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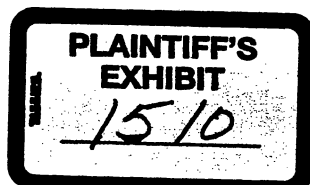
ECONOMICS AND SUBSTITUTES

Warren Muir, Ph.D.*
Session Chairman

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INTRODUCTORY REMARKS

Warren Muir, Ph.D.

I guess we have all had an opportunity to hear about health and ecological impact and other aspects of PCB's in the last day and a half. The history of PCB's, as I am sure most of you are aware, is several years old. By 1971 and 1972 there was sufficient concern over their potential environmental effects that a Federal task force was created under the sponsorship of the Council on Environmental Quality and the Federal Council for Science and Technology, which looked into the situation and made a variety of recommendations.

In addition, at that time the Monsanto Chemical Company developed a restricted sales policy with regard to uses of PCB's, and also shortly thereafter, the Organization for Economic Cooperation and Development had an international agreement with regard to uses of PCB.

All of these actions were directed in one fashion or another toward inappropriate uses of the chemical. Yet, as of this date, there is no Federal authority to control the use of these chemicals, despite 5 years of consideration of toxic substances control legislation.

This particular session of the conference deals with economics and substitutes; we will have a presentation or a brief description of two economic case studies that have been done on PCB's, and then several speakers will discuss the substitutability or nonsubstitutability for uses of PCB's.

In dealing with environmental problems such as PCB's and a variety of other chemicals, I am sure you are aware that there is a great deal of scientific uncertainty with regard to particular health or ecological impacts. For example, there is a certain amount of uncertainty as

to whether or not something is carcinogenic or whether it can bioaccumulate.

There typically appears to be, however, a much greater uncertainty about the economic implications or the economic impacts of any action that might be taken to mitigate the suspected problems. Much of this arises from uncertainty, about substitutes and also about the inability to predict the actual individual or corporate responses that would be made under a given type of regulatory action or other type of mitigating action. Thus in my view, there is much greater economic uncertainty in many of these issues than there is scientific uncertainty.

Also, irrespective of all the uncertainties, we know that the further along in the chemical marketing and development process, the longer it has been manufactured, and the larger the market, generally the greater the health and environmental effects of the particular chemicals and the greater the economic impact there is of mitigating action, to the extent that they are necessary.

Thus, if we are to deal with problems such as PCB's, we must change our approach toward environmental chemical problems; we must get out of a reactive posture. We must undertake the task of identifying potential hazardous chemicals early in the development process. By so doing, health and ecological problems can be avoided before they develop. And, by so doing, the economic dislocation and impacts from any potential regulatory action will be eliminated or minimized to the benefit of all.

PCB's IN CAPACITOR APPLICATIONS

Richard L. Rollins*

Abstract

Alternating current (AC) capacitors have used a grade of polychlorinated biphenyls (PCB's) since the 1930's. Long life, high reliability and a high degree of flame retardancy are imparted to the capacitors by these fluids.

The latter characteristic is very important in applications where high exposure to the general population exists such as in fluorescent lights and television sets. The main disadvantage with the fluid is its long persistence in nature. When the capacitor industry became aware of the environmental problem, it generated guidelines for handling and disposal of the material, then voluntarily imposed these restrictions upon itself. Now of the 70,000 pounds per day processed, only 7 pounds are being discharged into plant water effluents. Liquid waste materials are sent to proper incineration facilities and solid waste materials are placed in sanitary landfills to prevent escape into the environment. For 4 years the industry has been using a significantly more biodegradable grade of Aroclor identified as 1016 by Monsanto. In that time, Aroclor 1016 has not been identified as a PCB commonly found in the environment. Non-PCB materials are continuing to be evaluated, but there are not dielectric fluids available today which can be considered an acceptable substitute for PCB's in the broad range of AC capacitors.

On behalf of the electronic industrial association and the manufacturers of PCB capacitors, I appreciate this opportunity to present our point of view. I will discuss PCB capacitors, the industry's response to the environmental problem, and possible alternative candidates to PCB's.

Manufacturers of AC capacitors have used PCB's since the early 1930's, and have used them almost exclusively since World War II. They are presently used, for example, in capacitors for fluorescent lighting, air conditioners, and television sets. These capacitors are in the plant where you work, in the home, and in public gathering facilities. They are therefore near you a high percentage of the time. Manufacturers are very cognizant of their responsibilities in providing a capacitor that will operate satisfactorily in these applications for providing long life and high reliability at a reasonable cost.

The consequence of these requirements in a competitive marketplace is that the products and their components are constantly being reevaluated to increase life, increase reliability, decrease size, and decrease cost. The capacitor manufacturer indeed daily sees pressures for improvements. It is, therefore, an obvious question to ask why are PCB's still used after 40 years during which the best capacitor research and development scientists in the United States were constantly seeking substitutes.

One of the reasons lies in the nonflammability of the PCB material. Because of applications, such as lighting, where personnel and equipment safety are paramount, capacitors must be manufactured since they not only fail infrequently but also fail safely. In applications such as the World Trade Center in New York, where 250,000 fluorescent lights are installed, it is obvious that high reliability and a nonflammable capacitor characteristic are mandatory.

A capacitor which fails violently and contains a flammable fluid could create a serious problem, especially in densely populated buildings, giving visions of a towering inferno. The Consumer Products Safety Commission, as an example, has shown considerable concern over television set fires and has requested Underwriters' Laboratories to develop standards for safety for television set receivers.

A second reason lies in the reliability of the product as it is known today. Presently, the capacitors our companies manufacture have a survival rate per year greater than 99.9988 percent. The requirement that more than 95 percent of our capacitors must survive after 13 years of normal application conditions must also be met.

The test time and the amount of test necessary to guarantee the above reliability is mind boggling to say the least. Many thousands of units and millions of unit hours at or referred to application conditions are required to satisfy our statisticians that any change in product will conform to these present day standards.

Even with the large amount of previous testing and history on the PCB-containing capacitor, there have been many instances which despite all controls in existence cause consumer concern due to extreme failure rates. That is at a rate greater than 10 percent.

The first occurred in 1957, when a variation in the quality of the PCB fluid, as synthesized, resulted in a highly unstable capacitor. Standard analytical tests in use at the time did not detect the quality difference. The result was a large number of capacitors failing in a very short period of application life.

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The consequence was the requirement by the customer that the capacitor manufacturer not only provide compensation for the cost of the capacitor, but the cost of the equipment which contained the capacitor, plus the labor charge for placing the equipment in the installation. The total replacement cost the manufacturer 100 times the original price of the capacitor.

The second instance of numerous failures occurred 6 years later, this time involving the capacitors of most manufacturers. In this circumstance reduced-size capacitors were tested and approved by industry-accepted accelerated life testing and a new size was shipped to customers.

Approximately 1 year later, up to 15 percent of these capacitors began failing in some applications. A subsequent modification in the accelerated-life testing based upon findings in the field failure analyses now provides proper screening to eliminate the chance of such a problem occurring. Therefore the AC capacitor industry now does very extensive evaluations before releasing new designs or using new materials.

The capacitor industry became aware that PCB's were possible environmental problems in 1970. Soon thereafter, in 1971, a committee was formed under the sponsorship of the American National Standards Institute, ANSI, to develop standard industry guidelines for the handling and disposal of capacitor grade PCB's. An interim standard was published as an official standard proposal by the National Electric Manufacturers Association, NEMA, in January 1973. And a final document, C107.1 1974, was published in January 1974.

Briefly, properly planned housekeeping, considerations for employee safety, and scrap disposal procedures were detailed. Today, to the best of my knowledge, all manufacturers of PCB capacitors in the United States have applied these guidelines for the handling and disposal of PCB's.

The success of the manufacturer's control in handling practices is apparent from the fact that of the approximately 70,000 pounds per day used, less than .01 percent or 7 pounds per day is discharged into the water effluents of the plants. The ANSI guidelines also recommended that the capacitor companies change from Aroclor 1242 to a PCB with less toxic effects which Monsanto identified as Aroclor 1016.

Here it must be pointed out that various grades of PCB's cannot, as so often is assumed, be classified as having the same chemical, physical, or biological characteristics. For instance, in "A Comparative Study of Two Chlorinated Biphenyl Mixtures . . ." by Goldstein et al., significant differences were shown to exist in the biological effects of Aroclor 1242 and 1016 on equal doses of the two mixtures. Aroclor 1016 also reduces by greater

than 94 percent those higher homologs existing in Aroclor 1242 which were the most persistent in nature. With these benefits, and without sacrificing the capacitor characteristics, all capacitor manufacturers began using the new material by 1972, despite the fact that it was 50 percent more expensive.

After 4 years of use by the capacitor industries, Aroclor 1016 has not been identified as a PCB that is commonly found in the environment. Nor should it be suspected that 1016 would be commonly found, because the industry is exercising control over waste disposal from its capacitors, so that there is little or no opportunity for leaking PCB's.

Our industry believes it is much more important to reduce the environmental problems and to allow continued use of the capacitor-grade PCB than to be concerned with the material cost increase and immediately turn to a substitute which is not thoroughly evaluated and may be flammable.

Alternates have been considered ever since the original introduction of PCB's. The substitutes must be not only a satisfactory dielectric fluid providing acceptable life, reliability, and safety, but in addition must not cause environmental problems. Our experience with PCB's has demonstrated that some material will escape into the environment through processing and handling. Therefore, alternate fluids must be evaluated on this basis. The effects on man and his environment must be determined before the product is introduced. It would be a very serious error to replace capacitor-grade PCB's with a fluid which eventually becomes a greater threat to man.

Further PCB modification which would provide even less toxicity and persistence in nature but still maintain good dielectric properties and good non-flammability would seem to be one alternative to Aroclor 1016. Our companies respectfully urge Monsanto to pursue this possibility.

Non-PCB alternatives are now being offered and suggested. Some are new and some have been available for many years. The industry's position on these is as follows.

Mineral oil is a flammable fluid which was replaced by PCB's in the 1930's. Capacitors using it are 50 to 100 percent larger, much less reliable, and much less safe than those using PCB's. The substitution of mineral oil necessitates redesign of equipment to utilize the larger capacitor, an increase in the capacitor manufacture facility, and will result in increased use of basic materials which are presently in short supply.

Modified synthetic hydrocarbon oils have been developed which while flammable would allow capacitors to approximate today's size. Samples have been dis-

tributed for testing, but the material is not commercially available.

Phthalate ester, also a flammable fluid and also with biodegradability problems, has been used in certain restricted applications where conditions of limited temperatures exist. The unknown factors of reliability and safety in the broad consumer use areas such as lighting now prevent its use. Evaluations, however, are continuing.

Substituted aromatic compounds are possible candidates, and one has been proposed that has less fire resistance than PCB's; it is suggested to be a good dielectric fluid but only for high-voltage power factor correction. This, to our estimation, represents only 17 percent of the PCB used in closed systems, and leaves completely unanswered an alternative or alternatives for the remaining 83 percent of the applications. Some material has been produced but the fluid has not been made commercially available. In fact, our companies are having trouble obtaining samples from the manufacturer. When samples become available, the time-consuming testing can begin. It has been estimated that 3 years are required before final commercial use after initial testing of a change in capacitor fluids.

Also proposed for limited applications is the use of a plastic film replacing the kraft paper dielectric in the AC capacitor. Although evaluations with the highest quality film have been underway for more than 2 years using the current processing techniques, the reliability of

the product is only 1/20th of that of present capacitors in most applications. Significant additional testing is required to determine if the cause of poor reliability is totally inherent or if improvements can be made by modifications in capacitor design.

In summary, there are no commercially available fluids which today can be considered a totally acceptable substitute for PCB's in the broad range of AC capacitors, nor are there substitute dielectric systems which would satisfy the requirements of reliability and safety in most applications.

I would like to reiterate that our companies have shown responsiveness to the environmental problems of PCB's by the following actions.

1. Working as a group with government and consumers in providing guidelines for proper handling and disposal of capacitor- and transformer-grade PCB's.
2. Reducing discharge levels of PCB's in a 16-capacitor plant. Further reductions are now being planned.
3. Converting to a more expensive grade of PCB's which is less persistent and has less toxic effects.

Finally significant differences do exist between Aroclor 1016, which capacitor manufacturers are now using, and material which is predominantly being found in the environment. Our industry believes that all concerned should be aware of the differences.

We respectfully urge this awareness in environmental studies and in drafting of regulations.

THE ECONOMIC IMPACT OF A BAN ON POLYCHLORINATED BIPHENYLS

Duncan MacArthur* and Stephen F. Nagy†

Abstract

The study described below assessed the effects of a hypothetical total ban on PCB's. In order to compile a realistic scenario, the proposed Toxic Substances Control Act was used as a model. A complete phaseout was estimated to take 76 months, and would involve publication of rules, testing, hearings, halting of imports and manufacturing of PCB's, and depletion of stocks of PCB-containing products.

Mineral oil was assumed to be the primary substitute for PCB's, since a major technological breakthrough in the development of alternate fluids is unlikely in the near future.

Minimum estimates are given for the one-time and annual capital expenditures by industry of a ban on PCB's, and for the primary and secondary impact costs. Intangible issues, such as the effect of a PCB ban on public safety, are also discussed.

In the course of our work with private and public clients, we have examined polychlorinated biphenyls, PCB's, in a number of areas, ranging from product design to economic impact. The work to be discussed here was completed in 1975 as part of a study to examine the effects of the proposed Toxic Substances Controls Act, as illustrated by Senate Bill S776 (20 Feb. 75).

We selected as an example a case study to completely ban an existing product following the procedures outlined in the proposed bill. We use the case study for following reasons. It provides an example of the complete analysis required to assess the impact of a ban; it illustrates the direct and secondary impact on industry; and it enables us to estimate the economic consequences of a ban on one specific product. In our study, we also highlighted the unquantifiable factors.

In our methodology, and again this was done in the early part of the year, we assume all the steps in the proposed Toxic Substance Control Act as illustrated by Senate Bill S776 are taken. The end result of this is a total ban on PCB manufacture and use. We selected PCB's for illustrative purposes only. Our discussion was not intended to reflect on the actual health or environmental aspects of the example product.

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The scenario for banning the product is estimated to require about 76 months for complete phaseout of product use. Thirty-eight months were estimated for publications of the rules, testing, hearings, and so forth. The key element in this period is the 24-month period that we estimated would be required for testing. The key element in months 39 through 76 is phasing out the sale of some manufactured goods, particularly appliances. We also assumed that no legal action would be taken by industry until publication of the final ban on substances occurring after the 38 months of testing and hearings.

A possibility in the scenario of the second 38 months is that industry requests a judicial review but complies with the review. We estimated the judicial review takes 2 years and results in a complete product ban. In the second 38-month period the following types of activity would go on: documentation for control purposes; monitoring of shipments; limitation of stockpiling of PCB products; refining methods to prevent PCB's from entering the environment, such as controlled use and control proposal; stopping the production and import of PCB's or equipment containing PCB's, and finally banning the manufacture and sale of PCB-containing products.

In the analysis of our PCB's we have tried to consider the complete life cycle of the product. PCB's are produced by one manufacturer in the United States—the trade name is Aroclor—and about 40.5 million pounds were produced in 1974. The sale of PCB's is currently restricted to electrical use and casting waxes. In the past they were used as transfer fluids from heat exchangers, hydraulic fluids, and so forth. However, as you know, to avoid potential adverse environmental impact, Monsanto restricted domestic and export sales in 1972 to electric installation equipment applications in which the product is enclosed in a relatively well-maintained container throughout its use. Monsanto and others offer PCB disposal service.

We found that PCB applications are characterized by their long-term utilization with the majority controlled by utilities. Transformers, for example, were reported to last 20 to 30 years, and capacitors to last 7 to 10 years.

The number of transformer manufacturers vary; anywhere from 2 to 10 have produced PCB-containing transformers. Primary use is as nonflammable electric insulating oil. Previous estimates report approximately 5,000 transformers were produced per year with an aver-

age PCB amount of about 5,000 pounds per transformer. Value of shipments (1974 data) is estimated at \$35 to \$45 million.

The number of people using capacitors varies. Estimates range from 16 up to 50 capacitor manufacturers. There are approximately 90 to 100 million units per year produced with a value about \$105 to \$147 million. There are primarily two types: large utility capacitors, using about 9 to 13 million pounds of PCB's per year, and small industrial capacitors, using about 17 million pounds per year.

In the case of casting wax, there is only one manufacturer in the United States. PCB's represent 30 percent of the components of the wax. The annual usage is about half a million pounds. Primarily, it is imported. We also found another indirect importation of PCB's—in capacitors in electrical equipment.

The primary transformer users are utilities; others include manufacturers of and users of electrically powered rail equipment, furnace equipment, and electrostatic precipitators. About 85 percent of PCB transformers are used as network transformers by the utilities, and we estimate that approximately 90 percent of the transformer uses are controlled by the utilities, either through ownership or service contracts.

With respect to the capacitor users, electric utilities use large capacitors and manufacturers and consumers of goods use small capacitors. Electric utilities use them primarily for power factor correction, and smaller units are used for starting and other uses such as fluorescent lighting. We estimate that about 2 to 3 percent of large capacitors are consumed as replacements and about 5 to 10 percent of the small capacitors were consumed as replacements.

With respect to the casting wax, approximately 98 percent of that is now recycled and the people in the business maintain that the remaining 2 percent that is left in the mold is destroyed when the mold is prepared at high temperatures.

The final step is disposal. Monsanto and others have specialized incinerator facilities for PCB liquids, primarily for large uses such as transformers and capacitors used by utilities.

The ban of PCB's was estimated to result in a one-time cost of \$13.7 million. There would be additional expenditures of \$110 million annually. The ban would also affect regulatory codes, public safety, and other intangible areas, and, as always, the net result would be an increase in consumer costs.

The primary impact, which is on the manufacturer and users, is estimated at \$8.8 billion for one-time costs and approximately \$16 million for annual costs. Key elements in this, surprisingly enough, were "red tape"

required by Senate Bill S776. There are also disposal costs, plant rebuild costs, and salary costs.

Secondary impact on users of PCB's, PCB-containing products or services, and disposal organizations is estimated at \$4.9 billion for one-time costs and \$93 billion for annual costs. Elements of secondary impacts are primarily new plant rebuilds for increasing the capacitor output of the United States, disposal, and the increased cost of substitutes.

The annual costs reflect the forecasted increased costs of electrical equipment manufacture and use, including replacements of existing equipment. Since the lifetime of large transformers and capacitors is 20 to 30 years, the additional annual cost, over \$110 million, was forecast for the same period.

In the proposed 38-month time period, industry representatives indicated that for primary and secondary transformer use, there would essentially be a shift to mineral oil as a replacement for PCB's, since the environment and performance characteristics of other substitutes are not thoroughly researched. Major technological breakthroughs, such as development of substitute fluids, were not forecast.

We did use minimum cost estimates. The cost of replacing a PCB transformer, for example—not necessarily the transformer but the vault which is surrounded by the building—has been estimated as varying anywhere from \$5,000 to \$50,000. We used a figure of about \$10,000, which we consider low and very conservative.

The economic impact of changing the regulatory codes cannot be accurately quantified without a detailed survey. However, the impact of the changeover for those localities with regulations was estimated not to cause major dislocation in building activities. We do know that many cities permit only nonflammable, essentially PCB, electrical equipment to be installed in tall buildings; however, others do permit non-PCB transformers with a vault.

Intangible issues include public safety, which would be impacted by a ban on PCB's. Analysis would require a detailed analysis of the tradeoffs between the benefits of the product versus the benefits of the ban. Electrically driven trains use PCB transformers and it has been reported that the flammable liquid in the transformer would be a potential hazard. Uses of other transformers in rail cars, if possible, would require redesign and overhaul of existing equipment. Use of large quantities—over 20 gallons of liquid—in buildings would present a potential danger even in walls. Insurance underwriters have reportedly studied the problem but nothing has been presented as a request to change rates.

Other intangible areas are in replacements for all types of equipment. Dry transformers, for example, are

reported to have a low reliability. There are also specific areas, such as replacement capacitors for compact equipment in which the capacitors cannot be replaced with a non-PCB-containing unit similar in size and characteris-

tics, forcing either salvage or scrapping of the equipment.

In assessing all these costs, we forecasted pass-through to the consumer.

THE USE OF DOW CORNING® Q2-1090 DIELECTRIC LIQUID IN POWER TRANSFORMERS

Richard H. Montgomery*

Abstract

Dow Corning has developed Q2-1090 Dielectric Liquid to replace askarels in transformers. Five years of laboratory and field testing have shown it to be both efficient and safe. It is now being sold in commercial quantities both for new transformers and for retrofitting old transformers. With some redesign, competitive entries, and further restrictions on PCB use anticipated, it is expected to have favorable economics. A 3- to 5-year phase-in to completely commercially qualify the liquid in all applications is planned.

Thank you for the opportunity to come here today to represent the silicone industry, which in the United States consists of the Dow Corning Corporation, the General Electric Corporation, Union Carbide, and Stauffer Chemical. The global silicone industry is now 5 years into a program to qualify dielectric fluid replacements in both transformers and capacitors. The Japanese silicone industry and Dow Corning Corporation have led this effort to date. As a result of this extremely large effort by the industry, I am very pleased today to make two major announcements.

First, the technology to commercially manufacture a capacitor dielectric fluid with superior dielectric properties is being developed. This material appears to withstand any of the high electrical stresses the material would normally be used for in the industry. We plan to make this product commercially available during 1976. At its present state of development, we know of no environmental problems with this particular product. No chemistry would indicate there should be any. But this will be continually studied, as have other products from the silicone industry.

Second, Dow Corning now has commercial production available to manufacture silicone transformer liquids in sufficient capacity to handle the global transformer market, and that is a very large investment. So let me now turn in some detail to the transformer industry and the role silicones can play.

We must remember that today three environmentally safe transformer systems are available to replace transformers filled with PCB liquids. Gas-cooled,

air-cooled dry types, and liquid-silicone-filled transformers will meet almost every need where PCB-containing transformer fluids are used.

The silicone industry has produced insulating materials for transformers for 25 years. The industry's newest material, a silicone transformer liquid, is now in use in Japan as a direct replacement for PCB-containing transformer oils. In the United States, extensive field testing has been under way for 4 years and at the present time this material is being examined for inclusion in the U.S. National Electrical Code.

Now, to underscore Dow Corning's personal assurance in the safety, the efficacy, and the efficiency of this liquid, Dow Corning has notified its vendors that we will be specifying silicone-filled transformers for all the new transformers in our production plants around the world. Our existing askarel transformers, in which we have a very heavy investment, are being phased out rapidly through a silicone retrofit program. Over 6 transformers have been installed new or retrofitted in the past year, and this program will accelerate in the spring. It is, of course, not possible in Michigan during the winter months to drain the PCB's satisfactorily and replace these materials with a silicone fluid.

The material that we are talking about is known today as Q2-1090 dielectric liquid. Basically, Q2-1090 transformer liquid is a dimethyl silicone that has been specially formulated and qualified for use in electrical applications. The technical feasibility of using the silicone in transformers has been shown in over 20 years of experience in military transformers, in several years of use on the Japanese National Railway, and in a number of power transformers in the Midland, Michigan, area; several other areas around the United States will also test silicone transformers in the next few months.

In addition to these actual applications, which today are well known and have worked out nicely, support for the use of a silicone dielectric fluid in power transformers is contained in over 30 years of accumulated data on dielectric properties and compatibility with the common materials of transformer construction.

The present concern for fire, explosion, health, and environmental hazards are all strong reasons for an evolutionary approach to using silicones and qualifying them in this application for all major power transformer uses over the next few years.

The silicone liquids of this type are much less

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flammable than typical mineral oils. They actually have a higher flash point than many PCB-containing transformer fluids. Although they will burn, they have an extremely low heat of combustion, extremely high flash-points and firepoints, and they have been shown in catastrophic testing to be self-extinguishing. They appear to offer a level of fire safety greatly superior to mineral oils.

The silicone that we are now recommending, a dimethyl silicone, has been evaluated by Underwriters Laboratory, and has received an extremely low flammability classification number. In Japan and the United States, transformer cases containing PCB's, silicones, and mineral oil were subjected to catastrophic failure testing. In both tests, all liquids exploded. Most important, following this test, only the mineral oil continued to burn. Both the polychlorinated biphenyl materials and the silicone fluid self-extinguished. Normally, in a test of this type you would fuse the circuit cutout. The fault in the silicone fluid self-cleared, thereby extinguishing the arc. With the other materials, the backup fuse blew and extinguished the arc.

Following the review of some very extensive data (which is available to all of you by writing to me at Dow Corning, provided you are willing to put in 4 or 5 hours in reading it), the major insurance companies have given their permission to use silicone fluid in indoor transformers. Because it is a new material and since no general policy has been established, the insurers have indicated that they will evaluate each application on an individual basis; this is a conservative approach which we highly applaud.

Dow Corning feels that we should look at a 3- to 5-year evolutionary approach of gradually putting a larger and larger number of transformers into operation. We are offering financial inducements to companies who do this in order to collect a large body of case history data that can be used to convince ourselves and the industry that there are no fatal flaws that have been overlooked. It's an extremely conservative approach.

Silicones are often used in small concentrations in the preparation of certain foods. Any time you eat a jam or jelly or drink a glass of some of that good old Milwaukee beer, you are eating a food-grade dimethyl silicone. And if you have an ulcer and you eat Di-Gel, you are also eating it. They are excellent deflaccuants.

The toxicity of dimethyl silicones to mammals, aquatic life, and plants has been very thoroughly investigated. The extremely low toxicity of silicones has made it difficult to detect any toxic reactions in test subjects. Studies directed toward determining the tendency of silicone to bioconcentrate have been negative. It has not been possible to date to show that any bioaccumulation

was occurring.

It has been often stated that silicones are persistent in the environment because they do not biodegrade, under the evidence available at the present time. However, there is considerable evidence that silicones do chemically degrade in the environment. Contact with soil and water causes the liquid to depolymerize to low-molecular-weight species, and known chemistry definitely suggests that these degrade in water or in the atmosphere.

Silicones cost more money than the current liquids being used in transformers, but they are not outrageously expensive. Referring to the entire market of capacitors and transformers, and making some assumptions which would include the shipment of present products such as PCB's to the manufacturer's site, if we include the shipping costs, my estimate is that the industry PCB purchases would be about \$19.2 million.

If good engineering practices are followed to reduce the amount of fluid needed, which has never been a design criteria in the major manufacturer's mind, as mineral oil, of course, is cheap, those costs would probably rise with the use of silicone to an industry figure of \$25 million.

So the total increased cost to the electrical and electronics market would be about \$5.8 million or 29 percent. If we made the assumption that the dielectric fluids cost is 20 percent of the total material cost going into a transformer or capacitor, we are talking about an average cost increase of about 5.8 to 6 percent at the manufacturing level on new equipment.

I feel that this slightly higher initial cost of silicone liquid-filled transformers is more than offset by the cost of monitoring and controlling of PCB-filled transformers over their lifetimes. And with silicone, no known environmental hazards are incurred.

PCB-filled transformers currently in service can be changed over to Q2-1090 transformer liquid without undue problems. I think the work we have done over the past 4 years—some of it in conjunction with Dow Chemical, a lot of it in conjunction with leading transformer manufacturers—shows this.

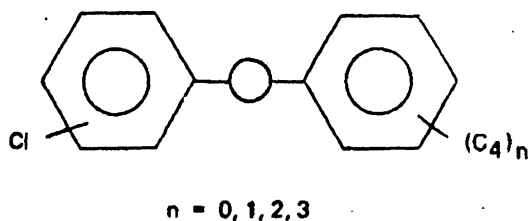
I think you will be hearing not only from Dow Corning in more detail on this subject. I highly suspect that our worthy competitors, who can manufacture dimethyl silicones to the same specifications once they learn what they are, will go into the market. At that particular time, the law of supply and demand will come into effect. The silicone industry at the present time has more capacity than it can sell. I anticipate the economics will be extremely favorable for further consideration of this product in both transformers and capacitors over the next three years.

DOW XFS-4169L: AN ENVIRONMENTALLY ACCEPTABLE CAPACITOR FLUID

Dean Branson, Ph.D.*

Abstract

Dow and McGraw-Edison Companies have developed a new capacitor fluid which is electrically, ecologically, and economically acceptable. Chemically, the new fluid can be described as butylated monochlorodiphenyl oxide.



Dow XFS-4169L capacitor fluid

Dow XFS-4169L capacitor fluid performs equal to or better than Aroclor 1016 in power capacitors. This conclusion is based on dielectric losses, discharge inception voltages, capacitor size, fire hazard, reliability, economics, and availability. Dow XFS-4169L capacitor fluid and its components are acceptable in terms of health and environment according to an assessment of biodegradability, bioconcentration in fish, toxicity to animals, and toxicity to fish. Other capacitor manufacturers are currently evaluating XFS-4169L for applicability in their respective companies. Field trials have been started with utility companies across the country.

The contents of this presentation represent 4 years of joint research between Dow and McGraw-Edison Company which has culminated in the development of an environmentally and electrically acceptable capacitor fluid.

When PCB's replaced mineral oils some 40 years ago in power capacitors, this represented another step forward in the electrical industry's continuing effort to provide the public with low-cost electrical power and safer electrical equipment. As a result of the use of PCB's, there has been a downward trend in the cost per kilovar

of power factor correction.

In 1971, Monsanto limited the sale of PCB's for dielectric uses where acceptable alternatives were not yet available. Since then, industry has been searching for alternatives which were ecologically, electrically, and economically acceptable.

Today, we want to report to you that Dow and McGraw-Edison have developed a butylated monochlorodiphenyl oxide known as XFS 4169L. It meets all the above criteria and can be used in high-voltage capacitors.

Initially, over 50 fluids representing several chemical families were selected as possible dielectric fluids on the basis of their chemical and physical properties. These fluids were then screened for both electrical performance in miniature capacitors and for potential hazard to the health and the environment in a battery of indicative tests.

The conclusion of these screenings was that the most promising chemical family was the alkylated monochlorodiphenyl oxides.

Electrically, several members of this family performed equal to or better than Aroclor 1016. It was the health and environmental data that demonstrated the significant advantages of the butylated monochlorodiphenyl oxides.

Electrical Performance

The confidence that McGraw-Edison Company has in high-voltage capacitors made with the XFS fluid is based on the following assessment of these six key electrical performances.

1. *Dielectrical losses.* The dielectric losses are as low or slightly lower than for capacitors with a PCB known as Aroclor 1016. This is true for both paper-film and all-film high-voltage power capacitors. This means that the capacitors will operate under normal temperatures and that the operating costs will be minimal. This is one of the same significant advantages that PCB's have relative to mineral oil.
2. *Discharge inception voltages.* Discharge inception voltage is significantly higher than for Aroclor 1016 in both paper-film and all-film capacitors. This means that operating voltages may surge at least 20 to 30 percent higher without resulting in temporary malfunction due to electrical discharges known as corona.
3. *System size.* The size or volume per unit of high-voltage power capacitor correction known as kilovar is

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the same as for comparative capacitors impregnated with Aroclor 1016. This means that it will not be necessary to redesign capacitors, the capacitor manufacturing, or the application of capacitors.

4. *Fire hazards.* As indicated with PCB's, there is a low risk of explosion and fires from power capacitors impregnated with XFS 4169L. A major problem associated with a failure in a paper-film power capacitor is the decomposition of the paper and, to a lesser degree, the film. The resulting pressure of the gases formed is a major cause of tank rupture. After failure, the flammability of the fluid may contribute to a fire only if the paper, the film, and the fluid, are above the ignition or flash temperatures.

Under normal operating conditions, a capacitor will operate between 40° and 80° C. At a time of failure, this temperature will have to exceed the flashpoint of the capacitor fluid before this fluid becomes contributive to the explosiveness or the flammability of the system. In this regard, the flash temperature for the existing dielectric fluids for mineral oil is 154° C; for Aroclor 1016, 166° C; and for XFS 4169L, 174° C. The fire temperature for mineral oil, 167 PCB, is greater than 316° C; for XFL 4169L, it is 199° C. This clearly shows that the flash and fire points are substantially above the operating temperatures.

The National Electric Code allows the installation of the electrical devices without a vault if they contain less than 3 gallons of burnable liquid. The most common size of our capacitor used today is a 200-kilovar unit. These units contain less than 3 gallons of fluid, and are installed predominantly outdoors.

5. *Capacitor reliability.* Power capacitors impregnated with XFS are more reliable than the same type of capacitors impregnated with Aroclor 1016. This conclusion is based on results of comparative evaluations. The following tests have been completed. Three years of accelerated life tests, more than 18 million kilovar hours in full-sized units without failures. Hundreds of sample capacitors operating up to 200 percent of the rated voltages for a wide range of temperatures, minus 60° to plus 125° C.

6. *Economics and availability.* The long-range price of power capacitors impregnated with XFS 4169L will be reasonable. The increased price or expense attributed to the fluid is expected to be less than \$20 for a 200-kilovar unit.

Dow has assured the electrical industry that it will have the manufacturing capabilities to produce XFS at a million pounds per year rate during the first quarter of 1976. Should this fluid prove to be acceptable to the industry, Dow is willing to make the commitment to

produce the fluid in multimillion pound quantities per year by the end of 1976.

Health and Environmental Assessment

The Dow Chemical Company's assessment of the health and environmental acceptability of XFS 4169L as a dielectric fluid in capacitors is based on the following criteria.

1. *Biodegradability.* The components in XFS 4169L are significantly more biodegradable than the components of Aroclor 1016. With micro-organisms, the rates of formation of radioactive carbon dioxide from radio-labeled components of XFS 4169L are much faster than for 2,5,2' trichloro biphenyl, a major component of Aroclor 1016. The major component in 4169L is 45 times more biodegradable than the representative PCB isomer. This rate of biodegradability is comparable to several nonpersistent industrial chemicals.

2. *Bioconcentration.* The bioconcentration factors in fish of the components of XFS 4169L are low relative to the components of Aroclor 1016. The environmentally significant components in each fluid show a factor 30 times less bioconcentratable in trout muscle for XFS.

3. *Toxicity to animals.* In both acute and 90-day toxicity tests with animals, XFS shows very little toxicity. For example, in rats, a dose of 10 grams per kilogram of XFS 4169L was administered orally and had no observable effect on rats.

The levels of the components of XFS that accumulated in the fat of rats fed the XFS in the diet for 150 days were significantly lower than for the comparable dietary tests with Aroclor 1016. For example, the accumulation in the fat was 22 times less for XFS; the apparent plateau level was achieved in 1 to 2 months compared to 6 to 7 months for the PCB, and the estimated half-life of the rat was 7 days with XFS compared to 60 days for the PCB. This indicates the relatively low degree of toxicity associated with XFS 4169L in animals.

4. *Toxicities to fish.* The XFS material is only moderately toxic to fish compared to capacitor-grade PCB, which is extremely toxic. The concentration of XFS that was toxic to fathead minnows was 15 milligrams per liter compared to 0.76 milligrams per liter of Aroclor 1016, which is a factor of 20 times less toxic to the fathead minnow.

Dow and McGraw-Edison Companies have determined that XFS 4169L is an acceptable alternative to capacitor-grade PCB in high-voltage power capacitors. This is based on the electrical performance and its low potential impact on health and the environment.

Today, McGraw-Edison is proceeding with field trials of capacitors at utility companies across the

country. Other U.S. manufacturers of power capacitors are currently evaluating XFS for applicability in their respective companies.

The information about XFS in this discussion is only a very brief summary of the toxicological and ecological data which have been generated.

CHLORINATED BIPHENYL DIELECTRICS— THEIR UTILITY AND POTENTIAL SUBSTITUTES

David Wood*

Abstract

The paper describes the major reasons for the use of chlorinated biphenyl in capacitors and transformers. These lead to establishment of objectives for research into potential substitutes. MCS-1238, a non-PCB capacitor fluid developed by Monsanto, is discussed and areas where further development work is required are indicated. The particular problems associated with definition of "fire resistance" relative to transformer fluids is raised.

I. INTRODUCTION

In 1970, Monsanto voluntarily began its program of terminating sales of chlorinated biphenyls to open applications—those which could result in losses to the environment. By late 1972, this program was fully implemented and Monsanto was selling these products only to manufacturers of sealed electric equipment such as transformers and capacitors.

Major applications affected by our withdrawal were carbonless paper, fire-resistant hydraulic fluids, heat transfer fluids, and plasticizers. Sales for other miscellaneous minor applications were discontinued during the same period. This action resulted in a reduction of some 45 million pounds per year in the use of chlorinated biphenyl in areas where entry to the environment was less controllable.

We decided at that time to continue supply to closed electrical applications because we believed that:

1. Entry of chlorinated biphenyl to the environment was limited and controllable;
2. A more biodegradable, lower chlorinated homolog had been developed which the capacitor industry could use;
3. Withdrawal would have brought to a halt production of equipment essential to the safe and efficient distribution and use of electrical energy because there was no known satisfactory replacement for chlorinated biphenyl dielectrics.

Today we continue to sell chlorinated biphenyl, observing the following policy:

1. We supply only to manufacturers of *sealed* electrical equipment such as capacitors and transformers.
2. We supply lower chlorinated homologs, Aroclor 1016, to the capacitor industry.

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3. We offer an incineration service for liquid PCB wastes.
4. We continue to work with ANSI Committee C107 and other bodies to establish appropriate handling and control procedures for equipment containing chlorinated biphenyl.
5. We allocated increased research resources in 1969 to seek and develop effective replacements; this program continues.
6. In seeking possible replacements, we will insure that differences between Aroclor and candidate fluids from our program are widely reviewed in order that the potential impact of any compromises is fully evaluated.

The implementation of these and other programs both by ourselves and electrical equipment manufacturers was prompted by the utility of this dielectric family and the difficulties inherent in developing substitutes to effectively and fully replace it.

II. UTILITY OF CHLORINATED BIPHENYL IN CAPACITORS

1. Fire Resistance

The adoption of chlorinated biphenyls in 1929 as capacitor dielectrics stemmed from their superior dielectric properties compared to mineral oil. However, recognition of the fire-resistant character of the fluids influenced system and equipment design and standards over the subsequent 45 years. It is probably true that today many people find it difficult to assess potential capacitor fire hazard purely because Aroclor has been used for 45 years.

Particular examples where fire resistance in a capacitor is of benefit include:

- a. fluorescent lighting ballasts,
- b. air-conditioner motor capacitors,
- c. television capacitors,
- d. large power capacitors where high fault currents can cause rupture and ejection of fluid from pole-mounted units close to people and buildings,
- e. industrial furnace capacitors.

2. Stability

The persistence of chlorinated biphenyl in the environment is associated with the high degree of thermal, chemical, oxidative, and hydrolytic stability which permits capacitor manufacturers to fulfill the exacting reliability requirements that exist today.

3. *Dielectric Constant/Dielectric Strengths*

These properties are important in determining the size of a capacitor. In a mixed dielectric system, e.g., paper/Aroclor or paper/polypropylene/Aroclor, the dielectric properties of Aroclor permit optimization of stress distribution between the components making up the dielectric layer. This has enabled capacitor manufacturers to reduce paper and film volumes for a given capacitance. I shall discuss under the heading of "potential substitutes" the impact that this could have on:

- a. paper/film availability and usage;
- b. design of equipment containing capacitors.

III. UTILITY IN TRANSFORMERS

Chlorinated biphenyl transformers represent less than 15 percent of transformers in service. Their use is associated with the need to limit fire hazard in installations.

1. *Railroad Transformers*

Multiple unit cars as used in rapid transit systems have transformers mounted beneath each car. By nature of the type of service, involving high passenger density, safety is essential.

2. *Urban Power Substations (e.g., Underground Vaults)*

These designs need to take into account city center space limitations and also the safety of the public and maintenance crews. Fire-resistant liquid transformers are helpful to all these objectives.

3. *Industrial Load Centers*

Efficient system designs for large, power intensive, manufacturing plants (e.g., automotive assembly, steel production) often incorporate transformers close to the electrical load centers. The use of Aroclor transformers at these centers, in the heart of the plants, or overhead in roof structures, protects both employees and plant.

4. *Transformer/Rectifiers*

Programs to reduce the emission of particulate matter from stack gases, for example in fossil fuel generating plants, include installation of electrostatic precipitators. The transformer/rectifiers energizing the precipitator field must be located close to the electrodes. In many designs, the multiple transformers are located in a penthouse above the precipitator. A fire in the penthouse could lead to shutdown of the precipitator, and thus the generating plant, if pollution control is to be

maintained. A fire-resistant fluid is of obvious benefit in this application.

In each of these applications, Aroclor protects the system from:

- a. initiation of a transformer fluid fire by an electrical fault beneath the liquid level,
- b. electrical breakdown of the fluid causing emission of flammable gases,
- c. propagation of fire if the transformer liquid content is involved in an external fire.

IV. POTENTIAL SUBSTITUTES IN CAPACITORS

1. *Research Objectives*

In seeking potential substitutes, our research objectives of necessity involved keeping those properties that gave Aroclor its value. We equally recognized the need that an Aroclor replacement should eliminate environmental concerns. A replacement should ideally operate across the full range of current Aroclor capacitor applications while requiring minimum changes in design of capacitors and equipment utilizing capacitors.

The use of chlorinated biphenyl is worldwide. Monsanto manufactures chlorinated biphenyls both in America and Great Britain. We supply to the capacitor industry of many countries. We sought potential replacement products that could be made available with the consistent quality control applied to Aroclor on a worldwide basis.

We referred earlier to availability of codielectric components in capacitors. A solution requiring substantial changes in availability of polypropylene film (quantity or quality) or a major increase in short-term availability of capacitor paper, we considered unsatisfactory. If in 1974 such increased quantities had been required, they would not have been available. Capacitor production would have fallen short of demand, further jeopardizing efficient power supply.

Our research objectives can be broadly summarized in table 1.

2. *Non-PCB Candidates*

The capacitor industry is currently examining two Monsanto non-PCB (candidate) dielectrics. These contain no chlorinated biphenyl and are not chlorinated products. The two fluids are designated MCS 1238 and MCS 1588. Both of these products are blends of synthetic hydrocarbons with a high dielectric constant additive to give a dielectric constant equivalent to Aroclor 1016. Table 2 lists some of the properties of MCS 1238 and MCS 1588 compared to Aroclor 1016.

Table 1. Research objectives in seeking potential substitutes for capacitors

1. Match or exceed Aroclor 1016 capability:
 - a. Dielectric constant - Usage of other components
Dielectric strength - Convertability
 - b. Stability - Reliability
Power factor
 - c. Fire resistance - Safety
2. Good environmental compatibility:
3.
 - a. Span existing applications - Complete solution.
 - b. Internationally available - Not solely U.S.A. situation.

Table 2. Some properties of MCS 1238 and MCS 1588 compared to Aroclor 1016

Property	Aroclor 1016	MCS 1238	MCS 1588
DK 25° C	5.9	6.0	6.1
100° C	4.85	5.1	5.1
Corona IV/EV ^a	-	-	-
Hydrolysis stability ^a (neutralization number)	0.00	0.00	0.00
Dissipation factor fluid tan δ 60 Hz. 100° C	0.0025	0.05	0.05
Dissipation factor model paper capacitor at 90° C	0.0032	0.0039	0.0035

^aSee text explanation, section IV 2.

Corona inception and extinction voltages are more a function of capacitor design than of the liquid itself. Preliminary industry results demonstrate functioning in capacitors equivalent to Aroclor 1016. Further full-scale work is required before final conclusions can be drawn.

Dielectric constants relate closely to those of Aroclor 1016 over the temperature range of capacitor operation. Hydrolysis stability is mentioned because of work carried out on earlier candidates based on esters, which gave concern because of hydrolysis instability. Hydrolysis was assessed by measuring the neutralization number of a sample with 0.5 percent water added, which had been heated for 168 hours at 210° F in a stainless steel bomb along with an aluminum and a mild steel coupon.

3. Fire Resistance

Neither MCS 1238 or 1588 is fire resistant. This deficiency versus Aroclor 1016 must be closely considered.

4. Environmental Considerations

The environmental/health evaluation of capacitor replacement fluids must be related to:

- a. Degradation—If some quantity enters the environment, at what rate and through which mechanism will it degrade?
- b. Tissue accumulation
- c. Toxicity—Occupational safety
Environmental compatibility

5. Degradation

Biodegradation has been studied using a semi-continuous activated sludge technique. Forty-eight-hour exposure of Aroclor 1254, Aroclor 1016, and MCS 1238 dielectric fluids to activated sludge using a semicontinu-

ous procedure resulted in the percent biodegradation rates and 95 percent confidence limits shown in table 3.

For the polychlorinated biphenyl (PCB) materials, the level of chlorination appears to be the most significant factor in their relative biodegradability. The rate of biodegradation decreases as the number of chlorine atoms per biphenyl molecule increases. Chromatograms representing samples after exposure to activated sludge show significant alteration in the Aroclor 1016 isomer distribution, but little for Aroclor 1254. Degradation of the nonhalogenated fluid, MCS 1238, proceeds much more rapidly than for the halogenated PCB fluids with no evidence of resistant components. The methodology for this technique is described in appendix B.

6. Tissue Accumulation

Figure 1 depicts the results of rat tissue residue level studies vs. time and compares Aroclor 1242, Aroclor 1016, and MCS 1238. A fraction of the ingested Aroclor 1242 and Aroclor 1016 was stored in rats' lipid reservoirs. However, most of this residue was depleted after the rats had been on the basal laboratory diet for several weeks. During the course of the feeding study, residues of Aroclor 1016 accumulated more slowly and to a significantly lesser extent than those of Aroclor 1242. During the recovery period, these PCB residues decreased to lower values for Aroclor 1016.

The residue concentrations of MCS 1238 quickly reached a stable level well below the concentration in the feed. The residues did not increase with continued exposure. After feeding of the treated chow was ceased, the MCS 1238 residues were rapidly metabolized and/or excreted. The tissue residue accumulation and depuration profile of MCS 1238 shown in figure 1 is markedly different than those of the Aroclor fluids, especially that of Aroclor 1242. Methodology is given in appendix A.

Table 3. Results of biodegradation using a semicontinuous activated sludge technique

Material	48-Hour percent biodegradation	Feed concentration, ppm
Aroclor 1254	15 ± 38	1
Aroclor 1016	33 ± 14	1
MCS 1238	70 ± 10	3

25 PPM FEED LEVEL FOR RATS

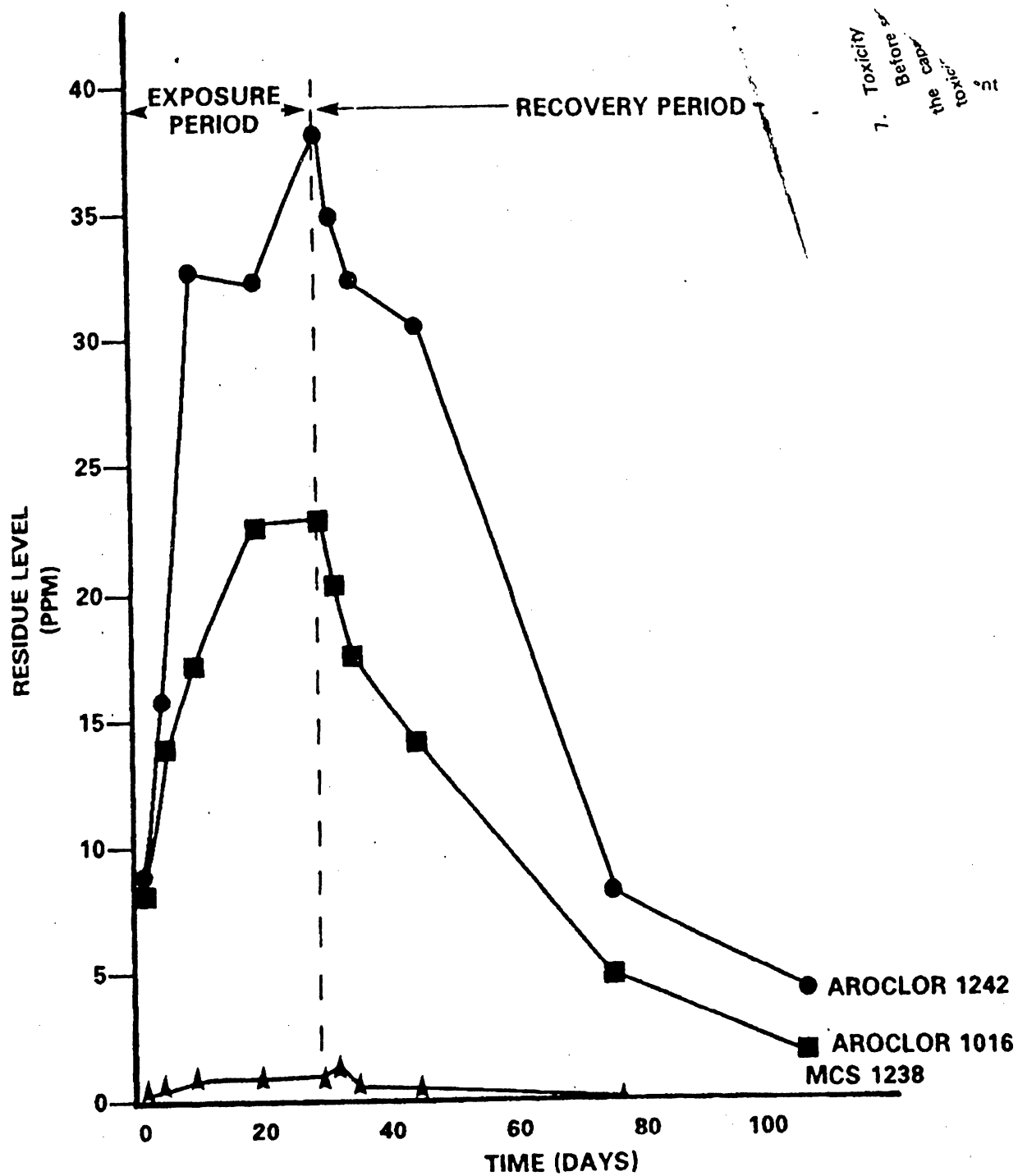


Figure 1. Results of rat tissue residue level studies vs. time, comparing Aroclor 1242, Aroclor 1016 and MCS 1238.

7. Toxicity

Before samples of MCS 1238 could be evaluated in the capacitor industry and within Monsanto, acute toxicity data was gathered:

- a. Rat—Acute single oral dose LD_{50} : 3,800 mg/kg.
- b. Rabbit—Dermal LD_{50} : 5,000-8,000 mg/kg.
- c. Rabbit—Potential eye irritation: A slight degree of irritation resulted when 0.1 ml of undiluted MCS 1238 was placed in the conjunctival sac of the rabbit eye. The average maximum score recorded at one and again at 24 hours after treatment was 12.0 on a scale of 110.0. All eyes had regained normal appearance 72 hours after dosing.
- d. Rabbit—Potential skin irritation: When undiluted, MCS 1238 was held in continuous 24-hour contact with intact rabbit skin, a moderate degree of irritation resulted. The maximum average score was 3.6 on a scale of 8.0.

Further programs are in process, or scheduled, to study the following:

- a. vapor inhalation,
- b. ultimate degradation,
- c. 90-day pilot feeding study,
- d. long-term (2-year) feeding studies, and
- e. fish tissue residues.

8. Conclusions

To summarize Monsanto research activities:

- A large number of single compounds and mixtures have been evaluated in terms of physical property data, environmental compatibility, fire resistance, and model capacitor life testing.
- These have led us to conclude that:
 - a. Aroclor 1016 may well be sufficiently degradable to remain in controlled use,
 - b. MCS 1238 is a potentially acceptable replacement with the qualification that it is not fire resistant.
- Further programs must be completed with MCS 1238 in order to:
 - a. deepen our knowledge of its environmental compatibility,

- b. permit complete evaluation by the capacitor industry across their range of applications,
- c. enable utilities, capacitor users, and agencies to evaluate the significance of decreased fire resistance.

As a closing thought to this section, I would like to comment that since 1929 when Aroclor was first developed as a capacitor dielectric, normal commercial pressures have spurred efforts to find superior replacements. The awareness of environmental accumulation of chlorinated biphenyls from other applications added further impetus for more intensive research in the chemical and electrical industries. Aroclor has defied 45 years of search for a superior replacement.

V. SUBSTITUTE TRANSFORMER FLUIDS

Neither Monsanto nor any other company, to our knowledge, has developed a transformer dielectric with equivalent fire resistance to that of Aroclor. The difficulties that we face in common with other workers in this field are twofold:

1. Aroclor has become the reference standard for fire resistance in transformers because it works and has worked for 45 years. To establish standards to guide research effort, there is a need for objective evaluation of the fire hazard associated with the major sectors of transformer use.

2. The chemistry which imparts fire resistance tends also to produce stable molecules. Monsanto seeks replacement products that will provide protection against:

- a. fire from transformer faults under the liquid surface,
- b. fire from secondary ignition of gaseous arc decomposition products,
- c. fire propagation if the transformer is involved in an externally initiated conflagration.

We strive to accomplish this and produce an environmentally compatible product. We have four candidates which are currently being evaluated by the transformer industry. These materials are in a sufficiently early stage of development that it would be premature to give detailed property data at this meeting.

APPENDIX A

METHODOLOGY FOR FEEDING STUDY

Feeding and Sampling

Rat chow containing 25 ppm Aroclor 1242, Aroclor 1016, or MCB 1238 was prepared by mixing the products into Ralston Purina rat chow. The treated chow was fed ad libitum to adult albino rats for an exposure period of 30 days. Following the 30-day exposure period, all remaining rats were placed on the basal laboratory diet. At predetermined intervals during the exposure and recovery periods, five rats from each exposed set and a control set were sacrificed. Fat tissue was excised for analysis and composited for each group. Samples were quick-frozen and stored in glass containers with aluminum foil-lined caps to minimize risk of contamination.

Isolation

The dielectric fluid residues were isolated from the fat by solvent extraction. A weighed amount of fat was placed in an Erlenmeyer flask and homogenized three times with 25 ml of pesticide-grade hexanes and anhydrous sodium sulfate using an ultrasonic homogenizer. The combined supernatants and washings were filtered through anhydrous sodium sulfate and diluted to 100 ml with hexane.

Lipid Weight Determination

A 5 ml-aliquot of the extract solution was pipetted into a tared 50-ml beaker. After evaporation of the solvent under a stream of nitrogen, the beaker and residue were reweighed to obtain the lipid weight of the aliquot. All residue levels are reported as ppm on a lipid weight basis.

PCB Cleanup And Measurement

Sample cleanup for the extracts containing Aroclor 1242 and Aroclor 1016 residues was accomplished by

pipetting an aliquot of the extract onto a 5 percent deactivated alumina column and eluting with 125 ml of hexanes. The column eluate was collected in a Kuderna-Danish evaporative concentrator, a 3-ball Snyder condenser was attached, and the solution was concentrated to 5 ml. The residue levels in the extracts were measured by gas chromatography using an electron capture detector.

Non-PCB Cleanup And Measurement

Sample cleanup for the extracts containing MCS 1238 residues required separation of the residues from the lipid by preparative scale gel permeation chromatography. Following the GPC separation, the extracts were further cleaned up on an alumina column, collected, and concentrated as above. The residue levels in these extracts were measured by gas chromatography using a flame ionization detector.

Calculations

Calibration curves for each product were prepared by plotting detector response (total peak area) versus nanograms of standard injected. Residue levels in the samples were determined by summation of the total area of peaks corresponding to peaks in the standard and use of the appropriate calibration curve. The calculations were done as follows:

$$\text{Residue (ppm)} = \frac{(N)(V_F)}{(V_I)(W)}$$

where N = Amount of product from calibration curve (ng),

V_F = Volume of final concentrate (ml),

V_I = Volume injected (ul),

W = Lipid weight of original sample (g).

APPENDIX B

TECHNIQUE FOR BIODEGRADATION METHOD

Biodegradation Method

Since activated sludge is one of the most important agents for sewage treatment, test procedures evaluating its action are of great importance.

The semicontinuous activated sludge (SCAS) method has been extensively utilized in the development of biodegradable detergents. In our SCAS procedure, patterned after the Soap and Detergents Association's

standard method (1,2) mixed liquor (activated sludge and supernatant) from a local domestic sewage treatment plant is charged to magnetically stirred glass vessels of 1.5-l capacity. Means for aeration and sampling are provided. The SCAS unit is generally operated using a retention or aeration time cycle of 24 to 72 hours. At the beginning of each cycle, synthetic sewage (300 mg glucose, 200 mg nutrient broth, and 130 mg K_2HPO_4) and the appropriate test material in ethanol solution are added to the mixed liquor (2,500 mg/l suspended solids concentration). Aeration is maintained until the end of the cycle, at which time the sludge is settled and 1 l of supernatant drained. The cycle is then reinitiated by the addition of tap water, synthetic sewage, and test material. Operation of the units can be continued for an indefinite period of time until consistent degradation rates are observed.

Sample Analysis

Biodegradation of the test material was determined during one cycle each week by analyzing 20 to 50 ml mixed liquor samples withdrawn after feeding and at the

end of the aeration cycle. The mixed liquor analytical procedure involved extraction with three successive 25-ml portions of hexane, and drying combined extracts with anhydrous sodium sulfate. Extracts were concentrated in a Kuderna-Danish evaporative concentrator equipped with a 3-ball Snyder condenser, and measured by electron capture or flame ionization gas chromatography. Calibration curves for each product were prepared by plotting detector response (total peak area) versus nanograms of standard injected.

The percent biodegradation was calculated from the following equation:

$$\text{percent biodegradation} = (C_o - C_n)/C_o \times 100$$

where C_o and C_n use the initial and final concentration of test material, respectively, on the mixed liquor.

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SOME COMMENTS ON ALTERNATIVES TO PCB's

Bruno Rey Coquais*

Abstract

In the transformer industry, the benefit of a non-flammable liquid seems to exceed the risks of pollution by polychlorinated biphenyls; however, to minimize eventual contamination of the environment, it is suggested to use, when possible, a mixture of chlorobenzene and trichlorobiphenyl or even chlorobenzene alone.

For the impregnation of capacitors, most of the substitutes which can be imagined are not very attractive, though they are useful for certain applications. It is proposed to use a mixture of pure dichlorobiphenyls and their alkylated derivatives. This impregnant, named chloralkylene, has dielectric properties very similar to the industrial trichlorobiphenyl.

The tests in progress already show that chloralkylene is easily biodegradable and has a low toxicity. This compound seems to be quite acceptable for the environment and should be a perfect substitute for polychlorinated biphenyls in capacitors.

To begin with, I would insist on the fact that heavy chlorinated biphenyls have been used for a long time in dispersive applications as plasticizers and for other uses. Although these types of applications have been stopped in accordance with the OECD recommendations of the February 14, 1973, it is not surprising to continue to find these persistent, highly chlorinated PCB's everywhere in the environment. It is therefore very difficult to know if the electrical uses of PCB's for transformers and for capacitors have a significant contribution to the pollution of our environment.

TRANSFORMERS

PCB's are used in transformers only when the fire hazard is high (department stores, theatres, movies, skyscrapers, factories); otherwise oilfilled transformers, which are cheaper, are always preferred. We do not think dry-type transformers would be a competitive alternative in spite of the fact that silicone and epoxy belong to the range of products we market. They may be very attractive in some cases, but in addition to certain economical and technical disadvantages, dry transformers do not offer a perfectly safe solution wherever flammable vapors (solvents, oil, gas) may be present accidentally.

We believe a nonflammable dielectric liquid is abso-

lutely necessary to prevent the risk of fire in transformers. In table 1 we have listed the different possible solutions. In the United States, at this time, transformers are filled with Inerteen 70-30, which is based on pentachlorobiphenyl, or with Inerteen 100-42. To minimize the pollution risk, a mixture of trichlorobiphenyl and chlorobenzene or even the chlorobenzene alone could be used in spite of some technological problems.

In any case, the systematic recovery of used PCB's will further limit pollution hazards; our company Prodelec has organized this practice throughout France since 1968, as soon as this pollution problem became known. This systematic recovery has now been enforced in France by the French law of July 8, 1975, on PCB's.

CAPACITORS

For capacitor impregnation, we have examined various possible solutions. We think that the performances of such compounds as silicone; sulfone or synthetic oil (alkylbenzene, polybutene); phthalate; and sebacate—which we are indeed selling ourselves for certain applications—are not really satisfactory enough for generalized or widespread use.

In our opinion, a substitute to PCB's should be characterized by:

- High permittivity;
- Nonflammability, at least not sustaining combustion;
- Compatibility with polypropylene film;
- Being a permanent liquid with no crystallization until -25°;
- Good thermal and electric subfield stability;
- Regarding its effect on the environment, being fairly easily biodegradable, to eliminate the risk of accumulation, and by having low toxicity.

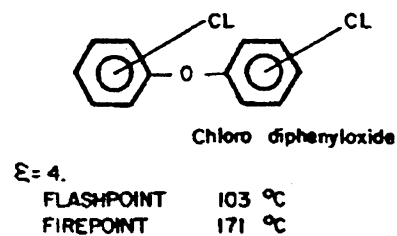
To get a good and nonflammable dielectric fluid means in practice that the compound must be a chlorinated aromatic hydrocarbon. We have studied, for instance, new structures, as shown in figure 1. With chlorobiphenyl oxide, we are afraid of the risk of metabolism in highly toxic dioxins and we feel that products of the family of the chlorobiphenylethane are technically and environmentally much more promising. Actually, introducing a totally new compound would require a long and expensive testing program and it seems better to take advantage of the huge amount of knowledge gathered about PCB's and to see how it may be possible to improve the present situation.

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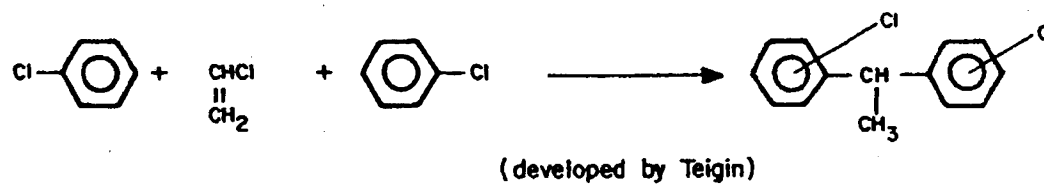
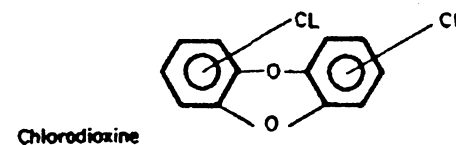
Table 1. Possible solutions for dielectric liquid

IEC type	Chloro-biphenyl	Chloro-benzene	Pour Point (°C)	Viscosity Cst at 20° C	ϵ at 20° C	Hydrogen index ^a	Askarels for transformer
T ₁	60% hexa	40% tri	<-33	21	4.5	<0 excess Cl	Pyralene T ₁ Pyrochlor
T ₂	45% hexa	55% tri and tetra	<-40	11	5	<0 excess Cl	
T ₄	70% penta	30% tri	<-30	20	5	0	Inerteen 70-30 Pyralene T ₄
	45% penta	55% tri and tetra	<-40	10		<0 excess Cl	Pyralene T ₂
T ₃	100% tri		<-18	65	6	16	Pyralene T ₃ Inerteen 100-42
	60% tri	40% tri	<-50	7	6	10	Pyralene 1460
	40% tri	60% tri and tetra	<-20			4	
		100% tri and tetra	Chrys-tallize -9		6	<0 excess Cl	

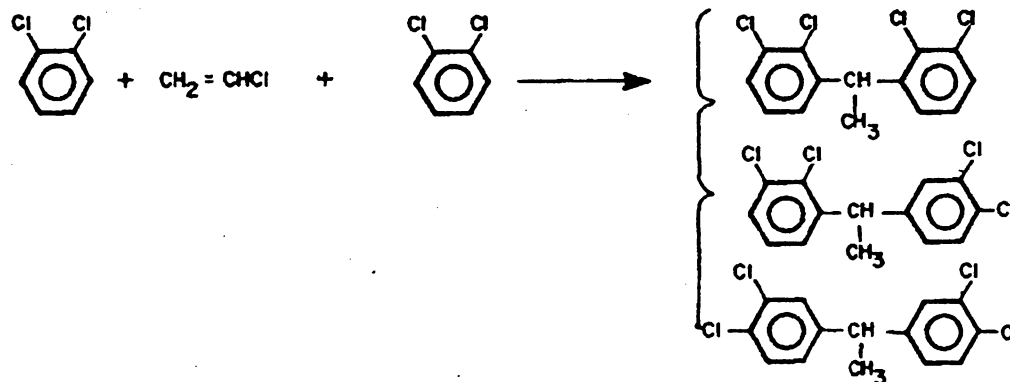
$$^a \text{Hydrogen index} = \frac{\text{No. hydrogen} - \text{No. chlorine}}{\text{Molecular weight}}$$



Metabolism →



$\epsilon = 5.6$
 FLASHPOINT 180 °C
 FIREPOINT 250 °C



$\epsilon = 8.3$
 FLASHPOINT 210 °C
 FIREPOINT NONE

Figure 1. New structures for nonflammable dielectric fluids.

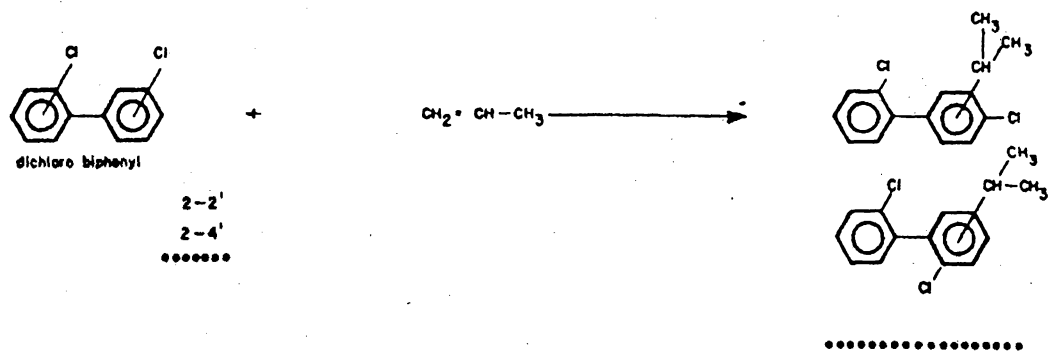


Figure 2. Structure of chloralkylene.

Table 2. Composition of various impregnants

Composition, percent	Chloralkylene 12	Pyralene 3010 (trichloro- biphenyl)	Pyralene 1500	Pyralene 2000
Biphenyl	0	0	0	1.6
Monochlorobiphenyl	0	0	0.5	18.4
Dichlorobiphenyl	20	11.4	37.5	44.0
Trichlorobiphenyl	0	57.1	40.0	23.4
Tetrachlorobiphenyl	0	29.4	20.5	11.7
Pentachlorobiphenyl	0	2.2	1.5	0.9
Alkylchlorobiphenyl isomers	80	-	-	-
Chlorine content, percent	25.8	42.	38.5	33.5

Table 3. Comparison of chloralkylene to commercial trichlorobiphenyls

Characteristics	Chloralkylene 12	Pyralene 3010 (trichlorodiphenyl)
Specific gravity at 20° C	1.163	1.391
100° C	1.097	1.319
Coefficient of expansion	7.5×10^{-4}	6.8×10^{-4}
Viscosity Cst. at 20° C	135	65
100° C	3.2	2.3
Pour point (ASTM D 97)	-25° C	-23° C
Firepoint (Cleveland)	258° C	none until boiling
Permittivity at 20° C	6.00	5.93
100° C	4.86	4.80
Resistivity		
100° C - 500 V - 1 mn	$>3000 \times 10^9$	$>3000 \times 10^9$
Dissipation factor		
+9δ 100° C - 50 cps	<0.02	<0.02

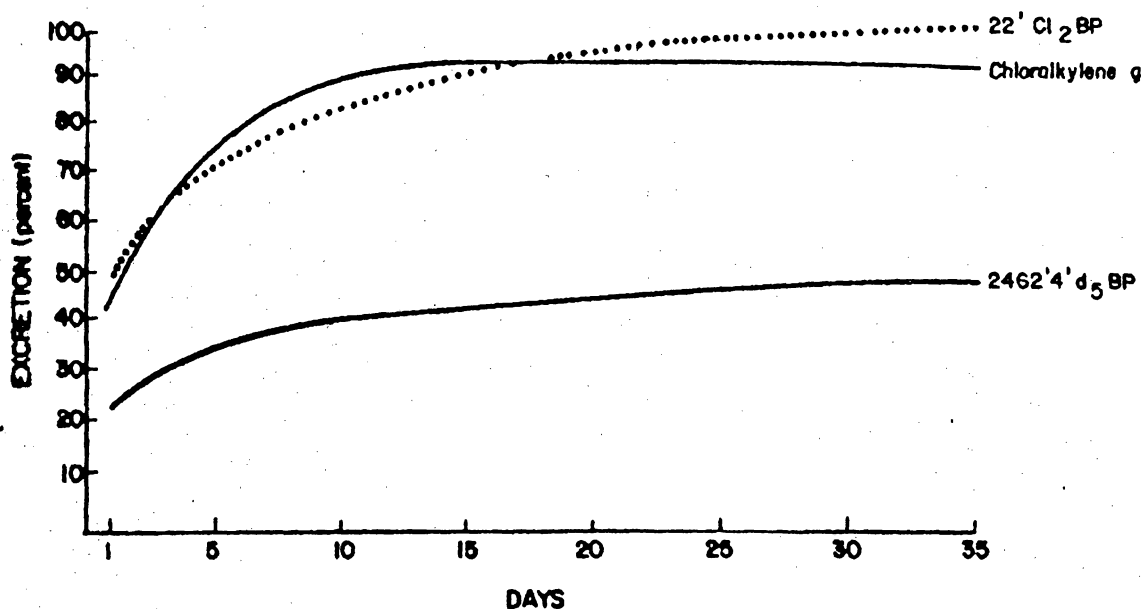


Figure 3. Excretion by rats, with diet of 2 ppm/day for 5 weeks.

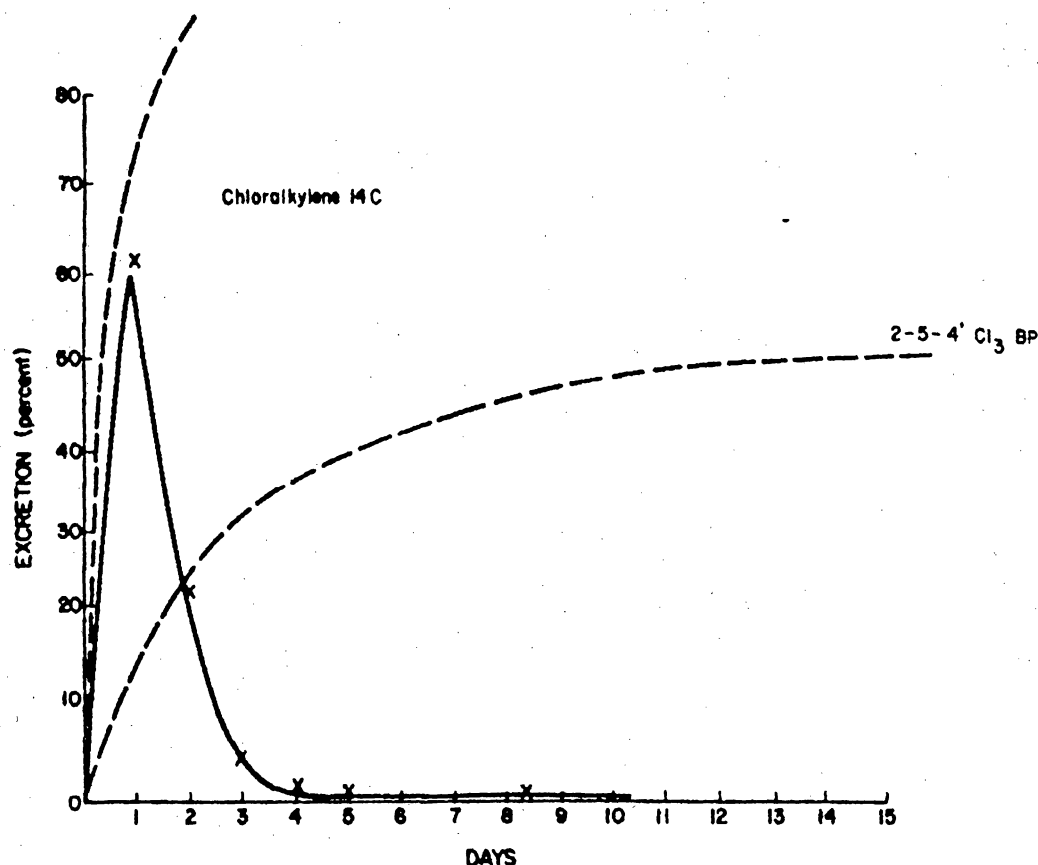


Figure 4. Excretion by rhesus monkey; single oral dose 1 mg/kg.

The studies carried on, in particular by Prof. Korte and Dr. Klein in Germany, seem to prove the easy biodegradability of PCB's when they have a very low chlorine content; therefore, pure mono- or dichlorobiphenyls could be quite acceptable for the environment.

As an impregnant consisting only of mono- and dichlorobiphenyls would crystallize at room temperature, it is necessary to produce a more complicated mixture to get a permanent liquid at all temperatures. We have therefore developed a product named "chloralkylene," obtained by addition of an alkyl chain, actually an isopropyl group, on a mixture of nearly pure dichlorobiphenyl isomers (figure 2).

As shown on table 2, chloralkylene contains no penta- nor tetrachlorobiphenyl and the trichlorobiphenyl content can be extremely low. Technically, for its dielectric and physical properties, the chloralkylene is a perfect substitute to the commercial trichlorobiphenyls (Pyralene 3010, Arochlor 1016), as shown in table 3 and as checked by some major capacitor manufacturers here

and abroad.

To assess its impact on the environment, we have given chloralkylene to the Institute for Ecological Chemistry in Bonn, Germany, Prof. Korte. This institute is engaged in an extensive investigation on "PCB's in the Environment." We therefore hope to have next spring the final results on the fate of chloralkylene in comparison with PCB isomers.

Tests on environmental acceptability are actually being carried out with chloralkylene based on 2-4' dichlorobiphenyl labeled with 14c. The tests consist of a study of the balance of the excretion, the storage, and the metabolism in rats and in monkeys (figures 3 and 4); the monkey studies are being completed at the Institute of Experimental Pathology and Toxicology, Albany Medical College, Albany, New York. These tests also examine the fate of chloralkylene in a soil plant ecosystem and in an aquatic ecosystem, as well as its behavior under atmospheric conditions, upon waste composting, and in sewage treatments. The results so far obtained prove that

chloralkylene does not accumulate, is metabolized quickly, and behaves generally like the dichlorobiphenyls isomers themselves.

Chloralkylene is two times less toxic than trichlorobiphenyl when one compares the acute toxicity values. At this time, there is no real reason to consider PCB's dangerous for the labor manufacturing capacitors, if the necessary precautions are taken. We think that with an easily biodegradable compound such as chloralkylene, long-term effects due to accumulation along the food

chain do not need to be feared.

The chloralkylene price is presently twice that of the currently commercially available polychlorobiphenyls, which would result in an increase of the capacitor costs of about 5/10 percent. However, by substituting mineral oil or other substitutes with less outstanding characteristics, the increase of the cost of capacitors would be much higher. We hope to improve its economy and are quite confident that chloralkylene could thus be an excellent substitute for trichlorobiphenyls.

PCB's AND THEIR SUBSTITUTES — A BRIEF LOOK AT SOME EXAMPLES OF PAST TRADEOFFS

Dale Hattis, Ph.D., and Albert Murray, Ph.D.*

Abstract

Some aspects are described of a study of the economic, health, legal, and other impacts of the past voluntary restriction on PCB sales. Examples illustrate the importance of examining the effects of substitute technologies in assessing regulatory policy by showing the potential for surprises in this regard. In the PCB case, substitutes may be producing both unanticipated economic benefits and unappreciated health and safety risks.

I am Dale Hattis of the Center for Policy Alternatives at M.I.T. My colleague at the center, Dr. Albert Murray, who was originally scheduled to speak here—and who would be the most appropriate speaker on this subject—was unfortunately taken ill about a week and a half ago and he is now still recuperating in the hospital. What I have done in his place for presentation today is to extract some particular examples of tradeoffs from Al's work on PCB's, which illustrate some occasionally surprising features of the technological changes that arise out of environmental/health concerns.

For context, I would like to say that our project, sponsored by the Council on Environmental Quality and EPA, and under the direction of Dr. Nicholas A. Ashford, has for the past year been exploring ways to analyze the economic, environmental health, legal, and other impacts of regulatory decisions related to environmental chemicals. In this exploration, we are now in the process of completing eight experiments in the analysis of the impacts of particular regulatory actions, primarily drawn from the past 5 years of history. The first of our eight experiments, though not strictly resulting from a mandatory governmental action, was the restriction a few years ago of the sale of PCB's for particular uses. Because our case studies are experiments to explore the practical use of methods, and because the resources we could devote to each case were relatively small, we could not perform as comprehensive an elucidation of effects as we would have wished. Nevertheless, we do think that our analyses have revealed important types of questions, similar to those referred to yesterday by Mr. Train, which are difficult to deal with in the single chemical

reactive context of most current regulatory authorities.

My initial two examples of such questions on PCB's illustrate the fact that it is sometimes difficult to be sure that technological changes introduced with the intent of reducing environmental health risks accomplish their purpose on balance, when the risks of substitute practices are considered. Sometimes there appear to be legitimate reasons for concern that particular changes—especially in the absence of continuing regulatory followup—might create environmental health hazards as dangerous or more dangerous than the ones that are eliminated.

As a first example, the substitutes for PCB's in some large heat exchangers and in some special hydraulic fluids for high-fire-risk uses are flammable at elevated temperatures. Concern for the lack of fire protection previously provided by PCB's in these situations has reportedly caused a substantial increase, as much as a doubling in some cases, in fire insurance rates on some industrial facilities employing high-temperature heat exchangers. In our case study, Al Murray estimated the total increase in premiums at possibly in the tens of millions of dollars annually. This, of course, reflects mainly property damage and not the human cost. However, if our information on the increased premiums is correct, and if the apparent perception of the insurance companies is correct as to the size of the added chance of catastrophic fires, then we must consider that such events would be likely to be accompanied by appreciable human casualties. The rise in insurance rates, of course, may not reflect an actual change in risk, and in that case the increased insurance cost is simply a transfer payment to the benefit of the insurance companies, but the matter seems to deserve further exploration with the aid of hard statistics on actual fire-risk experience. If the data confirm that appreciable human impact may be expected to occur, alternative means for reducing this risk might be productively evaluated.

Another, although probably less important, example of potential risk of substitute technology arises in the case of the former use of PCB's as a dye-solvent for carbonless carbon paper. It may be recalled that at some frequency PCB's from this source found their way into recycled paperboard products for food contact use, and this was a source of concern for the FDA. Now the PCB's formerly used for this purpose have been replaced, but unfortunately it is not public information what exactly has replaced them. The barrier of trade secrecy

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in this instance, as in many others, can frustrate attempts to assess the difference in environmental health risk produced by the change in technology.

Two other examples illustrate the potential for a different category of surprises—those in the economic area.

Formerly, PCB's costing on the order of 25 cents per pound were used in many paints and coatings, sometimes as a major ingredient. In this application PCB's were a chemically stable blender and conferred resistance to fire, impacts, water, and weathering. Our inquiries with paint manufacturers indicate that chlorinated paraffins now perform essentially all the technical functions of PCB's at about half the former cost. Our industry informants mention some increased problems in a few of their products with lowered stability to dechlorination—causing occasional discoloration and loss of weathering resistance—but over the great bulk of their product lines, the industry perception appears to be that the change has been economically beneficial. PCB's had evidently become established as paint additives before the availability and advantages of the chlorinated paraffins became widely appreciated. Later, when approximate technical equality and lower prices might have tempted paint manufacturers to substitute, the usual inertial resistance to any change appears to have caused this opportunity to be generally neglected. The real world and the economists' ideal one occasionally behave differently.

Another example of a surprise (at least to us) in the

economic area is the potential importance of even small adverse impacts on sport fishing. A U.S. Department of Interior survey (ref. 1) indicates that in 1970 a total of about 700 million person-days and five billion dollars were spent in pursuit of this pastime — mainly in fresh water. The five billion dollars must, of course, be considered an underestimate of the actual "value" of that activity to people. If PCB's had continued to be used as they were in the past, we might speculate that additional concern of people about residues (such as that now publicly in evidence), or possibly some declines in fish populations might have led to small fractional declines in participation or enjoyment of fishing by some portion of the population. If this were to occur, the loss of value to society of even less than a fraction of a percent of national sport fishing activities might be appraised at tens of millions of dollars annually—depending on the "value" realized by former fishers in substitute recreational activities.

The importance of examining subtle and uncertain effects, including the effects of substitute technologies, is illustrated by such occasional insights into their potential magnitude.

REFERENCES

1. Fish and Wildlife Service, Bureau of Sport Fisheries, U.S. Dept. Interior, "National Survey of Fishing and Hunting," Resource Publication 95, GPO, Washington, D.C., 1972.

ENJ-2065—AN ELECTRICAL INSULATING FLUID

E. J. Inchalik, Ph.D.*

Abstract

The need for an electrical insulating fluid whose use would avoid the adverse toxicological and ecological effects associated with polychlorinated biphenyls prompted a study of organic esters as possible substitutes. The study culminated in the identification of diisononyl phthalate (ENJ-2065) as a dielectric fluid of potential interest to the capacitor industry. ENJ-2065 has been made available to that industry and it is now being used in some commercial capacitors.

In late 1970, a study was begun at Exxon Research and Engineering Company by Drs. A. J. Rutkowski and E. O. Forster to develop an electrical insulating fluid whose use would avoid the adverse toxicological and ecological effects associated with polychlorinated biphenyls. This study culminated in the identification of diisononyl phthalate (ENJ-2065) as a dielectric fluid of potential interest to the capacitor industry. Exxon Chemical Company U.S.A. has made ENJ-2065 available to the industry for its evaluation and it is now being used in some commercial capacitors.

In the preliminary phases of this study, the dielectric properties of a significant number of mono- and dibasic acid esters were determined in order to obtain a general understanding of the interrelation between molecular structure and dielectric properties. From these data it was concluded that major attention ought to be directed at the esters of phthalic acid. The phthalates that we tested all had dielectric constants of 4-6, close enough to the desired level for fluids for the widely used paper-based capacitors to justify further evaluation. The optimum dielectric constant for these capacitor fluids is one which closely matches the dielectric constant of the paper. A close match reduces electric field inhomogeneities, increases dielectric strength and lifetime, and decreases capacitor size. Other important property criteria for a paper dielectric fluid include a low dissipation factor, to reduce energy loss and destructive heat buildup; a high dielectric strength, to reduce capacitor size and improve service life by permitting short-term exposure of the fluid to abnormally high stresses without breakdown; a low gassing tendency, to avoid production of gases that could lead to pressure buildup in sealed units; stability at elevated temperatures, to prevent capacitor

breakdown and stabilize performance; low viscosity, to allow for easier impregnation and filling of capacitors and elimination of air pockets; a low order of toxicity; and compatibility with the environment.

Consideration of these factors as well as availability and cost resulted in narrowing the choice of potential candidates to those shown in table 1. From this list, diisononyl phthalate (ENJ-2065) was selected as the most promising for additional study. ENJ-2065 was chosen on the basis that it has (1) a higher dielectric constant than the phthalates of higher molecular weight, (2) an advantage in its loss characteristics relative to the lower molecular weight dihexyl and dioctyl phthalates, (3) a relatively high flash point of 430° F, (4) a more highly branched molecular structure than dihexyl and dioctyl phthalates with the potential for improved hydrolytic stability and (5) a good balance of other physical and electrical properties. ENJ-2065 is manufactured in the United States by Exxon Chemical Company U.S.A. from phthalic anhydride and a mixture of branched isomeric alcohols in which C₉ alcohols predominate.

Electrical insulating fluids have to remain essentially unchanged chemically when subjected to temperature cycles. Once having chosen ENJ-2065 for further evaluation, it was desirable to know what effect certain contaminants might have on its stability, how these contaminants might be removed, and what additives, if any, might be useful in enhancing its stability.

The effects of small amounts of two potential contaminants, alcohol and water, on conductivity of ENJ-2065 are shown in tables 2 and 3. The results show that alcohol levels of less than about 1,000 ppm and water levels of less than about 100 ppm can probably be tolerated without affecting performance seriously. To remove small quantities of these impurities as well as any acids or catalyst residues from the production of ENJ-2065, we found percolation through a packed column of activated Attapulgus clay to be effective, but we did not carry out extensive studies to optimize a purification system. It is our feeling that systems now being used in the industry for purification of PCB's prior to use in capacitors, or slight modifications of them, will prove to be satisfactory for ENJ-2065.

Although the most widely used capacitors today are of the all-paper type, newer types based on polypropylene film and paper or on all-polypropylene film are growing in importance. With capacitors of this type, the dielectric constant of the fluid is less important.

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Table 1. Electrical and physical properties
of phthalate esters

Phthalate Ester	Diethyl	Di-2- ethylhexyl	Diisooctyl	ENJ-2065	Diisodecyl	Ditridecyl
Dielectric constant	5.64	5.33	4.97	4.66	4.45	4.08
Tan delta	--	0.14	0.30	0.05	0.02	0.01
AC conduc- tivity, 10^{-11} (ohm-cm) $^{-1}$	9.0	2.1	1.3	0.29	0.20	0.04
Breakdown voltage (KV/0.1 in.)	--	28	27	30	36	29
Boiling point--mid @ 5 mmHg, °C	210	230	235	252	256	286
Pour point, °C	-33	-50	-45	-48	-50	-37
Viscosity, cps., 20° C	50	81	83	95	110	230
Flashpoint, COC, °F	380	425	430	430	452	470
Firepoint, COC, °F	420	475	485	495	515	555

Table 2. Effect of residual alcohol on conductivity of ENJ-2065

Temperature cycle (1,000 V, 60 Hz)	Conductivity (10^{-12} ohm-cm) ⁻¹ Wt. percent alcohol added		
	0	0.01	0.1
25° C	0.78	1.97	1.98
90° C	40	65	320
25° C	3	4	12

Table 3. Effect of residual water on conductivity of ENJ-2065

Temperature cycle (1,000 V, 60 Hz)	Conductivity (10^{-12} ohm-cm) ⁻¹ Wt. percent water added			
	0	0.001	0.01	0.1
25° C	0.78	2.7	3.7	135
90° C	40	165	>400	>400
25° C	3	10	25	70

Table 4. Weight gain of PP film in contact with dielectric fluid

Fluid	Run number		
	1	2	3
ENJ-2065	11.0	10.9	13.8
Arochlor 1242	18.8	18.2	22.8

Impregnation of the polypropylene film with the fluid, however, is of great importance and prompted a brief study, summarized on table 4. These data show that ENJ-2065 swells polypropylene capacitor-grade films satisfactorily, as measured by the film weight gain after 2 days at 60° C, so that film impregnation should not be a serious problem. The next generation of capacitors

may well be based on metallized polypropylene film. Polychlorinated biphenyls cannot be used for this type of capacitor since they generate hydrogen chloride, which can lead to premature breakdown.

In summary, we believe that ENJ-2065 has a balance of properties such that it will find a niche in the capacitor fluid field.

GENERAL DISCUSSION OF SESSION V

CHAIRMAN MUIR: All right. I see that we have reached our scheduled departure hour. I think it's only fair to entertain a few questions from the audience and given the diversity, I would request that people raise a question from the floor and then address their questions to the individual they would like an answer from.

MR. BEN KININGHAM (Illinois Lung Association, Springfield, Illinois): I do not have any particular gentleman on the panel to address. I just want to refer to the breakdown of the film, if anyone could elaborate on how that comes about, and if so, is there any research that is being carried on now in development of films that would be any more stable.

MR. RICHARD ROLLINS (Jard Corporation, Bennington, Vermont): Are you talking about a biological breakdown?

MR. KININGHAM: Biological or chemical or both breakdowns.

MR. ROLLINS: It is a reduction type atmosphere in the capacitor so it does not see the oxygen that would normally be considered. The basic problem is not one of the degradation as much as it is an inherent characteristic of not being able to survive voltage levels or stresses in an AC application.

MR. KININGHAM: Would it be feasible to develop an alternative program?

MR. ROLLINS: The organic type films have been used or have been attempted to be used in AC capacitors. The basic problem is one of corona exception and corona distinction voltages, and this is inherently low and goes down to initiation of points 250 to 275 volts and the extinction voltage is extremely low. The meaning of the corona is that the capacitor slowly deteriorates by this ionic device which is the definition of corona. The interpretations of corona I am not going to get into today because every capacitor designer has his own opinion, but every capacitor designer is completely aware of what the corona problems can do. So essentially what we are saying is that organic films have the basic problem of not being able to withstand high AC voltages, especially in the dry system.

On an impregnated system, the circumstances are still there, so you are not really changing the circumstances a great deal in all polypropylene film or any organic film when you impregnate it.

VOICE: I have a question for Dave Wood. We heard a

number of things about environmental factors. How about a still lower chlorinated material than 1016 that might be a more desirable material? I believe Monsanto has passed a given developmental material such as 1043, which is a lower chlorinated material.

MR. DAVID WOOD (Monsanto Industrial Chemicals Company, St. Louis, Missouri): We have done considerable work with MCS 1043, but at the present time commercialization of such a product must hang in the balance pending further conclusions being drawn about the true significance in the differences observed between the trichlorinated materials and bichlorinated materials. Aroclor 1016 was itself a reduction in materials from the Aroclor 1042 widely used by the industry.

In order to carry through development of the dichlorinated material, I think we need some approvals from the community that they recognize a movement in that direction as one that should be taken.

So yes, some data are already available. Acceleration or stopping of that program depends largely, on some of the things that we hope will come out of this conference this week.

MS. NANCY STROUP (Environmental Defense Foundation, Washington, D.C.): I apologize for the openhandedness of my question, but I hope that the panel members will respond as concisely as possible.

One of the speakers mentioned that his concern was that we not jump from the frying pan into the fire, and I am sure it's the concern of everyone at this meeting. To that end I would like to know when the four or five compounds that are now being developed to replace PCB's will be tested for the health and safety of these compounds, including carcinogenic, immunogenic, and teratogenic tests before your marketing. And whether this information will be available for independent review.

DR. MUIR: Essentially, as I already outlined in my talk, we developed a date for the work and the work is going forward and we recognize the biphenyl problem and that replacing the product inevitably is going to have to satisfy the most thorough and rigorous testing.

DR. DEAN BRANSON (Dow Chemical, Inc., Midland, Michigan): In the case of methosilicones additional data will be published very shortly and will be publicly available. I think this is most in the minds of all manufacturers when they consider substitutes

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for the material which is dielectrically one of the best ever developed. This will seem to solve the problem when it comes out.

DR. E. J. INCHALIK (Exxon Chemical Company, Linden, New Jersey): A great deal of information is already available. You may recall in 1972 a program sponsored by the National Foundation of Health Sciences and one subject made by Dr. Tapper, what he observed at comparison of PCB and mercury, it was like an ideology searching for a disease, and that's a quote.

The recent study by Dr. Hartung of the University of Michigan has concluded that no problems attributable to polyesters have been noted due to the constant low level exposure of the general population, and that occupationally, only mild skin irritation has been observed at high exposures. But he did point out that ecological work should be continued. And I might add that Dr. Tapper suggested the same.

To help answer these questions, particularly related to these items, a research grant has been made by the University of Missouri to the Manufacturing Chemists Association, and they are starting tests. I think we can hope within the next year or so results will be coming from this study obviously available to all which will help answer these questions.

MR. DUNCAN MacARTHUR (Booze Allen and Hamilton, Inc., New York, New York): Well, some of the things that you have asked for are in progress and when these things are available, they will also be made available to the general public.

MR. DAVID C. MORRIS (Weyerhaeuser Company, Tacoma, Washington): You stated, sir, that a cost of \$4.9 million would be necessary for I guess you would call them secondary market users like my company, to replace our PCB with some substitute.

Did I understand you correctly, Mr. MacArthur?

MR. MacARTHUR: Yes.

MR. MOSS: Just for my own sake, I just believe in it very strongly, the cost alone is estimated at \$2 million and we are right in the midst of investing. And I think somewhere along the line the investing might not take into account the factors that we initially have to face. I would guess it's at least 50 times over.

CHAIRMAN MUIR: Yes, sir.

VOICE: There are three experimental items coming on the market. Will someone label these transformers--

MR. ROLLINS: Well, I'm not too sure, but there have been requests that major capacitors manufacturers

now conform by labeling all capacitors that have greater than I believe 5 pounds of Aroclor—I may be wrong, but on small capacitors, the basic problem is the label gets hidden because this is placed into another piece of equipment.

MR. STEVE NUMUS (Environmental Protection Agency): I have a question for Richard Montgomery regarding the use of silicone which was approved by Underwriters Lab for indoor use. Do you know the reasons why it was approved for indoor use and why it was not approved for outdoor use?

And secondly, can somebody give me an idea of the percent of transformers in the United States used for outdoor purposes as opposed to indoor purposes?

MR. RICHARD H. MONTGOMERY (Dow Corning Corporation, Midland, Michigan): First of all, Underwriters Laboratory does not approve of any particular material for any given use—once you exceed 600 volts in a transformer, Underwriter's Laboratories has no certification. The only certification received from Underwriters' Laboratories is as to the fire hazard of your particular material on a scale which ranges from 0 to 100, with the burnability of water as 0, and gasoline as 100. Therefore, Underwriter's Laboratory does not approve silicone material for indoor use.

In respect to the use of dielectric fluids in transformers, the electric code for outdoor uses does not specify nonflammable material. It does in subsection 450, paragraph 23 approve the use for the indoors. These are the only materials approved for use.

MR. NUMUS: I want to know the percentage as opposed to indoor use.

MR. MONTGOMERY: Well, my research seems to indicate 85 to 90 percent of the transformers sold in the United States are currently outdoor applications, and the other 10 to 15 percent are indoor applications, for safety is of paramount importance.

MR. WOOD: Essentially the figure that he is using is pretty accurate. Very large power transformers are filled with mineral oil because, if they're out in the field, there is not a substantial hazard, they can be screened out. In the medium voltage range the use of askarel is something under 15 percent of the transformers used in that medium voltage area.

MR. CLIFFORD H. TUTTLE (Aerovox Industries, Inc., New Bedford, Massachusetts): I really have two questions—another alternative mentioned up there, the capacitor for getting the high voltage can consume 20 to 50 million pounds a year. How long

would it take fluid to be available in that type of quantity; 1 year, 2 years, 3 years, or what? I don't want to pressure you, I just want to determine.

The second question is a third of that market is lighting, fluorescence. If you have an application at 100° C, are any of these fluids or alternatives capable of operating at that temperature without breaking?

MR. MONTGOMERY: Let me answer your second question first. The answer is yes. The answer to the first question is we do have the productive capabilities capable to handle that market. It could be

accomplished very quickly. It would probably be faster than the industry takes to evaluate and qualify new material.

MR. WOOD: In terms of Monsanto, alternatives could be made available on a production basis in calendar year 1976, in relationship to the stability of these materials at 100° in the HIB and the fluorescent lighting capacitors, these are test sequences which are going on under our test programs. And the results will be forthcoming. We are in a period now of collective work. We are not ready to go tomorrow.

PROPOSED REVISION TO ANSI C-167.1 (9TH)

1. SCOPE

This standard establishes guidelines for the safe transport, use, maintenance, and disposal of askarel and askarel-coated 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 since the early 1930's, but only recently was it 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 on specific species. Studies have shown that PCBs are an environmental contaminant. 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 as follows:

- (1) "Open-ended" applications; for example, in paints, speciality inks, paper coatings, plastics, etc.
- (2) "Nominally closed" applications; for example, as the working fluid in hydraulic and heat transfer systems.

- (3) "Closed electrical system" applications, specifically as the insulating fluid in certain kinds of transformers and capacitors.

Effective January 15, 1972, the Monsanto Company, sole domestic producer of PCBs discontinued supplying PCBs to all except manufacturers of electrical transformers and capacitors.

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 are used where fire-resistant properties are important. 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 dictate the present use of askarel-containing equipment in or adjacent to public, commercial, and industrial buildings, which locations present the greatest potential danger to life and property.

NEV 026100

2.3 Risks. In the United States, medical records since the early 1930's 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 result in 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 0.04% of the units in 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 users 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.

Several potential alternative transformer fluids are under intensive investigation to determine if they will have satisfactory electrical and operating performance characteristics. Such liquids must be acceptable environmentally, to the users, and from the fire risk standpoint.

The principal alternatives to askarels for capacitors are either mineral oil or various types of synthetic fluids. The latter types are under intensive investigation by the industry. Mineral oil and these newer fluids are flammable. The use of mineral oil 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. For the newer types of synthetic fluids under investigation it must be determined if they will yield satisfactory operating performance, are environmentally acceptable and that liquid non-flammability is not required.

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. Omitting economic considerations there are no technically equivalent fluids available today.

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 safe industrial usage, since the 1930's, except for minor skin and eye irritation. There have been no known instances of human injuries when they were used under the normally accepted precautions and conditions of handling in both manufacturing and user applications.

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 higher degree of resistance to burning, 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 resistance to burning 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 flammability (both are recognized as highly resistant to burning. It is for these reasons that Section 3 of this standard is intended to apply to capacitor-grade askarel.

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% or less by weight of the higher boiling homologues of the chlorinated biphenyls. [See ASTM D3303 -74(1)¹] 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. flammability rating as Aroclor 1242.

Commonly used solvents for clean-up purposes, 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

1
Numbers in brackets refer to corresponding numbers in 7.1, References to the Text.

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3.3 Employee Safety and Plant Housekeeping.

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

3.3.1 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.

3.3.1.1. 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 of vapors is referenced 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 very 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.

3.3.1.2 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. The use of porous gloves that can absorb and retain askarel is to be avoided. Resistant gloves² should be used if contact is unavoidable. Use of enclosed transfer and handling equipment, processing equipment, and mechanical washers reduces direct contact.

² For example, Edmont-Solvit S-352 (Mersick of Bridgeport, Bridgeport, Conn), or the equivalent.

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 askarel contacts the eyes, the eyes should be irrigated immediately with large quantities of running water for approximately 15 minutes and then examined by a physician (A drop of (U.S.P.) 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; However, should accidental ingestion occur, a physician should be consulted.

Hands should be cleaned of askarel before eating, drinking, smoking, or using toilet facilities by means of waterless hand cleaners³ and wipe towels which should then be properly disposed of.

3.3.2 Bulk Fluid Shipment: Receiving and Transfer. Shipment of askarel from point of manufacturing to point of receiving should be done in closed containers such as rail tank cars, truck tanks, marine or barge tanks, or sealed drums. In case of an askarel spill during bulk fluid shipment, reference should be made to paragraph 6.0 which provides procedures for control and listed authorities to be notified. Containers should be labeled as to contents and carry a label cautioning against loss of fluid to the open environment

(See section 3.6). 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 Manufacturing Housekeeping. Manufacturing equipment and operating procedures should safeguard against loss of askarels to the environment through proper containment and disposal procedures.

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

Establish containment methods and/or procedures for all askarel processing areas to prevent loss to sewer systems by spillage, leakage or other uncontrolled conditions or events.

³ For example, Pow'r Kleen Handcleaner, (Woodbine Chemical and Research, Inc., Medina, Ohio or Kan's Hands, Oak Industries, Inc., Moosick Falls, New York)

3.3.3.2 Types and Control of Liquid Askarel Wastes. Askarel-containing liquid wastes may occur in manufacturing from sources such as the following: 1) Liquid askarel contaminated during processing which is unsuitable for reclaiming as a dielectric fluid, 2) liquid askarel from solvent operations or water and detergent type washers, 3) vacuum pump oils contaminated with askarel, 4) steam jet vacuum system condensates contaminated with askarels, and 5) askarel containing materials from laboratory samples.

Waste fluids containing askarel should be collected (by means of traps, drip pans, trays, etc) and disposal should be in accordance with 3.5.

Spills of askarels should be contained and cleaned up promptly by means of absorptive material, such as sawdust, or trapped and removed by pumping or other suitable means. Disposal should be per 3.5.

3.3.3.3 Types and Control of Other Askarel Containing Wastes. Saturation of materials with askarels may occur in manufacturing from the following sources: 1) Saturated earth or other absorbent media from filtering operations or from cleaning up spills, 2) saturated filters from vapor control devices and other filters, 3) saturated wastes such as paper, rags, etc. 4) saturated spent gasket materials and 5) capacitors failing tests or otherwise designated for disposal.

All of the above items should be collected for proper disposal. Wiper rags, protective clothing⁴ and other extraneous materials which are likely to be soiled should preferably be made of disposable materials. Other materials

should be collected within the containment area for properly controlled laundering.

3.4 Control of Plant Effluents.

3.4.1 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 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.

3.4.1.2 Concentration Limits. The EPA has proposed water quality criteria to maintain PCB concentration in rivers and lakes below detection level. Requirements under Sections 307(a), 307(b) and 311 of the 1972 Amendments to the Federal Water Pollution Control Act are under review (1976-77) and the latest revisions will apply. State and municipal requirements must also be met.

Further information may be obtained from an Environmental Protection Agency Regional Office. A listing of these offices is contained in Appendix D.

3.4.1.3 Monitoring Streams. On a regular basis consistent with plant situations, all effluent streams should be analyzed. The procedure for performing the necessary analyses is per ASTM Method D1304. This procedure or its equivalent should be used.

⁴ For example, Edmont-Wilson, 1294 Walnut St., Coshocton, Ohio 43812, or Slossman Corp., P.O. Box 3014, Asheville, N.C. 28802

3.4.2.4 Methods for Minimizing Effluent Stream Contamination. The ideal approach is to isolate totally all effluents that could be contaminated with askarel during manufacturing processes and prevent them from being discharged from the plant. Carbon absorption, limestone beds, and solvent extraction are techniques that could 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.

3.4.2 Air Effluents. The industry goal is to eliminate askarel vapors in plant air effluents.

Plant operations involving askarels at elevated temperatures in excess of 55°C should be performed, wherever possible, within closed systems. Filtration of plant air effluents, to minimize PCBs entry into the environment, should be accomplished where involvement of air borne PCBs may occur from open operations.

3.4.2.1 Monitoring. All plant air effluents should be sampled and analyzed on a routine basis consistent with plant situations. The procedure for performing the analysis is per ASTM Method D3304 (See Appendix B3).

3.5 Scrap-Disposal Procedures. The manufacture and use of capacitors involves processes which 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 which 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.

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.

Capacitor units should be disposed of intact, or if leaking, in sealed drums. The small amount of liquid to be drained, the integrity of intact units and the necessity for complex control over drainage procedures make intact disposal preferable.

3.5.1.1 Production Rejects. Rejected capacitors in capacitor manufacturing plants represent a concentration of askarel. It is, therefore, important that disposition be made in a manner consistent with proper concern for the environment. Preference should be given to disposal of capacitors in sites approved for hazardous waste disposal (See Appendix A). Another alternative, but less desirable, would be disposal in approved landfill sites.

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

Incineration of scrap capacitors in facilities designed to accept such solids would provide a preferential alternative to approved landfill sites when such services become available.

3.5.1.2 Field Removal. Wherever practical, all askarel containing capacitors should be removed prior to disposal of equipment. This precaution will enhance environmental control procedures and insure that by removing these capacitors they do not ultimately disperse their askarel contents into an unapproved landfill site.

After removal from equipment, capacitors should be disposed in accordance with the procedures for production rejects (3.5.1.1). Where removal of askarel-containing capacitors from equipment is not practical, that equipment should be disposed of only in approved landfill sites.

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 or 3.5.2.2. However, preference should be given incineration, 3.5.2.1.

3.5.2.1 Incineration. 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 state requirements and should control effluents within the limits set forth in this standard.

3.5.2.2 Chemical Waste Disposal. Where incineration is not feasible, sites which have been classified by state agencies as suitable for disposal of chemical waste liquids should be used (See Appendix A).

3.5.3 Disposal of Solid Wastes (See 3.5.1 for scrap capacitors). All solid wastes which have been saturated with askarel should be placed in leak proof containers and preferably transported for disposal by incineration. A less

preferable disposal procedure is an approved landfill site. See Appendix A for listing of Facilities.

3.5.4 Packaging and Shipment.

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

3.5.4.2 Containers should be labeled as to contents and precautions relative to loss to the environment per 3.3.2.

3.5.4.3 Containers for this purpose cannot be used for any other materials or they should be 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.

3.6 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 of 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 labeling 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 pounds. They are hermetically sealed in metallic cases. It is recommended that shipping containers from capacitor manufacturers should be labeled as to contents and that transporters be given instructions, in accordance with paragraph 6.12 as to procedures in the event of a spill.

If, however, a label of the capacitor is required by statute or by specific manufacturers, the following is suggested:

Contains PCBs. Use care in disposal.

The shipping container label, yellow on black, should contain the following information:

"CAUTION" Contains PCBs (Polychlorinated Biphenyls) that are environmental contaminants. In case of leaks or spills, restrain discharge and consult manufacturer. In transportation emergencies, call National Response Center (800-426-8802) and Chemtrec (800-424-9300). Avoid prolonged breathing of vapors or mists, contact with eyes or skin. Disposal should be in accordance with ANSI C-107 Guidelines or applicable state and Federal statutes."

Small unit capacitors are applied as a component of a large piece of equipment. Manufacturers utilizing askarel-filled capacitors should affix a label referencing this standard or describing disposal procedures consistent with it.

3.6.2 Large Units. Large capacitor units are defined as those which contain more than 2 pounds of askarel. The manufacturer should affix a label in a conspicuous place on the capacitor, referencing this standard or describing disposal procedures consistent with it. As a minimum, the label should contain information listed in 3.6.1.

3.7 Information for Users of Large Capacitors

3.7.1 General. Large Askarel-filled capacitors contain more than 2 pounds of askarel and 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.

3.7.2 Transportation and Receiving. Immediately upon receipt of a shipment and following any transportation or handling accident that could affect the integrity of the capacitor enclosure, the transportation vehicle, enclosure, 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 kerosene or other approved solvent such as perchloroethylene. All materials used should be collected for proper disposition as described in 3.5.

3.7.3 Installation and Periodic Inspection.

Large capacitors should be installed in new facilities such that if a leak should develop, askarels can be restrained from reaching the environment. Depending upon the type of installation, consideration may be given to pans, dams, traps, standpipes, dry wells, absorbing agents, etc.

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

4. Transformer Guidelines.

4.1 General.

4.1.1 Askarels of various compositional types are currently in use (for the general properties and types, see ASTM D2283-73a(20)). The trademark designations used by manufacturers for liquids containing PCBs are given in Appendix C.

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 Vapor. 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 analysis is contained in ASTM Method D3504 (See Appendix D).

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 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 which is highly toxic, 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 arc'd 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 arc'd products 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.

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 such as the polyethylene or fluoro elastomer type should be used if contact is unavoidable. For some operations, it has been found advantageous to use non-porous, disposable aprons and gloves. In case of spillage on clothing, the clothing should be removed as soon as practical, the skin cleaned with waterless cleaners or solvents such as Kerosene, and wiped dry with disposable towels. These towels should be disposed of as PCB contaminated solid wastes. See Section 4.1.6.2.2. Clothing and shoes saturated with askarel should be discarded (burnable waste). Contaminated clothing may be reused providing that

*For example "VITON"

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It has been thoroughly cleaned using segregated solvents or a segregated degreaser, then followed by normal laundering. (Laundering alone is not sufficient.)

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 approximately 15 minutes and then examined by a physician. (A drop of (U.S.P.) castor oil has been found to reduce irritation.)

Ingestion or swallowing of askarels is not generally regarded as a problem of the industry; however, should accidental ingestion occur, a physician should be consulted.

Hands should be cleaned as noted above before eating, drinking, smoking or using toilet facilities.

4.1.3 Liquid Transport Containers.

4.1.3.1 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 (yellow on black):

"CAUTION" Contains PCBs (Polychlorinated Biphenyls) that are environmental contaminants. In case of leaks or spills, restrain discharge and consult manufacturer. In transportation emergencies, call National Response Center (800-424-8802) and Chemtrec (800-424-9300). Avoid prolonged breathing of vapors or mists, contact with eyes or skin. Disposal should be in accordance with ANSI C-107 Guidelines or applicable state and Federal statutes."

4.1.3.2 Spill Procedures - Bulk liquid shipments.

See Section 6.

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 should 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 in accordance with 4.1.6.2.1.

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 should 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 with similar containment capabilities.

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4.1.5 Control of Water Effluents. The industry goal is to eliminate askarel in 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 EPA has proposed water quality criteria to maintain PCB concentration in rivers and lakes below detection level. Requirements under Sections 307(a), 307(b), and 311 of the 1972 Amendments to the Federal Water Pollution Control Act are under review (1976-77) and the latest revisions will apply. State and municipal requirements must also be met.

Further information may be obtained from the Environmental Protection Agency Regional Office. A listing of these offices is contained in Appendix D.

4.1.5.2 Monitoring Streams. All plant effluent streams should be monitored on a regular basis. The procedure for performing the necessary analysis is contained in ASTM Method D3304 (See Appendix B).

4.1.5.3 Methods for Minimizing Effluent Stream Contamination. The ideal approach is to totally isolate all effluents 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 come from many sources including 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, sample containers and handling equipment.

4.1.6.2 Classification for Disposal of Materials Containing PCBs. In general, there are four types of materials requiring disposal: burnable liquids contaminated with PCBs; non-burnable liquids contaminated with PCBs; burnable solids contaminated with PCBs; and non-burnable solids contaminated with PCBs.

4.1.6.2.1 Burnable 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, sump accumulation, askarels from holding basins, drip and drain pans, washings, sample jars and containers, etc.

4.1.6.2.2 Nonburnable Liquids (Water) Contaminated with PCBs. Water contaminated with PCBs may be treated by such means as activated carbon filtration or by a reductive dechlorination process, providing that the effluent meets Federal and State water effluent standards. Such liquids may also be disposed of, packed in suitable containers, in approved landfills. See Appendix A.

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4.1.6.2.3 Burnable Solid Waste Materials

Containing or Contaminated with 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.

4.1.6.2.4 Burnable Solid Waste Materials

Containing or Contaminated with PCBs. These materials may consist of 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 liquids collected in drip pans, etc. Further removal of adhering PCBs should be accomplished by vapor degreasing, washing or solvent extraction with kerosene or other approved washing liquids such as perchloroethylene. Accumulated liquids should be disposed of as indicated in 4.1.6.2.1. Solid materials as cleaned above may be handled as normal scrap.

Coil structures may be dismantled with burnable material removed. Metals should be treated as noted above, and burnable solids disposed of in accordance with Section 4.1.6.2.3. An alternative but less desirable procedure for disposal of coils, cores, burnable waste, etc., is to suitably package and bury in an approved landfill site. See Appendix A.

4.1.6.3 Shipment of Scrap Liquids For Disposal.

All liquid scrap material should be placed in appropriate metal transport containers, properly labeled (Section 4.1.3.1) for shipment to a company offering an acceptable disposal service (Appendix A).

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

Material of this type should be placed in a liquid-tight container meeting Federal and State transportation requirements, and acceptable to the disposal organization. The container should be properly labeled (Section 4.1.3.1) for shipment to a company offering an acceptable disposal service (Appendix A).

4.1.6.5 Liquid and Solid Waste Disposal Service Organizations.

These facilities should meet the applicable requirements of the state in which they are located and should control effluents within the limits referred to in Section 4.1.5.1.

4.2 Guidelines for Original Manufacture, Service and Repair Shops.

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 It is desirable that the askarel filling area be adjacent to the test area and final shipping area to minimize the danger of damage to 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 constructed 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.

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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 DURNABLE ASKAREL WASTE" should be available for handling contaminated cellulose insulation, rags, paper, pressboard, wood, gaskets, 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 materials 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 DURNABLE 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, allowing 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 tank and place over a suitable drip pan.

4.2.1.4.3 Place all materials in the appropriate salvage containers during 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 and Shipment

4.2.2.1 New and Rebuilt Transformers. All new and rebuilt 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, yellow on black, includes the following:

"CAUTION" Contains PCBs (Polychlorinated Biphenyls) that are environmental contaminants. In case of leaks or spills, restrain discharge and consult manufacturer. In transportation emergencies, call National Response Center (800-424-0002) and Chemtrec (800-424-9300). Avoid prolonged breathing of vapors or mists, contact with eyes or skin. Disposal should be in accordance with ANSI C-107 Guidelines or applicable state and Federal statutes."

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

4.2.2.3 Shipping papers should contain the warning

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. All materials used should be collected for proper disposition as described in 4.1.6.

4.2.3.3 Installation and Periodic Inspection. Transformers should be installed so that if a leak should develop, askarels can be restrained from reaching the environment. Depending upon the type of installation, consideration may be given to pans, dams, traps, standpipes, dry wells, absorbing agents, etc.

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 manufacturers'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. (See Section 5).

4.2.3.6 Transformers Installed in Moving Vehicles. In the event of a leak or accidental spill, the procedures outlined in Section 6 should be followed.

4.3 Retrofilling Apparatus Containing Askarels.

It is not recommended that apparatus containing PCB liquids be changed to other liquids. It is recognized that the best possible change-out procedure will still leave appreciable PCBs in the apparatus. Apparatus that has contained PCBs which has been replaced with another fluid should be labeled as indicated below, and the disposal ultimately should follow the same disposal procedures as those recommended for PCB liquids and PCB-filled apparatus.

Label (yellow on black)

CAUTION: Contains liquid contaminated with PCBs an environmental contaminant. Changed to (describe liquid) on (give date).

4.4 Transformer Disposal.

The ultimate disposal of a PCB-containing transformer may be accomplished by the following procedures:

1. Contract with a qualified organization for disposal of the complete transformer.
2. Where acceptable facilities are available, the following alternative procedures are recommended:
 - (a) Always drain the liquid and dispose of it by approved incineration.
 - (b) For the solid components or for the entire structure, either of the following procedures are recommended:
 - i. Dismantle, wash and dispose in accordance with Section 4.1.6.
 - ii. Ship entire solid structure to acceptable organization for disposal.
 - iii. Ship to acceptable landfill disposal site. (See Appendix A).

5. Disposal of Laboratory Samples Containing PCBs.

The disposal of laboratory samples and materials used for testing and experimental purposes which contain, are impregnated with, or contaminated by PCBs (askarels) must be carefully controlled. Their disposition should be made in a manner consistent with procedures in 3.5.2 and 3.5.3 (Capacitors) and 4.1.6 (Transformers).

6. Spill Notification and Control Plan

Polychlorinated Biphenyl (PCBs)

The immediate actions needed are to contain or restrain liquid spills with the best means available and to notify "CHEMTREC" and "The National Response Center."

"The basis for this spill notification and control plan relies on Chemtrec to advise on the immediate actions needed to contain or restrain the liquid spill with the best means available based on listed instructions. The National Response Center will notify all interested parties, i.e. Federal and State authorities and the manufacturers involved, as well as give guidance on action to be taken."

FAILURE TO REPORT SPILLS TO PROPER AUTHORITIES MAY RESULT IN CRIMINAL PENALTIES.

6.1 Chemtrec

6.1.1 What is it. - Chemtrec stands for Chemical Transportation Emergency Center, a public service of the Manufacturing Chemists Association at its offices in Washington, D.C.

Chemtrec provides immediate advice for those at the scene of emergencies, then promptly contacts the shipper of the chemicals involved for more detailed assistance and appropriate follow-up.

Chemtrec operates around the clock - 24 hours a day, seven days a week - to receive direct-dial toll-free calls from any point in the continental United States through a wide area telephone service (WATS) number, 800-424-9300 (463-7616 for calls originating within the District of Columbia; 202-483-7616 for calls originating outside the continental U.S.).

6.1.2 It is recommended that all past and present manufacturers of PCBs and PCB-containing equipment be listed with Chemtrec.

Contact "Chemtrec" at the manufacturing Chemists Association, 1625 Connecticut Ave., N.W., Washington, D.C. 20009.

6.2 National Response Center.

6.2.1 What is it -

Location: U.S. Coast Guard Headquarters, Russell Building, 400 7th Street, S.W. Washington, D.C. 20590.

Mission: To coordinate pollution emergencies when national involvement is required. National Response Reporting Network for receiving pollution reports. The basis of this network is a well publicized toll-free telephone number (800-424-6302) which anyone may use to call the National Response Center reporting pollution incidents or accidents which may result in pollution.

Flow of Pollution Reports to the local representatives of the Federal Agency responsible for action when a pollution discharge has occurred. When necessary, other specific local, regional, or national representatives for the various agencies will also be notified.

6.3 Shipment of Liquids and Equipment Containing PCBs.

6.3.1 Labeling All containers and equipment containing PCBs shall be labeled in accordance with sections 3.6, 4.1.3, 4.2.2.1 and 4.3.

6.3.2 Shipping Papers. Shipping papers should contain the following warning statement:

CAUTION: Contains PCBs (askarel) that are environmental contaminants. In case of leaks, or spills, restrain discharge, DO NOT BURN. For further instructions call Chemtrec (800-424-6300) and the manufacturer. Also notify: National Response

6.4 Installed Equipment

It is recommended that all users should have an on-site spill prevention counter-measure and control plan which should be followed in the event of an accident.

6.4.1 Capacitors

Capacitors should be installed in accordance with 3.7.3.

6.4.2 Transformers

Transformers should be installed in accordance with Section 4.2.3.3.

6.4.3 Spills

In case of liquid spills due to leaks or equipment failures, the procedures outlined in sections 3.7.2 for capacitors and 4.2.3.2 for transformers should be followed.

7. REFERENCES

7.1 References to Text

- (1) Standard Method of Test for Rapid Gas Chromatographic Estimation of High Boiling Homologues of Chlorinated Biphenyls for Capacitor Askarels, [ASTM D3303-74].
- (2) American National Standard Method of Test for Specific Gravity of Askarels, C59.1965 (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 976-64 (1973), IP 139/65].
- (4) American National Standard Method of Test for Neutralization Number by Potentiometric Titration, Z11.59-1958 (R1971) [ASTM D664-53 (1966), 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)].

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(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 (Askarel) 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 Dissipation of Road Tars, A57.9-1974 [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, D11.6-1973 [ASTM D 92-74, TP 36/67].

(16) American National Standard Method of Test for Saybolt Viscosity, D11.2-1956 (R1971) [ASTM D 86-56 (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 (1973) [ASTM D 1905-63 (1973)].

(18) MURCH, R.H. Measuring the dissipation factor, dielectric constant, and resistivity of liquids. Insulation/Circuits, vol 16, Mar. 1973, pp 46-49.

(19) Chlorodiphenyls. Hygienic Guide Series. Hazenont, New Jersey: American Industrial Hygiene Association, Jan-Feb 1965.

(20) Standard Specification for Chlorinated Aromatic Hydrocarbons (Askarels) for Transformers, ASTM D 2203-72a1.

7.2 General References

Polychlorinated Biphenyls and the Environment, Interdepartmental Task Force on PCBs, Washington, D.C., May 1972. (National Technical Information Service, U.S. Dept. of Commerce, Springfield, Va. 22151.) (CON-72-10419).

DAWKIN, 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 199-199.

DAWKIN, C.K.; WARREN, M.F.; AND BENNET, G.A. The problem of possible systemic effects from chlorinated hydrocarbons. Journal of Industrial Hygiene and Toxicology, vol 19, 1937, pp 311-328.

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.

TRUON, J.F.; CLEVELAND, F.P.; CAPPEL, J; and ARCHLEY, R.W. The toxicity of the vapors of Aroclor 1242 and Aroclor 1254. American Industrial Hygiene Association Quarterly, vol. 17, 1956, pp 204-211

8. 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.

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APPENDICES

(These Appendices are not a part of American National Standard Guidelines for Handling and Disposal of Capacitor - and Transformer-Grade Askarels Containing Polychlorinated Biphenyls, C107.1 -197__, but are included for information purposes only.

APPENDIX A

Disposal Services

In addition to the supervised dry land fill sites that may be used for the disposal of askarel-containing scrap, the following additional known facilities and services have been established. For other facilities, call your regional Environmental Protection Agency Office. (See Appendix D).

The firms listed below (not all-inclusive) will accept PCBs for treatment or disposal, as noted. The Environmental Protection Agency does not endorse any of these firms or guarantee them for the environmental safety of their operations. Each of these firms has been contacted and reports having the required technical characteristics to adequately handle PCBs, in accordance with Recommended Procedures for the Disposal of PCB-Containing Waste (Industrial Facilities) as published by EPA in the Federal Register. The appropriate State or EPA Regional Office should be contacted for environmental suitability of the firm/site.

1. California Class I Landfills

- (a) Camalia Disposal Site
Santa Barbara, California (300-969-4703)
Bulk liquids and drummed materials.
- (b) IRI Corporation
Wilmington, California (213-775-3607)
All forms.
- (c) Environmental Protection Corporation
Richmond, California
All forms.
- (d) County of Los Angeles
Whittier, California (213-699-7411)
Facilities: Palos Verdes Calabasas
All forms.
- (e) San Diego County
San Diego, California (714-565-5703)
All forms.
- (f) Ventura County Dept. of Public Works
Ventura, California (805-648-2717)
All forms.

- (g) Richmond Sanitary Service
Richmond, California (415-234-3304)
All forms.

2. Chemical Waste Disposal Co.
Elizabeth, N.J. (201-351-5460)
Disposal by incineration.
3. Chem-Trol Pollution Services, Inc.
P.O. Box 200
1550 Balmor Road
Model City, N.Y. 14107
Phone: 716-754-8231

Can handle solids and liquids by incineration or land disposal.

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.

4. Hyon Waste Management Services, Inc.
Chicago, Ill. (312-646-0016)

Can handle solids and liquids by incineration.

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

Handles only liquid askarels manufactured by Monsanto. Disposal is by incineration.

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 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), gases are passed through a packed column scrubber to remove HCl. Asbestos liquids containing more than 1% water, or any phosphate esters cannot be accepted.

6. Nuclear Engineering Co., Inc.
Louisville, KY. (502-426-7160)

Facilities: Sheffield, Ill.
Deputy, Nev.

Disposal by landfill; Can handle drummed liquids and solids.

Nuclear Engineering Company
Eastern Division
P.O. Box 140
Northau, NY. 40551
Phone: 800-704-6011

Nuclear Engineering Company
Disposal Division
Sheffield, Ill. 61341
Phone: 315-454-2624

The 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.

7. Rollins Environmental Services, Inc.
P.O. Box 2349
Wilmington, Delaware 19899
Phone: 320-693-3541

This organization has facilities and services capable of handling:

(1) Liquids. Asbestos alone or mixed with solvents or oils. Disposal is by high-temperature incineration.

(2) Solids (software). Asbestos-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, New Jersey 08014

Baton Rouge:

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

Houston:

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

8. Texas Ecologists, Inc.
Robstown, Texas
Phone: 512-387-3518
Disposal by landfill..

9. Wes Con, Inc.
Twin Falls, Idaho (208-733-0897)

Receive packaged materials for disposal in missile silos.

10. Gadsco Environmental Protection Corp.
1313 Newburgh Rd.
Westland, Michigan 48185
Phone: 313-326-0600

Will accept transformers, capacitors and PCBs solidified in Imbiber* beads.

APPENDIX B

ANALYTICAL PROCEDURES AND LABORATORY SERVICE ORGANIZATIONS.

B1. General

Analysis for PCB in environmental samples is a tedious process due to the very low levels (ppb or ppt) which are of interest and due to the high sensitivity of the electron capture chromatographic procedure. It cannot be over-emphasized that extreme care must be taken to ensure first that the sample is representative and second that sufficient numbers of blanks,

and sample replicates are tested to define detectability limits and precision of the particular equipment and procedure being used. Cleanliness of sampling devices and containers and their extraction is also important. Analytical procedures for the determination of PCBs in air, water and sediments are given in section D3.

D2. Laboratories

For a listing of laboratories offering services for PCB analysis refer to Directory of Testing Laboratories publication STP333A available from the American Society for Testing and Materials (ASTM) 1916 Race Street, Philadelphia, Pa. 19103. If an outside laboratory is used, a verification of capability is recommended.

D3. Analytical Procedures

See ASTM D3304-74, "Analysis of Environmental Materials for Polychlorinated Biphenyls".

APPENDIX C

TRADEMARK DESIGNATIONS USED BY MANUFACTURERS FOR LIQUIDS CONTAINING PCBs.

Capacitors or transformers in service and liquid shipments showing the following trademark designations contain PCBs. Those have been or are in use and usually the designation appears on the nameplate or the warning label.

<u>DOMESTIC</u>	
<u>NAME</u>	<u>MANUFACTURER</u>
Aroclor	Monsanto
Aroclor B	Mallory
Asbestol	American Corporation
Askarel*	Hovi-Duty Corporation
Askarel*	Forrant-Packard Ltd.

DOMESTIC

<u>NAME</u>	<u>MANUFACTURER</u>
Askarel*	Universal Mfg. Company
Chlorextol	Allis-Chalmers
Clorinol	Sprague Electric
Clorphen	JARD Company, Inc.
Diaclor	Sangamo Electric
Dykanol	Cornell Dubilier
Elamox	McGraw Edison
Eucarel	Electric Utilities Corp.
Hylvol	Aerovox
Inertec	Westinghouse Electric
No-Flamol	Wagner Electric
Pyranol	General Electric
Saf-T-Kuhl	Kuhlman Electric

OFFSHORE

Clophen	Bayer (Germany)
Fenclor	Caffaro (Italy)
Kennecchlor	Kennecchlor (Japan)
Phenoclor	Prodelec (France)
DK	Caffaro (Italy)
Pyralene	Prodelec (France)
Pyroclor	Monsanto (UK)
Solvol	USSR

*World-wide generic name used for insulating liquids in capacitors and transformers that usually contain PCB's.

APPENDIX D

ENVIRONMENTAL PROTECTION AGENCY REGIONAL OFFICES.

Environmental Protection Agency
Region I, Room 2303
John F. Kennedy Federal Building
Boston, Massachusetts 02203
Telephone: 617-223-7265

Environmental Protection Agency
Region II, Room 909
26 Federal Plaza
New York, New York 10007
Telephone: 201-548-8730

Environmental Protection Agency
Region III
Curtis Bldg., 6th & Walnut Sts.
Philadelphia, Pa. 19106
Telephone: 215-597-9898

Environmental Protection Agency
Region IV
1421 Peachtree Street, N.E.
Atlanta, Georgia 30909
Telephone: 404-526-5062

Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, Illinois 60604
Telephone: 312-896-7591

Environmental Protection Agency
Region VI, Suite 1000
1600 Patterson Street
Dallas, Texas 75201

Environmental Protection Agency
Region VII
1765 Baltimore Avenue
Kansas City, Missouri 64108
Telephone: 816-374-5778

Environmental Protection Agency
Region VIII, Suite 900
1800 Lincoln Street
Denver, Colorado 80208
Telephone: 303-837-3600

Environmental Protection Agency
Region IX
160 California Street
San Francisco, California 94111

Environmental Protection Agency
Region X
1200 Sixth Avenue
Seattle, Washington 98101
Telephone: 206-442-1263

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ABSTRACT

This document presents the findings of a study of available wastewater management and treatment technology for the purpose of determining toxic pollutant effluents concentrations and daily load achievable in three industrial categories: polychlorinated biphenyls (PCBs) manufacturing; capacitor manufacturing; and transformer manufacturing.

All plants in the above categories have PCB discharges to either waterways or sewage treatment plants, under normal operating conditions. All plants have discharges to storm sewers or directly to waterways under heavy rainfall conditions.

Extensive survey of wastewater treatment technologies and cooperative laboratory work with several suppliers of treatment equipment and research facilities has confirmed that carbon adsorption technology is the best current candidate for successful removal of PCBs from the wastewaters. As an alternative uv-ozonation was considered. This technology is still in the research stage; however, it offers potential of complete destruction of PCBs all the way to CO_2 , water and HCl.

Another adsorbent technology now in the development stage, AMBERLITE polymeric adsorbents, has demonstrated a PCBs removal efficiency roughly equivalent to carbon during laboratory tests. Further testing is needed with this adsorbent to accurately assess its potentiality.

For scrap oils and burnable solid wastes generated at these plants, high temperature, controlled incineration offers a straightforward method of destruction, whereas scientific landfilling appears to be the best suited mode of disposal for nonburnable contaminated solids.

Zero discharge objectives can be best achieved by eliminating discharge streams and developing recycle systems. All non-contact cooling water would be segregated, cooled, and recycled. All other wastewater streams would be pretreated. The portion of the pretreated water which would be used in the plant would be treated with carbon, while the excess water would be

incinerated in a specially designed system which would allow for energy recovery.

Supporting data, rationale for the selection of above recommended treatment technologies and associated costs are contained in this report.