personal	129	193.5	48	173

N.D.¹ = Not detected (limit of detection 10.0 ug/sample).

N.D.² = Not detected (limit of detection 1.0 ug/sample).

N.D.³ = Not detected (limit of detection 2.0 ug/sample).

N.D.⁴ = Not detected (limit of detection 5.0 ug/sample).

APPENDIX F

AIR SAMPLING RESULTS: FACILITY F

SURVEY DATES: JUNE 21-28, 1976; APRIL 27-28, 1977

FACILITY F

MANUFACTURE OF LARGE & SMALL CAPACITORS
 SURVEY DATES: JUNE 21-28, 1976; APRIL 27-28, 1977

PERSONAL SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION (ug/m ³) Arochlor 1016
001	Moveman-Soldering	3/22/77	265	33.2	1,010
002	Moveman-Soldering	3/23/77	384	71.3	420
003	Moveman-Soldering	3/21/77	103	22.0	1,110
004	Floorman-Preassembly	3/23/77	380	65.9	230
005	Floorman-Preassembly	3/21/77	83	12.9	190
006	Floorman-Preassembly	3/22/77	380	76.4	140
007	Floorman-Preassembly	3/21/77	82	16.8	200
008	Floorman-Preassembly	3/23/77	380	82.4	140
009	Floorman-Preassembly	3/22/77	378	73.4	150
010	Tester	3/23/77	402	80.6	250
011	Tester	3/21/77	107	21.2	310
012	Tester	3/22/77	408	83.5	320
013	Pump Mechanic	3/22/77	377	73.0	280
014	Degreaser	3/23/77	381	72.9	1,260
015	Tanker	3/22/77	385	66.8	560
016	Tanker	3/21/77	93	6.3	800
017	Tanker	3/23/77	384	72.9	1,260
018	Tanker	3/21/77	87	17.6	510
019	Tanker	3/23/77	385	77.5	1,010
020	Tanker	3/22/77	262	35.5	540
021	Tanker	3/22/77	287	56.7	780
022	Tanker	3/21/77	93	15.8	940
023	Tanker	3/23/77	144	14.3	970
024	Solder	3/23/77	384	76.2	1,050
025	Solder	3/21/77	105	23.6	980
026	Solder	3/22/77	395	74.5	1,090
027	Heat Soak	3/23/77	287	81.1	500
028	Heat Soak	3/21/77	86	16.4	870
029	Heat Soak	3/22/77	399	83.1	710

FACILITY F (CONT.)

MANUFACTURE OF LARGE & SMALL CAPACITORS
 SURVEY DATES: JUNE 21-28, 1976; APRIL 27-28, 1977

AREA SAMPLES

SAMPLE CODE	JOB TITLE	DATE	SAMPLE TIME (MIN.)	SAMPLE VOLUME (LITERS)	CONCENTRATION ($\mu\text{g}/\text{m}^3$) Arochlor 1016
001	Impregnation	3/21/77	85	17.3	1,010
002	Impregnation	3/21/77	91	21.0	610
003	Shipping	3/23/77	373	75.7	80
004	Shipping	3/22/77	368	77.8	100
005	Pre-Assembly	3/23/77	379	60.9	40
006	Pre-Assembly	3/21/77	80	16.2	220
007	Pre-Assembly	3/22/77	376	84.1	170
008	Pre-Assembly	3/22/77	378	76.3	140
009	Pre-Assembly	3/21/77	81	16.2	180
010	Winding	3/21/77	80	16.2	70
011	Winding	3/21/77	72	26.2	30
012	Winding	3/22/77	375	79.8	80
013	Winding	3/22/77	110	15.5	100
014	Testing	3/22/77	401	78.6	310
015	Testing	3/21/77	106	23.8	370
016	Testing	3/21/77	105	21.8	330
017	Testing	3/22/77	405	86.4	210
018	Testing	3/22/77	407	77.7	360
019	Pumping	3/23/77	362	70.0	470
020	Pumping	3/22/77	358	68.7	480
021	Pumping	3/22/77	359	74.2	530
022	Cover Manufacturing	3/22/77	357	40.6	70
023	Cover Manufacturing	3/22/77	358	73.8	50
024	Cover Manufacturing	3/23/77	374	75.3	60
025	Office	3/23/77	370	51.9	50
026	Office	3/23/77	371	83.7	50

FACILITY F

NON-PCB AIR SAMPLING RESULTS

AGENT	SAMPLE NO.	DATE	SAMPLE TIME (MINS.)	VOLUME (L)	LEAD CONC. ¹ ug/m ³	ZINC CONC. ² ug/m ³	TIN CONC. ³ ug/m ³
Soldering	1	3/23/77	265	450.5	ND	ND	ND
Soldering	2	3/23/77	261	443.7	ND	ND	ND
Soldering	3	3/23/77	259	440.3	ND	4.5	ND
Soldering	4	3/21/77	100	170	ND	76.5	ND
Soldering	5	3/21/77	100	170	ND	94.1	ND
Soldering	6	3/21/77	100	170	41.2	29.4	ND
Soldering	7	3/21/77	105	178.5	ND	78.4	ND
Soldering	8	3/22/77	256	435.2	ND	2.3	ND
Soldering	9	3/22/77	259	440.3	ND	ND	-
Soldering	10	3/22/77	259	440.3	ND	ND	-
Soldering	11	3/22/77	257	436.9	ND	ND	-
Soldering	12	3/22/77	129	219.3	ND	ND	-
Soldering	13	3/22/77	129	219.3	ND	ND	-
Soldering	14	3/22/77	132	224.2	ND	ND	-
Soldering	15	3/22/77	134	227.8	ND	ND	-

ND = Non-Detectable

1 = Limit of detection - 3.0 ug/sample (NIOSH Method P&CAM 173)

2 = Limit of detection - 1.0 ug/sample (NIOSH Method P&CAM 173)

3 = Limit of detection - 15.0 ug/sample (NIOSH Method P&CAM 173)