

GENERAL ELECTRIC COMPANY

R.W. Lewis
Vice President and Group Executive

July 7, 1970

Mr. A. M. Salazar, Executive Secretary
Power Equipment Division
NEMA
155 East 44th St.
New York, N. Y. 10017

Dear Al:

At the last meeting of the Board of Directors of the Power Equipment Section, I recommended that NEMA take a leadership role in solving the problem of disposition of askarel contaminated materials because it is an industry-wide problem.

The background of this recommendation is that Monsanto, the sole manufacturer of askarels (technically known as polychlorinated biphenyls), notified us, and I presume all other purchasers of askarels, that there was a possibility of environmental contamination due to non-biodegradable materials used in their composition. Monsanto has offered a disposal service for handling scrap liquid askarels but the problem of disposing of askarel soaked materials, such as sawdust, rags, and insulations, has not been solved. It is the latter to which I recommended a NEMA Task Force address itself.

I would appreciate it if you would activate the mechanics for getting such a Task Force appointed as promptly as possible. As I indicated, E. L. Raab, Manager-Chemical and Processes section, Materials and Technology Laboratory, Pittsfield, Massachusetts, would likely be our candidate to serve on the Task Force.

Very truly yours,

R. W. Lewis/S

RWLewis:nt

cc: R. B. Ames
C. J. Meloun

PLAINTIFF'S
EXHIBIT

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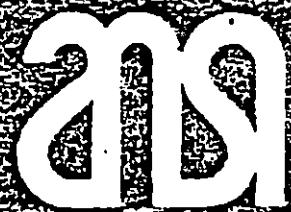
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American National Standard

guidelines for
handling and disposal of
capacitor- and transformer-grade askarels
containing polychlorinated biphenyls



american national standards institute, inc.
1430 broadway, new york, new york 10018

PLAINTIFF'S
EXHIBIT

769

ANSI
C107.1-1974

**American National Standard
Guidelines for Handling and Disposal of
Capacitor- and Transformer-Grade Askarels
Containing Polychlorinated Biphenyls**

Secretariat

National Electrical Manufacturers Association

Approved January 9, 1974

American National Standards Institute, Inc

Foreword

(This Foreword is not a part of American National Standard Guidelines for Handling and Disposal of Capacitor- and Transformer-Grade Askarels Containing Polychlorinated Biphenyls, C107.1-1974.)

Recognizing that the polychlorinated biphenyls present in askarels were being identified as environmental pollutants and the urgent need for procedures and guides for their safe use and disposal, the Board of Directors of the Power Equipment Division of the National Electrical Manufacturers Association (NEMA) in June 1970 appointed a committee to review the general problem and propose recommendations. In September 1970, the NEMA board approved, as recommended by the committee, the sponsorship of an American National Standards Committee for the use and disposal of askarels in electrical equipment.

American National Standards Committee C107 was established in April 1971. NEMA was designated as the secretariat. An organizational meeting was held on September 14, 1971. Mr W. B. Papageorge, Monsanto Company, was appointed chairman. Committee members included representatives of capacitor and transformer manufacturers, utilities, governmental departments and agencies, and maintenance and disposal service companies. A steering committee and two subcommittees — one to develop guidelines for the capacitor industry, the other for the transformer industry — were established.

The scope and primary objective of the committee was designated as the development of: Procedures and guides for the safe use, maintenance, and disposal of askarel and askarel-soaked materials used in electrical equipment.

Additional objectives proposed were as follows:

- (1) To serve as a source for technical information and advice for federal, state, and local authorities and for the information of all others concerned.
- (2) To encourage the development of suitable disposal facilities and maintain a list of their capabilities and locations, for the information of all concerned.
- (3) To serve as the advisory group for U.S. participation in the International Commission on Rules for the Approval of Electrical Equipment (CEE), the International Electrotechnical Commission (IEC), the Pan American Standards Commission (COPANT), the International Conference on Large High Tension Electric Systems (CIGRE), and other international organizations.

The final draft of the guidelines was completed in late November 1972. NEMA issued the guidelines as an Official Standards Proposal in January 1973. It was submitted to the American National Standards Institute for approval as an American National Standard and was approved by the Standards Institute on January 9, 1974.

Suggestions for improvement of this standard will be welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

This standard was processed and approved for submittal to ANSI by American National Standards Committee on Use and Disposal of Askarel and Askarel-Soaked Materials in Electrical Equipment, C107. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C107 Committee had the following members:

W. P. Papageorge, Chairman
A. M. Salazar, Secretary

<i>Organization Represented</i>	<i>Name of Representative</i>
Certified Ballast Manufacturers Association	N. R. Clark
	A. Pozefsky
Chem-Trol Pollution Services Inc	Louis E. Wagner
Doble Engineering Company	A. L. Rickley
Electrical Utilities Company	A. O. Hauser
	E. M. Moore (Alt)
Electric Light and Power Group	F. R. Lengefeld
	H. A. Onishi
	J. J. Cawley (Alt)

<i>Organization Represented</i>	<i>Name of Representative</i>
Electronic Industries Association	Arnold S. Doty
Environmental Protection Agency	Kenneth J. Hood
General Services Administration	Charles C. Travis
Gilbert Associates Inc	R. J. Schatz
Institute of Electrical and Electronics Engineers, Inc	E. L. Rabb
Monsanto Company	W. P. Papageorge
	P. G. Benignus (Alt)
National Bureau of Standards	Stanley P. Wasik
National Electrical Manufacturers Association	K. C. Chang
	W. S. Grogan
	R. D. McClain
	H. R. Rowe
	Ken McGee (Alt)
Rollins-Purle, Inc	H. A. Alsentzer
Tennessee Valley Authority	William R. Nicholas
U.S. Department of Agriculture, Rural Electrification Administration	John Leutritz, Jr
U.S. Department of the Army	D. M. Crabtree

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American National Standard Guidelines for Handling and Disposal of Capacitor- and Transformer-Grade Askarels Containing Polychlorinated Biphenyls

1. Scope

This standard establishes guidelines for the safe use, maintenance, and disposal of askarel and askarel-soaked material used in capacitors and transformers.

2. General Information

2.1 General. The term "askarel" generally describes a broad class of nonflammable synthetic chlorinated hydrocarbon insulating liquids widely used in capacitors, transformers, reactors, and accessory equipment operated at power frequencies.

Askarels consisting of or containing polychlorinated biphenyls (PCBs) have been used in many applications for more than 40 years, but only recently was evidence discovered that PCBs are widely dispersed in the environment. Systematic investigations of the biological effects of PCBs have been undertaken within the past few years to establish the effects of specific formulations upon specific species. Some studies have shown that PCBs may be an environmental contaminant. Simultaneously, significant steps have been taken by U.S. industry to limit further releases of PCBs to the environment.

PCBs have been used in three broad types of applications for the past 40 years, as follows:

- (1) "Open-ended" applications; for example, in paints, specialty inks, paper coatings, plastics, etc
- (2) "Nominally closed" applications; for example, as the working fluid in hydraulic or heat-transfer systems
- (3) "Closed electrical system" applications, specifically as the insulating fluid in certain kinds of transformers and capacitors¹

¹ The Monsanto Company is the sole U.S. producer of PCBs. It has discontinued supplying the material for all applications given in 2.1(1) and 2.1(2).

Evaluations of the benefits, risks, and alternatives involved in the continued use of PCBs in closed electrical systems are summarized in 2.2 through 2.4.

2.2 Benefits. Askarel-filled transformers do not burn or sustain fire under conditions of internal electrical arcing.

Askarel-filled power and industrial capacitors are significantly smaller, more reliable, more durable, and safer than oil-filled capacitors. As a result, askarels have supplanted mineral oils in more than 90% of the power and industrial capacitors made today. Over the past few decades most of the equipment that incorporates such capacitors has been designed to take particular advantage of the size, safety, and reliability benefits of askarel capacitors (for example, many types are today less than 14% of the size of equivalent oil capacitors and have a life expectancy of 10 to more than 20 years).

Various federal, state, and local codes, therefore, require their continued use in or adjacent to public, commercial, and industrial buildings, which locations present the greatest potential danger to life and property.

2.3 Risks. In the United States, medical records over a nearly 40-year period show that the only adverse health effects experienced by U.S. workers exposed to askarels, either during the manufacture of these liquids or of electrical equipment containing these liquids, have been limited to occasional cases of nonchronic chloracne or other temporary skin lesions or irritations.

Askarel-filled transformers and capacitors are delivered to customers as sealed units from which there is no escape of askarel under normal operation. Although certain types of equipment failures can permit loss of some askarel to the environment, transformer failures are limited to approximately 0.02% of the units in service per year. With respect to capacitors, such losses are limited to approximately 0.02% of the askarel put into service per year. In addition, limited amounts of PCBs can get into the environment during the manufacture, delivery, improper use, maintenance, repair, and disposal of transformers and capacitors.

Specific control measures have been instituted by individual manufacturers and are supplemented and strengthened by national standards and procedures such as this standard, which provides information to prevent the inadvertent loss of PCBs to the environment at all stages from initial askarel manufacture through ultimate disposal.

2.4 Alternatives. For technical and local and national code reasons, it would be impossible to replace most askarel-filled transformers now in service with oil-filled units of equivalent ratings without major construction changes that would be required to compensate for the fire resistance of the askarel-filled units. For certain applications and locations, dry-type transformers may replace askarel-filled transformers.

For new installations, although many of the foregoing limitations would still apply, building and installation design provisions could be made to accommodate the use of oil-filled, open dry-type, or sealed dry-type transformers, provided that necessary technical, code, physical size, and cost considerations are properly evaluated.

The principal alternative to askarels for capacitors is mineral oil, but such replacement would return capacitor technology to its pre-1932 level and would necessitate the redesign and replacement of such widely used equipment as fluorescent light fixtures and racks for power and induction-heating capacitors, which could not now accommodate the increased size of oil capacitors while maintaining their present ratings.

The cost of askarel liquids is about five to ten times more than mineral oil. Thus, long before there were any environmental concerns about PCBs, there was a strong economic incentive to find other, less expensive insulating liquids with the desirable characteristics of askarels. Since the 1930s at least ten major chemical or electrical companies have invested large amounts of time and money in this search, all with no success. Although potential substitutes that are more costly than askarels (such as fluorinated liquids) have also received some consideration, little is known about either their electrical performance or possible ill effects upon the environment. There are today no fluids that can be used as a direct replacement for askarels.

2.5 Interdepartmental Task Force on PCBs. An in-depth study of PCBs has recently been completed by five Executive Branch Departments of the federal government. This Interdepartmental Task Force on PCBs issued their report, entitled *Polychlorinated Biphenyls and the Environment*, in May 1972.² The following

conclusion is quoted from page 4 of this report:

"The use of PCBs should not be banned entirely. Their continued use for transformers and capacitors in the near future is considered necessary because of the significantly increased risk of fire and explosion and the disruption of electrical service which would result from a ban on PCB use. Also, continued use of PCBs in transformers and capacitors presents a minimal risk of environmental contamination. The Monsanto Company, the sole domestic producer, has reported voluntarily eliminating its distribution of PCBs to all except manufacturers of electrical transformers and capacitors."

Reference should be made to the Interdepartmental Task Force Report for additional information and conclusions.

3. Capacitor Guidelines

3.1 General. The environmental effects of askarels are under in-depth study by governmental and other agencies. Askarels have been considered relatively harmless to humans based on about 40 years of safe industrial usage. There has been no known instance of human injury when they were used under the normally accepted precautions and conditions of handling in both manufacturing and user applications.

Traces of askarels are being found in the environment and in fish and bird life. The long-term genetic and ecological effects are not yet completely understood. For these reasons, care should be taken to contain askarels and minimize their entry into the environment.

There are two general classes of askarels used by the electrical industry. The higher chlorinated grades are the more persistent in nature. Because of their high degree of nonflammability, they are used in transformers where personnel safety is of paramount importance.

Capacitor-grade askarel has a lower degree of chlorination (composed primarily of the 3-chlorine isomers of biphenyl) and a higher degree of biodegradability. Generally, it has not been found in animal life. It is used in capacitors, where the extreme degree of nonflammability required in transformers is of less importance.

Although capacitor- and transformer-grade askarels both contain members of the PCB family, they do differ in composition, degree of biodegradability, persistence in nature, electrical stability, chemical stability, and degree of nonflammability (both are recognized as nonflammable). It is for these reasons that Section 3 of this standard is intended to apply to capacitor-grade askarel.

² Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va 22151.

Table 1
Typical Properties of Aroclor 1016

Property	Test Method (See Note)	Typical Values
Color	APHA*	40, max
Condition	—	Clear
Specific Gravity at 25/15.5°C	ANSI C59.68-1965 (R1973) [2]	1.362-1.372
Acidity (mg KOH/g)	ANSI Z11.131-1964 (R1974) [3] ANSI Z11.59-1958 (R1971) [4]	0.010, max
Moisture	—	35 ppm, max
Refractive index at 25°C	ASTM D 1817-66 (1972) [5]	1.6215-1.6235
Inorganic (free) chlorides	ANSI C59.55-1963 (R1973) [6]	0.05 ppm, max
Pour point	ANSI Z11.5-1966 (R1972) [7]	-14°C or lower
Dielectric constant (1000 Hz at 100°C)	ANSI C59.22-1967 (R1973) [8]	4.70-4.90
Resistivity (500 V dc at 100°C, 0.1-inch gap)	ANSI C59.51-1965 (R1973) [9]	$500 \times 10^9 \Omega \cdot \text{cm}$, min
Hydrolysis stability test (as chlorides)	ANSI C59.106-1970 [10]	0.5 ppm, max
Thermal stability test (as chlorides)	ANSI C59.111-1970 [11]	0.4 ppm, max
Distillation range (corrected)	ANSI A37.9-1974 [12]	323°C, min 356°C, max
10% distilled by weight		
90% distilled by weight		
Higher-Boiling Homologues	ASTM D 3303-74 [1]	0.4%, max
Sulfates	ANSI C59.2-1974 [13]	None
Dielectric strength at 25°C	ANSI C59.19-1968 (R1973) [14]	35 kV, min
Flash point, Cleveland open cup	ANSI Z11.6-1973 [15]	338°F, min
Fire point	—	None to boiling point
Corrosion test (6 hours at 210°C with bright aluminum foil), change in weight of aluminum	—	0.0%
Viscosity at 100°F (SUS)†	ANSI Z11.2-1956 (R1971) [16]	71-81
Specific heat at 25°C	—	0.30
Coefficient of expansion	ANSI C59.57-1963 (R1973) [17]	$0.00068 \text{ cm}^3/\text{cm}^3/^\circ\text{C}$
Fixed chlorine	Carius	$41.3 \pm 0.5\%$
Power factor at 100°C, 60 Hz	Munch [18]	1%, max 4%, max
Bulk		
Drums		

NOTE: Numbers in brackets refer to correspondingly numbered test methods in 5.1, References to the Text.

*American Public Health Association.

†Saybolt Universal seconds.

3.2 Capacitor-Grade Askarel. In September 1971 a new grade of capacitor impregnant, Aroclor 1016, was made available to the industry. This new grade contains a typical concentration of 0.4% by weight of the higher-boiling homologues of the chlorinated biphenyls. (See ASTM D 3303-74 [1].)³ Aroclor 1016 replaces Aroclor 1242, which previously was the major capacitor impregnant and contained around 7% of the higher-boiling homologues (the more persistent in nature). This 0.4% level of the higher-boiling homologues should be the

maximum concentration acceptable in any capacitor impregnant. Aroclor 1242 and 1254, previously used as impregnants, do not meet this requirement and should no longer be used in capacitors designed and manufactured for alternating-current applications.

Aroclor 1016 has the same Underwriters' Laboratories, Inc. nonflammability rating as Aroclor 1242. Its typical properties are given in Table 1.

3.3 Plant Housekeeping and Employee Safety. The procedures and limits given in 3.3 are intended to be minimum requirements to be met by manufacturers and users of capacitors containing askarel. Handling, control, and disposal procedures are given, together

³ Numbers in brackets refer to corresponding numbers in 5.1, References to the Text.

with exposure limits and indicated antidotes and clean-up procedures.

3.3.1 Material. Askarel for use in capacitors should consist of homologues and isomers of chlorinated biphenyl with the concentration of the higher-boiling homologues at about 0.4%. (See ASTM D 3303-74 [1].) Aroclor 1016 is considered to be the standard impregnant meeting these requirements.

Commonly used solvents include benzene, kerosene, acetone, trichloroethane, trichloroethylene, and perchloroethylene. Typical vapor pressure data for Aroclor 1016 are:

0°C = 0.001 mmHg

25°C = 0.006 mmHg

150°C = 4.3 mmHg

200°C = 29.0 mmHg

At 25°C and 760 mmHg pressure, saturated air contains approximately 0.09 mg/l.

NOTE:

1 mg/l = 90.0 ppm (v/v)

1 ppm (v/v) = 0.011 mg/l

3.3.2 Bulk Fluid Shipment, Receiving, and Transfer. Shipment of askarel from point of manufacture to point of receiving should be done in closed containers such as rail tank cars, truck tanks, marine or barge tanks, or sealed drums. Containers should be labeled as to contents and carry a label cautioning against loss of fluid to the open environment. Containers used to transport askarel should not be used for storage or to transport other material without being completely cleaned of all traces of askarel. (Cleaning procedures must take cognizance of precautions against excessive exposure and of the need for proper disposal of contaminated cleansing solvents and materials as set forth in 3.5). Transfer from shipping containers to processing systems should be through closed piping or tubing with appropriate valves, pumps, etc. Provision should be made for trapping and disposing of fluid lost by leakage or spills from the transfer system and from the storage containers.

Drums to be retired from use should be cleaned before crushing, delivery to scrap dealers, or other disposal. Contaminated cleaning fluids and materials should be disposed of as indicated in 3.5.

3.3.3 General Safety Precautions. Although it is generally accepted that exposure to capacitor-grade askarel is not hazardous provided that simple precautions are taken, exposure should still be avoided.

3.3.3.1 Vapors. The odor of askarel is noticeable well below the maximum air concentrations considered safe. Up to 1.0 milligram per cubic metre of air has been determined to be the maximum safe level of exposure during an 8-hour workday. (See reference [19].) The procedure for performing the necessary analyses is

contained in Section B3 of Appendix B. This procedure or its equivalent should be used.

Breathing vapor or fumes from heated askarel should be avoided. Provisions should be made for adequate ventilation and regulation of manufacturing operations to avoid open exposure to askarel (especially at temperatures of 55°C or higher). The gases produced when askarel is decomposed by very high temperatures (such as that of an electric arc) in the presence of air or organic insulating materials contain a high percentage of hydrogen chloride, and small percentages of carbon dioxide, carbon monoxide, and oxygen. Minute concentrations of this combination of gases are very unpleasant and irritating, thus giving ample warning of their presence. If exposure to high concentrations of askarel is necessary under emergency conditions, an approved gas mask or self-contained breathing apparatus should be worn. Such exposure should be under the surveillance of other personnel capable of effecting rescue in case of an accident. If the odor of askarel is detected by the person wearing protective equipment, he should immediately go into fresh air. All gas masks, respirators, and replacement parts should have U.S. Bureau of Mines approval and be maintained on a regular schedule in accordance with the manufacturer's recommendation.

3.3.3.2 Liquid. In contrast to the situation in which mineral insulating oils are handled, there is virtually no fire hazard in handling askarel. A limited solvent action (similar to that for paint thinner) on the fats and oils of the skin with prolonged contact may lead to drying and chapping of the skin. As with insulating oil, some people are allergic to askarel, and continued exposure may result in skin irritation. Both the liquid and vapor are moderately irritating to eye tissue.

Operating procedures should be such as to minimize or eliminate contact with askarels. Use of eye protection is recommended. The use of porous gloves that can absorb and retain askarels is to be avoided. Barrier creams⁴ or resistant gloves⁵ should be used if contact is unavoidable. Use of enclosed transfer and handling equipment, processing equipment, and mechanical washers reduces direct contact.

Medicinal washes or mild detergents followed by the application of cold cream will reduce the irritation resulting from the contact of an open cut or abrasion with askarel.

Safety glasses with side shields or a face shield should be worn when handling askarels. If liquid aska-

⁴ For example, PLY No. 9 Gel (Milburn Company, Detroit, Mich.), or Kerodex No. 71 (Ayerst Laboratories, New York, N. Y.), or the equivalent.

⁵ For example, Edmont - Solvix 5-352 (Mersick of Bridgeport, Bridgeport, Conn.), or the equivalent.

rel contacts the eyes, the eyes should be irrigated immediately with large quantities of running water for 15 minutes and then examined by a physician. (A drop of castor oil has been found to reduce irritation.)

Persons developing a skin irritation or respiratory tract irritation while working with askarels should be placed under the supervision of a physician.

Ingestion or swallowing of askarels is not generally regarded as a problem of the industry. Should accidental ingestion occur, a physician should be consulted. Hands should be washed with warm water and soap before eating, drinking, smoking, or using toilet facilities.

3.3.4 Manufacturing Housekeeping. Manufacturing equipment and operating procedures should safeguard against loss of askarels to the environment through proper containment and disposal procedures.

Enclosed systems of sealed piping, properly gasketed joints, valves, containers, and processing chambers should be used for any portion of the operation where askarel temperatures may exceed 55°C. Enclosure should preferably extend to all other portions of the system insofar as practicable.

Containment provisions should be established around all askarel processing areas to ensure against inadvertent loss to sewer systems by spillage, leakage, or other uncontrolled conditions or events.

Spills of askarel should be removed promptly by means of absorptive material, such as sawdust, or trapped and removed by pumping or other suitable means.

Waste fluids containing askarel not suitable for reconditioning or reuse should be collected (by means of traps, drip pans, trays, etc) from the various parts of the manufacturing and processing area (including washers or other cleaning devices). Disposal should be made in accordance with 3.5.

Wiper rags, clothing, and other extraneous materials saturated with askarels should be collected within the containment area for properly controlled laundering or disposal (see 3.5).

3.3.5 Disposal of Askarel Wastes. Methods for disposal of liquids and saturated solids generated by the manufacturing operation should be in accordance with those outlined in 3.5, and should include (but not be limited to) the following wastes:

- (1) Contaminated liquid askarel that is unsuitable for reclaiming as a dielectric fluid
- (2) Liquid askarel from solvent operations or water and detergent type washers
- (3) Saturated earth or other absorbent media from filtering operations
- (4) Saturated sawdust or other absorptive materials from spills
- (5) Saturated filters from vapor-control devices and

other filters

- (6) Saturated wastes (paper, rags, etc)
- (7) Saturated, spent gasket materials
- (8) Askarel-contaminated vacuum pump oils
- (9) Askarel-contaminated stream jet vacuum system condensates

3.3.6 Miscellaneous Procedures. Other safety considerations include the following:

(1) Spills by leakage from finished capacitors should be cleaned up promptly by means of absorbent media, which should then be moved to containers provided for that purpose within the containment area, and later disposed of properly.

(2) Askarel wastes should never be disposed of down effluent drains or sewers. The utmost care must be exercised to prevent accidental loss by these avenues to the environment.

(3) Capacitors failing tests or otherwise designated for disposal must be controlled and handled in accordance with the intent of the procedures given in 3.3.6(1) and 3.3.6(2), finally being disposed of by one of the means outlined in 3.5.

3.4 Control of Water Effluents. The industry goal is to eliminate askarel in plant water effluent streams. However, it is recognized that existing drain systems in capacitor manufacturing plants are probably contaminated as a result of past practices, and askarel traces may continue to show up in effluent streams for some time. However, the level should continue to decrease with the proper containment of askarel wastes and no further discharges into drain systems. Other sections of this standard provide that no askarel wastes of any kind be disposed of in any water effluent streams and that accidental spills be prevented from getting into such streams.

3.4.1 Concentration Limits. The 1972 Environmental Protection Agency proposals are to keep PCB levels in rivers and lakes below 0.01 part per billion. This is currently under review by the EPA and standards are expected to be promulgated in 1974. Plant effluent streams should be managed and controlled in a manner anticipating these government standards.

3.4.2 Monitoring Streams. On a regular basis consistent with plant situations, all effluent streams should be analyzed. The procedure for performing the necessary analyses is contained in Section B4 of Appendix B. This procedure or its equivalent should be used.

3.4.3 Methods for Minimizing Effluent Stream Contamination. The ideal approach is to isolate totally all effluent streams that could be contaminated with askarels during manufacturing processes and prevent them from being discharged from the plant. Carbon adsorption, limestone beds, and solvent extraction are tech-

niques that can be applied to reduce the askarel content of effluent streams. These techniques may be most useful in cleaning up water used in plant processing and to permit recycling.

3.5 Scrap-Disposal Procedures. The manufacture and use of capacitors involve processes that produce askarel-saturated solids and liquids containing or composed entirely of askarel, which should be disposed of as wastes. Specific sources of these materials are described throughout this standard. They may be placed into three categories:

- (1) Capacitor units impregnated with askarel, production and field rejects
- (2) Manufacturing process liquid wastes containing askarel
- (3) Solid waste purposely or accidentally saturated with askarel

Disposal should be done in a manner that is consistent with proper concern for the environment and minimizes any release of askarels to the environment.

3.5.1 Disposal of Capacitor Units. Scrap capacitor units can be generated during manufacturing processes or during field service.

Production rejects are those capacitors that are rejected after the impregnation process in the course of production by the capacitor manufacturer. They may be rejected for mechanical or electrical reasons, or because of obsolescence.

Field rejects are those units that are rejected or, for other reasons, are to be scrapped after shipment from the plant where they were manufactured.

3.5.1.1 Production Rejects. Rejected capacitors in capacitor manufacturing plants represent a concentration of askarel. It is important that their disposition be made in a manner consistent with proper concern for the environment. Therefore, capacitors should be disposed of only in supervised dry landfill sites that meet all applicable state requirements.

Care should be exercised to ensure that no loss of liquid will occur during transportation to the disposal site.

Incineration of scrap capacitors in facilities designed to accept such solids should provide an alternative means of disposal as such services become available in the future.

3.5.1.2 Field Rejects. Small capacitors (defined as containing less than 2 pounds of askarel) are practically always used as components in other electrical or electromechanical equipment. Typical examples of large quantity usage of such capacitors are in fluorescent lamp ballasts and residential air conditioning equipment. Failure of such capacitors may result in scrapping of the device of which it is a part (as in a fluores-

cent ballast) or replacement and scrapping of the individual capacitor (as in a room air conditioner). However, the majority of such capacitors do not fail in service, but are scrapped as a result of wearing out or obsolescence of the devices in which the capacitors are used as components. Thus, the matter of disposal is characterized by a low concentration of small quantities of askarel throughout the country and, indeed, throughout the world. Fortunately, the nature of the devices and equipment in which such capacitors are used is such that they are normally disposed of in dry landfills as a matter of convenience. Since it is impractical at present to exercise any meaningful control over the disposition of the bulk of such devices and equipment, it is imperative that askarel used for impregnating small capacitors be limited to the recently introduced type, which contains a typical concentration of 0.4% of the higher-boiling homologues. (See ASTM D 3303-74 [1].)

Large capacitors (those incorporating more than 2 pounds of askarel) should be disposed of according to the procedure for production rejects (see 3.5.1.1).

3.5.2 Disposal of Liquid Wastes. All waste askarel or liquid wastes containing askarel should be disposed of in accordance with one of the procedures given in 3.5.2.1 through 3.5.2.3.

3.5.2.1 Incineration. Present knowledge indicates that proper incineration must involve a suitable balance between dwell time and temperature in the incinerator plus oxygen availability and, finally, suitable scrubbers to remove the HCl that will be formed; for example, 2-second dwell time at 2000°F and 3% excess oxygen in stack gas, or 1.5-second dwell time at 2700°F and 2% excess oxygen in stack gas.

These facilities should meet the applicable requirements of the state in which they are located, and should control effluents within the limits set forth in this standard.

3.5.2.2 Toxic and Hazardous Waste Disposal Sites. Certain landfill sites have been classified by state governments and the federal government as suitable for the disposal of toxic and hazardous liquids. Where such approved sites exist, they may be used for the disposal of liquid wastes described in this standard. (See Appendix A.)

3.5.2.3 Packaging and Shipment

3.5.2.3.1 Transportation to the disposal facility should be in containers that will prevent leakage and accidental loss of askarel to the environment.

3.5.2.3.2 Containers should be labeled as to contents and precautions relative to loss to the environment.

3.5.2.3.3 Containers used for this purpose should not be used for any such materials or retired from service until they are completely cleaned. Any

solvents used in cleaning these containers will be contaminated with askarel and should be disposed of according to the same procedures described in 3.5.2.

3.5.3 Disposal of Solid Wastes. (See 3.5.1 for scrap capacitors.) All solid wastes that have been saturated with askarel should be disposed of by the following procedure:

(1) The saturated wastes should be placed into leakproof containers and transported to a supervised dry landfill site meeting state requirements. Alternatively, they can be disposed of by incineration in state-approved facilities.

(2) Solid absorbents used for spills can be disposed of uncontained in the supervised dry landfill site; transport to the site should be in closed containers. Alternatively, incineration can be used in accordance with 3.5.2. (See Appendix A for a listing of facilities.)

3.6 Labeling. Capacitor units vary greatly in size and in end use or application. Small capacitor units are frequently applied as a component of another piece of equipment, such as a fluorescent lighting ballast, a roadway or area lighting luminaire, a motor, etc. In such applications a label on the capacitor unit referencing approved disposal procedure would not normally be visible when the piece of equipment is disposed of.

For the foregoing reasons the methods of providing disposal instructions for small capacitors and large capacitors are treated separately in 3.6.1 and 3.6.2, respectively.

3.6.1 Small Units. Small capacitors are defined as those that contain askarel in quantities up to about 2 pounds each and in which the free liquid does not exceed 0.4 pound. They are hermetically sealed in metallic cases. Such capacitors are applied as a component of a large piece of equipment. Attaching a label to such equipment referencing this standard or describing disposal procedures would be of limited practical value.

3.6.2 Large Units. Large capacitor units are defined as those that contain more than 2 pounds of askarel. The capacitor manufacturer should affix a label in a conspicuous place, referencing this standard or describing disposal procedures consistent with it. This label should contain, as a minimum, the following information:

CAUTION: This capacitor contains a polychlorinated biphenyl (PCB). To avoid possible environmental contamination, it should be disposed of only in supervised dry landfill areas meeting state requirements or in incineration facilities designed for disposal of PCBs. See American National Standard C107.1-1974 for further information. Copies are available from American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

4. Transformer Guidelines

4.1 General

4.1.1 Types of Transformer Askarels.⁶ Askarels of various compositional types are currently in use (for the general properties and types, see ASTM D 2283-73a [20]). Under arcing conditions, the gases produced, though predominantly consisting of noncombustible hydrogen chloride, can contain varying amounts of combustible gases depending upon the askarel type.

4.1.2 Safety Precautions. Based on about 40 years of safe industrial usage, askarels have been considered as relatively harmless materials to humans. There has been no known instance of human injury when askarels are used under the normally prescribed conditions of precaution and handling.

Although it has been generally thought that exposure to askarels is not hazardous provided that simple precautions are taken, exposure should still be avoided or minimized.

4.1.2.1 Vapors. The odor of askarel is noticeable well below the maximum safe air concentrations. Depending upon the composition of the askarel used, from 0.5 to 1.0 milligram per cubic metre of air has been determined to be the upper safe level of exposure during an 8-hour workday. (See reference [19].) The procedure for performing the necessary analyses is contained in Section B3 of Appendix B. This procedure or its equivalent should be used.

Breathing vapor or fumes from heated askarels should be avoided. High concentrations of vapors can cause irritation of the eyes, nose, throat, and upper respiratory tract. Provisions shall be made for adequate ventilation and regulation of manufacturing operations to avoid open exposure of hot askarels (55°C or higher). The gases produced when askarel is decomposed by very high temperatures (such as that of an electric arc) in the presence of air or organic insulating materials contain a high percentage of hydrogen chloride, and small percentages of other gases. Minute concentrations of this combination of gases are very unpleasant and irritating, thus giving ample warning of their presence. If exposure to high concentrations of askarels or its arced products is necessary under emergency conditions, an approved gas mask of the organic-canister type, or self-contained breathing apparatus, must be worn. Such exposure should be under the surveillance of other personnel capable of effecting rescue in case of accident. If the odor of askarel or its arced products is detected

⁶ The following trademarks are among those employed by electrical manufacturers to designate the askarels used in their products: Asbestol, Chlorexol, Inerteen, No-Flamol, Pyranol, and Saf-T-Kuhl.

by the person wearing protective equipment, he should immediately go into fresh air. All gas masks, respirators, and replacement parts should have U.S. Bureau of Mines approval and be maintained on a regular schedule in accordance with the manufacturer's recommendation.

4.1.2.2 Liquid. In contrast to the situation in which mineral insulating oils are handled, there is no fire hazard in handling askarels. A limited solvent action (similar to that for paint thinner) on the fats and oils of the skin with prolonged contact may lead to drying and chapping of the skin. As with insulating oil, some people are allergic to askarel, and continued exposure may result in skin irritation. Both the liquid and vapor are moderately irritating to eye tissue.

Operating procedures should require avoidance of contact with any askarels. The use of porous gloves that can absorb and retain askarels is to be avoided. Resistant gloves and aprons of the neoprene, polyethylene, or fluoroelastomer⁷ type should be used if contact is unavoidable. In case of spillage on the clothing, the clothing should be removed as soon as practical, the skin washed, and the clothing laundered.

Medicinal washes or mild detergents followed by the application of cold cream will reduce the irritation resulting from the contact of an open cut or abrasion with askarel.

Safety glasses with side shields or a face shield should be worn when handling askarels. Eyes that have been exposed to liquid askarel should be irrigated immediately with large quantities of running water for 15 minutes and then examined by a physician if the irritation persists. (A drop of castor oil has been found to reduce irritation.)

Persons developing a skin irritation or respiratory tract irritation while working with askarels should be placed under the supervision of a physician.

Ingestion or swallowing of askarels is not generally regarded as a problem of the industry. Should accidental ingestion occur, a physician should be consulted. Hands should be washed with warm water and soap before eating, drinking, smoking, or using toilet facilities.

4.1.3 Transport Container Marking. Any container, such as tank cars, tank trucks, drums, cans, etc, used to transport transformer askarels, new or used, should be labeled with the following:

CAUTION: This product contains polychlorinated biphenyls (PCBs). Care should be taken to prevent entry into the environment through spills, leakage, use, vaporization, or disposal of liquid or containers. Avoid prolonged breathing of vapors or mists. Avoid contact with eyes or prolonged contact with skin. If skin con-

tact occurs, remove by washing with soap and water. Following eye contact, flush with water. In case of spillage onto clothing, the clothing should be removed as soon as practical, skin washed, and clothing laundered.

4.1.4 Receiving, Handling, and Storage of Askarels. Askarels are shipped in tank cars, tank trucks, steel drums, metal cans, and test-sample containers. When received, all containers should be inspected for leaks.

4.1.4.1 Storage Tanks. Storage tanks should be erected so that inspection can be made for leaks or spills. Construction should be such that inadvertent leakage or spills are prevented from reaching streams and sanitary or storm sewers.

4.1.4.2 Tank Cars and Tank Trucks. All bulk shipment equipment should be inspected for leaks immediately upon receipt. Drain pans must be provided to prevent spillage from unloading hoses and connections. Askarel liquid collected in drain pans should be placed in drums labeled "SCRAP ASKAREL" for disposition.

4.1.4.3 Steel Drums, Cans, and Test-Sample Containers. On delivery, all such shipments should be carefully inspected for leaks. The containers should be stored indoors in an area especially selected for this purpose. A curb should enclose the area to provide a basin for containing the askarel from one or more containers should the containers be damaged. The area must not have a drain that is connected to a sanitary or storm sewer.

If an indoor storage area is not possible, the containers should be stored under a lean-to.

4.1.5 Control of Water Effluents. The industry goal is to eliminate askarel in plant water effluent streams. However, it is recognized that existing drain systems from manufacturing plants, repair shops, and installation sites may be contaminated as a result of past practices. Other sections of this standard provide that no askarel wastes of any kind be disposed of in any water effluent streams and that accidental spills be prevented from getting into such streams.

4.1.5.1 Concentration Limits. The 1972 Environmental Protection Agency proposals are to keep PCB levels in rivers and lakes below 0.01 part per billion. This is currently under review by the EPA and standards are expected to be promulgated in 1974. Plant effluent streams should be managed and controlled in a manner anticipating these government standards.

4.1.5.2 Monitoring Streams. All plant effluent streams should be monitored on a regular basis, consistent with plant situations. The procedure for performing the necessary analyses is contained in Section B4 of Appendix B. This procedure or its equivalent should be used.

⁷ For example, Viton.

4.1.5.3 Methods for Minimizing Effluent Stream Contamination. The ideal approach is to isolate totally all effluent streams that could be contaminated with askarels during manufacturing processes and prevent them from being discharged from the plant.

4.1.6 Disposal Procedures and Services

4.1.6.1 Sources of Materials Requiring Special Handling and Disposal Procedures. Liquids containing PCBs and solids containing or contaminated with PCBs may be obtained from any of the following sources: transport containers, transformer manufacturing processes, in-test failures, liquids contaminated beyond reclamation, in-service transformer leaks and failures, askarel-filled transformers scrapped for any reason, etc.

4.1.6.2 Classification for Disposal of Materials Containing PCBs. In general, there are three types of materials requiring disposal: liquids, burnable solid materials containing PCBs, and nonburnable solid materials contaminated with PCBs.

4.1.6.2.1 Liquids. Liquids containing PCBs requiring disposal by high-temperature incineration may consist of the following:

- (1) PCBs contaminated with mineral oil.
- (2) Mineral oil contaminated with PCBs.

(3) Nonreclaimable contaminated transformer askarels, arced askarels, askarels from manufacturing spills, and sump accumulation, etc, rich in PCBs, and askarels from holding basins, drip and drain pans, washings, sample jars and containers, etc.

4.1.6.2.2 Burnable Solid Waste Materials Containing PCBs. These materials can be disposed of by high-temperature incineration and consist of cellulosic materials, rags, pressboard, wood, sawdust, fuller's earth in bulk or in cloth bags, blotter papers, nitrile or cork gaskets, etc.

4.1.6.2.3 Nonburnable Solid Waste Materials Containing, or Contaminated with, PCBs. These materials may consist of coil structures, steel, copper, aluminum filter units of the steel mesh construction type, askarel drums, cans, etc.

Materials of this nature should be allowed to drain with the liquid collected in drip pans, etc. Further removal of adhering PCBs can be accomplished by washing or solvent extraction with kerosene or other approved washing liquids such as perchloroethylene or trichloroethylene. Accumulated liquids can be disposed of as indicated in 4.1.6.2.1. Solid materials may be handled as normal scrap.

4.1.6.3 Shipment of Scrap Liquids for Disposal. All liquid scrap material should be placed in appropriate metal transport drums, properly labeled, for shipment to a company offering an acceptable disposal service.

4.1.6.4 Shipment of Burnable Solid Waste Material Containing PCBs for Disposal. Material of this type

should be placed in open-head drums with suitable closures and with the drum properly labeled for shipment to a company offering an acceptable disposal service.

4.1.6.5 Liquid and Solid Waste Disposal Service Organizations

4.1.6.5.1 General. Disposal of askarels and askarel-soaked materials should be accomplished by means in which there is no significant release of askarel to the environment. At present, disposal is accomplished by carefully controlled incineration of liquids and soaked software, and by controlled landfill burial of apparatus and other hardware from which askarel has been previously drained and washed.

Present knowledge indicates that proper incineration must involve a suitable balance between dwell time and temperature in the incineration plus oxygen availability and, finally, suitable scrubbers to remove the HCl that will be formed; for example, 2-second dwell time at 2000°F and 3% excess oxygen in stack gas, or 1.5-second dwell time at 2700°F and 2% oxygen in stack gas.

These facilities should meet the applicable requirements of the state in which they are located and should control effluents within the limits set forth in this standard.

Controlled landfill or deep-well disposal can be used where permitted by federal, state, and local regulations.

4.1.6.5.2 Costs. In addition to the normal costs of collecting scrap liquids and solids for disposal, additional costs borne by the owner of such scrap include shipping containers, cost of transport to the disposal service organization, and a disposal fee usually based upon a per-gallon or per-pound charge.

4.1.6.5.3 Disposal Services. Organizations offering disposal services are listed in Appendix A, including their location, facilities available, types of material handled, and disposal procedures used. Specific shipping directions, disposal procedures, and costs should be obtained from the organization.

4.2 Specific Guidelines

4.2.1 Plant Housekeeping. It is necessary to assume that in filling equipment with askarel, and during further handling of this equipment, an askarel spill may occur. Therefore, it is necessary to provide facilities and a procedure for cleanup to prevent contamination.

4.2.1.1 Askarel Filling Area

4.2.1.1.1 The location of the askarel filling area should be adjacent to the test area and final shipping area to minimize the danger of damage of units during handling.

4.2.1.1.2 The main manufacturing area for filling equipment with askarel should be provided with impervious surface floors or suitable basins so con-

structed that any inadvertent leakage or spills are prevented from reaching streams, sanitary sewers, or storm sewers. All askarel-handling equipment, such as pumps, hoses, etc., shall be of the askarel-resistant type.

4.2.1.1.3 Drip pans shall be provided for hose connections and filling valves.

4.2.1.2 Special Containers for Scrap Materials

4.2.1.2.1 Drums labeled "SCRAP ASKAREL" should be available for handling all spilled and waste askarel from sumps, failed units, drip pans, sample jars, etc.

4.2.1.2.2 Open-head drums with suitable closures and labeled "SCRAP BURNABLE ASKAREL WASTE" should be available for handling contaminated cellulose insulation, rags, paper pressboard, wood, gas-kets, sawdust, etc.

4.2.1.2.3 Separate containers for handling steel, copper, and aluminum, each adequately marked, shall be provided for the components of contaminated core and coil assemblies. These containers are required for the various materials when repairing or scrapping assemblies.

4.2.1.2.4 Containers for supplies of material for absorbing small askarel spills or cleanup of larger spills should be provided.

4.2.1.3 Conditioning of Askarels

4.2.1.3.1 Askarel Conditioning Equipment.

The conditioning unit should be located either in the storage tank area or in the main transformer manufacturing area for filling with askarel.

4.2.1.3.2 Fuller's Earth. Conditioning of new askarel or recycled askarel requires fuller's earth treatment. The spent fuller's earth in cartridges or bags, when replaced, should be allowed to drain thoroughly over drip pans to remove as much liquid askarel as possible. The cartridge units of steel mesh construction should be placed in the "STEEL CONTAMINATED WITH ASKAREL" container for disposition. Cloth bags filled with fuller's earth should be placed in the "SCRAP BURNABLE ASKAREL WASTE" container for disposition.

4.2.1.4 Teardown of Units for Repair or Scrap

4.2.1.4.1 Drain all askarel from the unit either into a holding tank for reuse or into the drum labeled "SCRAP ASKAREL" for disposition, and then allow sufficient time for all of the askarel to drain from the core and coils.

4.2.1.4.2 Remove the core and coil assembly from the transformer. Sufficient absorbent material should be placed on the floor to absorb any askarel fluid that still drips from the transformer.

4.2.1.4.3 Place all materials in the appropriate salvage containers during the dismantling for later disposition.

4.2.1.4.4 All used materials, including rags, sawdust, tape, etc., regardless of quantity, shall be put into the appropriate containers for disposition.

4.2.2 Transformer Labeling

4.2.2.1 New Transformers. All new transformers that contain PCBs shall have a label of adequate durability, permanently and prominently attached to the tank by the manufacturer, giving adequate warning and instructions. A suggested label includes the following:

CAUTION: The insulating liquid in this transformer contains polychlorinated biphenyls (PCBs). Care should be taken to prevent entry into the environment. In case of malfunction or leaks, consult the instruction manual or the manufacturer.

4.2.2.2 In-Service Transformers. The transformer manufacturer should make available suitable labels with a similar warning as shown in 4.2.2.1 for use on existing transformers.

4.2.3 Information for Transformer Users

4.2.3.1 General. Askarel-filled transformers are delivered to customers as sealed units from which there is no escape of askarel under normal operation. Although certain types of equipment failures can permit loss of some askarel to the environment, such cases are extremely rare.

4.2.3.2 Transportation and Receiving. Immediately upon receipt of the equipment and following any transportation or handling accident that could affect the integrity of the tank, bushings, or radiators, the transportation vehicle, tank, and fittings should be examined for any leakage or spillage that may have occurred in shipping. If leakage is evident, the cause should be corrected and the spillage soaked up with absorbent materials such as sawdust, followed by a cleanup of the affected area with rags soaked with kerosene or other approved solvent such as perchloroethylene or trichloroethylene. All materials used should be collected for proper disposition as described in 4.1.6.

4.2.3.3 Installation and Periodic Inspection. Following installation, the unit should again be inspected for any damage or leakage. It is recommended that periodic in-service inspections be made for any leaks.

4.2.3.4 Filling, Filtering, or Drying Askarel.

Most askarel units are shipped with the proper amount of askarel, but if it becomes necessary to top off a unit, the manufacturer's instructions should be followed.

If it is necessary to dry an askarel unit or to treat an askarel unit with fuller's earth, instructions should be followed. When filtering or conditioning askarel, all of the precautions previously described for drip pans, proper disposal of filter media, etc., apply.

4.2.3.5 Sampling. It is common practice to sample askarel from a transformer for periodic maintenance testing. As previously described, such samples should be

taken in a manner to avoid any contamination of the environment. Washings should be collected for proper disposal. Field and laboratory test samples, washings, etc. should also be collected for proper disposal.

4.2.3.6 **Transformer Disposal.** The ultimate disposal of an askarel-filled transformer may be accomplished in either of two ways:

(1) Complete drainage and dismantling with the proper disposal of the askarel and askarel-soaked components as described in 4.1.6.

(2) Disposition of askarel transformers by means of junk or scrap dealers. This should be avoided unless a transformer is first drained, followed by soaking the interior with a suitable solvent. Accumulated liquids and washings are to be disposed of as described in 4.1.6.

5. References

5.1 References to the Text

[1] Standard Method of Test for Rapid Gas Chromatographic Estimation of Higher Boiling Homologues of Chlorinated Biphenyls for Capacitor Askarels, ASTM D 3303-74

[2] American National Standard Method of Test for Specific Gravity of Askarels, C59.68-1965 (R1973) (ASTM D 1810-63 (1973))

[3] American National Standard Method of Test for Neutralization Number by Color-Indicator Titration, Z11.131-1964 (R1974) (ASTM D 974-64 (1973), IP 139/65)

[4] American National Standard Method of Test for Neutralization Number by Potentiometric Titration, Z11.59-1958 (R1971) (ASTM D 664-58 (1968), IP 177/64)

[5] Standard Method of Test for Density of Rubber Chemicals, ASTM D 1817-66 (1972)

[6] American National Standard Method of Test for Inorganic Chlorides in Askarels, C59.55-1963 (R1973) (ASTM D 1821-63 (1973))

[7] American National Standard Method of Test for Pour Point of Petroleum Oils, Z11.5-1966 (R1972) (ASTM D 97-66 (1971), IP 15/67)

[8] American National Standard Method of Test for Power Factor and Dielectric Constant of Electrical Insulating Liquids, C59.22-1967 (R1973) (ASTM D 924-65 (1973))

[9] American National Standard Method of Test for

Specific Resistance (Resistivity) of Electrical Insulating Liquids, C59.51-1965 (R1973) (ASTM D 1169-64 (1973))

[10] American National Standard Method of Test for Hydrolyzable Chlorine Compounds in Chlorinated Aromatic Hydrocarbons (Askarels), C59.106-1970 (ASTM D 1820-65 (1971))

[11] American National Standard Method of Test for Thermal Stability of Chlorinated Aromatic Hydrocarbons (Askarels), C59.111-1970 (ASTM D 1936-64 (1971))

[12] American National Standard Method of Test for Distillation of Road Tars, A37.9-1974 (ASTM D20-72)

[13] American National Standard Methods of Testing Electrical Insulating Oils, C59.2-1974 (ASTM D 117-71 (1973))

[14] American National Standard Method of Test for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes, C59.19-1968 (R1973) (ASTM D 877-67 (1971))

[15] American National Standard Method of Test for Flash and Fire Points by Cleveland Open Cup, Z11.6-1973 (ASTM D 92-72, IP 36/67)

[16] American National Standard Method of Test for Saybolt Viscosity, Z11.2-1956 (R1971) (ASTM D 88-56 (1973))

[17] American National Standard Method of Test for Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels, C59.57-1963 (R1973) (ASTM D 1903-63 (1973))

[18] MUNCH, R. H. Measuring the dissipation factor, dielectric constant, and resistivity of liquids. *Insulation/Circuits*, vol 16, Mar 1970, pp 46-49.

[19] Chlorodiphenyls. *Hygienic Guide Series*. Westmont, N.J.: American Industrial Hygiene Association, Jan-Feb 1965.

[20] Standard Specification for Chlorinated Aromatic Hydrocarbons (Askarels) for Transformers, ASTM D 2283-73a

5.2 General References

Aroclor® Polychlorinated Polyphenyls (Biphenyls), Technical Bulletin O-FF/1R. St. Louis: Monsanto Industrial Chemicals Company, Nov 1971.

DRINKER, C. K. Further observations on the possible systemic toxicity of certain of the chlorinated hydrocarbons. *Journal of Industrial Hygiene and Toxicology*, vol 21, 1939, pp 155-159.

DRINKER, C. K.; WARREN, M. F.; and BENNET, G. A. The problem of possible systemic effects from certain chlorinated hydrocarbons. *Journal of Industrial Hygiene and Toxicology*, vol 19, 1937, pp 283-311.

ELKINS, H. B. *The Chemistry of Industrial Toxicology*. New York: John Wiley & Sons, Inc, 1959.

GREENBURG, L.; MAYERS, M. R.; and SMITH, A. R. The systemic effects resulting from exposure to certain chlorinated hydrocarbons. *Journal of Industrial Hygiene and Toxicology*, vol 21, 1939, pp 29-38.

Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment. Cincinnati: American Conference of Governmental Industrial

Hygienists, 1973.

TREON, J. F.; CLEVELAND, F. P.; CAPPEL, J.; and ATCHLEY, R. W. The toxicity of the vapors of Aroclor 1242 and Aroclor 1254. *American Industrial Hygiene Association Quarterly*, vol 17, 1956, pp 204-213.

6. Revision of American National Standards Referred to in This Document

When the American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, Inc, the revision shall apply.

Appendixes

(These Appendixes are not a part of American National Standard Guidelines for Handling and Disposal of Capacitor- and Transformer-Grade Askarels Containing Polychlorinated Biphenyls, C107.1-1974, but are included for information purposes only.)

Appendix A

Disposal Services

In addition to the supervised dry landfill sites that may be used for the disposal of askarel-containing scrap, the following additional known facilities and services have been established, and others may be available.*

Chem-Trol Pollution Services, Inc
P.O. Box 200
1550 Balmer Road
Model City, N.Y. 14107
Phone: 716 754-8231

This organization has facilities and services capable of handling:

- (1) Liquids. Askarels alone or mixed with solvents or oils. Disposal by high-temperature incineration.
- (2) Solids (software). Askarel-soaked compounds, rags cartons, absorbing earths, etc. Disposal by incineration or scientific landfill.
- (3) Solids (hardware). Capacitors, transformer tanks, cores, askarel-soaked metals. Disposal by scientific landfill. Has solvent extraction capability.

Monsanto Company
800 North Lindbergh Boulevard
St. Louis, Mo 63166
Phone: 314 694-3352

This organization has facilities and services capable of handling askarel liquids alone or mixed with other oils or solvents by high-temperature incineration. Liquid is pumped through a gun with atomizing steam into incinerator. Temperatures are maintained at 2000°F-2500°F with auxiliary natural gas. Exit gases are quenched to 180°F by contact with water. Gas is then passed through a high-energy venturi scrubber for removal of particulates. Before exhausting to air (110°F),

*The listing given herein is representative of some of the sources that provide this service, and is not presumed to be complete. Any other organizations that wish to be listed should notify the Standards Institute so that they may be included in the next edition of this standard.

gases are passed through a packed column scrubber to remove HCl.

Nuclear Engineering Company
Eastern Division
P.O. Box 146
Morehead, Ky 40351
Phone: 606 784-6611

Nuclear Engineering Company
Disposal Division
Sheffield, Ill. 61361
Phone: 815 454-2624

This organization provides containerization, transportation, and disposal services of all liquids and solids (including hardware). Disposal is in controlled chemical and scientific landfill area. Licensed by Atomic Energy Commission for radioactive waste disposal. The organization also has two West Coast locations, in the states of California and Washington.

Rollins Environmental Services, Inc
P.O. Box 2349
Wilmington, Del 19899
Phone: 302 658-8451

This organization has facilities and services capable of handling:

- (1) Liquids. Askarel alone or mixed with solvents or oils. Disposal is by high-temperature incineration.
- (2) Solids (software). Askarel-soaked compounds, rags, cartons, absorbing earths, etc. Disposal is by incineration at combustion temperatures up to 2500°F. Incineration gases are scrubbed, and entrained solids are removed before exhausting to air.

Rollins Environmental Services maintains disposal facilities in the following areas:

Philadelphia/Camden:
Rollins Environmental Services, Inc
Route 322
Logan Township
Bridgeport, N.J. 08014

APPENDIX

Baton Rouge:

Rollins Environmental Services, Inc
Scenic Highway & West Cheatham Lane
Scotlandville
East Baton Rouge Parish, La 70807

Houston:

Rollins Environmental Services, Inc
Tidal Road & Highway 134
Deer Park, Tex 77536

Appendix B

Analytical Procedures and Laboratory Service Organizations

B1. General

Analytical procedures for determining PCBs in air, water, and sediments are given in Sections B3 and B4.

B2. Laboratories

The following laboratories are representative of those offering services for PCB analyses:^a

Carus Chemical Corporation
1375 Eighth Street
La Salle, Ill. 61301
Phone: 815 223-1500

Limnetics, Inc. (Subsidiary of Carus Corporation)
6132 West Fond du Lac Avenue
Milwaukee, Wis 53218
Phone: 414 461-9500

Gollob Analytical Service Corporation
47 Industrial Road
Berkeley Heights, N.J. 07922
Phone: 201 464-3331

B3. An Analytical Procedure for the Determination of Airborne PCBs

B3.1 Scope. This procedure is based on techniques used by the Monsanto Industrial Chemical Company

^a The listing given herein is representative of some of the sources that provide this service, and is not presumed to be complete. Any other organizations that wish to be listed should notify the Standards Institute so that they may be included in the next edition of this standard.

for the isolation and determination of PCBs in water, soil/sediment, and biological materials. Absolute confirmation of PCB structures is not obtained with this method. Where needed, additional structure proof should be obtained using techniques such as mass spectrometry for further identification of gas chromatography fractions.

B3.2 Principle. Airborne PCBs are absorbed in toluene by drawing the air through one or more fritted bubblers or impingers in cylinders filled with toluene. After a suitable amount of air is sampled, the scrubbing solvent is diluted or concentrated, and interfering components, if present, are removed by chemical treatment and column absorption chromatography. The amount and type of PCBs present are determined by electron capture gas chromatography (EC/GC).

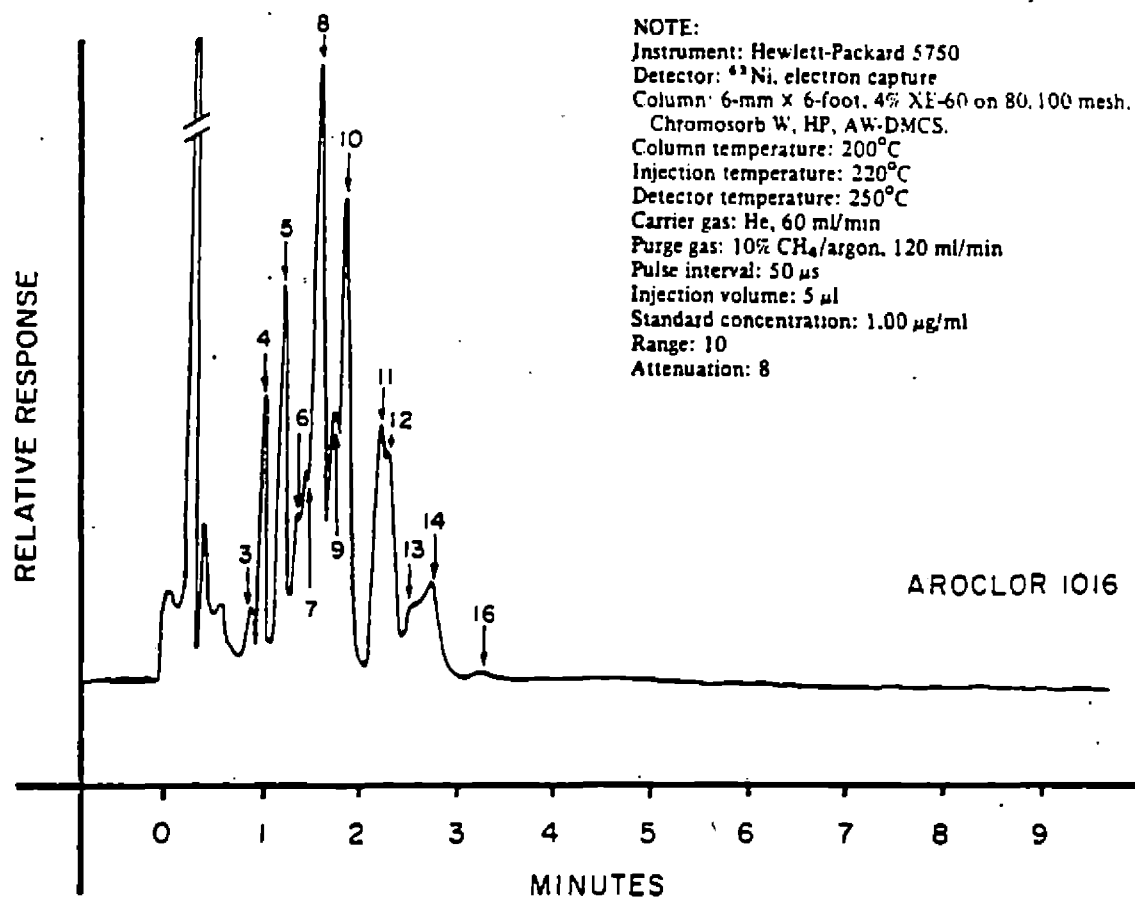
B3.3 Reagents

- (1) Hexane: Pesticide grade.
- (2) Toluene: Pesticide grade.
- (3) Sodium sulfate: Anhydrous, granular, analytical reagent (AR) grade. Heat at 400°C for 1 hour prior to use.

(4) Alumina adsorption: For chromatographic analysis, 80/200 mesh. Heat at 400°C for a minimum period of 4 hours and deactivate with 5% (w/w) distilled water.

For alumina column preparation fill a chromatographic column with hexane up to the point where the reservoir joins the column, and push a glass wool plug to the bottom with a glass rod. In a 50-ml beaker measure 35 ml (about 30 grams) of deactivated alumina, and pour this slowly into the column. Tap or vibrate the column to settle the alumina, and top the alumina with 2 to 3 cm of anhydrous sodium sulfate. Wash the column with 50 to 100 ml of hexane prior to the addition of the sample.

- (5) Distilled water: Extracted with hexane to re-



NOTE:

Instrument: Hewlett-Packard 5750

Detector: ^{63}Ni , electron captureColumn: 6-mm $\times$ 6-foot, 4% XE-60 on 80, 100 mesh.

Chromosorb W, HP, AW-DMCS.

Column temperature: 200°C

Injection temperature: 220°C

Detector temperature: 250°C

Carrier gas: He, 60 ml/min

Purge gas: 10% CH_4 /argon, 120 ml/minPulse interval: 50 μs Injection volume: 5 μl Standard concentration: 1.00 $\mu\text{g/ml}$

Range: 10

Attenuation: 8

Fig. B1
Aroclor 1016 Electron Capture Chromatogram

move hexane-soluble electron capturing impurities.

(6) Sulfuric acid: AR grade, specific gravity = 1.84.

(7) Potassium hydroxide: AR grade.

(8) Ethanol: Formula 2B.

(9) Alcoholic potassium hydroxide, 2.5% (w/v): Dissolve about 12.5 grams of AR grade KOH in 500 ml of ethanol.

(10) Sulfuric acid-water, 9:1 (v/v): Carefully add 270 ml of AR grade sulfuric acid to 30 ml of distilled water in a 500-ml iced beaker.

(11) PCB standards: Aroclor 1016, 1221, 1242, 1248, 1254, and 1260. (See Fig. B1 through B7.)

B3.4 Apparatus

(1) Gas scrubbing bottles, high form, ground-glass joint, fritted coarse disks.

(2) Separatory funnels equipped with ground-glass stoppers and TFE-fluorocarbon stopcocks, capacities of 125, 250, 500, 1000, and 2000 ml.

(3) Kunderman-Danish evaporative concentrators,

500-ml capacity, equipped with three-ball Snyder columns and graduated 5-ml capacity vials.

(4) Chromatographic columns, glass, 10 inches $\times$ 20 mm (OD), with a 5-inch $\times$ 50-mm (OD) reservoir at the top, equipped with TFE-fluorocarbon stopcocks.

(5) Flat-bottomed boiling flasks, 125 ml capacity.

(6) Liebig condenser, 200 mm in length.

(7) Hot plates.

(8) Water bath.

(9) 10- μl syringes.

(10) Dry-test meter or wet-test gas meter.

(11) Laboratory vacuum pump.

(12) Rotating vacuum evaporator.

(13) Usual laboratory glassware.

B3.5 Sampling. The air to be sampled for airborne PCBs is drawn through a gas scrubber (or scrubbers) and a dry-test meter using a laboratory vacuum pump. See Fig. B8. The sampling flow rate is controlled by bleeding in air via a needle valve located between the

APPENDIX

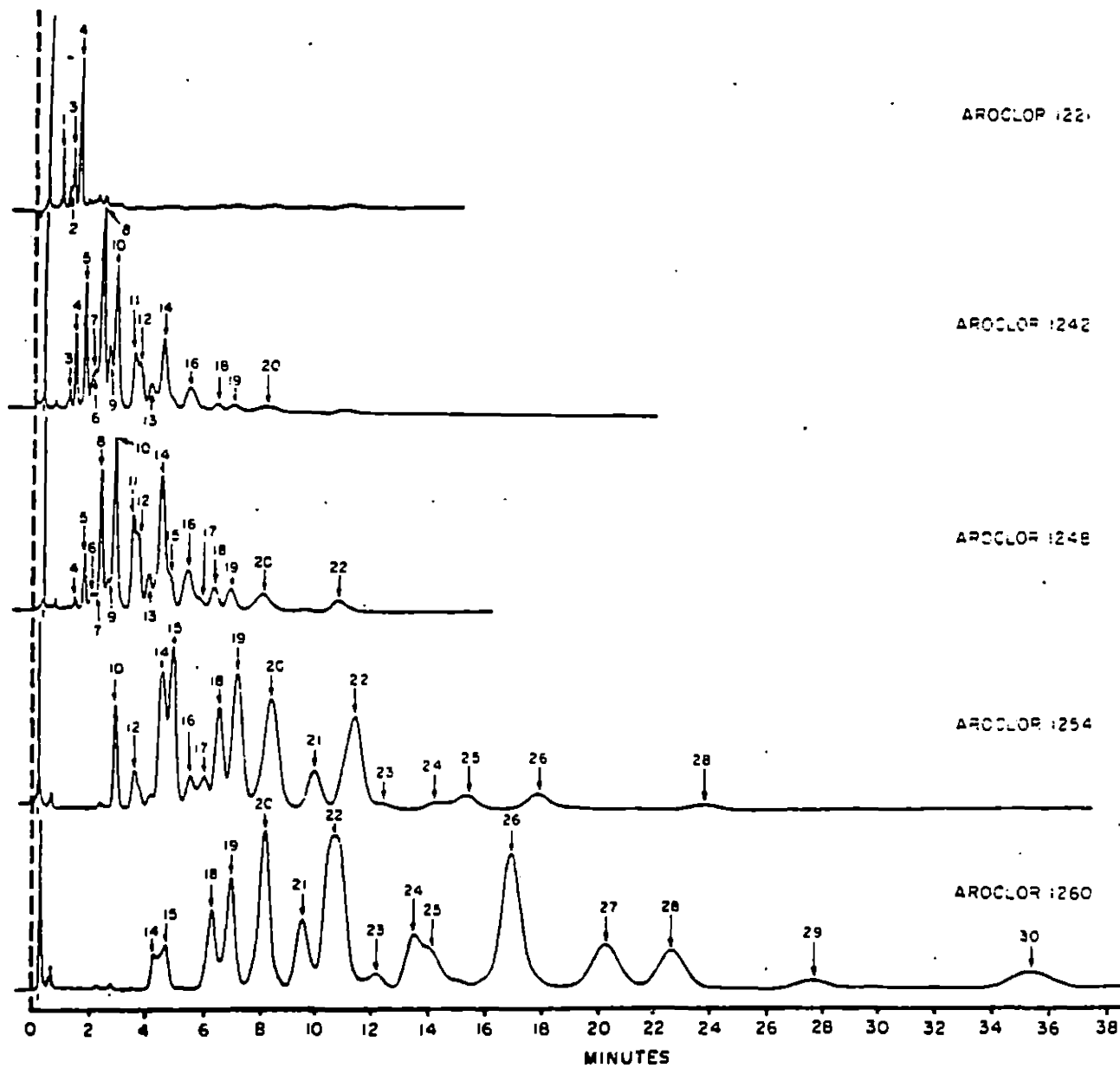


Fig. B2
Comparison of Electron Capture Chromatograms for
Aroclor 1221, 1242, 1248, 1254, and 1260

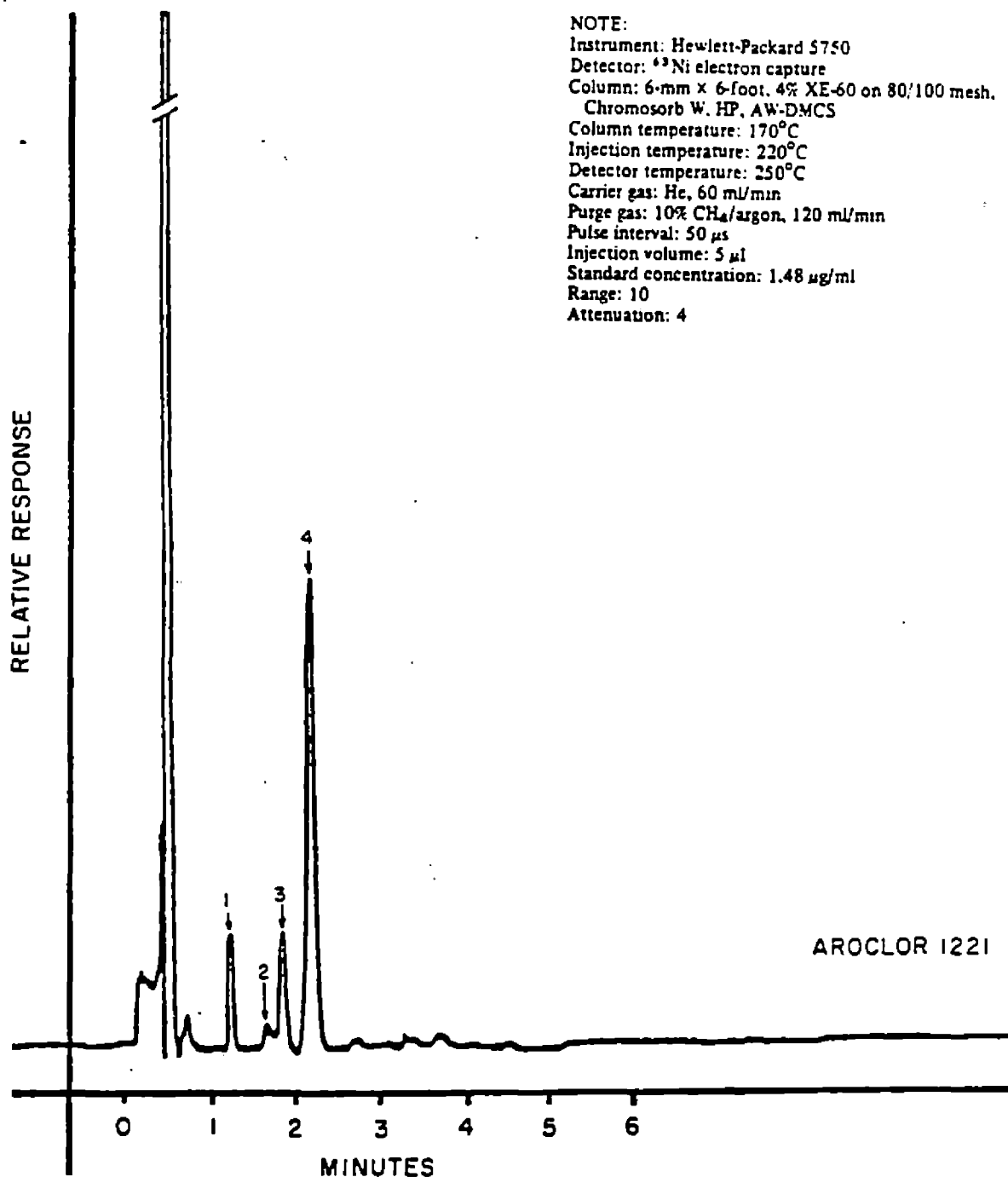


Fig. B3
Aroclor 1221 Electron Capture Chromatogram

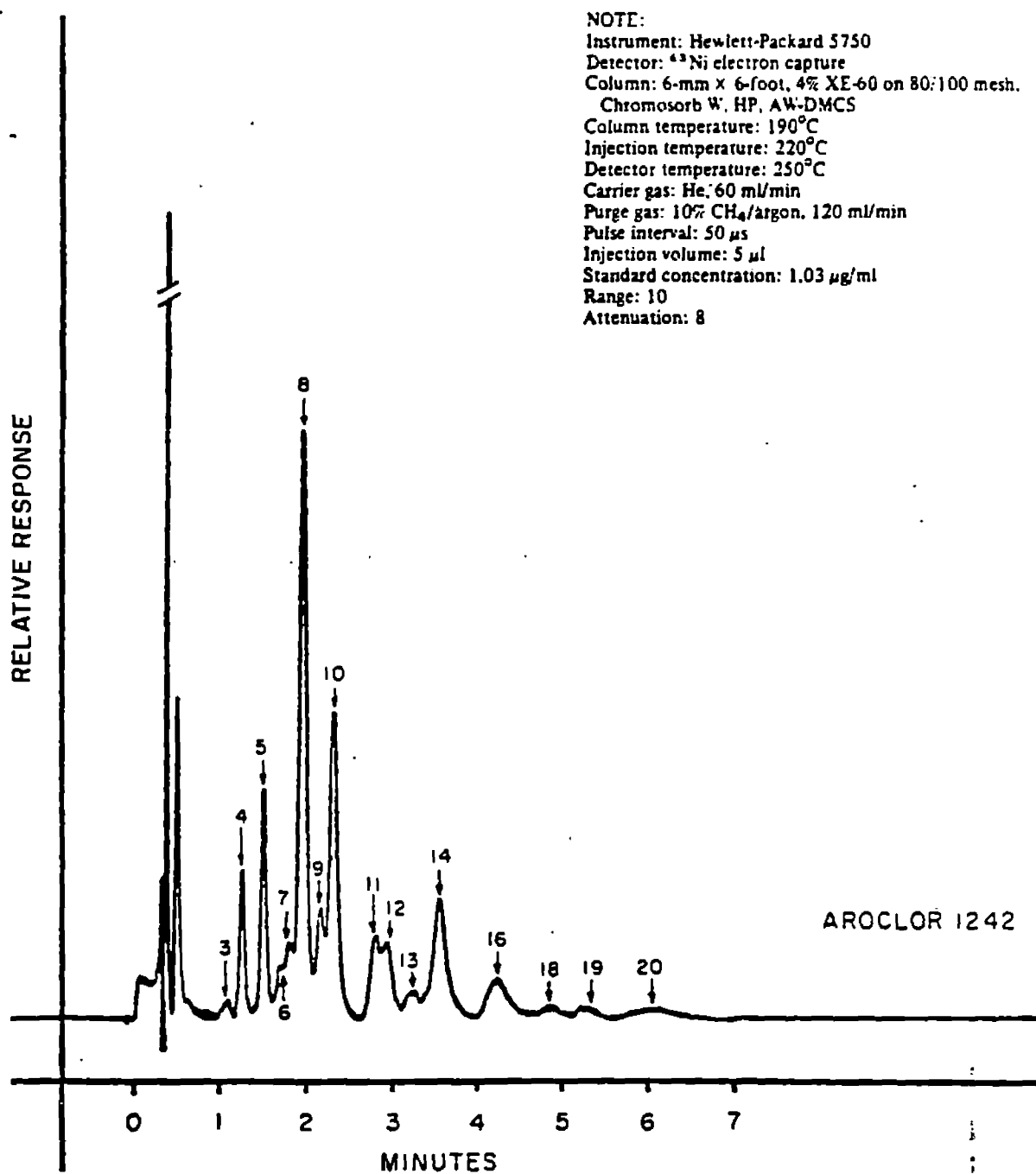


Fig. B4
Aroclor 1242 Electron Capture Chromatogram

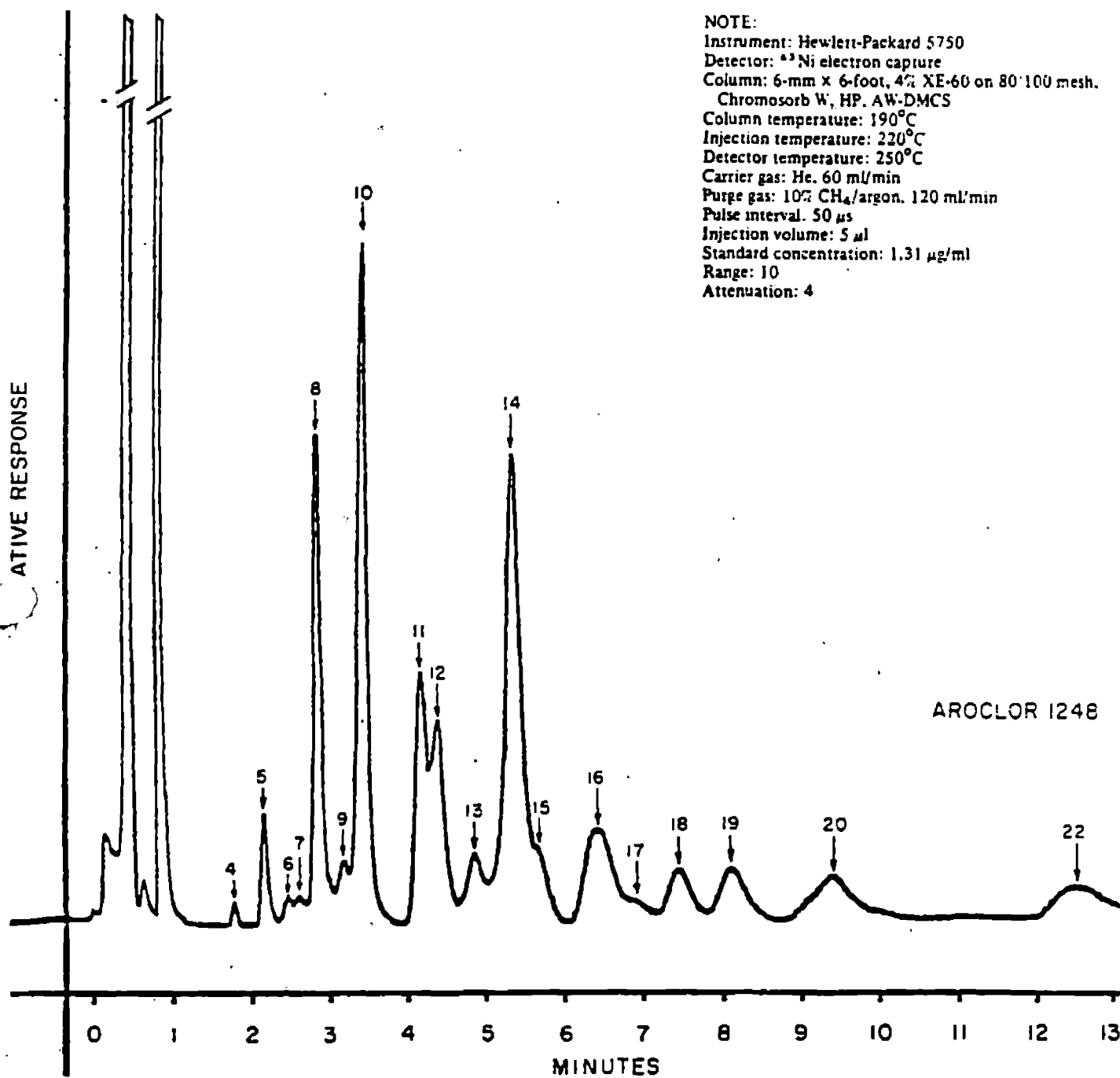


Fig. B5
Aroclor 1248 Electron Capture Chromatogram

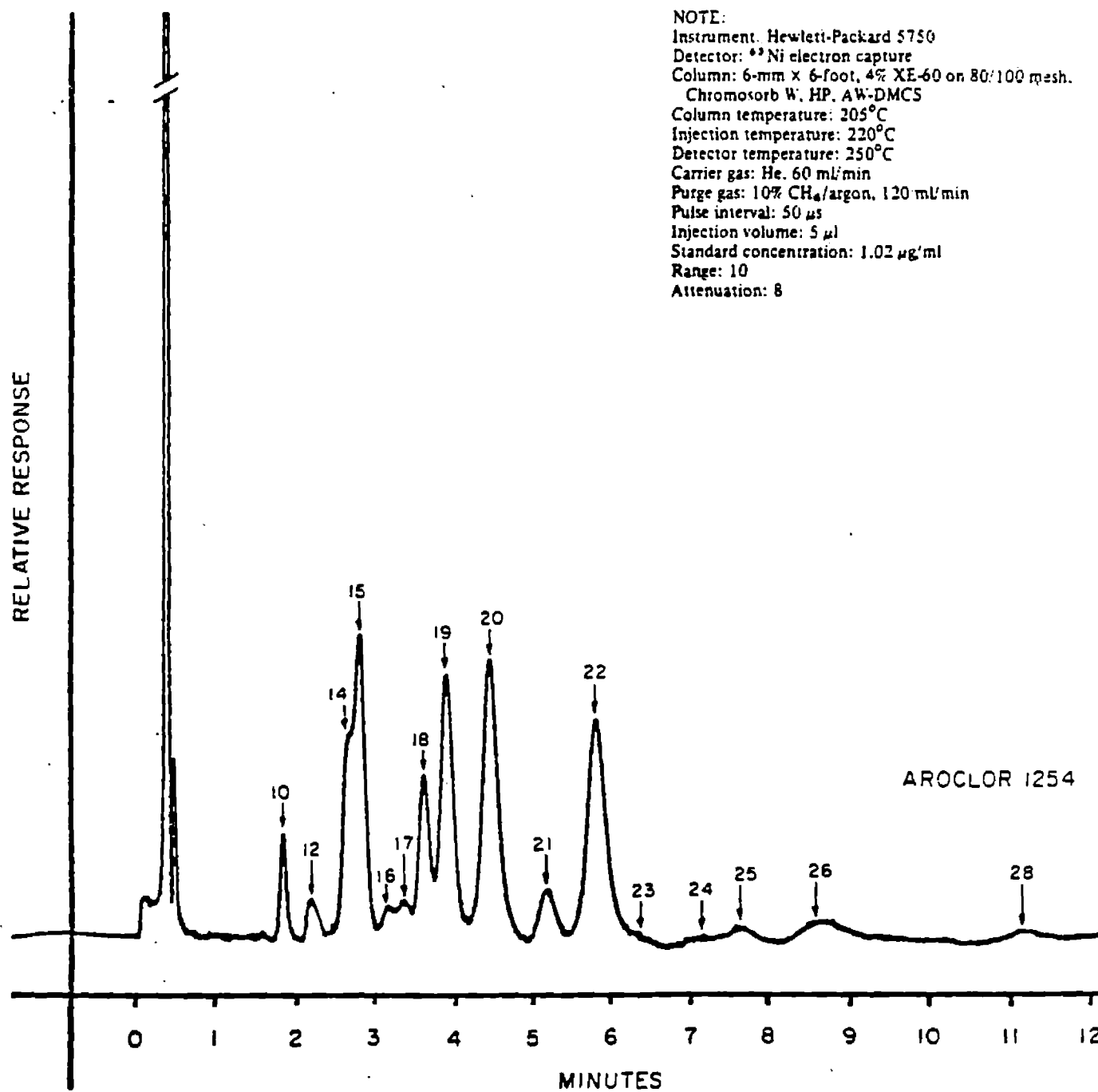


Fig. B6
Aroclor 1254 Electron Capture Chromatogram

NOTE:

Instrument: Hewlett-Packard 5750
Detector: ^{63}Ni electron capture
Column: 6-mm x 6-foot, 4% XE-60 on 80/100 mesh,
Chromosorb W, HP, AW-DMCS
Column temperature: 220°C
Injection temperature: 220°C
Detector temperature: 250°C
Carrier gas: He, 60 ml/min
Purge gas: 10% CH_4 /argon, 120 ml/min
Pulse interval: 50 μs
Injection volume: 5 μl
Standard concentration: 0.98 $\mu\text{g/ml}$
Range: 10
Attenuation: 8

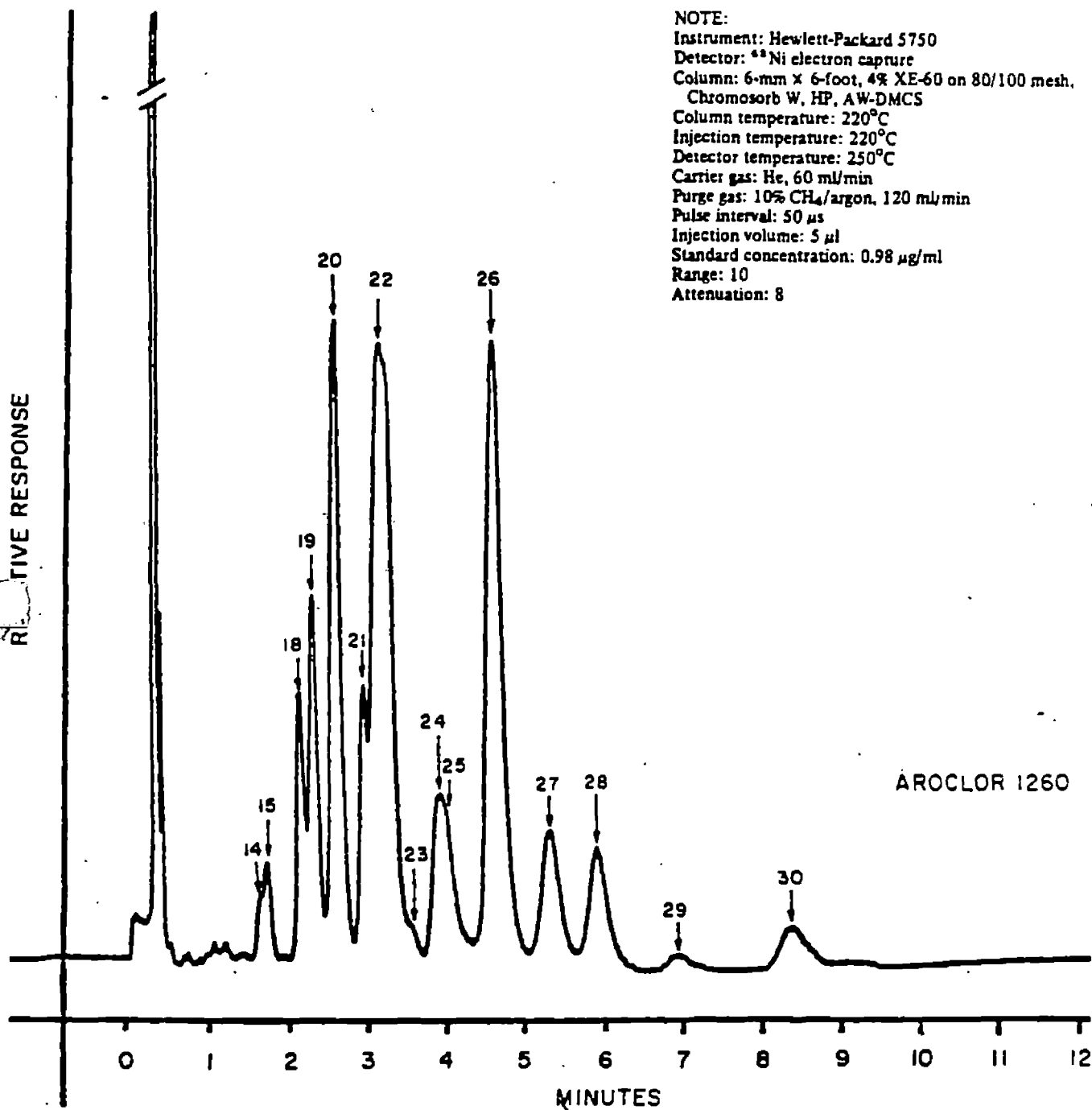


Fig. B7
Aroclor 1260 Electron Capture Chromatogram

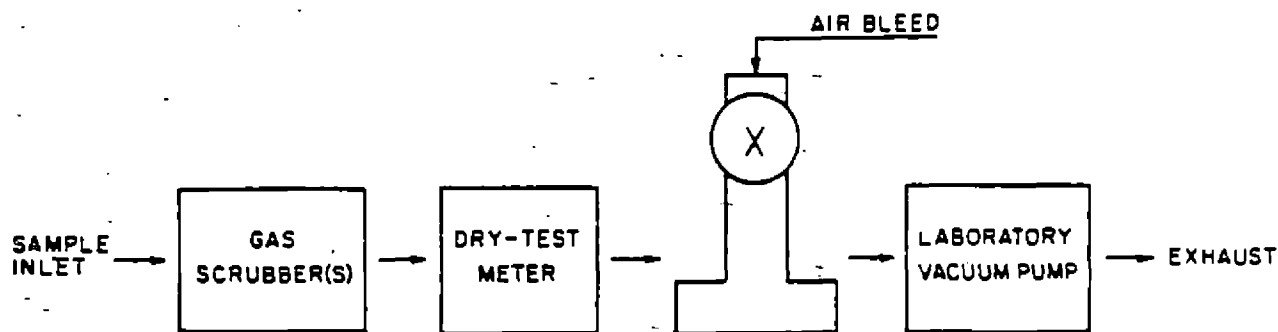


Fig. B8
Sampling Train

pump and the meter. At the end of the sampling period, the metered gas volumes are corrected for temperature and pressure to cubic metres at 25°C and 760 mmHg.

It is important to note that neither the capacity nor the efficiency of the gas scrubber(s) for removal of airborne PCBs have been experimentally evaluated. For this reason, it is best to minimize the sampling flow rate and maximize the sampling time period to obtain measurable amounts of PCBs. When high flow rates must be employed or a larger capacity may be needed, it is recommended that several gas scrubbers be used in tandem.

It is cautioned that until the efficiency and capacity of the toluene gas scrubber have been experimentally established, this procedure should be used only to measure relative PCB levels sampled under equivalent conditions.

B3.6 Procedure

(1) After scrubbing the desired amount of air, record the metered volume, pressure, and temperature.

(2) Quantitatively transfer the scrubbing solvent to a round-bottomed flask and reduce the volume to approximately 2 ml by rotary vacuum evaporation.

(3) Quantitatively transfer the concentrate to a 30-ml beaker with the aid of several small portions of toluene.

(4) Inject a fraction of a microlitre of the concentrate into the gas chromatograph to check for interferences and determine the approximate level of PCBs present. If no interferences are present, dilute or concentrate the sample to a known volume, as determined by the electron capture chromatogram, and proceed with the gas chromatographic analysis.

(5) If interferences are present, proceed with the chemical treatment and column chromatographic cleanup procedures.

(6) Transfer the concentrate to a 125-ml extraction

flask with the aid of several small portions of solvent.

(7) Evaporate the concentrate just to dryness with a gentle stream of dry, filtered air and add 25 ml of 2.5% alcoholic potassium hydroxide.

(8) Add a boiling chip, put a water condenser in place, and allow the solution to reflux for 45 minutes.

(9) After cooling, transfer the solution to a 250-ml separatory funnel with the aid of 25 ml of distilled water.

(10) Rinse the extraction flask with 25 ml of hexane and add it to the separatory funnel.

(11) Stopper the separatory funnel and shake vigorously for at least 1 minute. Allow the layers to separate, and transfer the lower aqueous phase to a second separatory funnel.

(12) Extract the saponification solution with a second 25-ml portion of hexane. After the layers have separated, add the first hexane extract to the second separatory funnel, and transfer the aqueous alcohol layer to the original separatory funnel.

(13) Repeat the extraction with a third 25-ml portion of hexane. Discard the saponification solution and combine the hexane extracts.

(14) Carefully add 25 ml of the sulfuric acid solution (9:1 concentrated sulfuric acid-water) to the hexane extracts.

(15) Stopper the separatory funnel and shake vigorously for at least 1 minute. Allow the layers to separate, and discard the lower aqueous acid layer. Repeat this step until the acid layer is colorless.

(16) Wash the hexane with a 25-ml portion of water. Discard the water wash.

(17) Filter the hexane extract through a 4-inch funnel, plugged with glass wool that is covered with a layer of sodium sulfate, into a Kundema-Danish evaporative concentrator.

(18) Add a small boiling chip, put the Snyder column in place, and reduce the hexane volume to less

than 5 ml by heating the apparatus in a 80°C to 90°C water bath.

(19) After cooling, remove the 5-ml graduated tube and transfer the hexane extract to an alumina adsorption column, washing it in with several 5-ml portions of hexane.

(20) Carefully add 100 ml of hexane to the column reservoir, and collect the total eluent in either a 250-ml volumetric flask or a Kunderna-Danish evaporative concentrator.

(21) If the column eluent is collected in a volumetric flask, dilute to volume with hexane, and proceed with the gas chromatographic analysis.

(22) If the column eluent is collected in a Kunderna-Danish evaporative concentrator, reduce solvent volume, cool, dilute to volume, and proceed with gas chromatographic analysis.

B3.7 Electron Capture Gas Chromatographic Procedure

(1) Instrument: Gas chromatograph (for example, Hewlett-Packard Model 5750, or the equivalent)

(2) Detector: High-temperature ⁶³Ni, electron capture cell

(3) Column: 6-mm X 6-foot glass column, 4% XE-60 on 80/100 mesh, Chromosorb W, HP, AW-DMCS

(4) Column temperature: 160°C to 190°C

(5) Injection port temperature: 195°C to 215°C

(6) Detector temperature: 300°C

(7) Pulse interval: 50 μ s

(8) Flow rates: Helium carrier, approximately 60 ml/min; argon-methane purge, approximately 120 ml/min

Using EC/GC as the determinative step, inject, in duplicate, 1 to 10 μ l of each solution into the chromatograph. By comparison with standard solutions injected, in duplicate, under the same operating conditions, determine the amount and type of Aroclor using the individual or total peak height and area methods.

B3.8 Sample Concentration. Concentration of sample extracts is necessary, prior to cleanup by chromatographic or chemical means, to reduce sample size and increase sensitivity. The preferred method of concentrating allows minimum loss through volatilization or chemical decomposition and requires a minimum time. The three methods of solvent volume reduction most commonly used are evaporation by exposure to a stream of air, evaporation employing a Kunderna-Danish evaporative concentrator equipped with a Snyder column, and evaporation under reduced pressure. All three techniques have been used without encountering any significant losses from volatilization or chemical alteration. However, the Kunderna-Danish evaporative concentrator and the stream-of-air methods are easier to use.

B3.9 Column Adsorption Chromatography and Chemical Cleanup. Silica gel, a magnesia silica gel,⁹ and alumina deactivated with 0%, 1.0%, 1.5%, 2.0%, and 5% water were investigated as adsorbants for the elimination of interferences. Alumina (5% water) was found to be more effective and reproducible than either silica gel or a magnesia silica gel.⁹ The activity of alumina varies with age and lot; therefore, 5% water was added to the alumina, after heating for a minimum of 4 hours at 400°C, to ensure a reproducible activity.

Saponification, and subsequent extraction of the sample with sulfuric acid, is an effective way to remove a number of chlorinated hydrocarbon interferences as well as other matrix interferences. PCBs are not affected.

B3.10 Column Performance. Column performance is the key to effective gas chromatographic analysis and, as such, the choice of column materials is particularly important. Ideally, the support employed should be inert, mechanically strong, and of high surface area. Chromosorb W, HP, AW-DMCS fulfills these requirements and is recommended for this work.

A variety of polar and nonpolar liquid phases have been investigated. The following columns have been found to provide adequate separation, etc., for use in PCB analysis by electron capture: 4% (w/w) DC-200, SF-96, OV-17, SE-30, SE-54, XE-60, Apiezon L, and 6% QF-1. DC-200 and XE-60 or QF-1 have been found to be the most suitable of these liquid phases.

Another important consideration when working with an extremely sensitive detector and, consequently, low levels of materials is column conditioning. With polar phases such as XE-60 and QF-1, operating a new column overnight at a temperature 25°C to 50°C higher than that to be used during analysis results in a more stable column. A no-flow conditioning technique is employed to condition nonpolar columns. The column is purged with carrier gas, heated for 30 minutes at an elevated temperature without carrier flow, and then cooled to room temperature. At the end of this cycle, the carrier flow is resumed and the conditioning is completed as in the case of the polar liquid phase. Two precautions should be observed: during conditioning, the column should not be connected to the detector, and the maximum safe temperature of the liquid phase should not be exceeded.

Since all liquid substrates bleed to one degree or another and columns eventually degrade, all new columns should be characterized with two column performance indicators: the number of theoretical plates (*N*) and a tailing factor (*T*). *p,p'*-DDT is employed to check these parameters because it is known to degrade on

⁹ For example, Florisil.

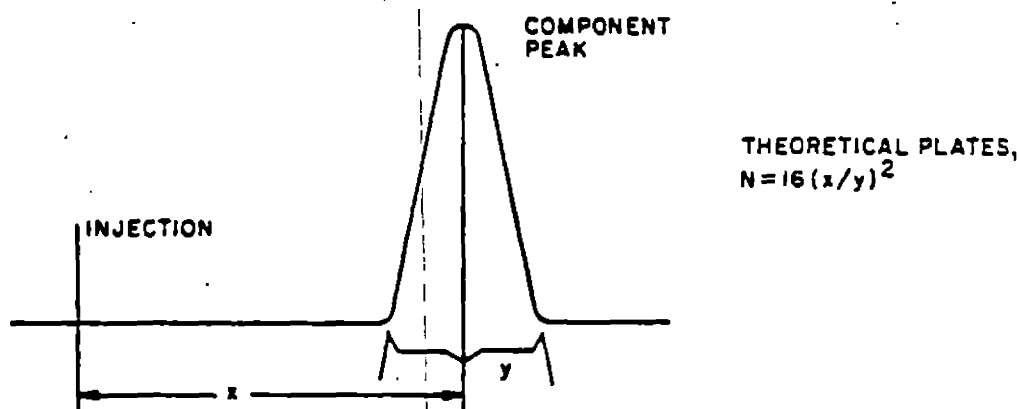


Fig. B9
Calculating Column Efficiency

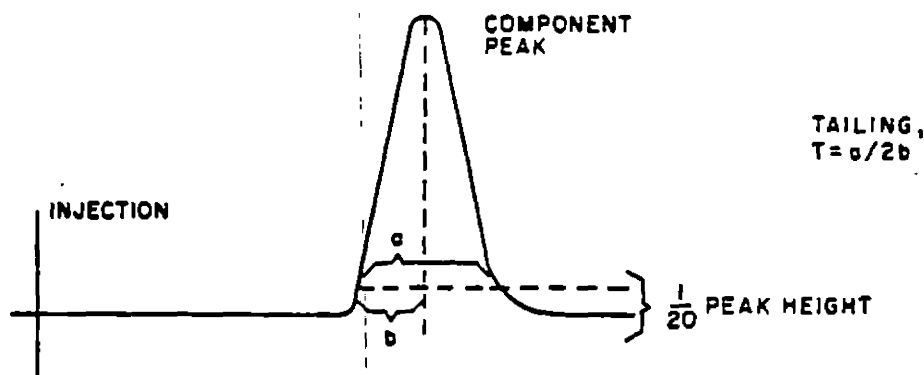


Fig. B10
Calculating the Tailing Factor

"poor" columns. In this manner, one can determine whether the performance of a new column is satisfactory and when the column performance begins to fall off. A column is considered good if the number of theoretical plates per foot is of the order of 400 to 500, with tailing factors of 1.0 to 1.3. Calculation of these parameters is shown in Fig. B9 and B10. Additionally, there should be no significant extraneous peaks upon injection of a pure *p,p'*-DDT standard.

Other chromatographic conditions that can be adjusted are column temperature and flow rates. Although resolution of a mixture increases with decreasing temperature, a temperature should be chosen that allows the elution of all components within a convenient time period. The flow rates shown are optimum for a given instrument, column, and detector system. These should be adjusted if better results can be achieved.

Any system of instrument and column suitable for chlorinated pesticide analysis is satisfactory for PCB analysis. The use of the high-temperature ^{63}Ni electron capture cell is highly recommended. The ability to operate at higher temperatures prevents maintenance problems due to contamination from high-boiling components. Glass columns also should be employed.

B3.11 Detection and Measurement. Quantitative determinations employing the electron capture detector are nonstoichiometric measurements made by comparing peak heights or areas for known concentrations with those for unknown compositions. Three variations of the peak height or area quantification procedures have been employed:

Case 1. EC gas chromatogram of PCB unknown, unchanged with respect to standard PCB with no evidence of interferences

Case II. EC gas chromatogram of PCB unknown, altered with respect to standard PCB with no evidence of interferences

Case III. EC gas chromatogram of PCB unknown, unchanged with respect to standard PCB with evidence of interference

The amount of PCBs in Case I samples is determined by preparing a plot of the major peak height or area versus concentration. With Case III samples, a peak free from interference is used. When dominant interferences are present, one or more of the chemical cleanup procedures is employed.

In all cases, the response of the electron capture detector must be linear for quantitative analysis.

B3.12 Contamination. In determining PCBs in biological materials by electron capture gas chromatography, laboratory sources of contamination can be a major problem. The samples and extracts should never be allowed to come in contact with materials other than glass, TFE-fluorocarbon, or metal. Laboratory glassware should be thoroughly washed with hot, soapy water, and rinsed with distilled water, acetone, and then hexane. All equipment should also be rinsed again with hexane just prior to use, and blanks should be frequently carried through all steps of the procedures to ensure against the possibility of contamination.

B3.13 Sensitivity

- (1) Concentration: 2 ppb (parts per billion)
- (2) Absolute sensitivity: 0.5×10^{-9} gram
- (3) Volume injected: 5 μ l
- (4) Final volume of extract: 5 ml
- (5) Sample size: 250 ml

B4. Analysis of Water and Sediment for PCBs

B4.1 Scope. This methodology is used by the Monsanto Industrial Chemical Company for the determination of the amount and type of PCBs in water and sediment samples. Absolute confirmation of PCB structures is not obtained with this method. Structure proof can be obtained using additional techniques such as mass spectrometry to further identify the gas chromatography fractions.

B4.2 Principle. The PCBs in water and sediment samples are extracted into an organic solvent. Interfering components are then removed from the extracts by chemical treatment and column adsorption chromatography. The amount and type of PCBs present are determined by electron capture gas chromatography (EC/GC).

B4.3 Reagents

- (1) Hexane: Pesticide grade.
- (2) Acetonitrile: Pesticide grade.
- (3) Sodium sulfate: Anhydrous, granular, analytical reagent (AR) grade. Heat at 400°C for 1 hour prior to use.

- (4) Alumina adsorption: For chromatographic analysis, 80/200 mesh. Heat at 400°C for a minimum of 4 hours and deactivate with 5% (w/w) distilled water.

For alumina column preparation fill a chromatographic column with hexane up to the point where the reservoir joins the column, and push a glass wool plug to the bottom with a glass rod. In a 50-ml beaker measure 35 ml (about 30 grams) of deactivated alumina, and pour this slowly into the column. Tap or vibrate the column to settle the alumina, and top the alumina with 2 to 3 cm of anhydrous sodium sulfate. Wash the column with 50 to 100 ml of hexane prior to the addition of the sample.

- (5) Distilled water: Extracted with hexane to remove hexane-soluble electron capturing impurities.
- (6) Sulfuric acid: AR grade, specific gravity = 1.84.
- (7) Potassium hydroxide: AR grade.
- (8) Ethanol: Formula 2B.
- (9) Alcoholic potassium hydroxide, 2.5% (w/v): Dissolve about 12.5 grams of AR grade KOH in 500 ml of ethanol.

- (10) Sulfuric acid-water, 9:1 (v/v): Carefully add 270 ml of AR grade sulfuric acid to 30 ml of distilled water in a 500-ml iced beaker.

- (11) PCB standards: Aroclor 1242, 1248, 1254, and 1260. (See Fig. B2 and Fig. B4 through B7.)

B4.4 Apparatus

- (1) Separatory funnels equipped with ground-glass stoppers and TFE-fluorocarbon stopcocks; capacities of 125, 250, 500, 1000, and 2000 ml.
- (2) Kunderna-Danish evaporative concentrators, 500-ml capacity, equipped with three-ball Snyder columns and graduated 5-ml capacity vials.
- (3) Chromatographic columns, glass, 10 inches $\times$ 20 mm (OD) with a 5-inch $\times$ 50-mm (OD) reservoir at the top, equipped with TFE-fluorocarbon stopcocks.
- (4) Sintered glass filter funnels, 600-ml capacity, 90-mm disk diameter, medium porosity.
- (5) Flat-bottomed boiling flasks, 125-ml capacity.
- (6) Liebig condenser, 200 mm in length.
- (7) Hot plates.
- (8) Water bath.
- (9) Reciprocating variable-speed shaker.
- (10) 10- μ l syringes.
- (11) 32-oz all-glass mortars and pestles.
- (12) 8-inch $\times$ 12-inch $\times$ 2-inch (2-1/2 qt) heat-resistant glass baking dishes.

APPENDIX

(13) U.S. Standard sieve, No. 30.

(14) Usual laboratory glassware.

B4.5 Sampling. It is to be assumed that a rather wide variety of sampling techniques may be employed in collecting samples submitted for analysis. For this reason, water and sediment samples should be treated as given in B4.5.1 and B4.5.2.

B4.5.1 Water. Where possible, the entire water sample, including the container in which it was collected, should be extracted with hexane. With larger samples, where this is not physically possible, the containers should be simply agitated and a 250-ml portion used for the analysis. (See B4.6.)

B4.5.2 Sediment. Any excess water should be decanted, and the entire sediment transferred to a glass baking dish to air-dry at room temperature. The dried material should be transferred from the dish into a mortar and ground. The ground sediment should be sieved, remixed, and a 250-gram portion taken for analysis. (See B4.7.)

B4.6 Extraction of Water Samples

(1) After agitating, transfer the entire aqueous sample or a 250-ml aliquot into a graduated glass cylinder. Record the volume of the sample and quantitatively transfer it to a separatory funnel with distilled water.

(2) Rinse the graduated cylinder with two 50-ml portions of hexane and add each to the separatory funnel.

(3) Stopper the separatory funnel and shake vigorously for at least 1 minute. Allow the layers to separate, and transfer the lower aqueous phase to a second separatory funnel.

(4) Extract the water sample a second time with a 50-ml portion of hexane. After the layers have separated, add the first hexane extract to the second separatory funnel, and transfer the aqueous layer to the original separatory funnel.

(5) Repeat the extraction with a third 50-ml portion of hexane. Discard the aqueous layer and combine the hexane extracts.

(6) Filter the combined extracts through a 4-inch funnel, plugged with glass wool that is covered with sodium sulfate. Collect the filtrate in a Kunderna-Danish evaporative concentrator, add a small boiling chip, put the Snyder column in place, and reduce the hexane volume to less than 5 ml by heating the apparatus in an 80°C to 90°C water bath. (CAUTION: Solvent vapors must be vented into a hood.)

(7) After cooling, remove the 5-ml graduated tube and transfer the hexane extract to an alumina adsorption column, washing it in with several 5-ml portions of hexane.

(8) Carefully add 100 ml of hexane to the column

reservoir, and collect the total eluent in either a 250-ml volumetric flask or a Kunderna-Danish evaporative concentrator.

(9) If the column eluent is collected in a volumetric flask, dilute to volume with hexane, and proceed with the gas chromatographic analysis.

(10) If the column eluent is collected in a Kunderna-Danish evaporative concentrator, reduce solvent volume, cool, dilute to volume, and proceed with the gas chromatographic analysis.

B4.7 Extraction of Sediment and Soil Samples

(1) Decant off any excess water and transfer the entire sediment sample to a glass baking dish. Air-dry at ambient temperature (heat should be applied).

(2) When dry, transfer the soil/sediment to a mortar and grind. Sieve the ground material through a No. 30 mesh sieve and weigh 250 grams (to the nearest 0.01 gram) into a 16-ounce narrow-neck screw-cap (aluminum-foil liner) glass bottle.

(3) Moisten the soil with about 10 ml of water and add 150 ml of acetonitrile. Cap the bottle tightly, and mechanically shake it for a minimum period of 1 hour.

(4) Quantitatively transfer the acetonitrile extract into a 600-ml sintered glass filter funnel containing a 1/4-inch layer of anhydrous sodium sulfate. Collect the filtrate in a 600-ml beaker (vacuum filtration may be necessary).

(5) After the acetonitrile has completely drained into the beaker, wash the bottle twice with 50-ml portions of acetonitrile, adding each wash to the funnel after the previous wash has completely percolated through the sediment.

(6) Quantitatively transfer the extract to a Kunderna-Danish evaporative concentrator, add a small boiling chip, put the Snyder column in place, and reduce the solvent volume to less than 5 ml by heating the apparatus in an 80°C to 90°C water bath. (CAUTION: Solvent vapors must be vented into a hood.)

(7) After cooling, remove the 5-ml graduated tube and transfer the concentrate of extracts to a 125-ml extraction flask with the aid of several small portions of solvent.

(8) Evaporate the extract just to dryness with a gentle stream of dry, filtered nitrogen and add 25 ml of 2.5% alcoholic potassium hydroxide.

(9) Add a boiling chip, put a water condenser in place, and allow the solution to reflux for 45 minutes.

(10) After cooling, transfer the solution to a 250-ml separatory funnel with the aid of 25 ml of distilled water.

(11) Rinse the extraction flask with 25 ml of hexane and add it to the separatory funnel.

(12) Stopper the separatory funnel and shake it

vigorously for at least 1 minute. Allow the layers to separate, and transfer the lower aqueous phase to a second separatory funnel.

(13) Extract the saponification solution with a second 25-ml portion of hexane. After the layers have separated, add the first hexane extract to the second separatory funnel and transfer the aqueous alcohol layer to the original separatory funnel.

(14) Repeat the extraction with a third 25-ml portion of hexane. Discard the saponification solution and combine the hexane extracts.

(15) Carefully add 25 ml of the sulfuric acid solution (9:1 concentrated sulfuric acid-water) to the hexane extracts.

(16) Stopper the separatory funnel and shake vigorously for at least 1 minute. Allow the layers to separate, and discard the lower aqueous acid layer. Repeat this step until the acid layer is colorless.

(17) Wash the hexane with a 25-ml portion of water. Discard the water wash.

(18) Filter the hexane extract through a 4-inch funnel, plugged with glass wool that is covered with a layer of sodium sulfate, into a Kunderna-Danish evaporative concentrator.

(19) Add a small boiling chip, put the Snyder column in place, and reduce the hexane volume to less than 5 ml by heating the apparatus in an 80°C to 90°C water bath.

(20) After cooling, remove the 5-ml graduated tube and transfer the hexane extract to an alumina adsorption column, washing it in with several 5-ml portions of hexane.

(21) Carefully add 100 ml of hexane to the column reservoir, and collect the total eluent in either a 250-ml volumetric flask or a Kunderna-Danish evaporative concentrator.

(22) If the column eluent is collected in a volumetric flask, dilute to volume with hexane, and proceed with the gas chromatographic analysis.

(23) If the column eluent is collected in a Kunderna-Danish evaporative concentrator, reduce solvent volume, cool, dilute to volume, and proceed with gas chromatographic analysis.

B4.8 Electron Capture Gas Chromatographic Procedure

(1) Instrument: Gas chromatograph (for example, Hewlett-Packard Model 5750, or the equivalent)

(2) Detector: High-temperature ^{63}Ni , electron capture cell

(3) Column: 6-mm X 6-foot glass column, 4% XE-60 on 80/100 mesh, Chromosorb W, HP, AW-DMCS

(4) Column temperature: 160°C

(5) Injection port temperature: 195°C

(6) Detector temperature: 300°C

(7) Pulse interval: 50 μs

(8) Flow rates: Helium carrier, approximately 60 ml/min; argon-methane purge, approximately 120 ml/min

Using EC/GC as the determinative step, inject, in duplicate, 1 to 10 μl of each solution into the chromatograph. By comparison with standard solutions injected, in duplicate, under the same operating conditions, determine the amount and type of Aroclor using the individual or total peak height and area methods.

The electron capture detector should also be used to guide the isolation procedures. Water and sediment extracts can be checked for the presence of PCBs or interferences, or both, by injection of microlitre portions of the extracts at various points in the extraction and concentration schemes. In this manner it can be determined whether the sample needs to be concentrated or diluted and whether the cleanup procedures should be employed.

B4.9 Extraction. The extraction of PCBs from water, employing hexane as the extractant, has been found to be quantitative and sufficiently simple and rapid for use as a routine procedure.

The evaluation of this method was based on spiking water samples with standard acetone solutions of PCBs. The spiking method consisted of adding the PCB in 25 to 50 μl of acetone to 500 ml of tap water in a 32-ounce narrow-neck screw-cap jar. After the sample was thoroughly mixed, duplicate 225- to 250-ml aliquots were taken and subjected to the proposed sample preparation and worked up as outlined. The results were quantified by preparing a calibration curve using standard hexane solutions of the PCBs used to spike the water samples. The major isomer peak height was used to construct the calibration plot.

The average recovery and deviation achieved substantiated the applicability of the method for the quantitative recovery and analysis of PCBs from water at the ppb-ppm level.

No PCB recovery experiments from spiked sediment and soil samples have been performed. Instead, several of the residual solids representative of some of the types of sediment or soil analyzed were reextracted with hexane/acetone (40:60) in a soxhlet extractor to test for the efficiency of the acetonitrile extraction step. The hexane, after isolation by dilution with distilled water, was then carried through the purification steps. Recoveries by soxhlet extraction have indicated that the acetonitrile extraction of PCBs was essentially quantitative in the cases checked.

B4.10 Sample Concentration. Concentration of sample extracts is necessary, prior to cleanup by chromato-

graphic or chemical means, to reduce sample size and increase sensitivity. The preferred method of concentrating allows minimum loss through volatilization or chemical decomposition and requires a minimum time. The three methods of solvent volume reduction most commonly used are evaporation by exposure to a stream of air, evaporation employing a Kunderna-Danish evaporative concentrator equipped with a Snyder column, and evaporation under reduced pressure. All three techniques have been used, and no significant losses from volatilization or chemical alteration have been encountered. However, the Kunderna-Danish evaporative concentrator and the stream-of-air methods are easier to use.

B4.11 Column Adsorption Chromatography and Chemical Cleanup. Silica gel, a magnesia silica gel,⁹ and alumina deactivated with 0%, 1.0%, 1.5%, 2.0%, and 5% water were investigated as adsorbants for the elimination of interferences. Alumina (5% water) was found to be more effective and reproducible than either silica gel or a magnesia silica gel.⁹ The activity of alumina varies with age and lot; therefore 5% water is added to the alumina, after heating for a minimum of 4 hours at 400°C, to ensure a reproducible activity.

Saponification, and subsequent extraction of the sample with sulfuric acid, is an effective way to remove a number of chlorinated hydrocarbon interferences as well as other matrix interferences. PCBs are not affected.

B4.12 Column Performance. Column performance is the key to effective gas chromatographic analysis and, as such, the choice of column materials is particularly important. Ideally, the support employed should be inert, mechanically strong, and of high surface area. For these reasons, Chromosorb W, HP, AW-DMCS is recommended for this work.

A variety of polar and nonpolar liquid phases have been investigated. The following columns have been found to provide adequate separation, etc, for use in PCB analysis by electron capture: 4% (w/w) DC-200, SF-96, OV-17, SE-30, SE-54, XE-60, Apiezon L, and 6% QF-1: DC-200 and XE-60 or QF-1 are the most suitable of these liquid phases.

Another important consideration when working with an extremely sensitive detector and, consequently, low levels of materials is column conditioning. With polar phases such as XE-60 and QF-1, operating a new column overnight at a temperature 25°C to 50°C higher than that to be used during analysis results in a more stable column. A no-flow conditioning technique is employed to condition nonpolar columns. The column is

purged with carrier gas, heated for 30 minutes at an elevated temperature without carrier flow, and then cooled to room temperature. At the end of this cycle, the carrier flow is resumed and the conditioning is completed as in the case of the polar liquid phase. Two precautions should be observed: during conditioning, the column should not be connected to the detector, and the maximum safe temperature of the liquid phase should not be exceeded.

Since all liquid substrates bleed to one degree or another and columns eventually degrade, all new columns should be characterized with two column performance indicators: the number of theoretical plates (*N*) and a tailing factor (*T*). *p,p'*-DDT is employed to check these parameters because it is known to degrade on "poor" columns. In this manner, one can determine whether the performance of a new column is satisfactory and when the column performance begins to fall off. A column is considered good if the number of theoretical plates per foot is of the order of 400 to 500, with tailing factors of 1.0 to 1.3. Calculation of these parameters is shown in Fig. B9 and B10. Additionally, there should be no significant extraneous peaks upon injection of a pure *p,p'*-DDT standard.

Other chromatographic conditions that can be adjusted are column temperature and flow rates. Although resolution of a mixture increases with decreasing temperature, a temperature should be chosen that allows the elution of all components within a convenient time period. The temperatures given are optimum for 42% chlorinated biphenyl; temperatures are increased when specifically analyzing for the higher chlorinated biphenyls; that is, 54%, 60%, etc. The flow rates shown are optimum for a given instrument, column, and detector system. These should be adjusted if better results can be achieved.

Any system of instrument and column suitable for chlorinated pesticide analysis is satisfactory for PCB analysis. The use of the high-temperature ⁶³Ni electron capture cell is highly recommended. The ability to operate at higher temperatures prevents maintenance problems due to contamination from high-boiling components. Glass columns also should be employed.

B4.13 Detection and Measurement. Quantitative determinations employing the electron capture detector are nonstoichiometric measurements made by comparing peak heights or areas for known concentrations with those for unknown compositions. Except for sharp peaks, peak area measurements are usually more reproducible than peak height measurements but are extremely time consuming unless a recording integrator is employed. However, peak height measurements are as accurate as disk integration of triangulation and, if the

⁹ For example, Florisil.

American National Standards

The standard in this booklet is one of nearly 5,600 standards approved to date by the American National Standards Institute, formerly the USA Standards Institute.

The Standards Institute provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation "American National Standards."

Each standard represents general agreement among maker, seller, and user groups as to the best current practice with regard to some specific problem. Thus the completed standards cut across the whole fabric of production, distribution, and consumption of goods and services. American National Standards, by reason of Institute procedures, reflect a national consensus of manufacturers, consumers, and scientific, technical, and professional organizations, and governmental agencies. The completed standards are used widely by industry and commerce and often by municipal, state, and federal governments.

The Standards Institute, under whose auspices this work is being done, is the United States clearinghouse and coordinating body for standards activity on the national level. It is a federation of trade associations, technical societies, professional groups, and consumer organizations. Some 1,000 companies are affiliated with the Institute as company members.

The American National Standards Institute is the United States member of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the Pan American Standards Commission (COPANT). Through these channels American industry makes its position felt on the international level. American National Standards are on file in the libraries of the national standards bodies of more than 50 countries.

For a free list of all American National Standards, write:

American National Standards Institute, Inc
1430 Broadway New York, N. Y. 10018

Miscellaneous Hazard No. 2581
Application No. 33C2060

September 29, 1934.

REPORT

on

LIQUID DIELECTRIC AND COOLING MEDIUMS

General Electric Co.,
Schenectady, N. Y.

PLAINTIFF'S
EXHIBIT

470

T A B L E O F C O N T E N T S

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INSTRUCTIONS
FOR
SEARCHING LISTS OF SERIAL
NUMBERS FOR PCB TRANSFORMERS

I. INTRODUCTION

Recent rulings by the EPA have put stringent regulations on the disposal of those transformer installation liquids which contain PCBs. The General Electric Company manufactured many transformers using an insulating liquid containing PCBs. We called this liquid Pyranol. We have been receiving lists of serial numbers from our customers with the request that we identify for them those transformers which were manufactured with PCBs.

The General Electric Company used no Pyranol in any transformer manufactured in Hickory or Shreveport and in no transformer manufactured at any location prior to 1930 or after December 31, 1976.

II. First PASS AT LIST

A. Check customer's request and identify units as requested.

B. If no specific requests are made, proceed as follows:

1. Since neither Hickory nor Shreveport ever built a pyranol filled transformer, put a "NO" after each serial number on the list which has either a "Y" or "T" after the usual letter plus six digits.

Example: G46389566Y (Hickory 1966)
J539450Y71 (Hickory 1971)
L706425TELA (Shreveport 1975)

2. Since no Pyranol filled transformers were ever built prior to 1930 or after December 31, 1976, if the date of manufacture can be identified as before 1930 or after January 1, 1977, put "NO" after the serial number.

Example: Serial numbers less than 4700000 were built before 1930.
Serial numbers higher than M310000 were built after January 1, 1979.

PLAINTIFF'S
EXHIBIT

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3. The list will usually have some serial numbers which are not General Electric Company. The GE serial numbers are either seven digits (up through 1956) or a letter followed by six digits (since 1950).

(The coding for place and date of manufacture was first introduced in the late 1950's and is not to be considered part of the serial number.)

Any number which does not follow one of the above patterns is not GE. Mark all such serial numbers "NOT GE".

III. NUMERICAL ARRANGEMENT

Give the list to Nancy for numerical arrangement. She will ignore all numbers marked either "NO" or "NOT GE". Nancy's listing gives each number a sequential number which corresponds to its position on the original list. This sequential number may be used later in locating a number when working back and forth between lists. Identify the last serial numbers in each column of the original list with the assigned sequence number to establish the range of sequence numbers in each column. Set original list aside.

IV. CHECK PLACE OF MANUFACTURE

Check numerically arranged list against HB 5405, page 2. If serial number is listed there as assigned to either Hickory or Shreveport, so indicate on this by "Y" or "T". Also, identify Oakland "K" and Merced "M" for possible later convenience. Pittsfield numbers may be left unmarked.

V. MICROFILM SEARCH

- A. Do nothing further on the numerically arranged list with the serial numbers marked "Y" or "T".

B. Try to identify all others as either "OIL" or "PYR" (for Pyranol).
As soon as one can be identified as either oil or Pyranol, so mark and proceed to next number.

1. Look for serial number on microfilm.

a) If found

- 1) Look for the word "OIL" or "Pyranol" somewhere on the test card or test report.
- 2) Look for the letter "A" before the P.O. (production order number). A P.O. number with "A" preceding it meant Pyranol.

- 3) Look for and examine the form designation, which is the last group of characters in the rating. Look for the letter "A" in this group, which meant Pyranol. Samples of ratings:

HSBA-60-25-2400/4160Y-120/240-W2F

THERE IS NO "A"

THEREFORE, TRANSFORMER
IS OIL-FILLED

HS-60-25-2400/4160Y-120/240-W2FA

"A" MEANS

PYRANOL-FILLED

OAT-60-600-7200-480Y-RA

FORM
DESIGNATION
GROUP

- 4) Look for a catalog number or T. S. number. If one can be found, write it down for checking against catalog number or T. S. number assignments.

Example of catalog numbers: 26H55

47X425

Examples of T.S. numbers:

5501AB0225XAL

HC40AG70CG045AA

PYRANOL
"W" 6th pos

PYRANOL
AW GLW
CW HW
DY MK
FX

- 5) If date of manufacture can be established as after January 1, 1977, identify unit as "OIL".

- b) If serial number cannot be located on microfilm, write "?" on numerical list.

PYRANOL UNITS
(FIRST DIGITS OF TS)

GW

TW

HW

MW

AW

W

Y

FX

NW

NX

SW

XX

"2" 5TH OR 6TH DIGIT OF CAT NO

VI. FINAL ACTION ON ORIGINAL LIST

(Omit this step unless it is specifically requested.)

A. Go down through list, addressing each number not previously marked during the "First Pass".

B. Locate the addressed number on the numerically arranged list.

C. Write the following after the number on the original list:

- 1) "NO" if marked "Y" or "T" on numerical list.
- 2) "NO" if marked "OIL" on numerical list.
- 3) "PCB Transformer" if marked "PYR" on numerical list.
- 4) "?" if marked "?" on numerical list.

Apr. 21, 1980

This information, which is approximate and subject to many exceptions, applies primarily to distribution transformers rated 500 kva below. It is intended to give a rough idea of transformer age and place of manufacture.

K—Oakland, Calif.

M—Merced, Calif. (starting 1967)

P—Pittsfield, Mass. (includes former Holyoke, Mass. plant)

T—Shreveport, La.

Y—Hickory, N. C.

All requests for distribution trans former replacement parts should be directed to Hickory.

Transformer Serial Numbers	Manufactured		Transformer Serial Numbers	Manufactured		Transformer Serial Numbers	Manufactured	
	Approx Year	Factory		Approx Year	Factory		Approx Year	Factory
0000 to 2569450	1887-1921	P	3218000 to 3287555	1935	P	8269100 to 8272430	1946	K
2569451 to 2836350	1922	P	3287556 to 3303099	1936	P	8272431 to 8274099	1947	K
2836351 to 3025765	1923	P	3303100 to 3318099	1936	K	8274100 to 8276375	1947	P
3025766 to 3032800	1924	P	3318100 to 3372099	1936	P	8276376 to 8278403	1947	K
3032801 to 3037800	1923	K	3372100 to 3377099	1936	K	8278404 to 8251099	1947	P
3037801 to 3182500	1924	P	3443000 to 3443899	1937	K	8251100 to 8259099	1947	K
3182501 to 3198100	1925	P	3443900 to 3444300	1936	K	8259100 to 8279000	1947	P
3198101 to 3203100	1924	K	3444301 to 3503500	1936	P	8279001 to 8310999	1948	P
3203101 to 3254100	1925	K	3503501 to 3517899	1937	P	8311000 to 8316999	1947	K
3254101 to 3255100	1924	K	3517900 to 3522899	1937	K	8317000 to 8384499	1948	P
3255101 to 3300000	1925	K	3522900 to 3524899	1937	P	8384500 to 8386099	1947	K
3300001 to 3374099	1926	P	3524900 to 3534200	1937	K	8386100 to 8391499	1948	K
3374100 to 3379099	1925	K	3534201 to 3534899	1938	K	8391500 to 9142999	1948	P
3379100 to 3456099	1926	K	3534900 to 3546000	1937	P	9143000 to 9169999	1948	K
3456100 to 3441099	1925	K	3546001 to 3577899	1938	P	9170000 to 9247900	1948	P
3441100 to 3523399	1926	P	3577900 to 3582500	1938	K	9247901 to 9344900	1949	P
3523400 to 3528399	1925	K	3582501 to 3584999	1938	P	9344901 to 9374999	1950	P
3528400 to 3613399	1926	P	3584900 to 3584300	1938	P	9375000 to 9583700	1948	K
3613400 to 3623399	1926	K	3584301 to 3598587	1939	P	9583701 to 9586999	1949	K
3623400 to 3700000	1926	P	3598588 to 3598600	1939	K	9587000 to 9638499	1949	K
3700001 to 3833699	1927	P	3598601 to 4142999	1939	P	9638500 to 9643799	1949	K
3833700 to 3843899	1926	K	4143000 to 4143999	1939	K	9643800 to 9648699	1950	K
3843900 to 3935699	1927	K	4144000 to 4190000	1939	P	9648700 to 9658499	1950	K
3935700 to 3936499	1926	K	4200000 to 4203200	1939	K	9658500 to 9672473	1950	K
3936500 to 4060899	1927	K	4203201 to 4207999	1940	K	9672474 to 9673699	1951	K
4060900 to 4064899	1927	K	4208000 to 4332499	1940	P	9673700 to 9683499	1951	K
4064900 to 4070899	1927	P	4332500 to 4337481	1940	P	9683500 to 9713499	1951	K
4070900 to 4071899	1927	K	4337482 to 4421300	1940	P	9713500 to 9723699	1951	K
4071900 to 4127299	1928	P	4421301 to 4432409	1941	P	9723700 to 9733699	1952	K
4127300 to 4137299	1927	K	4432500 to 4436134	1940	K	9733700 to 9733699	1952	K
4137300 to 4332199	1928	P	4436135 to 4437499	1941	K	9733700 to 9773699	1952	K
4332200 to 4342199	1928	K	4437500 to 4484599	1941	P	9773700 to 9783699	1952	K
4342200 to 4499499	1929	P	4484600 to 4490599	1941	K	9783700 to 9793699	1953	K
4499500 to 4509499	1929	P	4490600 to 4589338	1941	K	9793700 to 9809999	1953	K
4509500 to 4590999	1929	P	4589339 to 4590382	1941	K	9809999 to 9809999	1953	
4591000 to 4591999	1929	K	4590383 to 4704500	1941	P	9810000 to 9813699	1954	K
4592000 to 4648499	1929	P	4704501 to 4897999	1942	P	9813700 to 9833299	1954	K
4648500 to 4675499	1929	P	4898000 to 4898327	1941	K	9833300 to 9833299	1954	K
4675500 to 4731800	1929	K	4898328 to 4902999	1942	K	9833300 to 9833299	1955	K
4731801 to 4793499	1930	P	4903000 to 7089000	1942	K	9833300 to 9878299	1955	K
4793500 to 4803499	1930	K	7089001 to 7098200	1942	P	9878300 to 9878299	1955	K
4803500 to 4819700	1930	P	7098201 to 7219999	1943	P	9893300 to 9903299	1956	K
4819701 to 4912499	1931	P	7220000 to 7220410	1942	K	9903300 to 9913499	1956	K
4912500 to 4922499	1931	K	7220411 to 7224999	1943	K	9913500 to 9934999	1956	K
4922500 to 4974199	1931	K	7225000 to 7225007	1943	K	9935000 to 9943499	1956	K
4974200 to 4975199	1930	K	7225008 to 7316200	1943	P	8211000 to 8298099	1950	
4975200 to 4986599	1931	P	7316201 to 7316499	1944	P	8298099 to 8310999	1951	P
4986600 to 4993199	1931	P	7316500 to 7334333	1943	K	8311000 to 8337000	1951	P
4993200 to 5030299	1932	P	7334334 to 7334599	1944	K	8337001 to 8343999	1952	P
5030300 to 5032200	1931	K	7334600 to 7337250	1943	K	8344000 to 8447250	1951	P
5032201 to 5034700	1932	K	7337251 to 7339399	1944	K	8447251 to 8443099	1952	P
5034701 to 5036700	1933	K	7339400 to 7440399	1944	K	8443100 to 8491999	1952	P
5036701 to 5040299	1934	P	7440400 to 7443599	1944	K	8492000 to 8493999	1953	P
5040300 to 5044800	1933	P	7443600 to 7450000	1944	P	8494000 to 8532399	1954	P
5044801 to 5162999	1934	P	7450001 to 7692099	1945	P	8532400 to 8540399	1955	P
5163000 to 5163800	1934	K	7692100 to 7693143	1944	K	8540400 to 8540399	1955	P
5163801 to 5167999	1935	K	7693144 to 7697099	1945	K	8540401 to 8541999	1955	P
5168000 to 5194200	1934	P	7697100 to 7793099	1945	K	8542000 to 8543999	1955	P
5194201 to 5212999	1935	P	7793100 to 7797324	1945	K	8544000 to 8545999	1955	P
5213000 to 5214900	1935	K	7797325 to 7798108	1946	K	8546000 to 8547999	1955	P
5214901 to 5217999	1936	K	7798109 to 7854700	1945	P	8548000 to 8549999	1955	P
			7854701 to 8101108	1946	P	8550000 to 8551999	1955	P
			8101109 to 8106099	1946	K	8552000 to 8553999	1955	P
			8106100 to 8213700	1946	P	8554000 to 8555999	1955	P
			8213701 to 8269099	1947	P	8556000 to 8557999	1955	P

Serial Numbers

Apr. 21, 1980

Manufactured			Manufactured			Manufactured		
Transformer Serial Numbers	Approx Year	Factory	Transformer Serial Numbers	Approx Year	Factory	Transformer Serial Numbers	Approx Year	Factory
C19100 to C134099	1954		E922605 to E928999	1963	Y	H875910 to H878437	1970	K
C134100 to C134999	1955		E929000 to E934299	1962	P	H888500 to H890062	1968	M
C134100 to C134999	1955	P	E934300 to E999999	1963	P	H890063 to H895483	1968	M
C134100 to C134999	1956					H895484 to H898493	1970	M
C134100 to C134999	1956							
C186600 to C137499	1955		F100000 to F128999	1964	P	J100000 to J218999	1969	Y
C142200 to C144599	1956		F129000 to F130966	1961	K	J220195 to J230613	1972	P
C142600 to C147399	1955	P	F130967 to F138999	1962	K	J230614 to J230999	1973	P
C147400 to C150999	1956		F240000 to F259500	1962	K	J231135 to J231249	1972	P
C147400 to C150999	1956		F259501 to F271999	1963	K	J443496 to J431499	1971	Y
C111200 to C112099	1956							
C111200 to C112099	1956		F372000 to F444704	1963	Y	J734500 to J749850	1970	
C111200 to C112099	1956		F444705 to F472999	1964	Y	J749851 to J790700	1971	
C111200 to C112099	1956	P	F473000 to F501958	1964	P	J790701 to J790818	1973	K
C111200 to C112099	1956	P	F501959 to F524099	1965	P	J790819 to J790904	1974	
C111200 to C112099	1956	P	F524100 to F532099	1964	P	J791000 to J814400	1971	
C111200 to C112099	1956	P						
C111200 to C112099	1956	P	F532100 to F559532	1965		J814401 to J814499	1970	K
C111200 to C112099	1956	P	F559533 to F584099	1965		J814500 to J819182	1970	M
C111200 to C112099	1956	P	F584100 to F614700	1966		J819183 to J824499	1971	M
C111200 to C112099	1956	P	F614701 to F634099	1967		J824500 to J832699	1971	T
C111200 to C112099	1956	P	F634100 to F638099	1966		J832700 to J834999	1972	T
C111200 to C112099	1956	P						
C111200 to C112099	1956	P	F639100 to F649099	1966	P	K140000 to K232360	1971	Y
C111200 to C112099	1956	P	F649100 to F677999	1967	P	K232361 to K239999	1972	Y
C111200 to C112099	1956	P	F678000 to F687999	1963	K	K240000 to K250499	1973	Y
C111200 to C112099	1956	P	F688000 to F697480	1963	K	K250500 to K271432	1971	K
C111200 to C112099	1956	P	F697481 to F698999	1964	K	K271433 to K310011	1972	K
C111200 to C112099	1956	P				K310012 to K310074	1973	K
C111200 to C112099	1956	P	F803500 to F812199	1964	K			
C111200 to C112099	1956	P	F812200 to F824837	1964	Y	K311213 to K327499	1973	K
C111200 to C112099	1956	P	F824838 to F833999	1965	K	K327500 to K340499	1971	M
C111200 to C112099	1956	P	F834000 to F839999	1964	K	K340500 to K342399	1972	Y
C111200 to C112099	1956	P				K342400 to K344999	1973	Y
C111200 to C112099	1956	P	G164000 to G173999	1965	K	K345000 to K347499	1973	Y
C111200 to C112099	1956	P	G174000 to G301612	1965	Y	K347500 to K361499	1973	Y
C111200 to C112099	1956	P	G301613 to G304599	1966	Y	K361500 to K399999	1973	Y
C111200 to C112099	1956	P	G304600 to G314999	1965	K			
C111200 to C112099	1956	P	G315000 to G432304	1965	K	L100000 to L161167	1973	Y
C111200 to C112099	1956	P				L161168 to L169999	1973	Y
C111200 to C112099	1956	P	G432305 to G433399	1966	K	L170000 to L171499	1973	T
C111200 to C112099	1956	P	G433400 to G570399	1966	Y	L171500 to L180914	1973	K
C111200 to C112099	1956	P	G570400 to G590399	1966	K	L180915 to L192499	1973	Y
C111200 to C112099	1956	P	G590400 to G730900	1966	K			
C111200 to C112099	1956	P	G730901 to G730999	1967	K	L192501 to L192976	1973	P
C111200 to C112099	1956	P	G731000 to G867408	1967	Y	L192977 to L198500	1974	P
C111200 to C112099	1956	P				L198501 to L229999	1973	K
C111200 to C112099	1956	P	H200500 to H207999	1968		L229999 to L242499	1974	K
C111200 to C112099	1956	P	H208000 to H238441	1968		L242500 to L260300	1973	Y
C111200 to C112099	1956	P	H238442 to H254000	1969	P			
C111200 to C112099	1956	P	H254001 to H259161	1968		L260301 to L262449	1974	Y
C111200 to C112099	1956	P	H259162 to H267883	1969		L262450 to L264019	1973	P
C111200 to C112099	1956	P				L264020 to L264999	1973	Y
C111200 to C112099	1956	P	H267884 to H273999	1970		L265000 to L265483	1974	T
C111200 to C112099	1956	P	H274000 to H274340	1969		L265484 to L265999	1974	Y
C111200 to C112099	1956	P	H274341 to H277666	1970	P			
C111200 to C112099	1956	P	H277667 to H330062	1971		L266000 to L266404	1974	Y
C111200 to C112099	1956	P	H330063 to H361999	1973		L266405 to L266899	1973	Y
C111200 to C112099	1956	P				L266900 to L267499	1974	Y
C111200 to C112099	1956	P	H362000 to H366000	1972	P	L267500 to L267999	1974	Y
C111200 to C112099	1956	P	H366001 to H369508	1973	P			
C111200 to C112099	1956	P	H369509 to H369799	1974	P	L268000 to L273954	1974	Y
C111200 to C112099	1956	P	H369800 to H400299	1974	P	L273955 to L278673	1974	Y
C111200 to C112099	1956	P	H400300 to H422289	1967	M			
C111200 to C112099	1956	P				L278674 to L280727	1976	P
C111200 to C112099	1956	P	H422290 to H423498	1968	M	L280728 to L280823	1977	P
C111200 to C112099	1956	P	H423499 to H440444	1967	K	L280824 to L281099	1974	P
C111200 to C112099	1956	P	H440445 to H463498	1968	K	L281100 to L283739	1973	P
C111200 to C112099	1956	P	H463499 to H497110	1967	Y	L283740 to L290471	1974	K
C111200 to C112099	1956	P	H497111 to H524320	1968	Y	L290472 to L297999	1975	K
C111200 to C112099	1956	P						
C111200 to C112099	1956	P	H524321 to H734999	1969	Y	L703483 to L711116	1973	T
C111200 to C112099	1956	P	H735000 to H735124	1968	Y	L711117 to L718169	1976	T
C111200 to C112099	1956	P	H735125 to H735444	1969	Y	L718170 to L723481	1977	T
C111200 to C112099	1956	P	H735445 to H844341	1968	K	L723482 to L727429	1974	Y
C111200 to C112099	1956	P	H844342 to H875909	1969	K	L727430 to L891130	1973	Y
C111200 to C112099	1956	P				L891131 to L999976	1976	Y

Starting with 1957 and thru 1974, all serial numbers were suffixed by a dash and the last two digits of the year and a letter—"P" for Pittsfield, "Y" for Hickory, "K" for Oakland, and "M" for Merced, "T" for Shreveport. Example: C979401-37K.

In 1975 the serial number suffix was changed to use the GE date code. Example: M316674TEPA was built

in Shreveport, May 1978. The final "A" signifies aluminum windings.

• Some duplication of numbers has occurred between factories. Where this has happened, the suffix correctly indicates the approximate year of manufacture and the factory.

† Distribution Switches.

Serial Numbers

Page

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TRANSFORMER SERIAL NUMBERING SYSTEM

Starting with 1957 and thru 1974, all serial numbers were suffixed by a dash and the last two digits of the year and a letter — "P" for Pittsfield, "Y" for Hickory, "K" for Oakland, "M" for Merced, and "T" for Shreveport. Example: C979401-57K.

In 1975 the serial number suffix was changed to use the GE date code. For example, M316674TEPA can be interpreted as follows:

1. T = Shreveport (see above)

2. E = May

The month code began with "A" in January 1965 and ended with M in December, excluding the letter "I". This code will be used thru 1985. In 1986, with a new year code, the month code would be then begin with

the letter "N" through "Z", excluding the letter "C" and this sequence will run through the year 2006.

3. P = 1978

The year sequence was begun in 1965 with the letter "A", and excluding letters I, O, Q, V and Z, will end in 1985 with the letter "Y". This sequence will begin again in 1986 with the letter "A", but with different month code.

4. A = aluminum windings

This past history of the numbering system and what can be expected in the future should be of assistance in determining proper warranty procedures, and should also eliminate constant updating instructions on the serial number sequences.

Transformer Serial Numbers	Manufactured		Transformer Serial Numbers	Manufactured		Transformer Serial Numbers	Manufactured	
	Approx. Year	Factory		Approx. Year	Factory		Approx. Year	Factory
M000001 to M013933	1975..	Y	M585700 to M586199	1978	Y	N002094 to N002299	1980	Y
M039001 to M039183	1975	Y	M586200 to M589717	1978	T	N002300 to N007704	1979	T
M039184 to M039354	1976	Y	M590001 to M593173	1978	T	N007705 to N008744	1980	T
M039355 to M039499	1977	Y	M593174 to M606001	1979	T	N010001 to N020562	1980	T
M049500 to M130484	1976	Y	M606200 to M606967	1978	Y	N020563 to N022299	1981	T
						N022300 to N023028	1979	Y
M130485 to M295875	1977	Y	M606968 to M606989	1978	Y	N023029 to N199026	1980	Y
M300000 to M300392	1976	Y	M607000 to M701185	1978	Y	N199027 to N223592	1981	Y
M300393 to M303496	1977	Y	M701186 to M804951	1979	Y	N223593 to N224511	1980	Y
M303497 to M312770	1977	T	M807000 to M807573	1978	Y	N224512 to N225499	1981	Y
M312771 to M322859	1978	T	M807574 to M807775	1978	Y	N225500 to N229878	1981	T
M322860 to M323450	1978	T	M807800 to M808099	1978	Y	N230001 to N234963	1981	T
M323451 to M409959	1977	Y	M813100 to M813280	1978	Y	N234964 to N243284	1982	T
M409960 to M573456	1978	Y	M813281 to M815368	1979	Y	N243285 to M414941	1981	Y
M573457 to M573566	1977	Y	M815369 to M999569	1979	Y	M414942 to M439705	1982	Y
M573567 to M573800	1978	Y	M999570 to M999964	1980	Y	N443500 to M446156	1981	Y
M573801 to M574337	1977	Y	N000001 to N001335	1979	Y	M446157 to M446596	1982	Y
M574338 to M575700	1978	Y	N001336 to N002093	1979	Y	M446597 to M466797	1982	Y

L - 75

M - 76

N - 77

P - 78

R - 79

S - 80

T - 81

U - 82

W - 83

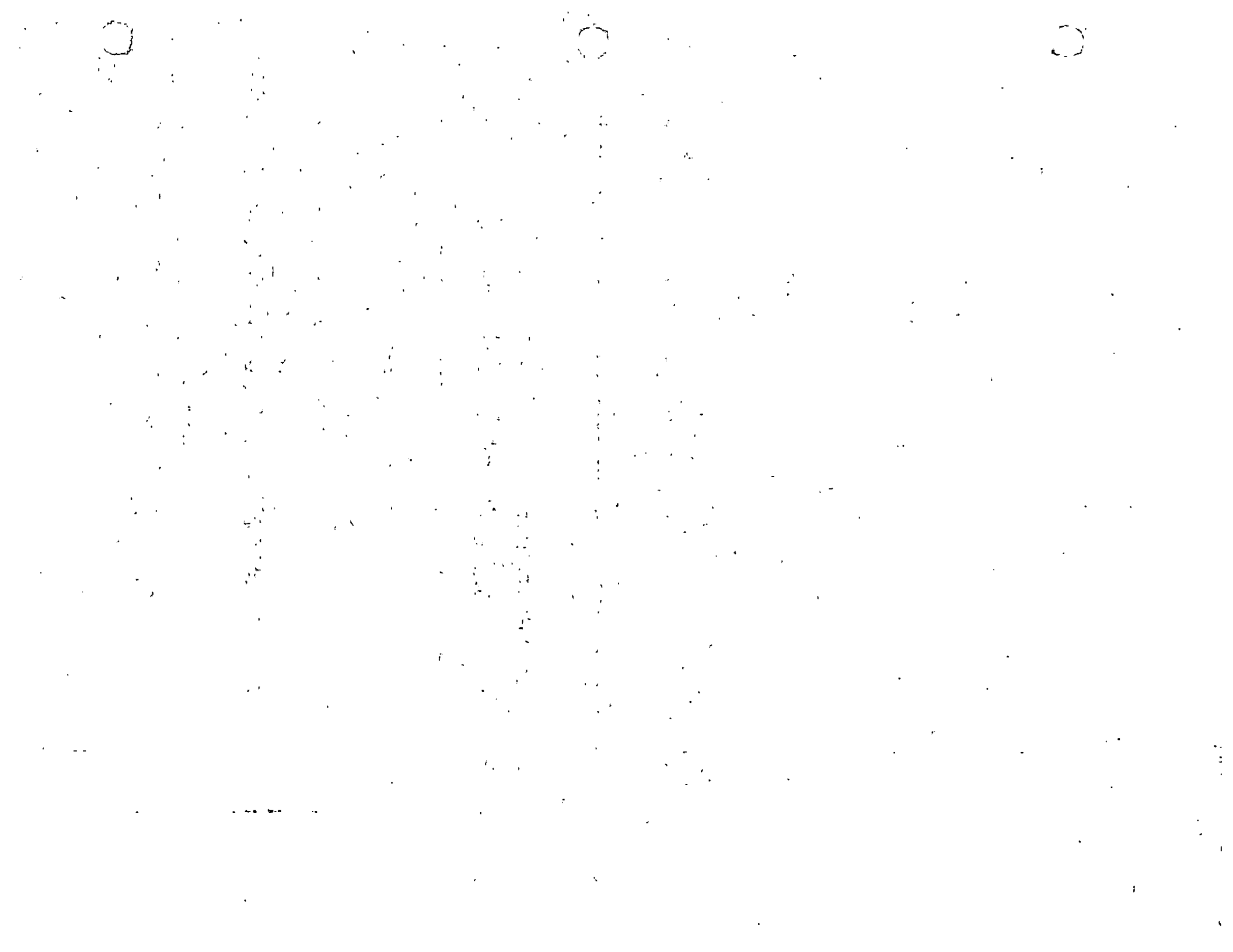
* Added or changed since Feb. 22, 1982 issue.

(m/c)

Data subject to change without notice

NA 700, 701, 702, 711-713, 721-723, 731-737

GENERAL ELECTRIC



**Toxicological
Profile
for**

**SELECTED PCBs (AROCLO-
1260, -1254, -1248, -1242, -
1232, -1221, and -1016)**

Draft
For Public Comment

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

Comment Period Ends:

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DEC 17 1987

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**PLAINTIFF'S
EXHIBIT**
476

WASHINGTON OCCUPATIONAL
HEALTH ASSOCIATES, INC.

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DRAFT

**TOXICOLOGICAL PROFILE FOR
SELECTED PCBs
(Aroclor-1260, -1254, -1248, -1242,
-1232, -1221, and -1016)**

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FOREWORD

The Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499) extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund). This public law (also known as SARA) directed the Agency for Toxic Substances and Disease Registry (ATSDR) to prepare toxicological profiles for hazardous substances which are most commonly found at facilities on the CERCLA National Priorities List and which pose the most significant potential threat to human health, as determined by ATSDR and the Environmental Protection Agency (EPA). The list of the 100 most significant hazardous substances was published in the *Federal Register* on April 17, 1987.

Section 110 (3) of SARA directs the Administrator of ATSDR to prepare a toxicological profile for each substance on the list. Each profile must include the following content:

- "(A) An examination, summary, and interpretation of available toxicological information and epidemiologic evaluations on the hazardous substance in order to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects,
- (B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure which present a significant risk to human health of acute, subacute, and chronic health effects, and
- (C) Where appropriate, an identification of toxicological testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans."

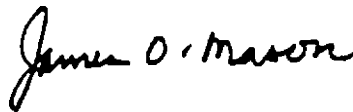
This toxicological profile is prepared in accordance with guidelines developed by ATSDR and EPA. The guidelines were published in the *Federal Register* on April 17, 1987. Each profile will be revised and republished as necessary, but no less often than every three years, as required by SARA.

The ATSDR toxicological profile is intended to characterize succinctly the toxicological and health effects information for the hazardous substance being described. Each profile identifies and reviews the key literature that describes a hazardous substance's toxicological properties. Other literature is presented but described in less detail than the key studies. The profile is not intended to be an exhaustive document; however, more comprehensive sources of specialty information are referenced.

Each toxicological profile begins with a public health statement, which describes in nontechnical language a substance's relevant toxicological properties. Following the statement is material that presents levels of significant human exposure and, where known, significant health effects. The adequacy of information to determine a substance's health effects is described in a health effects summary. Research gaps in toxicologic and health effects information are described in the profile. Research gaps that are of significance to protection of public health will be identified by ATSDR, the National Toxicology Program of the Public Health Service, and EPA. The focus of the profiles is on health and toxicological information; therefore, we have included this information in the front of the document.

The principal audiences for the toxicological profiles are health professionals at the federal, state, and local levels, interested private sector organizations and groups, and members of the public. We plan to revise these documents in response to public comments and as additional data become available; therefore, we encourage comment that will make the toxicological profile series of the greatest use.

This profile reflects our assessment of all relevant toxicological testing and information that has been peer reviewed. It has been reviewed by scientists from ATSDR, EPA, the Centers for Disease Control, and the National Toxicology Program. It has also been reviewed by a panel of nongovernment peer reviewers and was made available for public review. Final responsibility for the contents and views expressed in this toxicological profile resides with ATSDR.



James O. Mason, M.D., Dr. P.H.
Assistant Surgeon General
Administrator, ATSDR

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1. PUBLIC HEALTH STATEMENT

1.1 WHAT ARE PCBs?

The abbreviation PCB refers to polychlorinated biphenyls. PCBs are a family of man-made chemicals that contain 209 individual compounds. Because of their insulating and nonflammable properties, they have been used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The industrial manufacture of PCBs was stopped in the United States in October 1977 because it had been discovered that PCBs would accumulate and persist in the environment and could cause toxic effects. Some commercial PCB mixtures are known in the United States by their industrial trade name, Aroclor.

1.2 HOW MIGHT I BE EXPOSED TO PCBs?

Although PCBs are no longer manufactured, human exposure to these compounds is still occurring. Many of the transformers and capacitors that were filled with fluids containing PCBs when they were made still contain PCBs and are still in service. The useful lifetime of many of these transformers can be 30 years or more.

The two main sources of human exposure to PCBs are environmental and occupational. PCBs are very persistent chemicals that are widely distributed throughout the entire environment. Background levels of PCBs can be found in the outdoor air we breathe, on soil surfaces, and in water. Consumption of contaminated fish is a major source of PCB exposure to humans. Fish become contaminated with PCBs by exposure in water, which results in a very high accumulation of PCBs in the fish tissue. Most of the PCBs in the outdoor air we breathe may be present because of an environmental cycling process. Compared with the intake of PCBs through consumption of contaminated fish, exposure to PCBs as a result of breathing air containing PCBs is negligible. PCBs in water, or on soil surfaces, evaporate into the air and are then returned to earth by rainfall or settling of dust particles containing PCBs. Reevaporation repeats the cycle. Once in the air, PCBs can be carried long distances; PCBs have been found in snow and seawater in the Antarctic.

PCBs can be released into the environment from the following sources:

- Poorly maintained toxic waste sites which contain PCBs
- Illegal or improper dumping of PCB wastes, such as transformer fluids
- Leaks or fugitive emissions from electrical transformers containing PCBs

Some consumer products that may contain PCBs are:

- Fluorescent lighting fixtures made before PCB use was stopped
- Electrical devices or appliances containing PCB capacitors made before PCB use was stopped

Occupational exposure to PCBs can occur during:

- Repair or maintenance of PCB transformers
- Accidents or spills involving PCB transformers
- Disposal of PCB materials
- Contact at hazardous waste sites

1.3 HOW DO PCBs GET INTO MY BODY?

PCBs can enter the body when food containing PCBs is eaten, when air that contains PCBs is breathed, or when skin comes in contact with PCBs. Most exposure of the general population is by consumption of fish and shellfish from PCB-contaminated water. Exposure from drinking water is minimal. Infants can be exposed to PCBs from breastfeeding if the mothers have PCBs in their breast milk.

1.4 HOW DO PCBs AFFECT MY HEALTH?

Occasional skin irritations, usually acnelike lesions and rashes, and liver effects are the only significant adverse health effects that have been observed in PCB-exposed workers. Workers experience PCB exposures that are much higher than those received by the general public. Adverse health effects have not been observed in people in the United States with nonoccupational exposure. Effects of PCBs in experimentally exposed animals include liver damage, skin irritations, death, low birth weights and other reproductive effects, and cancer.

1.5 IS THERE A MEDICAL TEST TO DETERMINE IF I HAVE BEEN EXPOSED TO PCBs?

PCBs can be detected in the blood, body fat, and breast milk. Blood PCB levels are the best indicator of recent exposure to PCBs, and levels in the fat are the best indicators of long-term exposure. These tests are not routine clinical tests, but they could be used to detect PCBs in members of the general population as well as workers with occupational exposure to PCBs. Although these tests indicate if there has been exposure to PCBs, they cannot be used to predict potential health effects.

1.6 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

The graphs on the following pages show the relationship between exposure to PCBs and known health effects for the PCBs that are covered by this profile. Other PCBs may have different toxic properties. In the first set of graphs, labeled "Health effects from breathing PCBs,"

exposure is measured in milligrams of PCBs per cubic meter of air (mg/m^3). In all graphs, effects in animals are shown on the left side, effects in humans on the right.

In the second set of graphs, the same relationship is represented for the known "Health effects from ingestion of or skin contact with products containing PCBs." Exposures are measured in milligrams of PCBs per kilogram of body weight per day ($\text{mg}/\text{kg}/\text{day}$).

Figures 1.1, 1.2, and 1.3 show the relationship between exposure to PCBs and known health effects. The scales represent exposure levels. The first column on the graphs, labeled "Short-Term," refers to known health effects from exposure to PCBs for 2 weeks or less. The columns labeled "Long-Term" refer to PCB exposures of longer than 2 weeks. The level marked on Fig. 1.1 as the TLV (threshold limit value) is an average level recommended as a limit for workers over an 8-hour workshift and 40-hour workweek. The levels marked on the graphs as anticipated to be associated with minimal risk of developing health effects are based on information generated from animal studies; therefore, some uncertainty still exists. Based on information that PCBs cause cancer in animals, the Environmental Protection Agency (EPA) considers PCBs to be probable cancer-causing chemicals in humans and has estimated that ingestion of 1 microgram of PCB per kilogram per day for a lifetime would result in 770 additional cases of cancer in a population of 10,000 people and 770,000 additional cases of cancer in a population of 10,000,000 people. It should be noted that these risk values are plausible upper-limit estimates. Actual risk levels are unlikely to be higher and may be lower.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The government has made recommendations to limit exposure to PCBs in the workplace and exposure of the general public to PCBs in drinking water and food. The National Institute for Occupational Safety and Health (NIOSH) recommends an occupational exposure limit for all PCBs of 0.001 milligram of PCBs per cubic meter of air (mg/m^3) for a 10-hour workday, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends limits of 0.5-2 mg/m^3 for occupational exposures to specific PCBs (see Fig. 1.1).

EPA recommends that levels in drinking water of 0.0035 milligram PCB 1016 per liter of water (mg/L) for adults and 0.001 mg/L PCB 1016 for children are probably safe. These health advisories are for a specific PCB (1016) because other PCBs have not been detected in drinking water; an exposure period of approximately 7 years is assumed. With respect to cancer, however, it is assumed that "any exposure involves some risk" in the absence of information to the contrary.

The Food and Drug Administration (FDA) specifies PCB concentration limits of 0.2 to 3 parts per million (milligrams PCB per kilogram of food) in foods such as infant foods, eggs, milk (in milk fat), and poultry (fat).

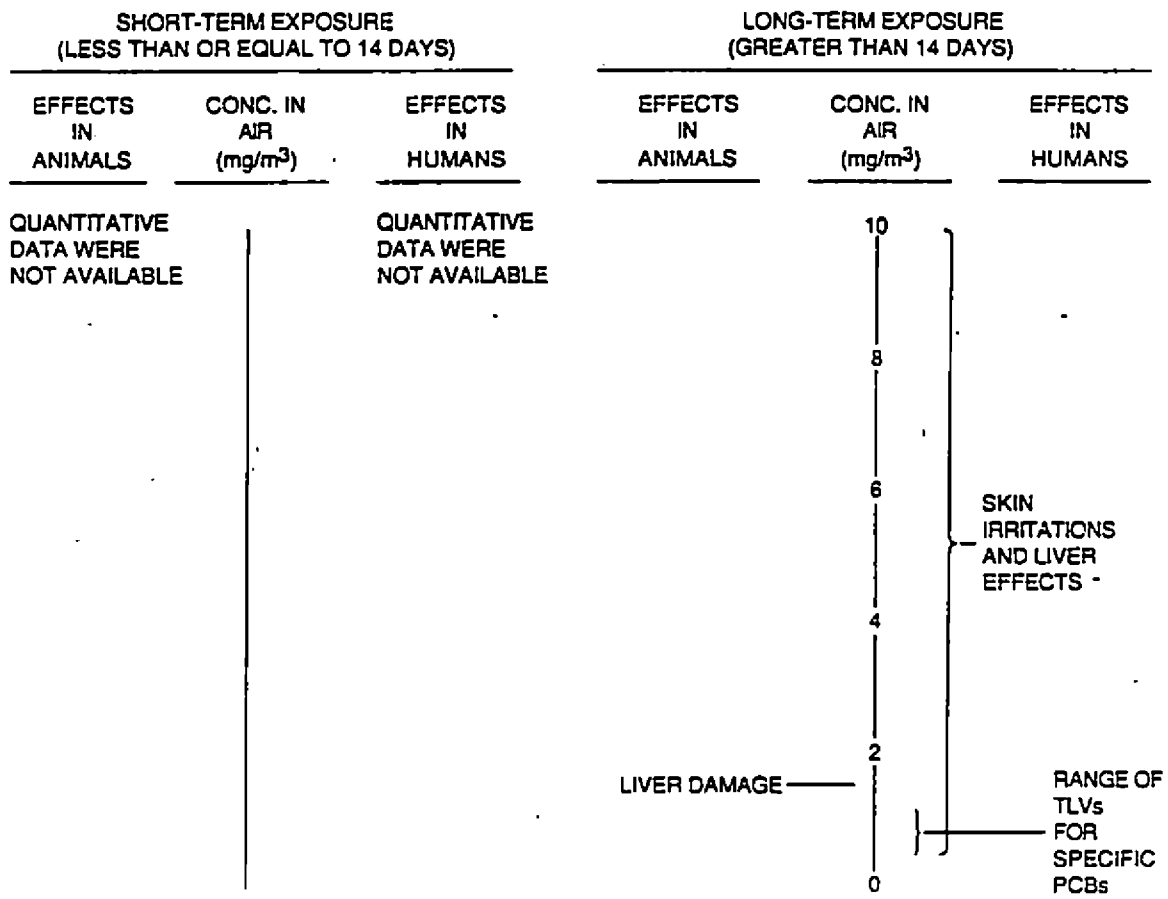


Fig. 1.1. Health effects from breathing PCBs.

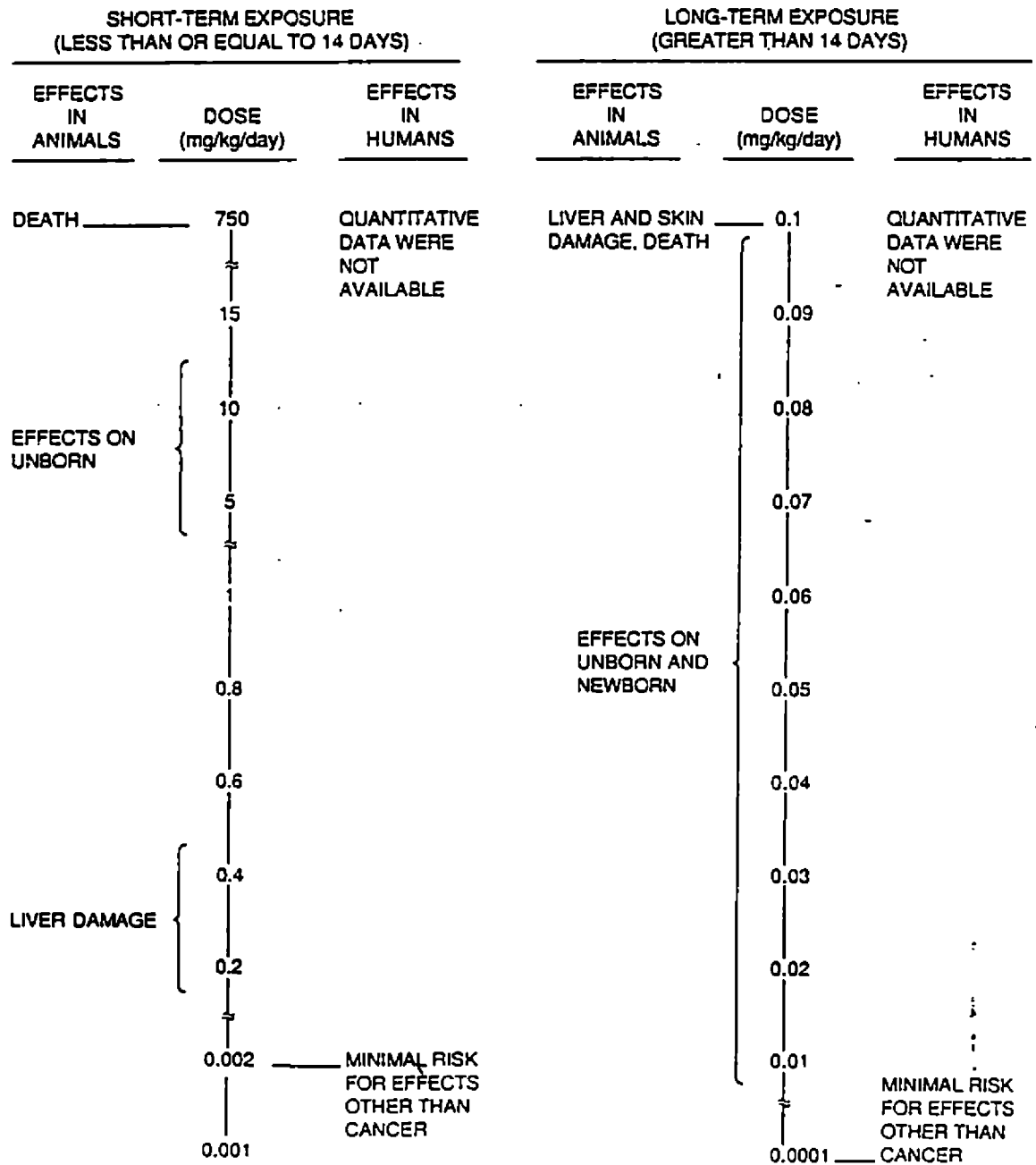


Fig. 1.2. Health effects from ingesting PCBs.

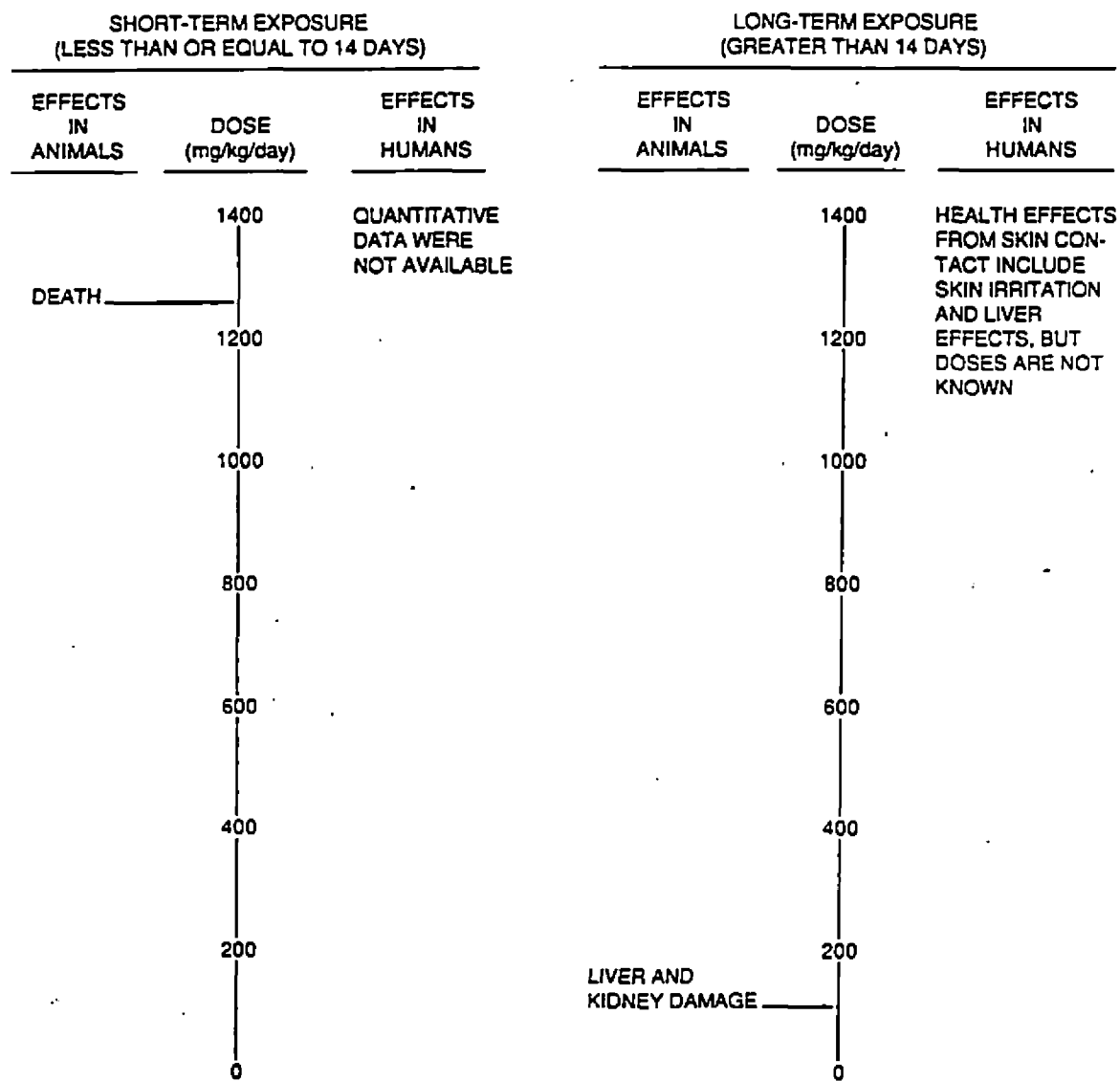


Fig. 1.3. Health effects from skin contact with PCBs.

2. HEALTH EFFECTS SUMMARY

2.1 INTRODUCTION

This section summarizes and graphs data on the health effects concerning exposure to PCBs. The purpose of this section is to present levels of significant exposure for PCBs based on key toxicological studies, epidemiological investigations, and environmental exposure data. The information presented in this section is critically evaluated and discussed in Sect. 4, Toxicological Data, and Sect. 7, Potential for Human Exposure.

This Health Effects Summary section comprises two major parts. Levels of Significant Exposure (Sect. 2.2) presents brief narratives and graphics for key studies in a manner that provides public health officials, physicians, and other interested individuals and groups with (1) an overall perspective of the toxicology of PCBs and (2) a summarized depiction of significant exposure levels associated with various adverse health effects. This section also includes information on the levels of PCBs that have been monitored in human fluids and tissues and information about levels of PCBs found in environmental media and their association with human exposures.

The significance of the exposure levels shown on the graph may differ depending on the user's perspective. For example, physicians concerned with the interpretation of overt clinical findings in exposed persons or with the identification of persons with the potential to develop such disease may be interested in levels of exposure associated with frank effects (Frank Effect Level, FEL). Public health officials and project managers concerned with response actions at Superfund sites may want information on levels of exposure associated with more subtle effects in humans or animals (Lowest-Observed-Adverse-Effect Level, LOAEL) or exposure levels below which no adverse effects (No-Observed-Adverse-Effect Level, NOAEL) have been observed. Estimates of levels posing minimal risk to humans (Minimal Risk Levels) are of interest to health professionals and citizens alike.

Adequacy of Database (Sect. 2.3) highlights the availability of key studies on exposure to PCBs in the scientific literature and displays these data in three-dimensional graphs consistent with the format in Sect. 2.2. The purpose of this section is to suggest where there might be insufficient information to establish levels of significant human exposure. These areas will be considered by the Agency for Toxic Substances and Disease Registry (ATSDR), EPA, and the National Toxicology Program (NTP) of the U.S. Public Health Service in order to develop a research agenda to provide this information.

2.2 LEVELS OF SIGNIFICANT EXPOSURE

To help public health professionals address the needs of persons living or working near hazardous waste sites, the toxicology data summarized in this section are organized first by route of exposure--inhalation, ingestion, and dermal--and then by toxicological end points that are categorized into six general areas--lethality, systemic/target organ toxicity, developmental toxicity, reproductive toxicity, genetic toxicity, and carcinogenicity. The data are discussed in terms of three exposure periods--acute, intermediate, and chronic.

Two kinds of graphs are used to depict the data. The first type is a "thermometer" graph. It provides a graphical summary of the human and animal toxicological end points (and levels of exposure) for each exposure route for which data are available. The ordering of effects does not reflect the exposure duration or species of animal tested. The second kind of graph shows Levels of Significant Exposure (LSE) for each route and exposure duration. The points on the graph showing NOAELs and LOAELs reflect the actual doses (levels of exposure) used in the key studies. No adjustments for exposure duration or intermittent exposure protocol were made.

Adjustments reflecting the uncertainty of extrapolating animal data to man, intraspecies variations, and differences between experimental vs actual human exposure conditions were considered when estimates of levels posing minimal risk to human health were made for noncancer end points. These minimal risk levels were derived for the most sensitive noncancer end point for each exposure duration by applying uncertainty factors. These levels are shown on the graphs as a broken line starting from the actual dose (level of exposure) and ending with a concave-curved line at its terminus. Although methods have been established to derive these minimal risk levels (Barnes et al. 1987), shortcomings exist in the techniques that reduce the confidence in the projected estimates. Also shown on the graphs under the cancer end point are low-level risks (10^{-4} to 10^{-7}) reported by EPA. In addition, the actual dose (level of exposure) associated with the tumor incidence is plotted.

2.2.1 Key Studies and Graphical Presentations

Dose-response-duration data for the toxicity and carcinogenicity of the PCBs discussed in this profile are displayed in two types of graphs. These data are derived from the key studies described in the following sections. The "thermometer" graphs in Figs. 2.1, 2.2, and 2.3 plot exposure levels vs NOAELs and LOAELs for various effects and durations of inhalation, oral, and dermal exposures, respectively. The graphs of levels of significant exposure in Figs. 2.4, 2.5, and 2.6 plot end point-specific NOAELs, LOAELs, and/or minimal levels of risk for acute (≤ 14 days), intermediate (15-364 days), and chronic (≥ 365 days) durations for inhalation, oral, and dermal exposures, respectively. Dermal exposure contributes significantly to occupational exposure, but the relative contributions of dermal and inhalation exposure in occupational settings has not been discerned (Wolff 1985). Furthermore, occupational exposure levels are expressed as concentrations of PCBs in air, making it difficult to quantitate dermal exposure doses. For this

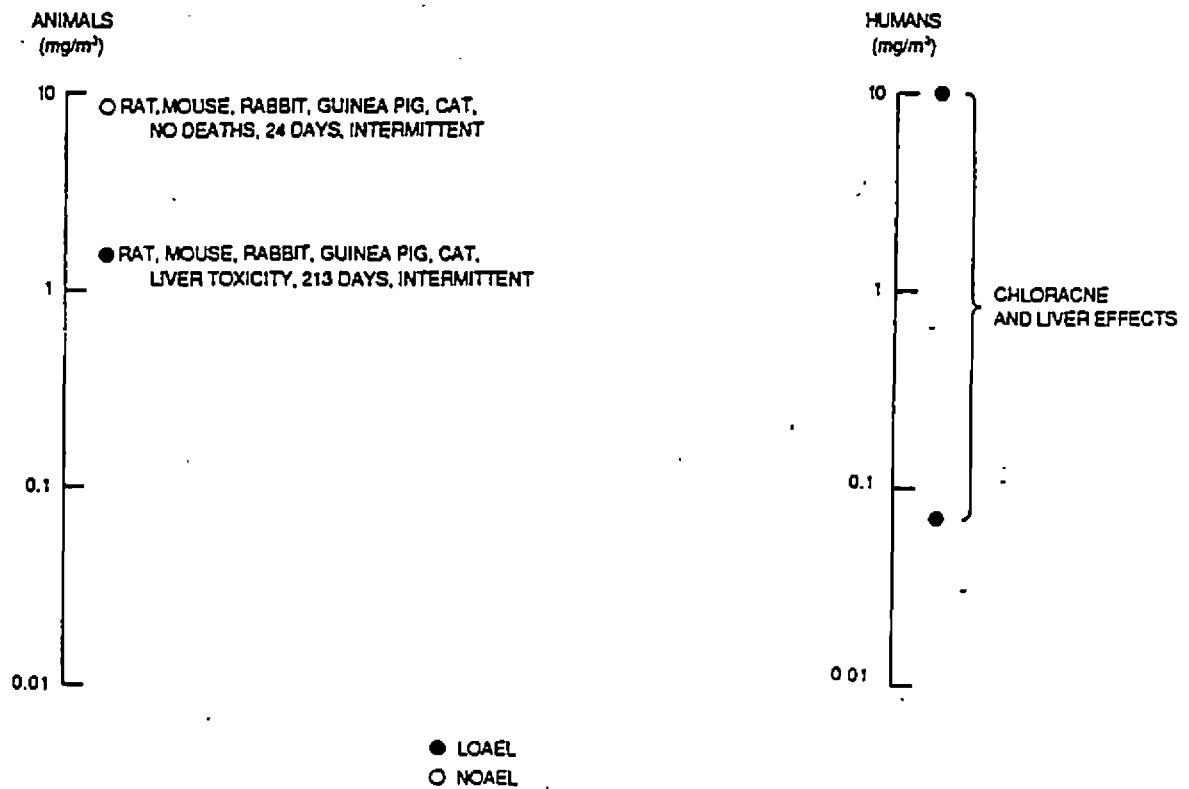


Fig. 2.1. Effects of PCBs—inhalaion exposure.

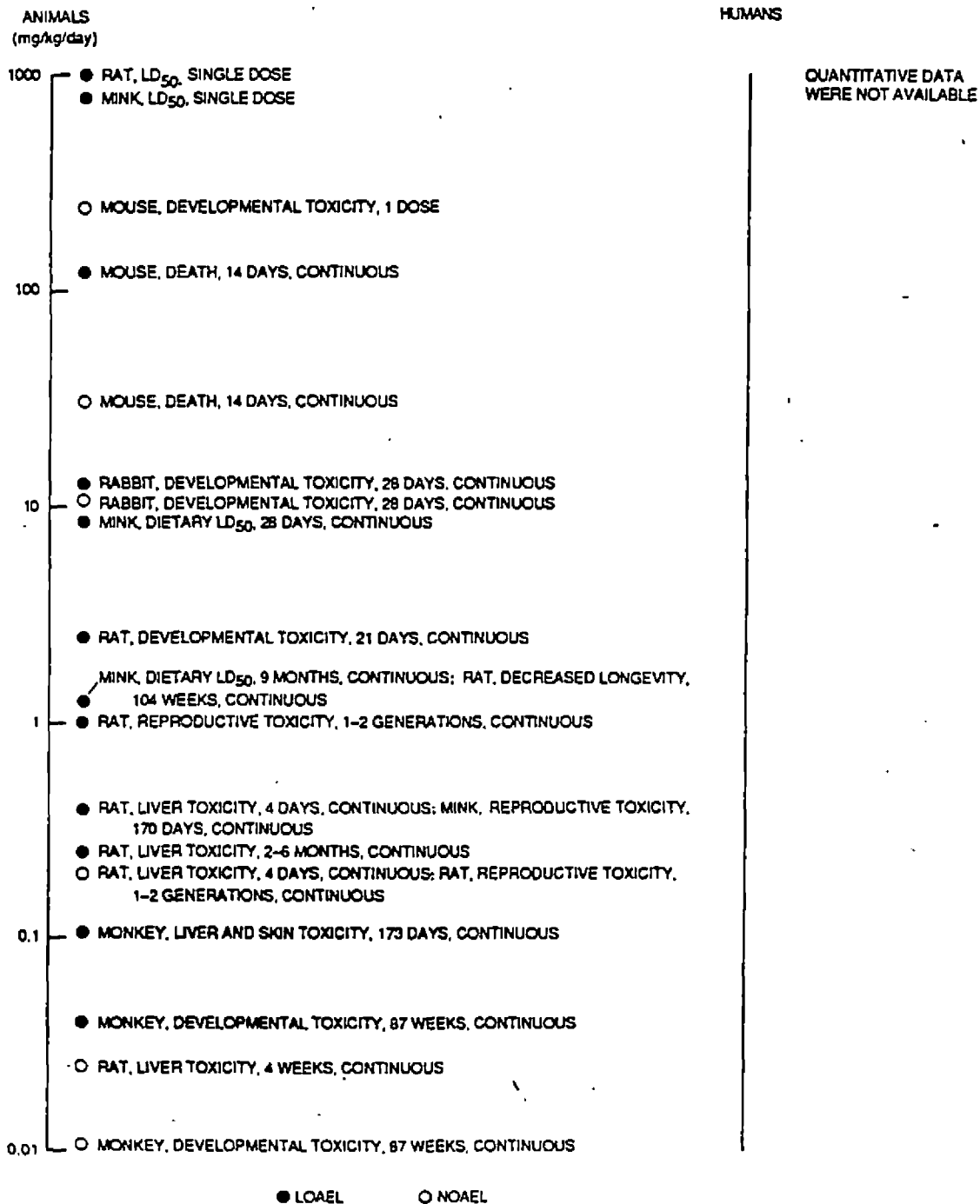


Fig. 2.2. Effects of PCBs—oral exposure.

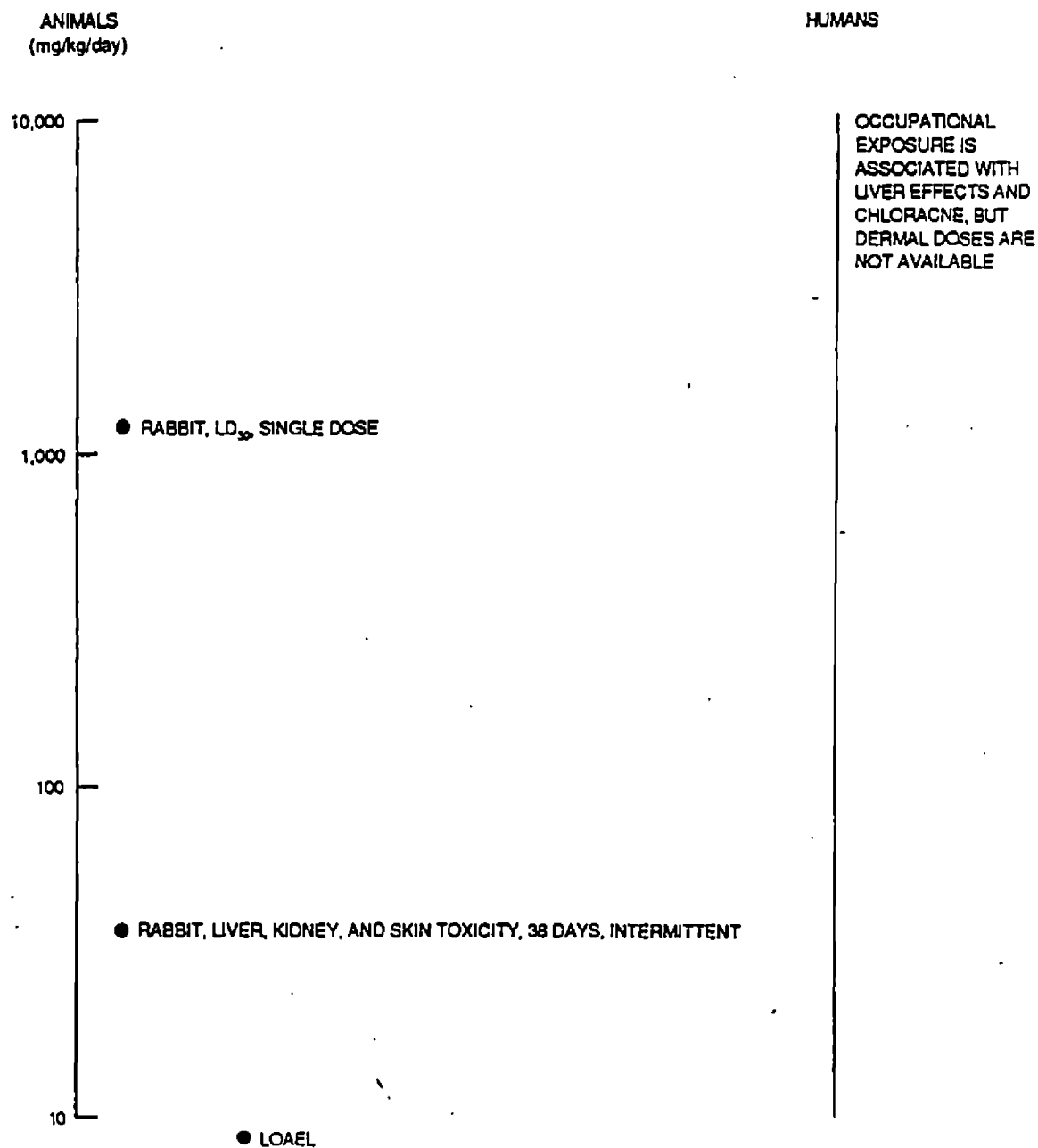


Fig. 2.3. Effects of PCBs—dermal exposure.

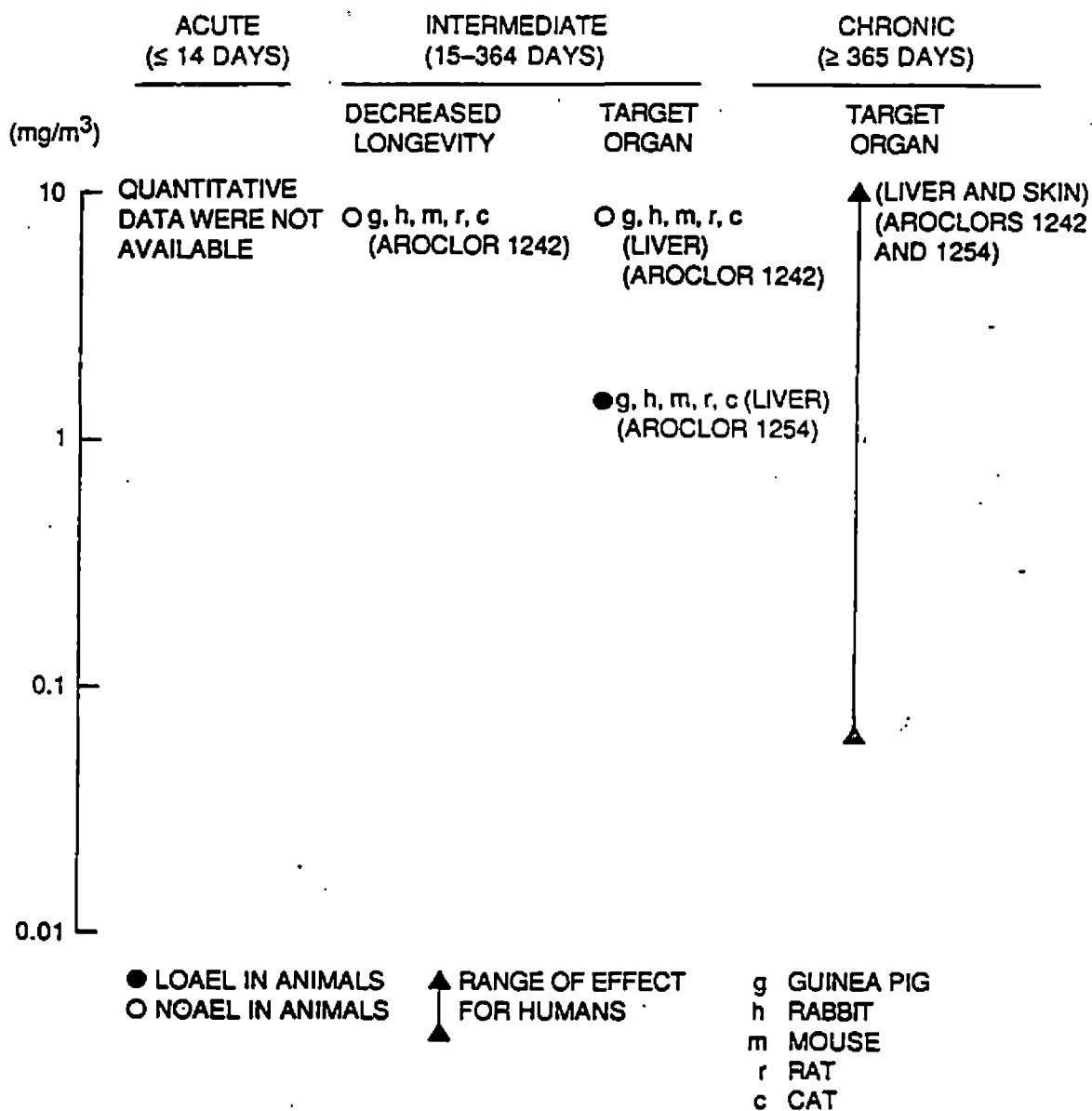


Fig. 2.4. Levels of significant exposure for PCBs—inhalaion exposure.

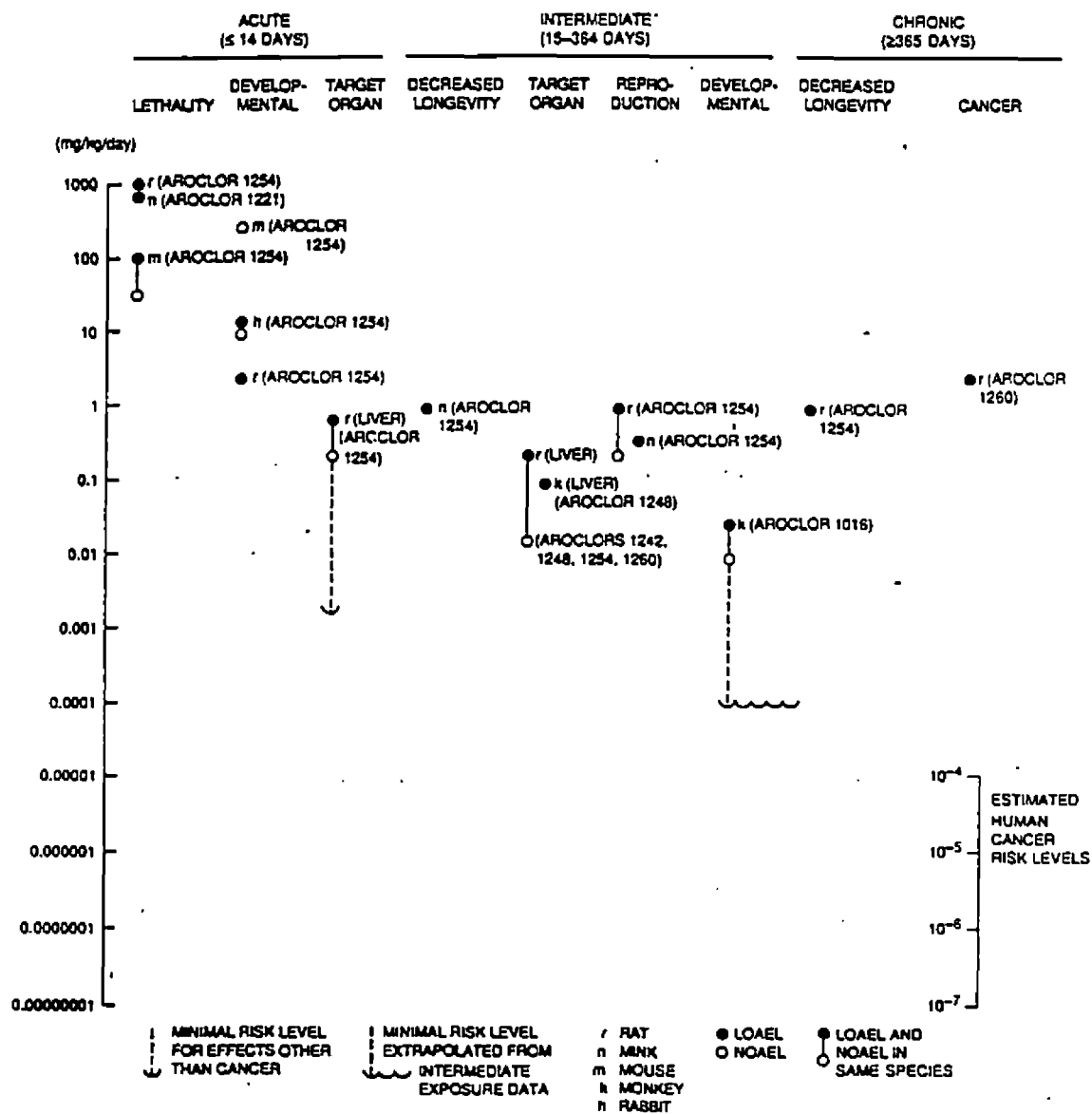


Fig. 2.5. Levels of significant exposure for PCBs—oral.

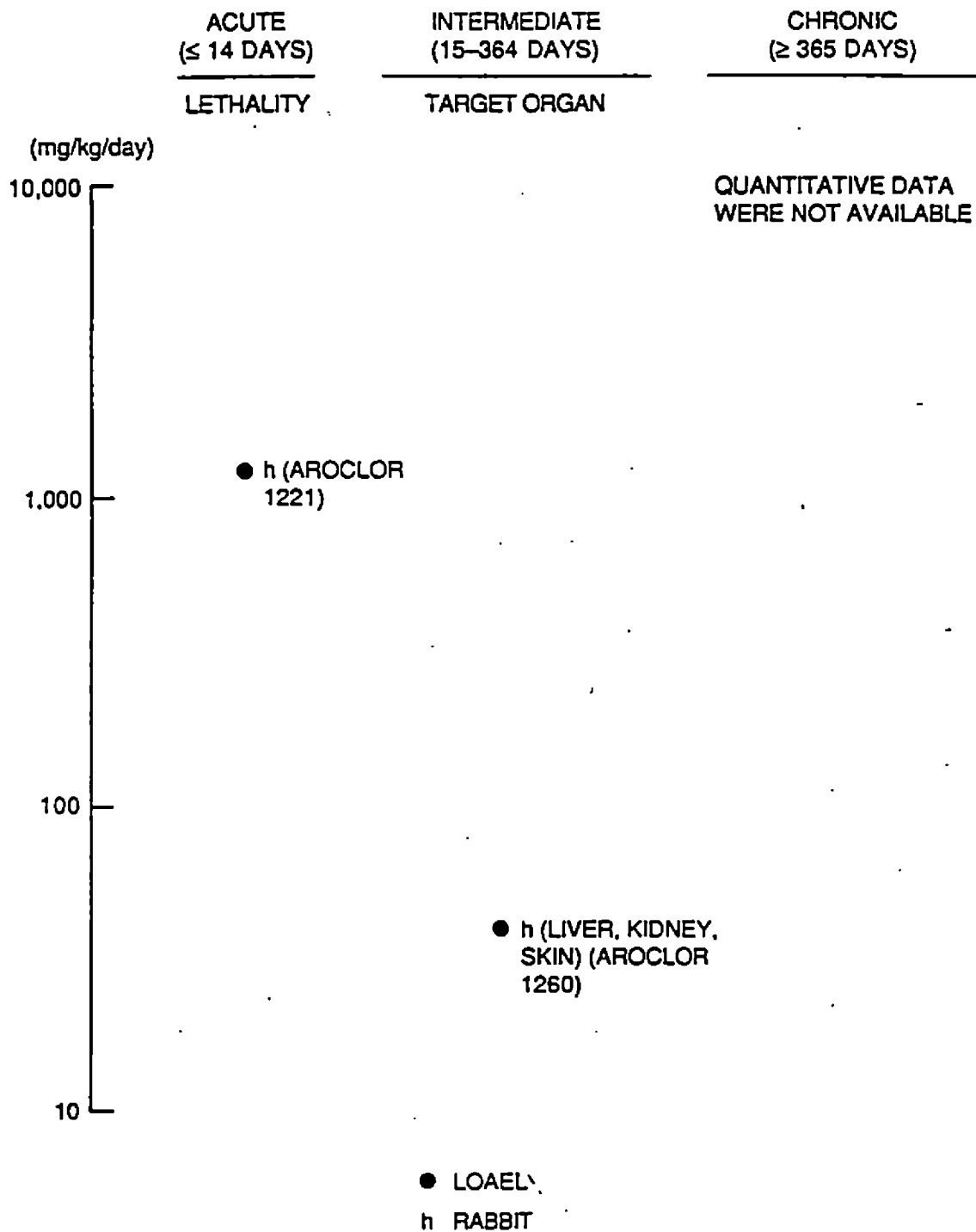


Fig. 2.6. Levels of significant exposure for PCBs—dermal exposure.

reason, effects of occupational exposure are discussed under inhalation exposure and plotted in Figs. 2.1 and 2.4 (graphs for inhalation exposure).

2.2.1.1 Inhalation exposure

Lethality and decreased longevity. Data regarding inhalation exposure levels that produce death in humans were not available. Exposure to near saturation vapor concentrations of heated Aroclor 1242 (8.6 mg/m^3) 7 h/day, 5 days/week for 24 days was not lethal for cats, rats, mice, rabbits, or guinea pigs (Treon et al. 1956). This concentration represents a NOAEL for lethality for intermediate inhalation exposures (see Figs. 2.1 and 2.4). No data were available regarding lethality/decreased longevity of animals due to acute or chronic inhalation exposure to PCBs.

Target organ/systemic toxicity. Oral toxicity studies have established that the liver and cutaneous tissues are primary target organs of PCBs. Occupational exposure to PCBs has been associated with alterations in serum levels of liver enzymes and dermatological effects such as chloracne (Meigs et al. 1954; Ouwet et al. 1976; Fischbein et al. 1979, 1982; Baker et al. 1980; Smith et al. 1981a,b,c). Although monitoring data were reported in some of the studies, exposure levels were not adequately characterized. Furthermore, although inhalation exposure is considered a major route of exposure, the contribution of dermal exposure to total occupational exposure is also significant. Fischbein et al. (1979) reported that occupational 8-h time-weighted average (TWA) concentrations of Aroclor 1242 and 1254 ranged from 0.07 to 11.0 mg/m^3 in workers who had increased SGOT levels and skin effects; the range is plotted on Figs. 2.1 and 2.4.

In the only animal inhalation study of PCBs, degenerative liver lesions, a frank effect, occurred in cats, rats, mice, rabbits, and guinea pigs that were exposed to 1.5 mg/m^3 Aroclor 1254 vapor for 7 h/day, 5 days/week for 213 days (Treon et al. 1956). This FEL is plotted on Figs. 2.1 and 2.4. Histologic effects were not produced in those species exposed to Aroclor 1242 (1.9 mg/m^3 7 h/day, 5 days/week for 214 days, 8.6 mg/m^3 7 h/day, 5 days/week for 24 days). The higher NOAEL of 8.6 mg/m^3 for intermediate-duration inhalation exposure is plotted on Fig. 2.4. Since the FEL for Aroclor 1254 is lower than the NOAEL for Aroclor 1242, a minimal risk level cannot be derived.

Developmental toxicity. Pertinent data regarding developmental effects of PCBs via inhalation exposure in animals were not located in the available literature. Slightly lowered mean birth weight and gestational age was observed in infants born to mothers with occupational exposure (dermal and inhalation) to PCBs, but monitoring data were not reported (Taylor et al. 1984).

Reproductive toxicity. Pertinent data regarding reproductive effects of PCBs via inhalation exposure in humans or animals were not located.

Genotoxicity. The PCBs have produced generally negative results in *in vivo* and *in vitro* genotoxicity assays (Sect. 4.3.5 on genotoxicity in toxicological data section).

Carcinogenicity. An increased incidence of malignant melanomas was reported in a group of workers exposed occupationally (considered inhalation, although dermal exposure is also considered to be likely) to Aroclor 1254 (Bahn et al. 1976). These and other data provide inadequate evidence of carcinogenicity in humans (Sect. 4.3.6 on carcinogenicity in toxicological data section). Data regarding the carcinogenicity of inhaled PCBs in animals were not available.

2.2.1.2 Oral exposure

Lethality and decreased longevity. Data regarding oral exposure levels that produce death in humans were not available. Single-dose oral LD50s for PCBs have been reported for rats and mink. The lowest values are 750 mg/kg for Aroclor 1221 in mink (Aulerich and Ringer 1977) and 1010 mg/kg for Aroclor 1254 in rats (Garthoff et al. 1981). These FELs are plotted on Figs. 2.2 and 2.5 for lethality due to acute oral exposure.

In mice fed diets containing 1000 ppm Aroclor 1254 for 14 days, 3 of 5 died by day 15 (Sanders et al. 1974). No mice fed diets containing 250 ppm Aroclor 1254 for 14 days died. Thus, 250 ppm is a NOAEL, and 1000 ppm is a FEL for lethality in mice for short-term oral exposure. Assuming that a mouse consumes a daily amount of food equal to 13% of its body weight (EPA 1986a), the NOAEL is equivalent to 32.5 mg/kg/day, and the FEL is equivalent to 130 mg/kg/day. These levels are plotted on Figs. 2.2 and 2.5 for lethality for acute oral exposure. Hornshaw et al. (1986) determined LC50s of Aroclor 1254 for dietary exposure in mink to be 79-84 ppm for 28 days and 47-49 ppm for 28 days followed by a 7-day withdrawal period. In mink fed Aroclor 1254 for 9 months, the LC50 was 6.65 ppm (Ringer et al. 1981). Assuming that mink consume 150 g of feed per day and weigh 800 g (Bleavins et al. 1980), 47 ppm is equivalent to an LD50 of 8.8 mg/kg/day (see Fig. 2.2), and 6.65 ppm is equivalent to an LD50 of 1.25 mg/kg/day. This FEL is plotted on Figs. 2.2 and 2.5 for intermediate exposure.

Reduced survival occurred in rats fed diets containing >25 ppm Aroclor 1254 for 104 weeks (NCI 1978). Assuming that rats consume the equivalent of 5% of their body weight per day in food (EPA 1986a), then 1.25 mg/kg/day represents a FEL for chronic oral exposure in rats (see Figs. 2.2 and 2.5). NOAELs for increased mortality were not identified in these studies.

Target organ/systemic toxicity. The liver and cutaneous tissues are primary targets of PCB toxicity in orally exposed animals.

Increased relative liver weight occurred in rats fed diets containing >8 ppm but not 4 ppm Aroclor 1254 for 4 days (Carter 1985). The 4- and 8-ppm levels, which correspond to 0.2 and 0.4 mg/kg/day, respectively, if rat food consumption is assumed to be 5% of body weight per day, represent a NOAEL and LOAEL for acute oral exposure (see Figs. 2.2 and 2.5). The NOAEL is the basis for the minimal risk level for acute oral exposure (see Fig. 2.5).

In intermediate-duration studies, hepatic microsomal enzyme activities were increased in rats treated with diet concentrations of 0.5, 5, or 50 ppm Aroclors 1242, 1248, 1254, or 1260 for 4 weeks (Litterst et al. 1972). Dietary exposure to 5 ppm Aroclor 1242 for 2 to 6 months produced increased liver lipid content in rats (Bruckner et al. 1974) and >20 ppm Aroclor 1254, or 1260 for 28 days (Chu et al. 1977) or 8 months (Kimbrough et al. 1972) produced frank degenerative liver alterations in rats. Dietary concentrations of 0.5 ppm Aroclors 1242, 1248, 1254, and 1260 and 5 ppm Aroclor 1242, therefore, represent the highest NOAEL and lowest LOAEL, respectively, for intermediate-duration hepatic effects in rats. Assuming that rats consume 5% of their body weight in food per day, the NOAEL and LOAEL provided 0.025 and 0.25 mg/kg/day, respectively (see Figs. 2.2 and 2.5).

Two monkeys that died from dietary exposure to 2.5 or 5.0 ppm Aroclor 1248 for 173 or 310 days, respectively, had frank liver lesions (Barsotti et al. 1976). Although this study is limited by the number of animals, other studies with monkeys corroborate these FELs, as chloracne and gastric lesions were also associated with intermediate-duration exposure to 2.5 or 5.0 ppm Aroclor 1248 (Barsotti and Allen 1975, Barsotti et al. 1976, Thomas and Hinsdill 1978). The lowest monkey FEL (2.5 ppm) is equivalent to 0.105 mg/kg/day (see Figs. 2.2 and 2.5) if it is assumed that monkey food consumption is 4.2% of body weight per day (EPA 1986a).

Chronic feeding studies with rats (NCI 1978; Morgan et al. 1981, Ward 1985, Norback and Weltman 1985, Kimbrough et al. 1975), conducted at concentrations (>20 ppm) that were higher than the lowest FELs in the intermediate-duration monkey studies, did not produce non-preneoplastic or nonproliferative liver lesions. Chronic (12 to 16 month) feeding studies were conducted with 2.5 and 5.0 ppm Aroclor 1248 in monkeys (Barsotti and Allen 1975, Barsotti et al. 1976), but skin lesions and other effects (as indicated above and in subsequent sections) occurred after several months of exposure. Therefore, it is inappropriate to identify effect levels for systemic effects resulting from chronic oral exposure because of the types of liver lesions (preneoplastic) in rats and the short latency for cutaneous and other effects in monkeys.

Developmental toxicity. Slightly decreased birth weight, head circumference, and gestational age were observed in newborns of mothers who were consumers of PCB-contaminated fish, but the effects were not associated with specific levels of intake (Fein 1984, Fein et al. 1984). Rogan et al. (1986) found that levels >3.5 ppm PCBs in milk fat were significantly correlated with decreased muscle tone, decreased activity, and abnormal reflexes in human infants. Jacobson et al. (1985) found that consumption of PCB-contaminated fish by mothers and serum cord levels of PCBs were predictors of poor visual recognition memory and fixation to novelty in infants. The doses of PCBs consumed by the mothers cannot be determined in these studies.

Collins and Capen (1980a) fed diets containing Aroclor 1254 at 0, 50, or 500 ppm to female rats during gestation and lactation. Significantly ($P < 0.001$) reduced litter size occurred at 500 ppm. At both 50 and 500 ppm, the neonates and weanlings had ultrastructural

lesions in the thyroid follicular cells and reduced serum levels of thyroid hormone. Thus, 50 ppm is the LOAEL for fetotoxicity due to oral exposure in rats. Assuming that a rat consumes a daily amount of food equal to 5% of its body weight (EPA 1986a), 50 ppm is equivalent to 2.5 mg/kg/day. The LOAEL is indicated on Figs. 2.2 and 2.5 for developmental toxicity in rats.

Gestational exposure to Aroclor 1254 by gavage produced fetotoxic effects in rabbits exposed on days 1-28 at doses >12.5 mg/kg/day but not <10 mg/kg/day (Villeneuve et al. 1971). The dose of 10 mg/kg/day, therefore, represents a NOAEL for developmental effects in rabbits (see Figs. 2.2 and 2.5, acute exposure). The dose of 12.5 mg/kg/day represents a FEL for developmental effects in rabbits because it produced fetal deaths.

Haake et al. (1987) reported that treatment of pregnant C57BL/6 mice with Aroclor 1254 by gavage at 244 mg/kg on day 9 of gestation did not result in any fetuses with cleft palate. This dose is plotted on Figs. 2.2 and 2.5 as a NOAEL for developmental toxicity in mice.

Monkeys that were fed diets containing 1.0 ppm of Aroclor 1016 for approximately 7 months prior to mating and during pregnancy delivered infants with reduced birth weights, but this effect did not occur at 0.25 ppm (Barsotti and Van Miller 1984). Assuming that a monkey consumes a daily amount of food equal to 4.2% of its body weight, the daily dosages in the 1.0 ppm (LOAEL) and 0.25 ppm (NOAEL) groups were 0.04 and 0.0105 mg/kg/day, respectively. The NOAEL serves as the basis for the minimal risk level for intermediate and chronic oral exposure as derived by EPA (1987a). Fetal mortality, a frank effect, occurred at >2.5-ppm (0.1-mg/kg/day) dietary concentrations of Aroclor 1248 in other studies with monkeys (Allen and Barsotti 1976; Allen et al. 1979, 1980).

Reproductive toxicity. There are no studies regarding reproductive effects of PCBs in humans. Diets that provided >2 ppm of Aroclor 1254 for 4 months prior to mating and during gestation were lethal to fetuses and caused reproductive failure in mink (Aulerich and Ringer 1977, Bleavins et al. 1980). Assuming that mink consume 150 g of feed per day and weigh 800 g (Bleavins et al. 1980), then the 2-ppm FEL provided 0.38 mg/kg/day (see Figs. 2.2 and 2.5).

Reduced litter sizes occurred at Aroclor 1254 dietary concentrations of >20 ppm but not <5 ppm in one- and two-generation reproduction studies with rats (Linder et al. 1974). The dietary concentrations of 5 ppm (NOAEL) and 20 ppm (FEL) provided 0.25 and 1 mg/kg/day, respectively, if rat food consumption is assumed to be 5% of body weight per day (EPA 1986a). These levels are plotted on Figs. 2.2 and 2.5 for reproductive effects of intermediate oral exposure in rats.

Genotoxicity. The PCBs have produced generally negative results in in vivo and in vitro genotoxicity tests (Sect. 4.3.5 on genotoxicity in toxicological data section).

Carcinogenicity. EPA (1987a) used the Norback and Weltman (1985) study as the basis for a quantitative carcinogenicity risk assessment for PCBs. The dietary level of 100 ppm Aroclor 1260 was converted to an intake of 5 mg/kg/day by assuming that a rat consumes food equal to 5% of its body weight per day. This dosage was converted to a TWA dosage of

3.45 mg/kg/day (see Fig. 2.5) to reflect the fact that rats received 100 ppm for 16 months, 50 ppm for 8 months, and 0 ppm for the last 5 months. The rat dosage was converted to an equivalent human dose of 0.59 mg/kg/day on the basis of relative body surface areas. Incidences of trabecular carcinomas, adenocarcinomas, and neoplastic nodules in the liver were combined to produce total incidences of 45/47 in treated females and 1/49 in controls. Using these data, EPA (1987a) calculated a human q_1^* of $7.7 \text{ (mg/kg/day)}^{-1}$. Dosages corresponding to risk levels of 10^{-4} , 10^{-5} , 10^{-6} , and 10^{-7} are 1.3×10^{-5} , 1.3×10^{-6} , 1.3×10^{-7} , and 1.3×10^{-8} mg/kg/day, respectively. The 10^{-4} to 10^{-6} risk levels are indicated on Fig. 2.5.

2.2.1.3 Dermal

Occupational exposure to PCBs is considered to be by the inhalation route in this profile, since air levels are commonly monitored in the workplace setting. It is clear, however, that under occupational conditions dermal exposure would also occur. This was recognized by ACGIH (1986) when a skin notation was placed with the TLV. Dermal adsorption and exposure can occur from contact of the skin with the vapors of PCB as well as actual dermal contact with the compound or with contact with dust or surfaces to which the PCBs are absorbed. Although it is realized that dermal exposure may be a major route of exposure in the occupational setting, quantitation of the relative contribution to body burden of absorbed PCBs from the inhalation and dermal routes is not possible.

Lethality and decreased longevity. Human data are not available. Median lethal doses for single dermal applications of PCBs to rabbits ranged from >1269 mg/kg for Aroclors 1242 and 1248 to <3169 mg/kg for Aroclor 1221 (Fishbein 1974). As only ranges of median lethal doses were reported, the lowest dose (1269 mg/kg) is indicated on Figs. 2.3 and 2.6.

Systemic target organ toxicity. Occupational exposure to PCBs involves dermal contact, but, for reasons discussed previously, occupational exposure data were discussed under inhalation exposure.

Dermal application of Aroclor 1260 to rabbits on 5 days/week at a dose of 118 mg/day for 38 days (27 total applications) produced degenerative lesions of the liver and kidneys, increased fecal porphyrin elimination, and hyperplasia and hyperkeratosis of the follicular and epidermal epithelium (Vos and Beems 1971). As body weight appeared to be approximately 2.7 kg (Vos and Beems 1971), the FEL of 118 mg/day is equal to a dose of 43.7 mg/kg/day (see Figs. 2.3 and 2.6).

Developmental and reproductive toxicity. Pertinent data regarding developmental and reproductive effects of dermal exposure to PCBs were not located in the available literature.

Genotoxicity. The PCBs have produced generally negative results in in vivo and in vitro genotoxicity tests (Sect. 4.3.5 on genotoxicity in toxicological data section).

Carcinogenicity. Occupational exposure to PCBs, which involves inhalation as well as dermal exposure, provides inadequate evidence of carcinogenicity in humans (Sect. 4.3.6 on carcinogenicity in

toxicological data section). Aroclor 1254 has shown weak tumor initiator but not promoter activity in two-stage carcinogenesis studies with mouse skin. Dermal studies of PCBs as whole carcinogens have not been conducted in animals (Sect. 4.3.6.3 on carcinogenicity of dermal exposure in toxicological data section).

2.2.2 Biological Monitoring as a Measure of Exposure and Effects

2.2.2.1 Exposure

PCBs are pervasive environmental contaminants that are found in body tissues and fluids of the general population, including adipose tissue, blood, and breast milk.

In the National Human Adipose Tissue Survey (NHATS), 46 composite adipose tissue samples collected during surgical procedures or during autopsies during fiscal year 82 were analyzed for organochlorine compounds (EPA 1986b). Of the 46 samples, 83% contained PCBs as follows: 22% contained trichlorobiphenyl, 53% contained tetrachlorobiphenyl, 73% contained pentachlorobiphenyl, 73% contained hexachlorobiphenyl, 53% contained heptachlorobiphenyl, 40% contained octachlorobiphenyl, 13% contained nonachlorobiphenyl, and 7% contained decachlorobiphenyl. EPA (1985a) performed a statistical analysis for baseline estimates and time trends for PCBs in human adipose tissue in the NHATS for 1970-1983. The findings indicated that 5.5% of the population had a PCB level >1 ppm compared with the historic percentage of 28.9%. The percentage of people who had >1 ppm PCB levels increased with age and was greater in males than in females, but there was no significant race difference. Historically, the Northeast Census Region has had the greatest percentage of people with levels >1 ppm, but, in recent years, the difference between the northeast and other regions no longer exists. Although 100% of the samples contained detectable levels of PCBs, there was a steady decrease over time in the percentage of people with >1 ppm.

Anderson (1985) discussed the use of adipose tissue biopsy in assessing human exposure to PCBs. Because adipose tissue is the primary storage site of PCBs, adipose tissue samples have been the preferred biological specimen. Analysis of PCBs in adipose tissue provides a direct measure of body burden, but has disadvantages over analysis of serum levels because collection of samples is invasive and time-consuming. Based on data that adipose tissue levels of PBBs (polybrominated biphenyls) and DDT are directly correlated with serum levels of PBB and DDT, it can be predicted that PCB adipose levels will also correlate with serum levels. Anderson (1985) recommended that whenever an adipose tissue sample is obtained at biopsy, a paired serum sample should be collected and the two tissues be analyzed for PCBs. Once the correlation is characterized, blood samples may become the preferred choice for monitoring, unless identification of low exposures is required.

Wolff (1985) reported data on blood levels of PCBs in workers in relation to exposure levels (Table 2.1) and blood and adipose tissue

**Table 2.1. PCB levels in blood of exposed workers
(Aroclors 1016, 1242, 1248)**

Air levels (mg/m ³)	Blood levels (ng/mL)			N	
	Mean	High			
0.3-2	1060	3500	19	19	"Inside" ^a
	440	1400	14	14	"Outside" ^a
0.05-0.275	130	407	60		
0-0.26	355	3330	26	26	High exposed
	149	1500	55	55	Low exposed
	89	370	140	140	Never exposed
0.1-1	118	2530	110	110	High exposed
	48	604	180	180	Other

^aWorkers who were exposed inside or outside the impregnation room.

Source: Wolff 1985.

levels of PCBs in workers in relation to duration of employment (Table 2.2). Generally, higher exposure levels result in higher blood and adipose tissue levels of PCBs, but because PCBs accumulate in the body, exposure duration is at least as important as exposure level.

Kreiss (1985) reviewed available data, including unpublished Centers for Disease Control (CDC) data, for serum PCB concentrations in U.S. populations without occupational exposures for 1968-1983. Mean serum levels were usually between 4 and 8 ng/mL, with 95% of the individuals having concentrations <20 ng/mL (Table 2.3). Cross-sectional data concerning PCB levels in a representative sample of the U.S. population are not available because the various groups were monitored during investigations of pesticide residues, food chain contamination, hazardous waste sites, and occupational exposure in which a nonexposed control group was necessary. Subpopulations consuming fish taken from contaminated waters have mean serum PCB levels that are several times higher than those in other general population groups and comparable to those usually associated with occupational exposure (Table 2.4). Interpretation of the data in Tables 2.3 and 2.4 is complicated by differences in analytical methodology and methods of population selection and data reporting (Kreiss 1985).

PCB levels in adipose tissue and in human milk fat are 100 to 200 times higher than serum levels (Kimbrough 1987a). PCB concentrations averaged 1.5 ppm in the breast milk of 1057 women in Michigan (Wickizer et al. 1981). These levels are relatively high and apparently due to consumption of contaminated fish.

2.2.2.2 Effects

Several studies of general population subjects attempted to correlate serum PCB levels with health indices. Baker et al. (1980) found that plasma triglyceride levels increased significantly with serum PCB concentrations in residents of Bloomington, Indiana, including workers occupationally exposed to PCBs. Chloracne or systemic symptoms of PCB toxicity were not noted, and there were no significant correlations between PCB levels and hematologic, hepatic, or renal function indices. Kreiss et al. (1981) reported that serum PCB levels were positively associated with serum cholesterol levels, gamma-glutamyl transpeptidase (GGTP) levels, and measured blood pressure in residents of Triana, Alabama, that were exposed via consumption of contaminated fish. The associations in the above studies were independent of predictors of PCB levels such as age, sex, and/or consumption of alcohol and fish. Although PCBs may be related to elevated blood pressure (Kreiss et al. 1981), the effect has not been validated and has uncertain relevance to PCB exposure because the fish also contained high concentrations of DDT residues.

Steinberg et al. (1986) determined that five serum analytes (β -glucuronidase, 5'-nucleotidase, triglycerides, cholesterol, and total bilirubin) correlated positively and significantly with log concentrations of serum total PCBs in residents who lived or worked in the vicinity of an electrical manufacturing plant. Aroclor 1260 was significantly and positively correlated with several of the analytes.

Table 2.2. PCB blood levels (Aroclor 1254) and duration of exposure

Mean duration of employment (years)	Mean blood concentration (ng/mL)	<i>N</i>	Mean adipose concentration (μ g/g)	<i>N</i>
12 $\pm$ 6	238	80		
16 $\pm$ 8	24 ^a	258	17	53
	6 ^b	32	4	8
17	33 ^c	86	5.6	36
3.8	14 ^d	15	1.4	5
4.3	12 ^e	19	1.3	9

^aPersons with more than 5 years employment; geometric means; geometric mean of 53 plasma samples which matched the adipose samples was 54 ng/mL.

^bPersons with less than 5 years employment; geometric means.

^cPersons exposed.

^dPersons nominally exposed.

^eNonexposed.

Source: Wolff 1985.

Table 2.3. Serum PCB concentrations in U.S. populations without occupational exposure to PCBs and in subpopulations consuming fish from PCB-contaminated waters

Area and sampling method	Number of subjects	Year	PCB level, ng/mL					References
			Arithmetic mean	Geometric mean, median ^a	Arithmetic standard deviation	95% confidence interval	Range	
Populations without occupational exposures, 1968-1983								
Charleston County, S.C., volunteers	616	1968	4.9	—	—	—	0-29	Finklea et al. 1972
Lake Michigan random non-fish eaters	29	1973	17.3	15 ^a	—	—	<5-41	Humphrey 1983a
Bloomington, Ind., volunteers and controls	110	1977	18.8	—	10.8	17-21	6-79	Baker et al. 1980
Michigan PBB cohort	1631	1978-79	7.7	6.4	—	—	<1-57	Kreiss et al. 1982
Billings, Mont., random packinghouse workers	17	1979	7.5	5.8	6.8	4-11	2-30	Drotman et al. 1981
Franklin, Idaho, volunteers	105	1979	—	—	—	—	<5	Drotman et al. 1981
Random unexposed workers	19	1979	12	—	—	—	10-27	Chase et al. 1982
Newton, Kans., volunteers	7	1979	4.9	4.2	3.1	2-8	2-11	Vernon et al. 1981
Lake Michigan random non-fish eaters	418	1980	—	6.6 ^a	—	—	<3-60	Humphrey 1983a
Canton, Mass., volunteers	10	1980	7.1	5.2	5.2	3-11	1-18	Condon 1983
Old Forge, Pa., volunteers	138	1981	3.6	—	—	—	<3-43	Reid and Fox 1982

Table 2.3 (continued)

Area and sampling method	Number of subjects	Year	PCB level, ng/mL					References
			Arithmetic mean	Geometric mean, median ^a	Arithmetic standard deviation	95% confidence interval	Range	
Jefferson, Ohio, volunteers	59	1983	5.8	4.4	6.5	4-8	1-45	Welty 1983
Fairmont, W. Va., volunteers	40	1983	6.7	5.0	5.3	5-8	1-23	Welty 1983
Norwood, Mass., volunteers	990	1983	4.9	4.2	3.5	4-6	2-30	Condon 1983
Populations without occupational exposures consuming PCB-contaminated fish								
Lake Michigan volunteer sportfishers	90	1973	72.7	56 ^a	—	—	25-366	Humphrey 1983b
Triana, Ala., volunteers	458	1979	22.2	17.2	22.3	20-24	3-158	Kreiss et al. 1981
Lake Michigan volunteer sportfishers	572	1980	—	21.4 ^a	—	—	<3-203	Humphrey 1983b
New Bedford, Mass., volunteers	11	1981	31.4	23.6	29.3	13-50	5-101	Condon 1983

^aMedian.

Source: Kreiss 1985.

Table 2.4. Serum PCB concentrations in populations with occupational exposure

Facility	Number of subjects	PCB levels, ng/mL				References
		Arithmetic mean	Geometric mean	95% confidence interval	Range	
Railway car maintenance	86	33.4	—	—	10-312	Chase et al. 1982
Capacitor plant	34	394 ^a	—	234-554	trace-1700	Ouw et al. 1976
Capacitor plant	290	124 ^b 48 ^c	67 ^b 21 ^c	98-150 ^c 38-58 ^c	6-2530 ^b 1-546 ^b	Fischbein et al. 1979 Wolff et al. 1982a
Capacitor plant	80	342 ^a	—	—	41-1319	Maroni et al. 1981a
Capacitor plant	221	—	119 ^b 25.3 ^c	—	1-3330 ^b 1-250 ^c	Smith et al. 1982
Public utility	14	—	24 ^b 24 ^c	15-39 ^b 16-35 ^c	5-52 ^b 7-24 ^c	Smith et al. 1982
Private utility	25	—	22 ^b 29 ^c	17-25 ^b 20-43 ^c	9-48 ^b 7-250 ^c	Smith et al. 1982

^aBlood level.

^bLower PCB homologs.

^cHigher PCB homologs.

Source: Kreiss 1985.

but Aroclor 1242 was correlated significantly and negatively only with HDL-cholesterol.

Umbilical cord serum levels of PCBs have been correlated with reduced birth weight and size, shorter gestation, and neonatal behavioral effects in a few reports (Fein 1984; Fein et al. 1984; Jacobson et al. 1984a, 1985; Rogan et al. 1986). Although increased levels of PCBs in cord blood may be predictors of these kinds of effects, the effects are not well validated. Cord serum levels associated with these effects are reported in Sect. 4.3.3 (developmental toxicity in toxicological data section).

Workers with occupational exposure to PCBs (see Table 2.4) have also been evaluated for subclinical associations with serum lipids and other health indices (Kreiss 1985). Significant correlations between plasma PCB and serum triglycerides (Chase et al. 1982), plasma triglycerides (Smith et al. 1982), SGOT (Chase et al. 1982, Smith et al. 1982, Fischbein et al. 1979), SGTP (Ouw et al. 1976), and GGTP (Smith et al. 1982, Maroni et al. 1981a, Fischbein 1985) have been reported. Measures of liver enzyme induction (e.g., GGTP) are not commonly associated with PCB levels, and possible hepatocellular damage (as indicated by SGOT, SGTP) has been demonstrated only in occupationally exposed groups with higher ranges of PCB levels (Kreiss 1985).

Maroni et al. (1981a) examined the health condition and PCB blood levels of 80 electrical workers exposed to PCBs (42% mean chlorine content) for many years. They found that hepatic involvement was associated with blood concentration of trichlorobiphenyls (Student t test, $P < 0.001$), but the association with pentachlorobiphenyls was not as great ($P < 0.01$). Individuals with abnormal liver findings had average blood trichlorobiphenyl concentrations of 215 $\mu\text{g/kg}$ (range 77-407 $\mu\text{g/kg}$), while workers without abnormal liver findings had average concentrations of 92 $\mu\text{g/kg}$ (range 13-345 $\mu\text{g/kg}$). The abnormal liver findings include hepatomegaly and altered liver enzyme levels, with well-defined liver failure noted in a few cases. The authors suggested that trichlorobiphenyls may reflect current PCB exposure levels more closely than pentachlorobiphenyls.

2.2.3 Environmental Levels as Indicators of Exposure and Effects

2.2.3.1 Levels found in the environment

The purpose of this subsection is to summarize available data that suggest that levels of PCBs found in environmental media (primarily soil, drinking water, and food) are associated with significant human exposure and/or effects. Schwartz et al. (1983) found a significant positive correlation ($P < 0.001$) between fish consumption measures and PCB levels in maternal serum and milk. The specific PCBs present were not correlated with the various Aroclor mixtures. From their data, Schwartz et al. (1983) determined that serum PCB levels increase by 0.15 ng/mL and milk levels increase by 0.12 ng/g for every 0.45 kg of PCB-contaminated fish consumed. The rate of fish consumption was not stated. Drotman et al. (1983) found a positive correlation between the PCB concentration in human breast milk and the number of contaminated eggs consumed by lactating women.

2.2.3.2 Human exposure potential

The purpose of this subsection is to discuss the chemical-specific issues involved in human exposure of PCBs from water, soil, and food. Experimental monitoring data have shown that PCB concentrations are higher in sediment and suspended matter than in the associated water column, and this is in agreement with the high soil adsorption constants for PCBs. The partitioning between suspended matter and water will be isomer specific and should correlate with the octanol/water partition coefficient of individual isomers. Thus, lower chlorinated PCBs should have a greater tendency to partition to the water than higher chlorinated PCBs. This implies that human exposure to the higher chlorinated isomers from whole water (water + sediment) will be greater than from settled water. Therefore, the human exposure potential to higher chlorinated PCBs from contaminated waters will increase as exposure to sediment and suspended matter increases. The exposure of lower chlorinated PCBs from drinking water from contaminated sources should remain about the same whether the water is filtered or not.

In general, PCBs are strongly adsorbed in most soils; therefore, leaching will not generally occur. This implies that the exposure will be greatest at the point of initial adsorption. In many instances, this may be at or near the soil surface. The principal route of human exposure to PCBs from a spill in soil at a restricted outdoor site is through inhalation of air (EPA 1987b). Soil ingestion and dermal contact with soil would not be expected to be significant routes of exposure at a limited access site. Nonetheless, ingestion is considered the primary route of exposure from spills at a nonrestricted residential site, although it is anticipated that some exposure would occur through inhalation also. Although dermal exposure can occur at soil sites where access is possible, it is expected that the PCBs will adsorb to the soil particles, reducing the rate of dermal absorption. The bioavailability of PCBs through inhalation may be higher for the lower chlorinated congeners since their tendency to volatilize from soil is greater than the tendency of the higher chlorinated congeners to volatilize.

2.3 ADEQUACY OF DATABASE

2.3.1 Introduction

Section 110 (3) of SARA directs the Administrator of ATSDR to prepare a toxicological profile for each of the 100 most significant hazardous substances found at facilities on the CERCLA National Priorities List.

- *(A) An examination, summary, and interpretation of available toxicological information and epidemiologic evaluations on the hazardous substance in order to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects.
- (B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure which present a significant risk to human health of acute, subacute, and chronic health effects.

- (C) Where appropriate, an identification of toxicological testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans."

This section identifies data gaps in current knowledge relevant to developing levels of significant exposure for PCBs. Such gaps are identified for certain health effects end points (lethality, systemic/target organ toxicity, developmental toxicity, reproductive toxicity, and carcinogenicity) reviewed in Sect. 2.2 of this profile in developing levels of significant exposure for PCBs, and for other areas such as human biological monitoring and mechanisms of toxicity. The present section briefly summarizes the adequacy of existing human and animal data, identifies data gaps, and summarizes research in progress that may fill such gaps.

Specific research programs for obtaining data needed to develop levels of significant exposure for PCBs will be developed by ATSDR, NTP, and EPA in the future.

2.3.2 Adequacy of Database for Health Effect End Points

2.3.2.1 Introduction and graphic summary

The adequacy of the PCB database for health effect end points in humans and animals is depicted on bar graphs in Figs. 2.7 and 2.8, respectively.

The bars of full height indicate that there are "adequate" data to meet at least one of the following conditions:

1. For noncancer health end points, one or more studies are available that meet current scientific standards and are sufficient to define a range of toxicity from no effect levels (NOAELs) to levels that cause effects (LOAELs or FELs).
2. For human carcinogenicity, a substance is classified as either a "known human carcinogen" or "probable human carcinogen" by both EPA and the International Agency for Research on Cancer (IARC) (qualitative), and the data are sufficient to derive a cancer potency factor (quantitative).
3. For animal carcinogenicity, a substance causes a statistically significant number of tumors in at least one species, and the data are sufficient to derive a cancer potency factor.
4. There are studies which show that the chemical does not cause this health effect via this exposure route.

Bars of half height indicate that "some" data for the end point exist but do not meet any of the criteria for "adequate" data.

2.3.2.2 Descriptions of highlights of graphs

Data concerning effects of PCBs in humans that are useful for quantitative risk assessment are not available. The available data pertain primarily to intermediate- or chronic-duration occupational exposures in which the exposures are inadequately monitored and do not

HUMAN DATA

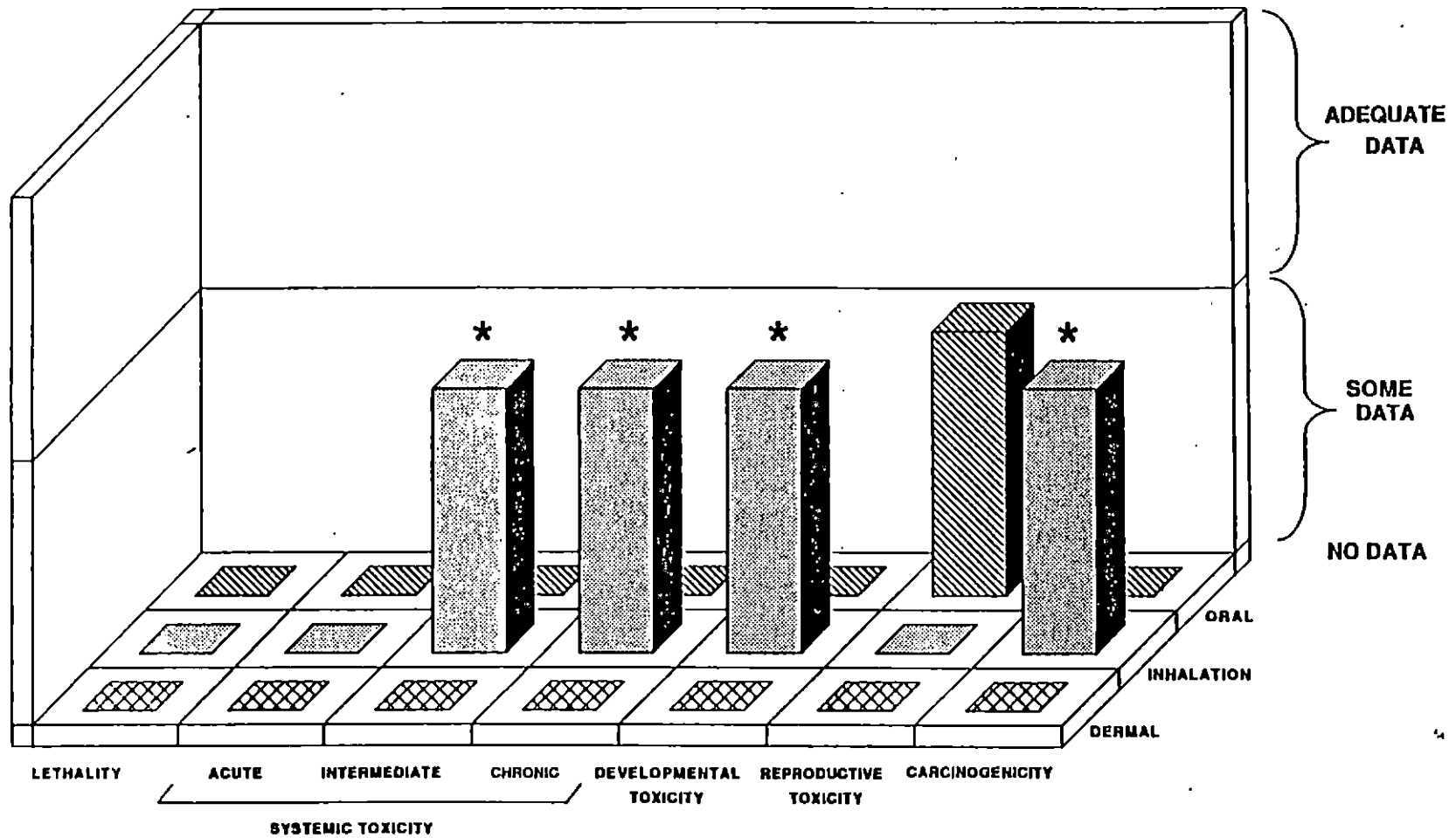


Fig. 2.7. Adequacy of the database on health effects of PCBs (human data).

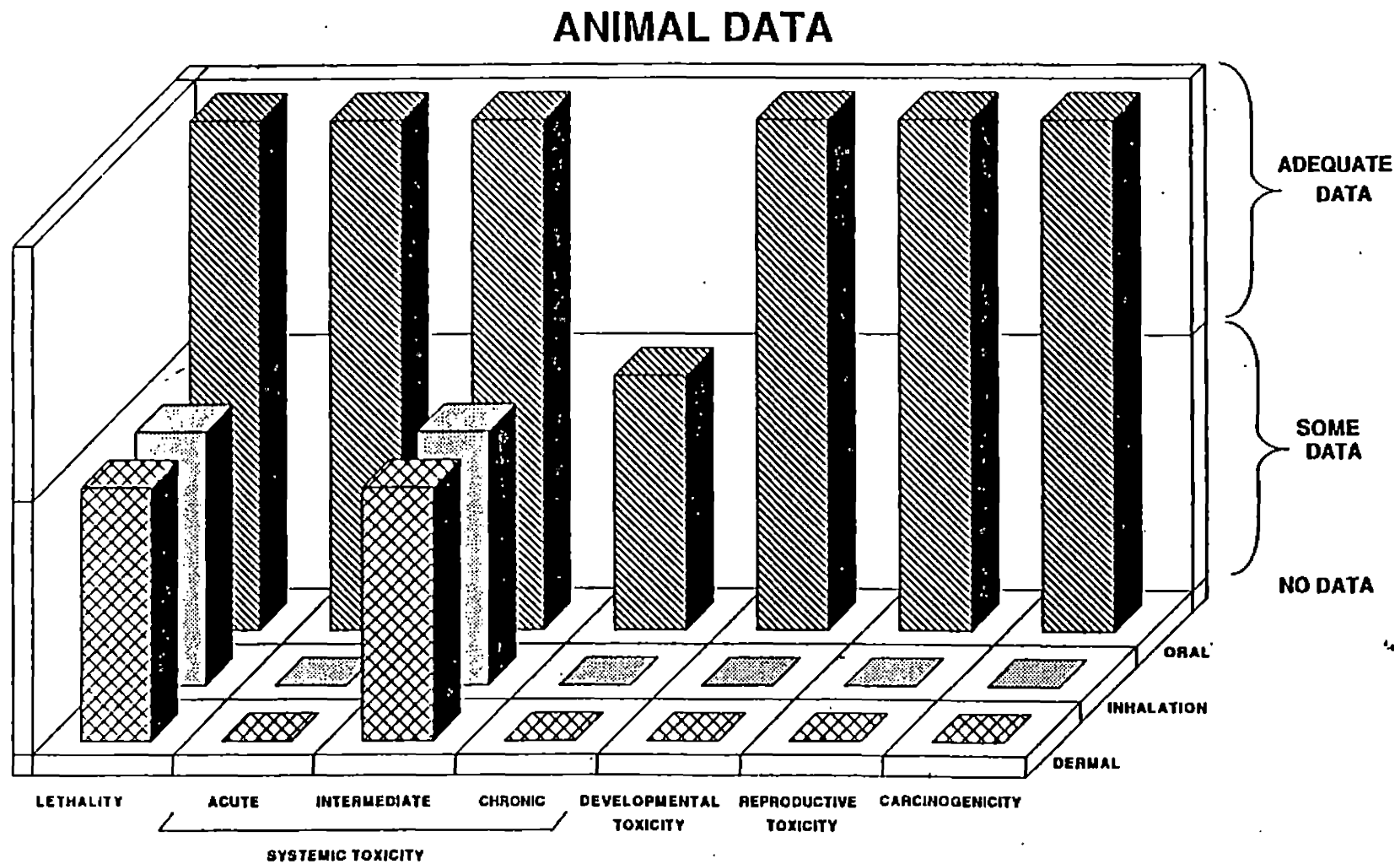


Fig. 2.8. Adequacy of the database on health effects of PCBs (animal data).

correlate with duration and intensity of exposure. Occupational exposures to PCBs involve significant dermal exposure, but, as discussed previously, occupational concentrations are expressed milligrams per cubic meter of air (mg/m^3). For this reason, occupational exposure data were discussed under inhalation exposure. Children born to mothers who consumed PCB-contaminated fish had some developmental effects, but the effects cannot be directly attributed to PCBs; therefore, the bar for developmental effects due to oral exposure indicates that there are some data.

The toxicity and carcinogenicity of the PCBs in animals by the oral route are reasonably well characterized. Determination of toxicity effect levels for chronic oral exposure is precluded by occurrence of proliferative/neoplastic alterations. Effects of acute oral, inhalation, and dermal exposures to the PCBs in animals have not been extensively investigated because concern for effects in humans is centered on intermediate/chronic-duration oral exposures.

2.3.2.3 Summary of relevant ongoing research

J.L. Jacobson of Wayne State University is conducting a study sponsored by the National Institute of Environmental Health Sciences to evaluate the impact of PCBs on physical, cognitive, and neurological development in early childhood. The children, examined at age 4, were exposed to moderate levels of PCBs, or maternal serum PCB levels were high near the time of their birth (NTIS 1987).

W.J. Rogan of the National Institute of Environmental Health Sciences is conducting a follow-up study of children exposed to PCBs through breast milk. The children under study are a cohort of 856 North Carolina children exposed to relatively low levels of PCBs and a cohort of 108 children from Taiwan exposed to relatively high levels of PCBs (NTIS 1987).

2.3.3 Adequacy of the Database for Other Information Needed for Risk Assessment

2.3.3.1 Pharmacokinetics and mechanism of action

Quantitative data concerning the pharmacokinetics of PCBs following inhalation and dermal exposure are lacking. Such data could greatly assist efforts to evaluate health effects resulting from inhalation and dermal exposure to PCBs. Further studies should be conducted concerning the distribution of PCBs, especially regarding the distribution of PCBs in the plasma compared to adipose tissue.

Ongoing studies concerning pharmacokinetics and mechanisms of action were not located.

2.3.3.2 Monitoring of human biological samples

PCBs can be measured in serum, adipose tissue, and milk. These measurements can indicate elevated exposure but do not provide information concerning the route of exposure. Although biological monitoring is useful for documenting exposures, it cannot be used for predicting health effects.

Biological monitoring methods indicate body burden of PCBs that have accumulated over a lifetime. Adequate methods are not available to distinguish exposure routes, short or intermittent exposures, or low-level exposures due to the bioaccumulation and slow excretion of PCBs.

Several studies concerning monitoring of biological samples are ongoing. The Massachusetts Department of Health (population survey in New Bedford, Massachusetts) and the Indiana State Department of Health (population survey in Monroe County, Indiana) are conducting studies that will provide information on PCB body burden levels in conjunction with selected health outcomes. Several smaller studies are being conducted by the CDC.

2.3.3.3 Environmental considerations

Methodology of sufficient sensitivity and specificity to measure PCBs in the environment exists.

The bioavailability of PCBs from environmental media appears to be fairly well understood.

There appears to be a fairly good understanding of the environmental fate and transport of PCBs; however, more experimental data are required to understand the potential importance of photolysis in degrading the more highly chlorinated PCBs, which are more persistent in the environment. In addition, a better understanding of the environmental cycling of PCBs is needed to assess future exposure from current environmental sinks such as PCBs adsorbed to sediments.

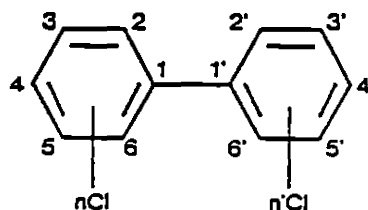
No studies were found that involve the environmental interaction of PCBs with other pollutants.

There are no known ongoing experimental studies pertaining to the environmental fate of PCBs, which would help to fill the data gaps as mentioned above.

3. CHEMICAL AND PHYSICAL INFORMATION

3.1 CHEMICAL IDENTITY

Data pertaining to the chemical identity of the Aroclors are listed in Table 3.1. Aroclors are mixtures of chlorinated biphenyls. The general chemical structure of chlorinated biphenyls is as follows:



(where n and n' may vary from 0 to 5).

The numbering system for the biphenyl structure is also shown above.

Aroclor products are identified by a four-digit numbering code in which the first two digits (12) indicate that the parent molecule is biphenyl and the last two digits indicate the chlorine content by weight. Thus, Aroclor 1242 is a chlorinated biphenyl mixture with an average chlorine content of 42%. The exception to this designation method is Aroclor 1016, which retained the 1016 designation by which it was known during development (Mieure et al. 1976). Aroclor 1016 is a mixture that contains primarily mono-, di-, and trichloro isomers and has an average chlorine percentage (41.5%) that is very similar to Aroclor 1242.

3.2 PHYSICAL AND CHEMICAL PROPERTIES

Selected physical and chemical properties of the Aroclors are presented in Table 3.2. Table 3.3 identifies the approximate molecular composition of the Aroclors.

Data pertaining to the pyrolysis of PCBs which results in the formation of polychlorinated dibenzofurans (PCDFs) have been reviewed (EPA 1987a). Several studies involving pyrolysis of specific PCB isomers have found that the pyrolysis products include PCDFs, chlorinated benzenes, naphthalenes, phenyl ethynes, biphenylenes, and hydroxy PCBs. There appear to be four major paths for production of PCDFs from PCBs: (1) loss of two ortho chlorines, (2) loss of ortho hydrogen as well as chlorine, (3) loss of an ortho hydrogen as well as chlorine but involving a shift of chlorine from the 2- to the 3-position, and (4) loss of two ortho hydrogens (EPA 1987a). The formation of PCDFs from the pyrolysis of PCBs occurred when an electrical transformer in an office

building in Binghamton, New York, accidentally caught fire on February 5, 1981 (Schecter and Tiernan 1985, Tiernan et al. 1985).

Table 3.1. Chemical Identity of the Aroclors

	Chemical name ^a							References
	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	
Synonyms	PCB-1016 Polychlorinated biphenyl with 41.5% Cl	PCB-1221 Polychlorinated biphenyl with 21% Cl	PCB-1232 Polychlorinated biphenyl with 32% Cl	PCB-1242 Polychlorinated biphenyl with 41.5% Cl	PCB-1248 Polychlorinated biphenyl with 48% Cl	PCB-1254 Polychlorinated biphenyl with 54% Cl	PCB-1260 Polychlorinated biphenyl with 60% Cl Chlorodiphenyl (60% Cl)	SANSS 1987
Trade names	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>	
Chemical formula	See Table 3.3	See Table 3.3	See Table 3.3	See Table 3.3	See Table 3.3	See Table 3.3	See Table 3.3	
Wiswesser line notation ^c	NA	NA	NA	NA	NA	NA	NA	
Chemical structure	See text	See text	See text	See text	See text	See text	See text	
Identification Nos.								
CAS Registry No.	12674-11-2	11104-28-2	11141-16-5	53469-21-9	12672-29-6	11097-69-1	11096-82-5	SANSS 1987
NIOSH RTECS No.	TQ1351000	TQ1352000	TQ1354000	TQ1356000	TQ1358000	TQ1360000	TQ1362000	SANSS 1987
EPA Hazardous Waste No.	3502	3502	3502	3502	3502	3502	3502	EPA 1980a
OHM-TADS No.	8500400	8500401	8500402	8500403	8500404	8500405	8500406	EPA-NIII 1987
DOT/UN/NA/IMCO Shipping No.	UN2315	UN2315	UN2315	UN2315	UN2315	UN2315	UN2315	Chemline 1987
STCC No.	4961666	4961666	4961666	4961666	4961666	4961666	4961666	Stone 1981
Hazardous Substances Data Bank No.	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	1822	IISDB 1987
National Cancer Institute No.	Unknown	Unknown	Unknown	Unknown	Unknown	C02664	Unknown	NCI 1978

^aThese are the current chemical names as indexed by the Chemical Abstracts Service (CAS).^bAroclor is the trade name for chlorinated biphenyls used by Monsanto.^cWiswesser line notations are not applicable for mixtures.^dDesignation prior to May 19, 1980.

Table 3.2. Physical and chemical properties of PCBs

	Aroclor designation							References
	1016	1221	1232	1242	1248	1254	1260	
Molecular weight ^a	257.9	200.7	232.2	266.5	299.5	328.4	375.7	Hutzinger et al. 1974
Color	Clear	Clear	Clear	Clear	Clear	Light yellow	Light yellow	Monsanto 1974
Physical state	Oil	Oil	Oil	Oil	Oil	Viscous liquid	Sticky resin	Monsanto 1974
Odor	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	
Melting point, °C	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	
Boiling point, °C (distillation range)	325-356	275-320	290-325	325-366	340-375	365-390	385-420	Monsanto 1974
Autoignition temperature	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	
Solubility								
Water, mg/L	0.42	0.59 (24°C)	Unknown	0.24 0.34 0.10 (24°C)	0.054 0.06 (24°C)	0.012 0.057 (24°C)	0.0027	Monsanto 1974, Paris et al. 1978, Hollifield 1979
Organic solvents	Very soluble	Very soluble	Very soluble	Very soluble	Very soluble	Very soluble	Very soluble	EPA 1985a
Density, g/cm ³ at 25°C	1.33	1.15	1.24	1.35	1.41	1.50	1.58	Monsanto 1974
Partition coefficient Log octanol-water ^b	5.6	4.7	5.1	5.6	6.2	6.5	6.8	b
Vapor pressure, mm Hg at 25°C	4×10^{-4}	6.7×10^{-3}	4.06×10^{-3}	4.06×10^{-4}	4.94×10^{-4}	7.71×10^{-3}	4.05×10^{-3}	Monsanto 1974, Callahan et al. 1979
Henry's law constant, atm-m ³ /mol at 25°C ^c	2.9×10^{-4}	3.5×10^{-3}	Unknown	5.2×10^{-4}	2.8×10^{-3}	2.0×10^{-3}	4.6×10^{-3}	c
Refractive index	1.6215-1.6235 (25°C)	1.617-1.618 (20°C)	Unknown	1.627-1.629 (20°C)	Unknown	1.6375-1.6415 (25°C)	Unknown	IARC 1978

Table 3.2 (continued)

	Aroclor designation							References
	1016	1221	1232	1242	1248	1254	1260	
Flash point, °C (Cleveland open cup)	Unknown	176	238	None	None	None	None	Hubbard 1964
Flammability limits	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	
Conversion factors								
Air (25°C) ^d	1 mg/m ³ = 0.095 ppm	1 mg/m ³ = 0.12 ppm	1 mg/m ³ = 0.105 ppm	1 mg/m ³ = 0.092 ppm	1 mg/m ³ = 0.08 ppm	1 mg/m ³ = 0.075 ppm	1 mg/m ³ = 0.065 ppm	
Water	ppm (w/v) = mg/L = µg/mL	Same	Same	Same	Same	Same	Same	

^aAverage mass from Table 3.3.

^bThese log K_{ow} values represent an average value for the major components of the individual Aroclor. Experimental values for the individual components were obtained from Hansch and Leo 1985.

^cThese Henry's law constants were estimated by dividing the vapor pressure by the water solubility. The first water solubility given in this table was used for the calculation. The resulting estimated Henry's law constant is only an average for the entire mixture; the individual chlorobiphenyl isomers may vary significantly from the average. Burkhard et al. (1985) estimated the following Henry's law constants (atm·m³/mol) for various Aroclors at 25°C: 1221 (2.28×10^{-4}), 1242 (3.43×10^{-4}), 1248 (4.4×10^{-4}), 1254 (2.83×10^{-4}), 1260 (4.15×10^{-4}).

^dThese air conversion factors were calculated by using the average molecular mass as presented under molecular weight.

**Table 3.3. Approximate molecular composition of PCBs
(percent)**

Empirical formula	Aroclor designation						
	1016	1221	1232	1242	1248	1254	1260
$C_{12}H_{10}$	<0.1	11	<0.1	<0.1	ND ^a	<0.1	ND
$C_{12}H_9Cl$	1	51	31	1	ND	<0.1	ND
$C_{12}H_8Cl_2$	20	32	24	16	2	0.5	ND
$C_{12}H_7Cl_3$	57	4	28	49	18	1	ND
$C_{12}H_6Cl_4$	21	2	12	25	40	21	1
$C_{12}H_5Cl_5$	1	<0.5	4	8	36	48	12
$C_{12}H_4Cl_6$	<0.1	ND	<0.1	1	4	23	38
$C_{12}H_3Cl_7$	ND	ND	ND	<0.1	ND	6	41
$C_{12}H_2Cl_8$	ND	ND	ND	ND	ND	ND	8
$C_{12}H_1Cl_9$	ND	ND	ND	ND	ND	ND	ND
Average molecular mass	257.9	200.7	232.2	266.5	299.5	328.4	375.7

^aND = none detected.

Source: Hutzinger et al. 1974.

4. TOXICOLOGICAL DATA

4.1 OVERVIEW

Evaluation of the toxicokinetics and toxicity of PCBs is complicated by the fact that PCBs are mixtures of a variety of different congeners and impurities, each with its own characteristics. Impurities include the highly toxic PCDFs. Aroclor PCBs are the subject of this profile, but toxicokinetics studies often examined specific congeners, and many toxicity studies used mixtures of PCBs other than Aroclors, particularly Kaneclors. Kaneclors are similar to Aroclors but are produced in Japan rather than the United States and differ in method of production, chlorine content, and PCDF contamination. The reported range of PCDFs in Kaneclors and Aroclors is 5 to 20 ppm and 0 to 2 ppm, respectively. Reference to Kaneclors is made occasionally to support statements about Aroclors because effects produced by Aroclors and Kaneclors are similar. Kaneclor toxicity data are not considered in detail because of the aforementioned differences in composition and because reported lowest effect levels are lower for Aroclors than Kaneclors.

The general population is exposed to PCBs primarily by the oral route (through food, particularly fish). Inhalation and dermal exposure are the primary routes of occupational exposures, but the relative contribution of these routes is unknown.

Studies of the absorption of PCBs following oral exposure indicate that gastrointestinal absorption of most isomers is >90%. The limited data concerning the absorption of PCBs following inhalation and dermal exposure indicate that PCBs can be absorbed via these exposure routes.

Distribution of ingested or injected Aroclors follows a biphasic pattern. During the first day following dosing, the PCBs distribute to the liver and muscle tissue. The compounds are then redistributed to fat, skin, and other fat-containing organs. Heavily chlorinated congeners redistribute to adipose tissue to a greater extent than the less chlorinated congeners, although the type of chlorine substitution is also a factor.

A number of studies indicate that PCBs can cross the placenta and locate in the fetus. PCBs also concentrate in milk. Higher PCB levels may reach the offspring through nursing than through placental transfer.

The metabolism of PCBs is dependent on the number and position of chlorine atoms, with lesser chlorinated isomers metabolized more readily than more chlorinated isomers. PCB metabolites tend to be 3- or 4-hydroxy compounds produced via an arene oxide intermediate. The presence of vicinal unsubstituted carbon atoms at the 3-4 positions may be helpful but not essential to this process.

PCBs that are metabolized with more difficulty tend to be excreted almost exclusively through the biliary route, while the metabolites of mono-, di-, and trichlorinated isomers are also eliminated through the urine. Urinary metabolites are in the form of conjugates, including glucuronides and sulfates. Glutathione conjugates have also been identified.

Higher chlorinated PCBs tend to persist in the body longer than lower chlorinated PCBs. For example, biological half-lives in the rat range from 1.15 days for 2,2'-dichlorobiphenyl to 460 days for 2,2',4,4'-hexachlorobiphenyl.

Aroclors appear to have a low order of acute lethality. Data for non-Aroclor PCB mixtures and specific PCB isomers suggest that mice and guinea pigs are more sensitive than rats. Aroclors are lethal at much lower total doses when administered subchronically or chronically than acutely, indicating that PCBs bioaccumulate to concentrations that are toxic.

Animal studies have shown that the liver and cutaneous tissues are the major target organs for Aroclors. Aroclors have also been shown to produce stomach and thyroid alterations, immunosuppressive effects, and porphyria in animals. Animals are sensitive to repeated exposures to Aroclors as a result of rapid bioaccumulation to toxic levels. Monkeys are particularly sensitive to the toxic effects of Aroclors. Gross toxic effects other than reversible skin lesions have not been associated with Aroclor exposure (occupational) in humans. Biochemical effects, however, such as increased liver enzyme levels, have been associated with Aroclor exposure in workers and in the general population.

More serious health effects were observed in humans who consumed rice oil that had been contaminated with Kaneclors in Japan ("Yusho" incident) and Taiwan ("Yu Cheng" incident). Although there is an historical linkage between Yusho and PCBs and some regulatory documents ascribe health effects from these incidents to PCBs, effects from the incidents are not reviewed in this report because exposure was to Kaneclors and because the effects cannot be attributed specifically to the Kaneclors. The Kaneclors were heated in thermal heat exchangers before the rice oil contamination and during cooking and contained relatively high concentrations of PCDFs and polychlorinated quaterphenyl contaminants. There appears to be general agreement that the PCDF contaminants, particularly the more potent isomers, contributed significantly to the health effects observed in the Yusho and Yu Cheng patients. Please refer to Kuratsune and Shapiro (1984) for a more complete discussion of this topic.

Aroclors appear to be fetotoxic but not teratogenic in various species of animals, including rats, mice, rabbits, and monkeys, but the possibility that contaminants (e.g., PCDFs) may be responsible for the effects should be recognized. Effects such as decreased birth weight, shortened gestation age, and neonatal behavioral alterations have been associated with PCB exposure in humans.

Oral exposure to Aroclors produced deleterious effects on reproduction in monkeys, mink, and, at higher doses, rodents.

PCBs have produced generally negative results in in vitro and in vivo mutagenicity assays.

Feeding studies in laboratory animals demonstrated the carcinogenicity of several PCB mixtures, but it is not clear which components of the mixture or metabolites are actually carcinogenic. The liver is the primary target of PCB carcinogenicity.

4.2 TOXICOKINETICS

4.2.1 Absorption

4.2.1.1 Inhalation

Human. Inhalation exposure and dermal exposure are the primary routes of occupational exposure to PCBs, but the relative contribution of each route has not been discerned (Wolff 1985).

Animal. Six rats were exposed to an aerosol of a PCB mixture (Pydraul A200, 42% chlorine) at a concentration of 30 g/m³ (0.5 to 3 μ m particles) for 30 min (Benthe et al. 1972). PCB concentrations in the liver 15 min after cessation of exposure were >50% of the maximum concentration attained after 2 h (70 μ g/g tissue). These data indicate that the PCBs were readily absorbed.

4.2.1.2 Oral

Human. The general population is exposed to PCBs primarily by the oral route (primarily by consumption of contaminated fish). Schwartz et al. (1983) found elevated levels of PCBs in the serum and breast milk of women who ate PCB-contaminated fish from Lake Michigan. Humphrey (1976) reported blood levels of PCBs in people who consumed contaminated sport fish from Lake Michigan in 1973. Annual consumption of ≥ 24 lb resulted in a mean blood level of 0.073 ppm, while annual consumption of ≤ 6 lb resulted in a mean blood level of 0.020 ppm. Blood levels of PCBs in persons who ate no fish averaged 0.017 ppm. These studies indicate that PCBs are absorbed by the gastrointestinal tract, but do not provide information regarding the extent of absorption.

Animal. Drill et al. (1981) and EPA (1985a) reviewed a number of animal studies indicating that PCBs, including Aroclors, are absorbed readily from the gastrointestinal tract following oral administration. Albro and Fishbein (1972) examined the absorption of 19 PCB congeners and unchlorinated biphenyl in rats treated by gavage at doses of 5, 50, or 100 mg/kg. Determination of PCBs in feces collected for 4 days indicated that absorption of all congeners was >90%. Using rhesus monkeys, Allen et al. (1974a,b) determined over 2-week periods that >90% of a single oral dose of 1.5 or 3.0 g/kg Aroclor 1248 was absorbed. Bleavins et al. (1984) determined over 5 weeks that European ferrets absorbed 85.4% of a single dose of [¹⁴C]-labeled Aroclor 1254 (0.05 mg) given in food.

In contrast to the above studies, Norback et al. (1978) claimed that 59.3 to 87% of a single oral dose of 2,4,5,2',4',6'-HCB passed unabsorbed through the intestine of monkeys during the first week after dosing. It was unclear why relatively little of this isomer was

absorbed. There are no data on the effect of the environmental matrix or vehicle on the bioavailability of specific PCBs and PCB mixtures. Studies with 2,3,7,8-TCDD indicate that the vehicle may play a significant role in the relative bioavailability of 2,3,7,8-TCDD and related compounds (e.g., PCBs) (EPA 1985b).

4.2.1.3 Dermal

Human. In a study of occupational exposure of electrical workers to PCBs (Pyralen 3010 and Apirolino, 42% chlorine content), Maroni et al. (1981b) concluded that absorption of PCBs occurred mainly through the skin. Quantitative data were not available.

Animal. Miller (1944) reported the deaths of guinea pigs and rabbits treated dermally with a mixture of PCBs containing approximately 42% chlorine. The guinea pigs were treated with 34.5 mg/day for 11 days, while rabbits were treated with 86 mg every other day for 7 doses or 172 mg every other day for 8 doses. Lesions observed in guinea pigs and rabbits included fatty degeneration and centrolobular hepatocellular atrophy of the liver.

Using tritium-labeled PCBs (40% chlorine), Nishizumi (1976) found evidence for dermal absorption of PCBs in rats via follicular diffusion. Quantitative data were not provided.

4.2.2 Distribution

4.2.2.1 Inhalation

Human. Wolff et al. (1982b) examined the relative concentrations of PCB congeners in plasma and adipose tissue of 26 persons occupationally exposed to PCBs (20 to 54% chlorine). Exposure was not discussed, but it probably included both inhalation and dermal exposure. The results indicated that PCB congeners with chlorines in both 4-positions were the major components in plasma and adipose tissue. PCBs with unsubstituted 3,4-positions on at least one ring were observed at lower concentrations in plasma and adipose. The adipose-plasma partition ratio calculated for Aroclor 1248 residues was 185, while the partition ratio for Aroclor 1254 residues was 190. In a more recent study of 173 workers from the same population, adipose-plasma partition ratios of 210, 190, and 200 were determined for Aroclors 1242, 1254, and 1260, respectively (Brown and Lawton 1984).

Animal. Maximum PCB concentrations in the liver and brain of rats occurred 2 and 24 h, respectively, after a single 30-min exposure to 30 g/m³ of Pydraul A200 aerosol (42% chlorine) (Benthe et al. 1972). Concentrations in these tissues subsequently declined, while adipose concentrations reached a maximum after 48 h.

4.2.2.2 Oral

Human. A number of studies reviewed by EPA (1987a) indicate that PCBs concentrate in human breast milk. Exposures in these studies were most likely oral, but may have included both inhalation and dermal exposure. Wolff (1983) reported the half-life of PCBs (percentage chlorine in compounds not stated) in breast milk at 5 to 8 months and found that the concentration of PCBs in breast milk was 4 to 10 times

that in maternal blood. Similar results were reported by Jacobson et al. (1984b).

Ando et al. (1985) examined the PCB concentration in maternal blood and milk and the placenta of six Japanese women. They found that the congeners present were more typical of Kanechlor 500 than Kanechlors 300, 400, or 600. The results indicated that as the chlorine content of the PCB congeners increased, the correlation between the placental content of congeners and maternal blood and milk also increased.

PCBs were detected in the umbilical tissues, umbilical blood, amniotic fluid, and baby's blood from a woman who was occupationally exposed to Kanechlors 300 and 500 in a capacitor factory (Yakushiji et al. 1978). PCB levels in these tissues and fluids were considerably less than in the mother's blood. Maternal serum concentrations of PCBs were also higher than cord serum concentrations in women who resided in western Michigan (Jacobson et al. 1984b) and upstate New York (Bush et al. 1984) (i.e., in regions with easy access to fish from the Great Lakes).

Kraul and Karlog (1976) determined PCB levels in abdominal fat, brain, and liver from necropsies completed in 1972 and 1973 in Copenhagen, Denmark. The ratios of PCB levels were reported as 1:3.5:81 for brain:liver:fat, indicating that adipose was the site of greatest bioaccumulation of the tissues studied.

Animal. Following absorption, PCBs, including Aroclors, are distributed in a biphasic manner. The compounds rapidly (minutes to hours) clear from the blood and accumulate in the liver and muscles (Drill et al. 1981). PCBs may be translocated from the liver to adipose tissue for storage or be metabolized in the liver, with metabolites excreted in the urine or bile.

Muehleback and Bickel (1981) treated rats by gavage with a single dose of 0.6 or 3.6 mg/kg [^{14}C]-2,4,5,2',4',5'-hexachlorobiphenyl. The rats were examined 1 h, 24 h, 6 weeks, 20 weeks, or 40 weeks after dosing. The results showed the highest levels of PCBs in muscle, liver, fat, and skin early in the study. By the end of the study, the highest PCB levels were found in adipose tissue followed by skin, muscle, and liver. During the 40-week study period, only 16% of the total dose was excreted.

Gage and Holm (1976) determined concentrations in abdominal fat of mice 7 and 21 days after the mice were dosed by gavage with a single dose (13-165 $\mu\text{g}/\text{mouse}$) of 1 of 14 PCB congeners. Relatively low levels (<10 ng/g/ μg dose) were found at 7 days for 4,4'-, 3,2',4',6'-, and 2,3,4,2',4',6'- isomers, with relatively high levels (≥ 100 ng/g/ μg dose) for 2,4,5,2',4',5-, 4,2',4',6'-, and 2,4,2',4'- PCBs.

Kurachi and Mio (1983a) exposed mice to Kanechlor-400 at 100 mg/kg in the diet for 5 to 20 days. Analysis of tissues at the end of the feeding period indicated high levels of PCBs in the gonads. High levels of PCBs were also found in skin, adipose tissue, adrenals, and kidneys. A second group of mice were kept on the PCB diet for 20 days in a rotation cage to cause fatigue. Mobilization of fat deposits was observed with liver PCB levels in fatigued mice 10 times greater than in mice fed the same diets but allowed to rest.

A number of animal studies have demonstrated that PCB mixtures and specific congeners and isomers can cross the placental barrier and accumulate in fetuses (EPA 1987a). High levels of PCBs also accumulate in the mammary gland where they are secreted in the fat portion of the milk. Masuda et al. (1979) fed PCBs to pregnant mice through the first 18 days of gestation and found the highest levels of serum PCBs in offspring 1 to 2 weeks old. In studies in which monkeys were exposed prior to and during gestation, signs of PCB-induced intoxication in nursing but not newborn offspring were observed (Allen and Barsotti 1976, Iatopoulos et al. 1978). Results such as these have led some investigators to conclude that transfer through nursing may account for higher exposure of young than does placental transfer. This conclusion may be inappropriate, as it is often based on the fact that the absolute quantity of PCB residues is substantially higher in breast milk than cord serum; relative to fetal body weight, even low-level prenatal exposure can cause substantial concentrations (Jacobson et al. 1985).

Groups of 24 rhesus monkeys were maintained on diets that provided Aroclor 1016 at doses of 0, 4.5, or 18.1 mg/kg/day throughout gestation and a 4-month gestation period (Barsotti and Van Miller 1984). At birth, the concentrations of the PCBs in the skin of infants were similar to concentrations in the subcutaneous fat of the mothers. At weaning, the PCB content in the mesenteric fat of the infants was 4 to 7 times greater than in the subcutaneous fat of the mothers. Gas chromatographic patterns showed that the adult adipose tissue did not include the total spectrum of peaks observed in the Aroclor 1016 standard, that all of the peaks observed in the standard occurred in the neonate skin, and that the peaks in the mesenteric fat at weaning and 4 months after weaning were qualitatively similar to those in the adult adipose tissue. These data suggested an inability of the fetus to metabolize and excrete certain congeners that are more readily metabolized and eliminated by adults and older infants.

Bleavins et al. (1984) fed female European ferrets a single dose of [^{14}C]-labeled Aroclor 1254 in the diet (0.05 mg) early (day 14) or late (day 35) in gestation and determined the placental transfer of PCBs. They found that placental transfer to the kits was 0.01% (per kit) of the maternal dose when dams were exposed early in gestation and 0.04% (per kit) when dams were exposed late in gestation. Placental transfer of PCBs was considerably less than mammary transfer, with the ratio of placental to mammary transfer at 1 week of lactation 1:15 and 1:7 for offspring of dams dosed early and late in gestation, respectively.

4.2.2.3 Dermal

Data concerning the distribution of Aroclors following dermal exposure of humans or animals were not located. Because PCBs are lipophilic, the compounds should concentrate in adipose tissue regardless of the route of exposure.

4.2.3 Metabolism

4.2.3.1 Human

2,2',4,4',5,5'-Hexa-CB was the PCB congener found in the highest concentration in human adipose tissue, while 2,2',4,4',6,6'-hexa-CB was