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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Because of the health hazards, the military use (application and disposal) of Polychlorinated Biphenyls (PCB) was questioned. This was a survey study conducted to determine: the advantages of PCB's to the military; disposal problems; what applications exist and what alternative fluids exist to replace PCB's. Some related compounds were also reviewed to determine if these should be monitored.

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POLYCHLORINATED BIPHENYLS, TR-232

I. INTRODUCTION

Polychlorinated Biphenyls (PCB) have properties that make them extremely desirable for military applications as well as a host of civilian applications. Because of the hazards to the human, the use of PCB's has been restricted by federal regulatory means. Basically, they are used in only "closed" systems; essentially, this has resulted in only electrical system applications, e.g., transformers and capacitors. A problem still exists when it is necessary to dispose of these items. It is this PCB disposal problem for the Army which brought PCB to the attention of AMSAA.

A study defining the problem was conducted, including the following aspects:

PCB Applications - types of components

- systems involved
- quantity
- geographic dispersal of "dead" units

Outline of PCB advantages and disadvantages

Disposal alternatives - theoretical possibility

- present availability to the Army
- use in civilian life

Those related compounds (chemical or physical properties) which should be monitored are: -

- new engine coolants
- electric wire insulation
- hydraulic fluids

This report presents sufficient background material to understand the problem and the ramifications of Army decisions concerning PCB's. While PCB's had great potential in many Army systems, they never were adopted in a significant number of systems. The issues are not connected with whether the Army should take advantage of their potential, but with how to dispose of PCB in two major existing applications. The Army has large transformers and capacitors, mostly associated with camp-post-station facilities and very little with the Army-in-the-field. The disposal technology exists in the commercial world. Considering the investment cost of the disposal facilities and the limited extent of the Army problem, the Army should use the commercial facilities as they develop. The only problem pertinent to the purpose of this report is one of management.

It is necessary that the Army develop a management system to identify PCB containing components, to provide the temporary storage facilities to accumulate components to be eventually destroyed in the commercial facilities, and to establish the procedures to control and account for these components. Related to this is the need for an education program to alert individuals to the danger and the need to utilize the system established.

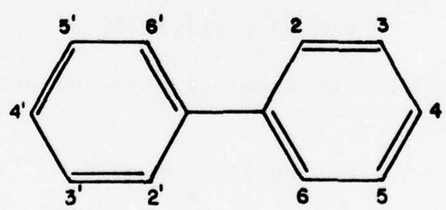
II. BACKGROUND

A. Polychlorinated Biphenyls

During the 1970's, increasing concern was generated over the use and disposition of polychlorinated biphenyls. This concern led, in October 1976, to a law which first limits then later bans the manufacture and use of PCB. (1)* Although this law may succeed in eliminating the initial source of PCB, it is believed that about 95 percent of all PCB ever produced are still available: (2) thus, the disposal of PCB is likely to be a problem for a long time to come.

B. Properties

"Polychlorinated Bipenyl" describes a group of compounds produced from the chlorination of biphenyl, and having the following basic structure:



Each number may represent the presence of either a hydrogen or a chlorine atom. There are 209 possible variations of PCB.

As individual compounds, each of these PCB is a solid at room temperature. PCB, however, are manufactured and distributed in mixtures

* Numbers refer to Bibliography

where due to the mutal depressing of the melting point, the physical state varies from that of oils to that of a sticky resin.

The physical properties of PCB have made them very useful in a variety of applications. These properties include low solubility in water, low vapor pressure, low flammability, high heat capacity, high dielectric constant, and low electrical conductivity. PCB are highly stable and are resistant to chemical, thermal and biological degradation.

C. Production and Usage

PCB were first introduced commercially in 1929. Since that time they have been used in a variety of applications in various industries. The applications of concern here include:

1. Use as filler fluid for transformers (askarel);

2. Use as impregnating fluid for capacitors;

3. Use as fire resistant hydraulic fluid;

4. Use as a fire resistant heat transfer fluid;

5. Use as a wax filler in the investment casting industry;

6. Other miscellaneous uses such as plasticizers and in carbonless copy paper.

Monsanto Company is the sole US producer of PCB, marketing them under the trade name of AROCLOR^R. Since 1971, Monsanto has voluntarily restricted the sale of PCB to use in "closed" systems (transformers and capacitors).

D. The Toxicity Problem

PCB enjoyed widespread usage for many years because they did not exhibit any noticeable short term detrimental health effects. Significant attention was given to the PCB health problem when in 1968 in Japan, over 1,000 people were poisoned by consuming rice oil that had been contaminated with PCB.

The principal toxic health effects of PCB include:

1. Chloracne - an acne-like skin inflammation leading to swelling and pigmentation.

2. Hepatotoxicity - injury to the liver.

3. Taratogencity - some studies have sown reduction in reproductive capabilities on exposure to PCB.

4. Carcinoginity - The link of PCB with cancer while inconclusively, is suspect and still under study.

5. Bioconcentrate, particularly in fish where the PCB concentration in the animal has been shown to be up to several thousand times the concentration in the water. This is significant in that consumption of these fish can result in further bioconcentration in the consumer.

E. Legislation on PCB's

In October 1976 the Congress passed Public Law 94-469, the Toxic Substances Control Act [3] a section of which specifically addressed the problem of PCB.

This law declared that PCB not be used except in a "totally enclosed manner." This "totally enclosed" restriction is merely a statement of the status quo since Monsanto has been voluntarily abiding by this restriction since 1971.

This law further provides that 2 years following the passage (Oct 1976) PCB shall not be manufactured and after 2-1/2 years they may not be distributed.

The law also indicates that disposal methods and marking requirements will be prescribed - but at a later date. [4]

Currently, OSHA uses a TWA (10 hour time weighted exposure average) of 1.0 mg/m^3 for lower PCB (less than 42 per cent chlorine) and 0.5 mg/m^3 for higher PCB. This standard has been recommended for revision to .05 mg/m^3 which should afford adequate protection against known effects. [5]

PCB are currently banned in Japan and are essentially banned in Sweden. Manufacturers in other countries have taken voluntary action to restrict sales and use.

III. APPLICATIONS

A. Uses and Distribution

Capacitors - about 65-70 per cent of PCB produced today are used as an impregnating fluid for paper-wound capacitors. About 95 per cent of the production of this type of capacitor uses PCB. Smaller capacitors, such as those found in radios and other electronic equipment, are solid state units and do not contain PCB.

Small PCB-containing capacitors may be found in electrical appliances such as fluorescent lamps, air conditioners, TV sets and smaller AC motors. Larger industrial capacitors are used in power distribution systems, electric motors and welding machines. Distribution of PCB in capacitor applications is widespread.

Transformers - PCB (in a 60-70 per cent solution in trichlorobenzene called askarels) are used in transformers for electrical insulation and cooling. Only about 5 per cent of the transformers in service in the US contain PCB, the rest contain mineral oil. Askarel-filled transformers are generally used in or near buildings where protection against explosion and fire is a necessity.

Transformers and capacitors represent the only "totally enclosed" uses of PCB. Under normal operating conditions these uses do not generally pose a health threat.[6] Spills and leakage are generally rare. The primary problem with this use is the ultimate disposal of PCB. Askarel-filled transformers have a life expectancy of 40 years, and seldom require maintenance or repair. Capacitors occasionally fail in service and are usually replaced. Capacitors generally are discarded along with the major piece of equipment upon the end of its useful life. Disposal of these items will be discussed later.

Most other uses of PCB have been discontinued, since they have been, in general, "open" type applications, and suitable replacements have been available.

Heat resistant lubricating fluids, heat transfer fluids and hydraulic fluids - PCB were developed for this use during the 1950's and 1960's. At its peak, about 15 per cent of PCB production went into this type service. Since 1971 most users have gone to substitute materials although some PCB hydraulic fluids are still in use in some deep mining equipment using imported PCB.

Investment Castings - Investment casting is a process where the pattern, made from wax is removed from the mold by melting prior to casting. Some twenty-five companies out of one hundred thirty-five in the industry use PCB as a filler in their mold waxes to control shrinkage. Adequate substitutes are available and conversion of this industry is not a problem.

B. Replacement for PCB

Capacitors - PCB have been used as dielectric fluids in capacitors since 1929. Their high dielectric constant and high resistance to decomposition make them well suited for this application. Capacitors used in domestic applications contain from .005 to .09 gallons of PCB; industrial type capacitors contain up to 6.7 gallons. The most popular size contains about 3.1 gallons. In each case, the bulk of the PCB are not present as free liquids, but rather are impregnated into the paper dielectric in the capacitor.

Replacement fluids are under development by several US companies. Each of these fluids has better environmental characteristics than PCB. [7] The outlook for some of these fluids in certain applications is promising. Another alternative is the development of dry film capacitors which would not require an impregnating fluid.

Unfortunately there is appreciable resistance to the replacement of PCB since the reliability of replacement fluids has not been adequately proven. It appears that capacitor manufacturers may seek a temporary exemption from the ban on PCB usage, based on the current lack of an acceptable substitute.

Transformers - PCB have served as coolants for large power and distribution transformers. A mixture of PCB and trichlorobenzene (known as askarel) is used where the use of mineral oil could pose a fire hazard. The volume of askarel used in transformers varies from 40 to 1500 gallons, with an average of 230 gallons.

There are several alternatives to the use of PCB (askarel) transformers -

1. Use of air cooled transformers. Air cooled transformers are generally larger and not as efficient as askarel transformers.

2. Use of mineral oil transformer enclosed in vault. The National Electric Code requires enclosing mineral oil-cooled transformers in vaults when located in or near buildings. Askarel transformers need to be enclosed in vaults only when they are rated above 35,000 volts.

3. Use of a substitute fluid. Substitute fluids are becoming available. Probably the most likely replacement for PCB is a silicone-based fluid. [8] This type of fluid could be used in existing transformers as a direct replacement for askarel. Toxicology studies to date have been favorable. This fluid, however, is not quite as fire-safe as PCB. Large scale conversion to an alternate

transformer fluid, as with capacitors, will be dependent on long term testing.

At present it would seem unlikely that a replacement fluid would be used to replace askarel in existing transformers. The service life of transformers is relatively long, and losses of PCB from transformers have been quite small. Leaving PCB-filled transformers in service would eliminate conversion expenses and would allow time to develop technology for disposal of PCB from these transformers at the end of their useful life.

C. Hydraulic and Lubricating Oils

With the exception of a few hydraulic systems in use in deep mining applications the use of PCB as fire resistant hydraulic and lubricating oils has been eliminated. Several replacements have already gained acceptance.

Phosphate Esters have probably the best record in this type of service as they have been widely used as fire resistant hydraulic fluids in the aircraft industry for several years.[9] There are many types of phosphate esters available from several manufacturers.[10] The toxicity of phosphate esters is variable from harmless to extremely poisonous, thus the toxicity for each formulation must be determined prior to use. In any event it is unlikely that the phosphate esters will be banned as a class as have PCB.

IV. DISPOSAL

A. Available Technology

The only method acceptable to the EPA for disposal of PCB is incineration. The technology is currently available to achieve nearly 100 per cent destruction of liquid PCB material. Disposal of PCB-containing solids (capacitors) is more of a problem, and EPA will accept "Scientific Landfills" as an interim measure, until the technology and capacity is available for incineration.

The manufacturer of PCB and several commercial ventures maintain incinerators for the disposal of liquid PCB. These incinerators inject separate streams pf PCB material and a high BTU fuel into a long cyclindrical combustion chamber. This mixture burns at about 2200^{o}F for a residence time of 3 to 4 seconds. The resultant gasses are sent through an afterburner, then cooled, scrubbed and neutralized to remove the resultant HCl byproduct.

Technology does exist for the incineration of solid PCB wastes. Solids, in fiber drums are burned in a rotary kiln, or tumble burner at a temperature of 2200^{o}F. The effluent gasses are treated like those from liquid incineration. Preparation of solid materials for incineration will include removal of PCB articles from equipment, and storage in marked containers. Solids must then be shredded or crushed prior to incineration. Facilities for solids disposal, however, are not yet available in sufficient capacity to handle the existing volume of PCB wastes. Thus the EPA will accept landfill as a temporary alternative.

"Scientific landfills" exist that are designed to accept drummed PCB wastes. One such landfill* is constructed above ground on a 40 foot bed of thick clay. Cells are constructed above ground, lined with polyethlene film and covered with 5 feet of clay when filled with drums. Sumps are located in the bottom of each cell to gather any liquid that may collect. Such liquids are subsequently tested and treated prior to release to the environment.

EPA Regulations for the disposal of PCB state that the responsibility for storage and disposal of PCB materials rests with the owner. This is interpreted to mean that even if the PCB materials are stored in a chemical landfill, the owner is still responsible for their ultimate disposal. Inventories are kept on the contents of chemical landfills.

Since approved landfills will require maintenance, and the containers will deteriorate in time, it is expected that the contents of these landfills will need to be mined and incinerated or otherwise treated once the capacity is available.

There are other technologies under consideration for removal and destruction of PCB. These include biodegradation, carbon adsorption, ultraviolet-assisted ozonation and resin adsorption. These methods, still under development, are primarily designed to eliminate fairly low concentrations of PCB from water.

B. Handling of PCB Material

EPA regulations developed for the implementation of the Toxic Substances Control Act require the eventual labeling of PCB articles. This will mean that capacitors and transformers will need to be marked with the appropriate labels. In some cases this may be performed incidental to servicing operations but may also require special efforts.

Demand for more PCB incineration capacity will likely generate more commercial disposal operations. Hopefully these

*operated by the Chemtrol Pollution Services Co., Model City, NY, under approval from the New York State EPA.

operations would be geographically distributed such that their use would be practical for owners of PCB materials.

Although the Army possess significant quantities of PCB material, there is little reason for it to attempt its own PCB disposal. This is better left up to private industry having the technology and facilities. For the Army then, PCB disposal would become primarily a management problem.

Open-ended contracts with the commercial disposal contractors should probably be entered into on the DA or DoD level. Centralized waste PCB accumulation sites would then be designated to collect waste PCB materials from surrounding military locations.

The nature of PCB-containing equipment is such that it is much more likely to be found on installations rather than in the field, simplifying the segration problem.

At the user level, removal of PCB articles from discarded equipment would become the responsibility of the post engineers or property disposal office. Collection of PCB articles at this level would likely require little more than segregation into specially marked drums. Drums of discarded PCB articles, would then periodically be transported to the PCB collection site and subsequently to the contractor for ultimate disposal.

While the disposal of PCB from capacitors is strictly an expense, the recovery of salvagable metal from scrapped transformers make this operation somewhat more economically attractive. The current commercial rate for burning the PCB wastes is about 7-1/2 cents per pound plus any handling fees.

It is interesting to note that the EPA apparently makes a distinction between PCB articles owned by individuals as opposed to PCB articles owned by institutions although the articles may be identical. PCB from households may be disposed of in municipal dumps while institutions (including household appliance servicemen) must dispose of their PCB by EPA approved means. The rationale behind this appears to be that PCB in household wastes are of sufficiently small quantity and are likely to be so widely scattered as to not pose an environmental threat.

V. SOURCE OF INFORMATION

Significant quantities of information concerning many aspects of PCBs have been published, and are available for more detailed studies.

Of particular interest is a report prepared for the Environmental Protection Agency by Versar Inc. (12) in 1975. This document reports in detail the uses and distribution of PCB in the US, and is available through NTIS.

Due to the intensity of the PCB problem, some of the technology reported in publications more than 2 or 3 years old may already be obsolete.

Several individuals at the Army Environmental Hygiene Agency at Edgewood are involved in the PCB problem and are generally aware of the current state of the art. In addition, they have many of the PCB publications already in their possession.

Several of the shorter, and most pertinent references have been included in this report as appendices.

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APPENDIX A

Interagency Briefing

On

Implementation of Public Law 94-469 6(e)

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HSE-EW-S

MEMORANDUM FOR RECORD

SUBJECT: Interagency Briefing on Implementation of Section 6(e) of the Toxic Substances Control Act (Public Law 94-469)

1. Section 6(e) of PL 94-469 relates to the control of Polychlorinated Biphenyls (PCB). EPA is charged with the responsibility of drafting regulations and effecting such control. The following information delineates EPA strategy as stated in the subject briefing to accomplish the above referenced task.

2. Proposed EPA Regulations will be applicable to:

a. Manufacturers

b. Processors

c. Users

d. Distributors

e. Disposal Operators

f. Transporters

g. State and Local Government

h. Federal Government

3. The following definitions were given as pertaining to the proposed regulations and the EPA briefing:

a. PCB Chemical - Pure isomer or blend of biphenyl molecule chlorinated to varying degrees.

b. PCB Equipment - Equipment which contains components containing PCBs. (Equipment containing capacitors, etc.)

c. PCB Article Container - Container of a PCB article i.e. the box a capacitor is shipped in.

d. PCB Mixture - A substance containing 10% and up of PCB chemical i.e. transformer askarel.

e. PCB Material - A substance containing .05% and up of PCB chemical i.e. refilled transformer fluid, rinsing solvents, contaminated soil.

f. PCB Article - A device which contains a PCB mixture or material i.e. capacitor, transformer, etc.

g. PCB Container - A vessel which holds PCB mixtures or material such as a drum, can, etc.

h. Transformers - No definition to date

i. Capacitors - Large High Voltage (3 lbs and up @ 2000 vac and up)
Large Low Voltage (3 lbs and up)
High Intensity Discharge (HID) lighting capacitors
Small capacitors (less than 3 lbs)
Fluorescent Light Ballasts (less than .22 lbs)

4. Disposal of PCBs. The only method of disposal that EPA considers acceptable for PCBs is incineration. However, the present State of the Art is such that only liquid PCBs have been destroyed by incineration in a full scale operation. There are to-date several firms with this capability according to EPA. Since technology to destruct solid materials has not been developed, EPA will condone disposal in an approved chemical landfill on an interim basis for solid PCB wastes. EPA also favors storage of such wastes until technology is developed for solid waste destruction.

5. Disposal of PCB Liquids by Incineration. The following criteria will be set forth in EPAs proposed regulations:

a. Combustion Temperatures - $2000^{\circ}F$ and 2 second Dwell Time
$2700^{\circ}F$ and 1-1/2 second Dwell Time

b. Controlled Waste Feed

c. Continuous Monitoring for Combustion Parameters

(1) O_2

(2) CO_2

(3) CO

(4) NO_x

(5) THC

(6) RCL

d. Automatic Shutoff when:

(1) Temperatures are too low

(2) Monitoring equipment failure

e. Wet scrubbers will be mandatory

f. EPA Regions and States must approve facilities

6. Incineration of PCB Solids. The following criteria will be established in EPA regulations to govern incineration of PCB solids as technology is developed.

a. Combustion Criteria (not finalized)

b. Solids must be shredded or crushed before combustion (capacitors opened)

c. Overall emission criteria of 0.001g PCB/kg of PCB incinerated

d. EPA Regions and States must approve destruction by this method on a case by case basis

7. Chemical Waste Landfills. EPA will establish minimum criteria in the following categories:

a. Soils

b. Hydrology

c. Topography

d. Monitoring

e. Leachate collection

f. Supporting activities

Approval of all sites will be by EPA Regions and States.

8. Storage for Disposal. EPA will establish minimum criteria in the following categories:

a. Storage must be under roof

b. Concrete floors and retaining barriers to contain spillage of 25% of material stored.

c. Monthly inspection of stores for leaks

d. Specifications for containers

e. Records to permit retrieval by date of entry into storage

9. Decontamination of Transformers and PCB Containers. (Successful decontamination of transofrmers has not been demonstrated to-date) EPA will establish the following criteria:

a. Procedures for solvent rinsing of PCB containers.

b. Provisions for the adminsitrator of EPA to approve decontamination procedures when successfully demonstrated.

10. The following disposal requirements will be established by EPA:

a. Liquid PCB mixtures and materials will be incinerated.

b. Drained transformers will be disposed of in chemical waste landfills unless they are decontaminated.

c. PCB articles are to be incinerated.

d. Chemical waste land fills may be used for two years for PCB articles as a transition until incinerator capability is established.

e. Drained PCB containers will be disposed of in chemical waste landfills or by incineration.

f. PCB materials from spills, including contaminated soil (500 ppm contaminant) will be incinerated.

g. PCB articles (capacitors, etc.) will be removed from equipment prior to disposal.

h. Small PCB capacitors and light ballasts from private households may be disposed of as municipal solid wastes by the household (if serviced by others this does not apply).

i. Municipal solid wastes and municipal sewage sludges are not governed by this regulation unless they contain in excess of 500 pm PCB.

j. Any capacitor or light ballast will be controlled by this regulation unless it is clear they do not contain PCB's. (Unlabeled capacitors and ballasts will be assumed to contain PCB's).

11. Marking of PCBs

a. PCB articles, equipment and transport vehicles must display markings as shown in Incl 1

b. Small PCB articles must display markings as shown in Incl 2

c. Transport vehicles must display a placard as shown in Incl 3

12. Marking Implementation. The following time table will be established for marking of PCB articles, materials, containers, (times are from effective date of regulations)

a. All new PCB equipment to be marked within six months

b. All new existing PCB containers to be marked within six months

c. All PCB articles, equipment, article containers in inventory to be marked within six months or before distribution in commerce

d. All storage areas to be marked within six months

e. After six months each PCB article removed from service to be marked or placed in a marked container

f. Transport vehicles to be marked within nine months if transporting:

(1) 40 kg of liquid PCBs

(2) 200 kg of liquid PCBs in PCB articles

(3) Any transformers

g. Large Low Voltage PCB capacitors and HID capacitors to be marked after nine months when serviced

h. Transformers to be marked after twelve months

i. High Voltage PCB capacitors to be marked after twelve months either directly on capacitor or on enclosure.

j. All semi-enclosed PCB equipment to be marked within twelve months.

13. Reporting and Monitoring Requirements

a. Records are to be kept and reports submitted to EPA for:

(1) PCB incinerators

(2) PCB chemical waste landfills.

(3) PCB storage areas.

(4) Generators of large PCB waste volumes.

b. Objective of Reports.

(1) To determine compliance with criteria.

(2) Early warning of potential problems.

(3) Basis for enforcement actions.

14. Responsibility. The owner of PCB is responsible for its storage and disposal. This responsibility cannot be delegated.

3 Incl
as

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Sanitary Engineer
Water Quality Engineering Division

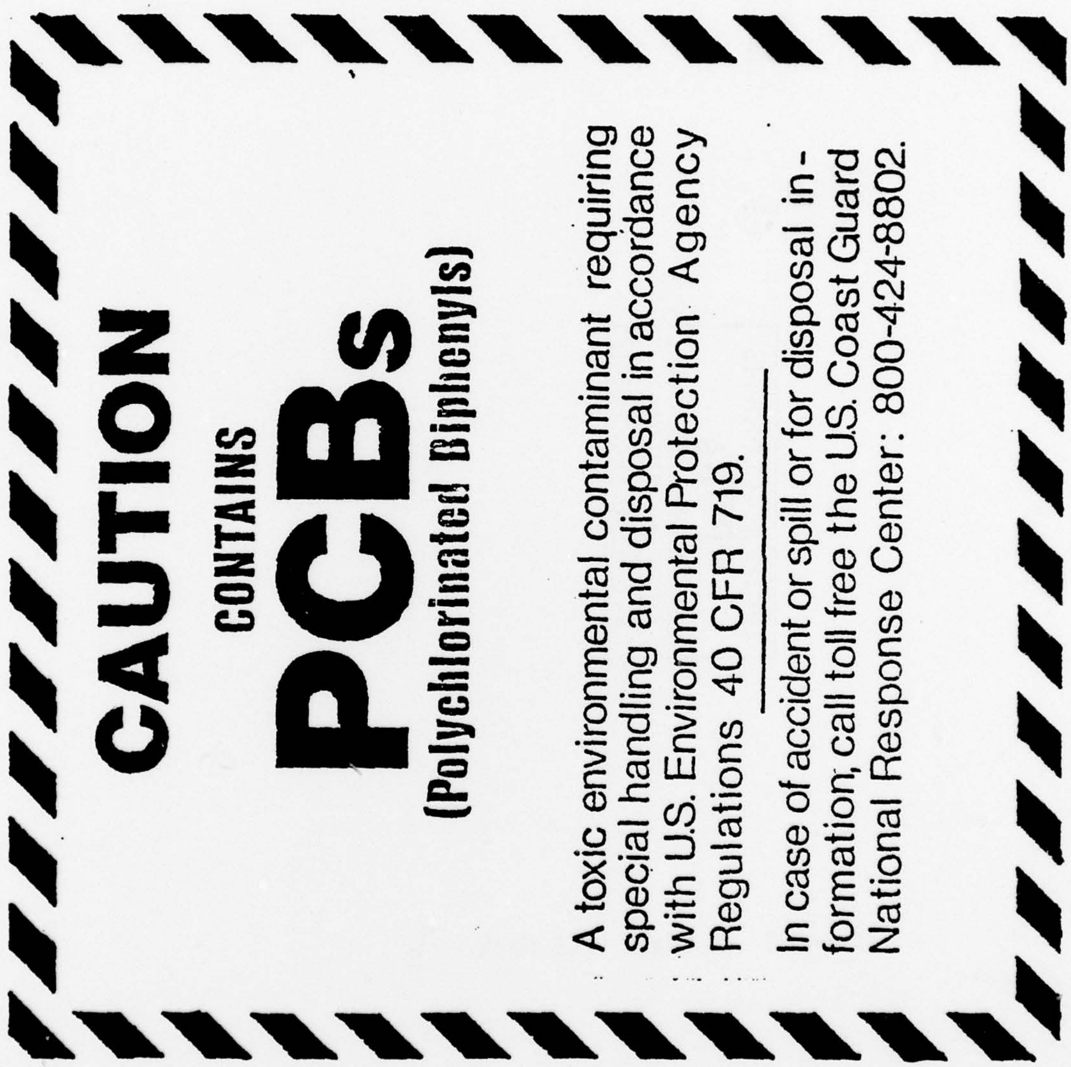

Figure 1 - Large PCB Mark - M_L

Encl 1

Figure 2 - Small PCB Mark - M_S

Incl 2

Figure 3 - PCB Transportation Placard

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Incl 3

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