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Topics:
PCB
Chemical analysis
Fires
Transformers
Pollution control
Insulating oils

EPRI EA/EL-5612
Project 2028
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Proceedings: 1987 EPRI PCB Seminar

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REPORT SUMMARY

SUBJECTS Hazardous and toxic waste management / Risk assessment and management methods / Transmission substation design and operation / Distribution substations

TOPICS

PCB	Transformers
Chemical analysis	Pollution control
Fires	Insulating oils

AUDIENCE Environmental managers / Distribution engineers

Proceedings: 1987 EPRI PCB Seminar

An EPRI-sponsored seminar explores the increasingly complex issues of PCB management. This year, retrofill and decontamination technologies discussed at the last seminar are reaching maturity or are commercially available. Participants also addressed the necessity of spill cleanup and methods that meet that need.

BACKGROUND EPRI regularly sponsors an industrywide seminar to update utilities on the newest equipment and processes for managing the complex problems posed by polychlorinated biphenyl (PCB). Discussion topics ranged from initial development of equipment and methods to processes now commercially available.

OBJECTIVES To provide a forum for discussing equipment and methods for PCB management; to avoid duplication of research effort through an information exchange; to inform equipment suppliers of utility PCB management needs.

APPROACH Approximately 325 representatives of utilities, government agencies, research groups, and private industry from around the world attended a PCB seminar held October 6–9, 1987, in Kansas City, Missouri. More than 60 presentations summarized research in such areas as PCB destruction, analysis, spill cleanup, risk analysis, and fires, as well as mineral oil decontamination and retrofill and replacement fluids. PCB destruction discussions focused on thermal treatment of PCB and PCB-contaminated soils, as well as sampling and analysis criteria for evaluating destruction methods. Other areas of discussion included processes for removing PCB from contaminated transformer oil and coolants, equipment for testing PCB-contaminated soils, PCB environmental transports, and pyrolysis and combustion of PCB-contaminated transformer fluids. Several papers described pilot plant projects, case studies demonstrating new equipment, processes and cleanup methods, and commercial PCB removal processes.

RESULTS Some technologies described at previous seminars have advanced to commercial or semicommercial stages. One such technology is retrofilling, replacing either PCB or contaminated oil with fresh oil to reduce PCB content, usually to below the strictest EPA regulatory level of 50 ppb. Improved techniques for decontaminating mineral oil containing PCB are commercially

available. Spill cleanup and disposal of askarel transformer carcasses are areas that still require improvements. Ongoing EPRI work (project RP2028-19) is studying disposal techniques for detanking transformers and dismantling and cleaning components for scrap or disposal.

EPRI PERSPECTIVE

The large number of people attending the 1988 PCB seminar reflects the need of those involved in PCB management to discuss common problems and goals. Participants—nearly 125 of whom were from member utilities—came from the United States, Canada, Great Britain, Belgium, Mexico, and Japan. They represented many disciplines, including PCB analysis, risk assessment, and disposal, as well as research and development of equipment to facilitate these tasks. EPRI reports EL-2572, EL-3581, and CS/EA/EL-4480 present proceedings from the 1981, 1983, and 1985 seminars.

PROJECT

RP2028
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Environment Division; Electrical Systems Division

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October 6–9, 1987

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ABSTRACT

The 1987 PCB seminar continued EPRI's series providing timely information on PCB research to utilities, regulators, and contractors. The papers in this seminar showed a significant increase in technical level over those presented in the 1981, 1983, and 1985 meetings.

Subjects covered in the three and one-half days meeting were:

PCB Destruction
Mineral Oil Decontamination
Analytical Techniques for PCBs
Spill Cleanup and Management
Risk Analysis and Management
PCB Fires and PCDF Analysis
Retrofill and Replacement Fluids
Miscellaneous Subjects

[redacted]

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ACKNOWLEDGMENTS

We would like to acknowledge the help of our session chairmen who kept the long meeting on schedule throughout. Claudia Runge again did a superb job on meeting arrangements and administration. Roseanne Frank and Yolanda Gale contributed both to the preparations for the meetings and these proceedings.

Thanks to all.

CONTENTS

PART 1:

REGULATIONS

UPDATE ON PCB REGULATIONS

An Address

by

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EPRI PCB Seminar
Kansas City, Missouri
October 6, 1987

Areas to be Addressed

I. PCB Spill Cleanup Requirements

II. Changes in the Rules Affecting the Use of PCB Transformers - 52 Fed. Reg. 31738 (Aug. 24, 1987)

III. Changes in the Rules Affecting the Use of PCBs in Concentrations Under 50 ppm - 52 Fed. Reg. 25838 (July 8, 1987)

IV. Disposal of PCBs: To Be or Not To Be Under RCRA

Materials Attached

1. H.R. 2685 submitted by Rep. McCloskey

2. H.R. 3070 submitted by Rep. Synar

3. The coalition group's regulatory proposal to EPA

4. EPA's response to the coalition

For those of you who do not know me, I must begin by stating that for the past 8 years I have been legal counsel to the electric utility industry on PCB issues. It is a wonder to see all of you here this morning, still fascinated with PCBs eleven years after the passage of Section 6(e) of the Toxic Substances Control Act which specifically regulated the substance. This turnout is either a great tribute to EPRI and Gil Addis or a reaffirmation that in 1976 Congress created yet another relief act for lawyers, consultants, regulators, vendors and assorted others.

Gil Addis asked me to open the program by updating what has happened to PCBs on the federal regulatory front since the last seminar in early 1986. Given the longevity of the PCB regulatory program, one might think that such a review would be quite short. Surely, by now, you would think the program must be fairly regularized and unchanging. The opposite is true in fact. A fair amount has happened over the last 20 months. These activities fall roughly into four areas: 1) establishment of

specific spill cleanup requirements; 2) changes to the 1985 regulations affecting the use of PCBs in PCB Transformers, 3) changes to the regulations affecting the use of PCBs in concentrations under 50 ppm, and, finally, 4) the apparent resolution of the question whether the regulation of PCB disposal would be transferred from TSCA to the Resource Conservation and Recovery Act (RCRA). A few of these matters will be addressed in detail by later speakers. I will therefore try to restrain my remarks so as not to intrude unduly into their efforts. However, to set the stage for these speakers and provide a backdrop for the week's presentations, I will run through these four significant actions.

Spill Cleanup Requirements

EPA's PCB spill cleanup requirements under TSCA were signed by the Administrator on March 20, and published April 2, 1987, in the Federal Register (52 Fed. Reg. 10688). This action ended a lengthy period of negotiation, agitation and frustration that began about four years ago when the issue of spill

cleanup was first discussed by the utility industry with the Agency.

Early in those discussions, the electric utility industry presented a study to EPA urging a performance standard approach to cleanup. EPA listened, but that was about all.

Then in May 1985, the utility group joined in the development of a consensus proposal with NEMA, CMA, EDF and NRDC in which the cleanup requirements were based on the mass of the PCBs spilled and the location of the spill, including a performance-based approach for contaminated mineral oil spills -- that is, for spills of fluid containing a PCB concentration of 50 ppm and over. EPA did not act on the proposal until the late spring of 1986, at which time the Agency raised concerns about several of the provisions in the consensus.

Further discussions ensued with EPA during the summer of 1986, followed by additional discussions among the consensus groups. A revised

consensus agreement was submitted to EPA in October 1986 in an attempt to deal with some, but not all, of EPA's concerns. Thus, although certain changes were made in the October 1986 Agreement, the basic structural approach remained the same, including continuation of performance-based, visible trace/wash-wipe cleanup requirements for contaminated mineral oil spills (again only those from a source contaminated with 50 ppm or more of PCB).

The EPA requirements reflect the basic structure proposed by the consensus group by imposing different cleanup requirements based on the mass of PCBs spilled and the location of the spill. In addition, other very important aspects of the consensus also were adopted, such as: the visible trace/double wash-wipe approach for contaminated oil spills; the soil cleanup standards for most substations; the avoidance of penalties for improper disposal if there is good faith compliance with the cleanup requirements, and imposition of national cleanup standards for the vast majority of spills.

Along with the good, of course, came some changes which were not welcome; but more of this later.

In brief, the more significant requirements cover the following matters:

Scope: The requirements became effective May 4, 1987, and apply to the cleanup of new spills from sources contaminated with PCBs in concentrations of 50 ppm and above. Spills directly into water, sewers, vegetable gardens and animal grazing land are not covered and will be considered by the regions on a site-by-site basis. This approach varies somewhat from the consensus agreement which only excluded spills into water and sewers.

Definition of Spills: Adopting the language contained in the consensus proposal, a weep is not a spill.

Mass of PCBs Spilled: The requirements distinguish between spills involving at least 500 ppm or more than one pound of PCBs versus those below 500 ppm and one pound. This demarcation is not exactly as proposed in the consensus, but it is largely the same as a practical matter.

Low Concentration Spills: A visible trace/double wash-wipe standard applies to all spills under 500 ppm, assuming less than one pound by weight of PCBs is spilled, wherever located as proposed in the consensus. Mineral oil equipment that is not tested can be assumed to contain less than 500 ppm as set forth in the current regulations. One important change, however, is that cleanup must be completed within 48 hours, whereas, under the consensus, cleanup only had to be initiated within that time. There are exceptions for bad weather conditions, operating emergencies, etc., as proposed in the consensus. In addition, if the spill reaches an indoor, residential surface, that surface must be cleaned to 10 ug/100 cm^2.

Higher Concentration Spills: The cleanup requirements for spills of 500 ppm and greater (or more than one pound of PCBs by weight) vary depending on location. Some changes have been made in both the definition of the various locations and the levels of cleanup required. The basic distinction among substations, other restricted areas and non-restricted areas (residential/commercial area in EPA'S parlance) are retained, but with some changes that still may be significant.

For example, EPA accepted the consensus soil standard of 25 ppm or 50 ppm with a posted notice for the outdoor substations, but removed the wash-wipe (plus notice) performance standard option for solid surfaces, requiring instead cleanup to 100 ug/100 cm^2. EPA also adopted the alternative of getting regional guidance if meeting these standards would jeoperdize the structural integrity of the substation.

EPA, however, defined outdoor substations to include only those that are at least 0.1 km from a residential/commercial area. Similarly, other

restricted access industrial areas must be a like distance from a residential/commercial area to so qualify. This limitation for many utilities essentially brought a large proportion of their substations, and even some generating facilities, within what would be defined as a residential/commercial area.

Because of their concern about such a result, the utilities approached EPA on this issue. Specifically, we urged EPA to set aside the 0.1 km limitation. EPA, however, had based this limitation, at least in part, on its risk assessment and would not delete the 0.1 km limitation until further analyses are made. The Agency, though, did recognize the problem and clarified that for purposes of measuring the 0.1 km distance, the measurement can be taken from the actual spill site to the building in which people live or work. Thus, measurements from property lines, roadways and fence lines need not be made. We obtained a letter from EPA confirming this clarification just before the requirements became effective.

Another major change from the consensus agreement involves the cleanup standard for indoor vaults. Under the consensus, all of these vaults would have been classified as restricted access areas and the owner of the equipment would have the option of using a triple wash/wipe approach to solid surface cleanup or to sample and clean to a level of 100 ug/100cm^2. EPA, however, classified all of the vaults in a way that requires additional cleanup and removes the performance based option. Under EPA's approach, if the vault is in an industrial location, there is an option, but the option is to clean up to 10 ug/100 cm^2 or to 100 ug/100 cm^2 plus encapsulation. If the vault is within a residential/commercial area, there is no option and cleanup is to 10 ug/100 cm^2. Encapsulation is not yet defined, but EPA has indicated that encapsulation includes painting, although its clear preference is for an epoxy-type application.

Another change from the consensus involves the cleanup level for soil in residential/commercial areas. EPA's standard is set at 10 ppm plus a

10-inch cap. This change was one we expected, but do not welcome. In addition, solid surface cleanup requirements for residential/commercial areas are more stringent than proposed by the consensus group and largely require clean up to 10 ug/100 cm^2. These requirements are confused by adding distinctions based on whether the area is low-contact or high-contact, indoors or outdoors, and whether the surface is impervious or non-impervious. All of these terms are specifically defined; however, in general terms, cleanup to 10 ug/100 cm^2 is required for sidewalks and most everything else in or around a house or populated building. An option is provided to clean up to 10 ug/100 cm^2 or 100 ug/100 cm^2 plus encapsulation for wooden utility poles, roofs, and asphalt or concrete roadways.

Reporting: One change that initially appeared to be significant seemed to require a report to the regional offices for all spills over 50 ppm involving at least 10 pounds of PCB material (i.e., 10 pounds of contaminated oil). This provision may have been based on the OTS office's misunderstanding

of the Superfund reporting requirements, or something more sinister may have been intended. Whatever, EPA clarified that its "intent" was to carry forward the Superfund requirement; thus only spills involving 10 pounds of PCBs by weight are reportable. This "clarification" also is included in the letter I received.

The reporting requirements, however, nonetheless expand previous standards by requiring a report to the EPA regional office of spills of any size (50 ppm and greater) into surface waters, sewers, drinking water, grazing lands and vegetable gardens.

Ability of Regions to Impose More Strigent Requirements: For industry, one of the more advantageous provisions involves the issue of compliance and what the regions and the enforcement offices can and cannot do. Thus, for spills covered, a region cannot impose a more stringent requirement unless it first consults with the director of the Office of Toxic Substances in Washington, makes a

specific finding regarding the need for the added cleanup and notifies OTS of this finding prior to implementing the cleanup. On the other hand, regions can allow less stringent cleanups in particular situations; here, all the region need do is notify OTS of its decision and the reason therefor. Finally, if the cleanup requirements are followed, there can be no enforcement against the spill itself as improper disposal.

Future Use: As a last item, let me mention what happens when the use of the land changes. Our interpretation is that this should involve a change in ownership as well as use, but the provision could be read much more narrowly. The consensus proposed that where the use changed, the property would be cleaned to the level associated with that use. EPA modified the provision to require cleanup to the most strigent standard whenever the use changed. Thus, as I read it, if a substation were sold for industrial use, the land would have to be cleaned down to 10 ppm.

Miscellaneous: Other aspects of the requirements largely incorporate the consensus approach, e.g., definition of spill area, recordkeeping requirements and sampling methods.

While EPA adopted some of the consensus group's proposals, several of the requirements are proving to be infeasible. Most notable are the standards for cleaning vaults and substations. In addition, EPA has raised the question of whether these or other uniform standards should be adopted for cleanup of old spills. The utilities are therefore again gearing up for another round of data gathering, argument, persuasion and negotiation.

Use of PCB Transformers

The next two areas of activity affecting the use of PCB Transformers, on the one hand, and the use of PCBs in concentrations below 50 ppm, on the other, both emanate from judicial challenges to rules earlier adopted. I will discuss each of these actions in turn.

As you may recall, in July 1985, EPA issued new rules substantially restricting the use of PCB Transformers in or near commercial buildings -- here we are talking only of transformers that contain PCBs in concentrations of 500 ppm or more. Those rules also grew out of an earlier challenge to the 1982 use rules, which in turn were issued in response to a challenge to the original 1979 use rules.

To bring the matter a little more down to earth, let me only go back to the 1982 rules in which, with one exception relating to food and feed facilities, EPA permitted the continued indefinite use of PCB Transformers. An appeal of that determination was filed by the Environmental Defense Fund and the Natural Resources Defense Council. That appeal eventually was settled when EPA agreed to hold a new rulemaking relating to the use of PCB Transformers and the effects of their involvement in fires.

That rulemaking culminated in July 1985 when EPA issued amended rules severely restricting the use of PCB Transformers in or near commercial buildings. In brief, the changes:

- Prohibited the installation of a PCB Transformer in or near commercial buildings as of October 1985.

- Prohibited the use of higher secondary voltage network PCB Transformers in or near commercial buildings as of October 1990.

- Required the installation of certain protective equipment on lower secondary voltage network PCB Transformers and all radial PCB Transformers in or near commercial buildings as of October 1990, and

- Provided certain registration requirements to building owners and fire departments by December 1985.

Judicial review of these rules was sought by Mississippi Power Company. Negotiations ensued to resolve several issues for nearly a year. These matters included the prohibition on the reinstallation of PCB Transformers after October 1, 1985, the requirement to install certain protective devices on lower secondary voltage network PCB Transformers in or near commercial buildings by October 1990, and the absence of a time schedule in which to comply with many of the requirements if a mineral oil transformer assumed, as allowed under the rules, to contain under 500 ppm of PCBs, later was determined to have a concentration above that level.

The negotiations were concluded in the fall of 1986 and a settlement agreement between Mississippi Power, EPA and the Department of Justice was submitted to the court.

The settlement covered a number of areas.

For example, two provisions in the July 1985 rules posed particular practical and technical problems. The first concerned the prohibition on the installation of a PCB Transformer after October 1, 1985. The second involved the requirement to provide electrical protection for lower secondary voltage network PCB Transformers. A third major concern focused on the failure of the rules to provide any time frames for complying should a mineral oil transformer later be determined to be a PCB Transformer.

Two important concerns were raised regarding the prohibition on installing a PCB Transformer in or near a commercial building as of October 1, 1985. The first involved a situation where an outrage could occur depriving customers of service if a replacement PCB Transformer could not be installed. The second involved the "Catch-22" circumstance of retrofilling a PCB Transformer for purposes of reclassifying it and yet being unable to place it into service so that it could meet the 90-day in-service requirement to

qualify for such reclassification. EPA recognized both of these practical concerns and was affirmatively responsive on these issues.

The Agency's willingness to change the requirement for additional protective equipment for the lower secondary voltage network transformers was somewhat less enthusiastic. Much information was submitted to show the addition of this protective equipment is in most cases technically and economically infeasible. The dispute therefore focused on the time frame in which this equipment will be phased out and resulted in a different schedule applying to network transformers in sidewalk vaults as opposed to such equipment inside buildings. In the latter case, non-sidewalk vaults, there is a choice: protective equipment by October 1990, or removal or retrofill of the PCB Transformer by October 1993. PCB Transformers in sidewalk vaults are to be removed or retrofilled to below 500 ppm by October 1993.

The third principal area of concern, as I said, focused on the question of what you have to do when, after you discover that a mineral oil transformer, permitted under the rules to be considered to be PCB-Contaminated Electrical Equipment, actually contains PCBs in a concentration of 500 ppm or more. This problem, of course, has always existed in terms of complying with the marking and inspection requirements, but the matter became more acute with the changes imposed by the July 1985 rules. A reasonable schedule was agreed upon that addresses each of the added requirements that would attach to the continued use of such a transformer.

A number of other concerns also were raised regarding the practical application of the rules. For the most part, satisfactory clarifications have been made in Q and A form published in the Federal Register on December 31, 1986. The provisions include the definition of residential property, the notification required to be made to building owners, the storage of combustibles, the question of whether a fuel oil storage tank is a combustible material as

that term is used in the rules -- it is not -- and the question of whether an office facility within an industrial plant is a commercial building -- it may be depending on certain factors.

To further implement the settlement, EPA published proposed changes to the rules in the Federal Register on August 21, 1987. The proposal tracked the proviaions agreed upon, but EPA raised the poasibility of modifying a couple of the proposals and sought comment on those matters. For example, the settlement would require newly-discovered PCB Transformers to be registered within 30 days of identification. The question of whether thia time frame is too long is raised. In addition, EPA asked whether a deadline should be placed on the time period allowed for reclassification of a PCB Transformer. Comments on the proposed rule changes were due October 5. The utilities have opposed changing the 30-day registration requirement and have argued that no deadline be placed on the time period allowed for reclassification, or if one is imposed, that it be no shorter than 36 months.

Under the settlement a final rule is expected in late spring 1988. Even with the settlement, though, the real impact of the July 1985 use rules is that a large proportion of PCB Transformers will be removed from service over the next several years at great cost. I only hope that the materials used in substitution are free from the problems that have been perceived about PCBs.

Under 50 ppm

Changes affecting the use of PCBs under 50 ppm also have been proposed recently to implement a settlement reached following a judicial challenge to the July 1984 incidental generation rule. The proposal was published July 8 in the Federal Register and the comment period closed September 8. Tim Hardy, who speaks next, will talk broadly about the myths and realities of EPA and stste regulation of so-called non-PCB electrical equipment. Let me, therefore, just outline some of the changes EPA proposed and the reaction of the utility industry to those changes.

In brief, the current proposal expands the category of materials that are excluded from regulation and addresses several conditions that will and will not apply. Thus, EPA proposes

- to eliminate the requirement for workers to wear Viton elastomer gloves when working on heat transfer or hydraulic systems;
- to exclude from the TSCA bans, products containing less than 50 ppm PCBs and to allow the continued use and distribution in commerce of component parts derived from the rebuilding or salvaging of electrical equipment containing PCBs at levels less than 50 ppm, and
- to allow the recycling and burning of used oil containing less than 50 ppm PCBs, subject, however, to certain conditions.

The utilities were generally supportive of these proposals, with certain exceptions.

Specifically, the utilities urged EPA to exempt from all regulation the burning of used oil containing concentrations of PCBs less than 50 ppm in utility boilers and to expand the product exclusion to permit the use, processing and distribution in commerce of component parts from PCB-Contaminated Electrical Equipment, i.e., parts from equipment that contained PCBs in concentrations between 50 and 500 ppm.

EPA generally proposes to exclude used oil containing under 50 ppm PCBs from the prohibitions of TSCA Section 6(e), by including such material within the class of "excluded PCB products." The Agency conducted a comprehensive analysis of the risks posed by these materials and correctly, the utility industry believes, determined that the minimal risks presented by materials containing less than 50 ppm PCBs are far outweighed by the enormous costs associated with regulating these materials.

To fall within the exclusion, however, burning of under-50 ppm used oil must be conducted in

certain units. Among these units would be "qualified incinerators," which include high efficiency boilers that operate under the conditions now set forth in the TSCA regs, as well as industrial boilers and furnaces allowed to burn off-specification used oil fuel under the RCRA rules.

Notwithstanding EPA's findings that the burning of used oil in "qualified incinerators" and industrial boilers and furnaces does not pose an unreasonable risk to health or the environment, the Agency nonetheless proposed to impose certain notice and certification requirements on owners and operators engaged in these burning activities (i.e., "burners"). Specifically, the proposed regulations would require that before a "burner" accepts the first shipment of used oil containing less than 50 ppm PCBs from a marketer, the burner would have to provide the marketer with a one-time written and signed notice certifying that the burner had complied with the "notification requirements" applicable to (1) qualified incinerators under TSCA's PCB control program or (2) industrial furnaces or boilers under RCRA's used oil burning rule.

The utilities believe that requiring qualified burners of used oil containing less than 50 ppm PCBs -- particularly owners and operators of utility boilers -- to notify EPA of their burning activities is not only unwarranted from an environmental perspective, but equally important, will significantly deter otherwise qualified burners from engaging in used oil recycling activities. Indeed, the Agency itself acknowledges that such controls may be unwarranted: it states that the submission of comments "regarding actual boiler combustion conditions and overall impact of the proposal on the recycling of used oil" may persuade EPA not to impose any controls on the burning of used oil containing under 50 ppm PCBs, including the above-referenced notification requirements.

The Agency's primary concern underlying the proposed controls on burners is the potential for the formation of polychlorinated dibenzofurans ("PCDFs") resulting from the incomplete combustion of used oil. As the Agency itself recognizes, however, the potential for PCDF formation during the burning of

used oil containing under 50 ppm PCBs in qualified combustion units is insignificant. In fact, in a study conducted by EPA's Office of Toxic Substances evaluating the influents and effluents from seven coal-fired utility boilers, the Agency detected no level of PCDFs from any of the media sampled from the seven utility boilers analyzed.

This result is to be expected in view of the fact that temperatures in the main furnace chamber of utility boilers generally are in excess of 1,500 degrees centigrade, far above the 270 to 700 degree centigrade range where PCBs have been shown to be precursors to PCDFs. Moreover, temperatures in the furnace outlet of utility boilers range anywhere from between 1200 to 1300 degrees centigrade, again, far above the temperatures where PCB combustion may lead to the formation of PCDFs. Finally, the residence time of fuel in the combustion zone of a coal-fired boiler is approximately 1.57 seconds, with an additional 3.22 seconds to the base of the superheater platens under maximum operating conditions.

In short, due to high boiler temperatures and relatively long residence times, the potential for PCDF formation from the burning of used oil containing under 50 ppm PCBs in utility boilers is virtually nil, and certainly does not "present an unreasonable risk to health or the environment."

Not only is the proposed notification requirement unwarranted from an environmental perspective, but such controls would also have a "chilling effect" on utilities wishing to engage in used oil recycling activities. Simply put, the imposition of any additional regulatory controls -- including notification requirements -- on used oil burning activities may well serve as a disincentive to engage in such practices. Specifically, the industry is wary of the fact that a purportedly innocuous notification requirement (such as exists today to burn 50-500 oil) can and has been used as a "hook" by regulatory authorities to impose operating controls on PCB management operations which go far beyond the scope of the applicable regulations. This over-reaching on behalf of enforcement personnel has

resulted in many utilities shying away from the use of their boilers to burn used oil containing PCBs in concentrations between 50 to 500 ppm, although they otherwise easily meet all of the criteria specified in the regs.

In addition, a simple notification submitted to EPA declaring that a facility is engaged in the burning of used oil containing PCBs -- no matter how small the concentration or how safe the practice -- is often the basis of unwarranted public outcry and the genesis of groundless litigation.

In sum, there is no reason to require notification from an environmental perspective and every reason to withdraw such a requirement. The imposition of a notification requirement on utilities burning used oil containing less than 50 ppm PCBs will serve as a significant deterrent to qualified utility boilers recycling this valuable material. This result is completely antithetical to EPA's stated goal of encouraging used oil recycling in qualified combustion units. Accordingly, USWAG urged

EPA to abandon the proposed burner notification requirement as it applies to utility boilers burning used oil containing under 50 ppm PCBs.

Looking now at the proposal regarding component parts EPA proposes to extend the definition of "excluded PCB products" to those products which consist of component parts derived from the rebuilding or salvaging of electrical equipment containing PCBs at levels less than 50 ppm. The proposal does not go far enough, however.

EPA acknowledges that "recycling activities involving these components [do not] present any significantly greater risks than other activities connected with the unrestricted use of 'non-PCB' electrical equipment." The same conclusion applies to the recycling activities involving components derived from the unrestricted use and servicing activities of PCB-Contaminated Electrical Equipment. EPA previously has determined that the unrestricted use and servicing of PCB-Contaminated Electrical Equipment does not pose an unreasonable risk of

injury to human health or the environment. Therefore, no reason exists to restrict the use and distribution in commerce of components derived from such activities. The utilities, therefore, urged EPA to expand ths final rule to include within the definition of "excluded PCB products" those products which consist of components/parts derived from the rebuilding or salvaging of PCB-Contaminated Electrical Equipment.

Regulation of PCB Disposal: To Be or Not to Be RCRA?

Let me close this report by briefly commenting on an upcoming matter, the question of whether the regulation of PCB disposal would be transferred from TSCA to RCRA.

About one year ago, EPA established a working group within the Office of Solid Waste to develop regulations that would transfer the regulation of PCB disposal from TSCA to RCRA. It was generally understood that the impetus for EPA's action stemmed from statements made by Lee Thomas,

when he was Assistant Administrator for Solid Waste, to the Committee of Conference on the 1984 RCRA amendments that PCBs would be brought into the RCRA program. In addition, Congressional inquiries during the summer of 1986 concerning a few facilities handling PCBs raised concerns that the TSCA program might not be adequate. Specifically, hearings had been held by Rep. Synar of Oklahoma concerning disposal practices and the Rose Chemical facility in Missouri and by Rep. McCloskey of Indiana concerning the siting of Unison's plant in Henderson, Kentucky.

At about this same time, a combination of industry and environmental groups were completing discussions with EPA concerning PCB spill cleanup requirements. The conversations inevitably turned to the question of what, if anything, EPA was going to do in response to the concerns raised in Congress and statements by those within the Agency that the regulation of PCB disposal would be brought into RCRA. While the consensus group had diverse views on the ultimate resolution of the spill cleanup requirements, there was unanimous agreement within

the group that not one of them was enthusiastic about moving the PCB disposal program to RCRA and some were outright opposed to such an endeavor. There also appeared to be a willingness on EPA's part to discuss the issues on a consensus basis, in part drawing on the procedures followed to address the spill cleanup issues.

As a result, beginning some time last fall a series of informal discussions ensued, principally at the request of industry, to review the questions of whether the PCB disposal program should be transferred to RCRA, what problems such a transfer would cause, and whether there were alternative solutions to the perceived deficiencies -- putting aside whether those problems were genuine from an environmental perspective or merely political.

Over the next several months -- really into the spring of this year -- a number of exchanges took place with EPA concerning the myriad of issues arising from any proposal that would transfer the PCB disposal program from RCRA to TSCA. Suffice it to

say, that many of these problems were major and were recognized as such by EPA

There emerged quite soon from these discussions a decided narrowing of what the real concerns were; they included, manifesting, identification of brokers, financial responsibility, and permitting requirements.

In addition, it was clear that changes would have to be made in the EPA enforcement program to avoid or at least minimize the concerns that developed following an examination of the history of enforcement at the Rose Chemical site and at a few other facilities. For example, Rep. Synar again held hearings in April 1987 focusing on the Rose Chemical case. While the attempt to cause a sensation with an unidentified, masked, secret witness later backfired when the witness recanted his testimony, it was nevertheless clear that enforcement efforts had perhaps been less forceful than required.

All though this period the utility industry and others urged EPA and interested members on the Hill to act under TSCA to implement any needed modifications since this approach would provide an orderly and cost-effective accommodation to the concerns raised.

As time went on, we began to receive signals that EPA was seriously changing course back to TSCA. Congressional staffers to whom I spoke clearly wanted new initiatives from EPA on manifesting and permitting, but they seemed less concerned over what statute underlay those controls than the need for timely action.

While no specific announcements have been made by EPA, the matter seems to rest squarely on the TSCA side of the house today. The leader of the RCRA working group has been reassigned, and the Chemical Control Branch within the Office of Toxic Substances is developing new regulations. On the Hill, things are less clear since new measures proposed go in diverse directions.

H.R. 2685, submitted by Rep. McCloskey, would apply all of the regulations under Sections 3004 and 3005 of RCRA relating to the siting of disposal, storage or treatment facilities to all new and existing facilities treating, storing or disposing of PCBs. The bill, in my view, would create an impossible, if not chaotic, situation. If adopted without change, it imposes, rather than confronts and solves, most of the major and minor problems recognized early on when a possible wholesale transfer of the PCB disposal program from TSCA to RCRA was discussed. The bill was referred on June 24 to the Subcommittee on Transportation, Tourism and Hazardous Materials of the House Committee on Energy and Environment. The Subcommittee is chaired by Rep. Luken of Ohio; Rep. Dingell of Michigan chairs the full committee.

The second bill, H.R. 3070, was submitted in August by Rep. Synar. It seeks to fill certain perceived gaps in the TSCA regulatory program by requiring manifesting, permitting of intermediaries -- that is, brokers and others who arrange on a

commercial basis for remuneration for the transportation, treatment, storage or disposal of PCB waste for others, and the implementation of financial responsibility requirements for these middlemen. This bill, too, was referred to Mr. Luken's subcommittee.

Turning back to EPA, activities at the Agency roughly fall into two categories.

The first activity, known as the National Evaluation Plan (NEP), involves a review of enforcement initiated by the Office of Toxic Substances last October. That effort was an attempt to respond to external criticisms of EPA's enforcement program and the activities, or lack thereof, of the regions. The program was completed in May. While I have not seen the report, it is my understanding that the most significant recommendation is that the headquarters office maintain closer oversight of the regions, particularly regarding implementation and enforcement of disposal facilities. Steps, I understand, are being taken to implement this recommendation.

The second activity was triggered -- or at least prodded if not triggered -- by the submission of suggested regulatory language by the industry and environmental coalition. These proposals cover manifesting, permitting for intermediate activities, identification of commercial storage facilities and an attempt to regularize permitting conditions for disposal facilities by requiring implementation of certain training programs, the establishment and implementation of closure and post-closure plans, and a demonstration of financial responsibility in connection with closure and post-closure activities. In large measure these proposals are similar to the changes contemplated in Rep. Synar's bill, but they would provide a bit more flexibility for the regulated community.

The coalition recently received a response to its proposal from EPA. The Agency expressed its agreement with the group "that the necessary changes can be accomplished more expeditiously through regulatory amendments based on existing. TSCA authority than through mandated changes." EPA also

indicated that it has formed a working group within the Office of Toxic Substances to address these matters and tailor RCRA-type requirements to the "unique attributes of the PCB waste universe...." The Agency then turned to the coalition's proposal and first noted that it considers "manifesting and notification regulations to be the highest priority among the areas which the....[coalition] identified as candidates for regulatory amendments." I will leave for another time the comments EPA addressed to several specific aspects of the coalition's proposals since the whole matter is in a state of flux.

However, in a separate communication, EPA has indicated that it intends to propose new TSCA rules next March or April to cover many, if not all, of these areas. The OTS staff has been thinking about these matters for quite some time. Therefore, while EPA's response to the coalition's suggested language may be somewhat indicative of the direction in which the Agency will go, the actual proposals may reflect a fresh view by OTS and well may contain some surprises.

In conclusion, then, let me draw on a phrase made famous in Congressional hearings years ago -- while there once may have been an intention on EPA's part to regulate the disposal of PCBs under RCRA, there is not now and may never be such a program.

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EPA AND STATE REGULATION OF NON-PCB ELECTRICAL EQUIPMENT: THE MYTHS AND THE REALITIES

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Despite unique and sweeping Congressional declarations in 1976 on all polychlorinated biphenyls (PCBs), when the Environmental Protection Agency (EPA) issued in 1979 the comprehensive regulatory scheme mandated by the Toxic Substances Control Act (TSCA), its controls applied only to materials containing 50 parts-per-million (ppm) or more PCBs. Over the last eight years, concerns have arisen about the viability of the 50 ppm cutoff -- leading some to question whether such low-concentration materials are truly unregulated. Review of the history of EPA's PCB regulations and their interpretation, and of state regulations that supplement the Federal rules, shows the answer is yes.

I. A SHORT HISTORY OF TSCA PCB REGULATION

In 1976, with the passage of TSCA, Congress banned future manufacture of PCBs and directed EPA to regulate comprehensively all processing, distribution in commerce, use, and disposal of previously manufactured PCBs.[1] In 1978, in its disposal rules, and again in 1979 in its rules for processing, distribution in commerce, and use, EPA determined that no such regulation was required for materials containing less than 50 ppm PCBs. [2]

EPA's 1979 decision not to regulate less than 50 ppm PCB-containing material (but not its 1978 disposal decision) was challenged by the Environmental Defense Fund (EDF) in the U.S. Court of Appeals for the District of Columbia. [3] Although agreeing that some cutoff might be justified, the Court, in 1980, found EPA lacked substantial evidence to justify the 50 ppm cutoff.[4] The Court thus remanded to the Agency the 1979 rules.

Thereafter, in each of the Agency's subsequent five PCB rules, the 50 ppm cutoff has been reiterated as an important part of the regulatory framework:

First, the disposal regulations have always applied only to materials containing 50 ppm or greater PCBs.

Second, EPA's new national spill cleanup guidelines apply only to spills of material containing 50 ppm or more PCBs. [7]

Third, the TSCA regulations of various types of equipment containing PCBs, as issued in both the 1982 Electrical Equipment Rule that addressed spills and leaks and the 1985 Transformer Fire Rule that addressed combustion by-products, are keyed to the 50 ppm cutoff. For example, while authorizing use of PCBs "at any concentration" in transformers, EPA imposes a number of controls on all transformers containing 50 ppm or more PCBs, up to and including prohibition of use in certain locations of transformers containing more than 500 ppm PCBs. [8] EPA, moreover, permits transformer owners to avoid these regulatory controls and prohibitions by servicing transformers to reduce PCB concentrations below 50 ppm -- labeling such reclassified transformers "non-PCB." [9] Such less than 50 ppm equipment is not only authorized for use and reuse, but also for distribution in commerce. [10]

Fourth, EPA's rules allow products with concentrations of inadvertently generated PCBs below 50 ppm to be manufactured, processed, distributed in commerce, and used without being subject to TSCA rules. [11]

Finally, EPA's marking and recordkeeping regulations apply only to materials with more than 50 ppm PCBs. [12]

In its most recent regulatory action on PCBs -- proposed amendments pursuant to a settlement agreement of judicial challenges to the Inadvertent Generation rule -- EPA reaffirmed that: "The 'non-PCB' status of [electrical] equipment is a favored status under the TSCA PCB regulations." [13] The Agency continues: "Indeed, the regulations encourage owners and operators of electrical equipment to perform servicing that 'reclassifies' their more highly contaminated equipment as 'non-PCB' equipment, which equipment is essentially free from TSCA regulation."

The Agency goes on to discuss the inapplicability of the PCB disposal regulations to "non-PCB" equipment. It notes that any disposal, including salvaging, that terminates the life of non-PCB fluid or equipment falls outside the TSCA disposal regulations. It further notes that although salvaging that leads to reuse of "non-PCB" equipment involves both "use" and "disposal," the reused parts are "excluded PCB products" that can "be freely incorporated into other electrical equipment, or distributed in commerce for the purpose of reuse in electrical equipment."

The only TSCA restrictions relevant to non-PCB fluids are the two mixed use/disposal requirements, one prohibiting use of waste oil with any detectable PCBs as a coating, sealant or dust control agent, [14] and the other considering the burning of waste oils for fuel recovery as an

unauthorized use. In the recent proposed revisions, EPA clarified the latter interpretation by proposing to prohibit burning of used oil containing quantifiable levels of PCBs in nonindustrial boilers, while authorizing such burning in qualified TSCA PCB incinerators and high efficiency boilers or RCRA incinerators.

In sum, seven years after the Court of Appeals told EPA it had not compiled substantial evidence to justify an across-the-board 50 ppm cutoff, the Agency has issued five new major regulations and proposed another that each factually justifies and retains the cutoff.

II. CONCERNS ABOUT THE 50 PPM CUTOFF

Despite the continued recognition of the 50 ppm cutoff in EPA regulations, a number of questions have arisen.

First, fears are heard persistently that EPA is planning to reduce the 50 ppm cutoff for reclassification of electrical equipment as non-PCB. Such fears are unwarranted and should be quieted by the Agency's recent declaration that it "has no plans at present to regulate the use of PCBs ... in transformers containing less than 50 ppm." [13]

Second, questions also began to arise about the viability of the 50 ppm cutoff when EPA issued its 1984 Inadvertent Generation Rule. That rule deleted from the TSCA regulations the previously included definition that PCB means only materials containing 50 ppm PCBs or more. [14]

When confronted with the problem created by the 1984 regulations, EPA admitted it had not fully considered the widespread implications. The Agency agreed to roll back the 1984 prohibition on use and distribution in commerce of less than 50 ppm material. EPA, moreover, made it clear that the 1984 rule amendments do not apply to authorized electrical equipment. EPA's proposed revisions of its PCB rules this summer were consistent with the Settlement Agreement. [15]

Third, more recent questions about the viability of the 50 ppm cutoff have arisen at several "PCB Symposia" where the position has been taken that EPA's anti-dilution rules prevent fluids and carcasses that were once "PCB" from being outside the disposal rules once they have been reclassified "non-PCB." To the contrary, EPA has strongly encouraged reclassification, and part of the intended encouragement is the authorization for such transformers, once reclassified, to avoid not only the use regulations for higher classifications, but also the corresponding disposal rules. The Agency has just recently reaffirmed that once reclassified, a non-PCB transformer "shall retain that reclassification status for the remainder of its useful life, even at the time of its ultimate disposal." [16]

Finally, EPA has announced on several occasions since 1984 that it is contemplating transferring PCB disposal regulations to the Resource Conservation Recovery Act (RCRA) hazardous waste regulatory system. A number of industry and environmental groups have urged the Agency not to transfer the PCB disposal rules to RCRA. It is, moreover, quite unlikely that disposal regulation revisions will alter the 50 ppm lower limit. Writing to EPA in support of industry's position in opposition to RCRA

transfer, the Environmental Defense Fund and Natural Resources Defense Council noted explicitly that they are opposed to "reopening every single issue regarding the disposal of PCBs, such as the 50 ppm cutoff." [17] Marcia Williams, head of EPA's RCRA Office of Solid Waste, also has noted that "[i]t's very likely we won't open" the 50 ppm issue. [18]

III. STATE REGULATION OF PCBS

Despite the comprehensive system of Federal PCB regulation, a few states have found it appropriate to issue their own unique regulations. Almost without exception, those state regulations however, also apply only to above 50 ppm PCB material.

Approximately half of the states have no PCB regulations and thus leave PCB regulation entirely up to the Federal TSCA rules. Several states have listed materials containing more than 50 ppm PCBs as hazardous wastes under their state administered RCRA programs. One state regulates materials with 500 ppm or greater PCBs as RCRA hazardous wastes.

A few other states enacted laws in the mid-1970's, and others did so more recently, paralleling TSCA Section 6(e). Some, like TSCA, impose bans on manufacture and controls on use, processing and distribution in commerce. Others are limited to disposal regulations. Each of these states have, however, implemented these statutes in a fashion identical to, or paralleling, the Federal regulations and, accordingly, following the 50 ppm cutoff.

Questions arise in only a few states about regulation of PCB concentrations below 50 ppm. California has listed as RCRA hazardous wastes liquids containing more than 5 ppm PCBs. Washington and Wisconsin have implemented disposal rules for less than 50 ppm material. And Texas, although having no PCB regulations or statutes, considers any spill containing more than 1 ppm PCBs as reportable if it endangers state's waters.

In each of these four states, the rules are of limited practical significance to owners of non-PCB, less than 50 ppm, electrical equipment. Washington and Wisconsin, for example, basically exempt equipment owners from disposal and spill cleanup requirements that otherwise apply to less than 50 ppm material. California and Texas, although imposing cleanup requirements on such fluid, recognize the requirements are not difficult to achieve for such low concentration material and that the other benefits of non-PCB status still essentially apply.

CONCLUSION

One consistent thread runs throughout the history of PCB regulation. EPA has consistently concluded that it need not regulate materials containing less than 50 ppm PCBs based on findings that such materials do not pose unreasonable risks. State regulations -- with few exceptions -- follow the same pattern and thus do not alter the basic EPA conclusion that less-than 50 ppm PCB material is "essentially free" of regulation. If electrical equipment is non-PCB, or is reclassified as "non-PCB," it is unregulated just as new transformers are unregulated.

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[1] Section 6 (e) of the Toxic Substances Control Act, 15 U.S.C. § 2605 (e).

[2] 43 Fed. Reg. 7150 (Feb. 17, 1978); 44 Fed. Reg. 31514 (May 31, 1979).

[3] EDF v. EPA, 636 F.2d 1267 (D.C. Cir. 1980).

[4] EDF v. EPA, 636 F.2d at 1279-84.

[5] 52 Fed. Reg. 10688, 10689, 10705 (April 2, 1987).

[6] 40 C.F.R. § 761.30 (a).

[7] 40 C.F.R. § 761.30 (a)(2)(v).

[8] 40 C.F.R. § 761.20(c)(4).

[9] 40 C.F.R. §§ 761.1(f), 761.3 & 761.20 (b)(1).

[10] 40 C.F.R. §§ 761.40, 761.180.

[11] 52 Fed. Reg. 25838, 25854 (July 8, 1987).

[12] 40 C.F.R. §761.20(d).

[13] Letter from Martin P. Halper, Director, Exposure Evaluation Division, EPA Office of Toxic Substances, to Timothy S. Hardy (Feb. 27, 1987).

[14] 49 Fed. Reg. 28172 (July 10, 1984).

[15] 52 Fed. Reg. 25838 (July 8, 1987).

[16] Letter from John J., Neylan III, Director, Policy and Grants Division, EPA Office of Compliance Monitoring to Timothy S. Hardy (July 1, 1987).

[17] Letter from Jacqueline Warren to Marcia Williams (April 24, 1987).

[18] See, "Pesticide & Toxic Chemical News," at 6 (May 20, 1987).

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ABSTRACT

This paper was generated to provide an overview of the options available to Canadians for the handling of their PCB wastes. Without going into the merits of specific technology available for each option, it is meant to show that progress is being made to formulate a long range, permanent solution for the control of Polychlorinated Biphenyl waste material within Canadian borders.

CURRENT STATUS AND OPTIONS FOR
HANDLING AND DISPOSAL OF PCB'S WITHIN CANADA

As recently as the early 1980's, Canadian opinion surveys designed to determine general knowledge of Polychlorinated biphenyls inevitably would evoke a response ranging from total ignorance of the substance to mere mild interest. Since that time, however, there has been a dramatic increase in public concern and knowledge of P.C.B.'s. This public awareness has been initiated by the media coverage of the April, 1985 spill of PCB waste material on Highwey #7 in Northern Ontario near the city of Kenora. This instance involved the shipment of PCB contaminated transformers from the Province of Quebec to a storege site in the Province of Alberta. Media coverage of this event drew a very large response in the public sector due to the fact it involved a large stretch of well travelled highway and the direct involvement of a family who had been following the transport truck as the liquid waste was leaking.

Although there had been more serious instances involving P.C.B.'s prior to the Kenora spill, noteably the December 9, 1977 Toronto fire involving some 450 litres of askarel, the response to this particular media event acted as an encouragement for similar future coverage of P.C.B.'s and their related hazards.

Far from being a critique of the media, it was, and is, coverage such as this which has enhanced public awareness (although not necessarily complete), of Polychlorinatad biphenyls and particularily their biproducts Polychlorinsted dibenzofurans (PCDF's) and Polychlorinated dibenzo-p-dioxins (PCDD's). Recently there has been a spate of daily news reports concerning PCB spills and the long term effects of the compound. Each of these reports inevitably questions what is to be done with this material, if not today then in the very near future. This constant exposure to the public eye has heightened awareness of

the problem and in turn increased the pressure on the politicans to come up with an answer, and soon.

It should be stressed at this point that the particular problems involving PCB's, especially with regard to distribution and handling, have been a major concern of Environment Canada as well as the Provincial Ministries of the Environment since the early 1970's. Originally conducted in response to the results of studies carried out in connection with the PCB contamination of rice oil in Yusho, Japan in 1968, Environment Canada's research culminated in the enactment of the Environmental Contaminants Act on April 1, 1976. In its initial form this act required the full disclosure of all equipment containing PCB's (primarily for cataloguing purposes). The ECA has been expanded upon since its inception to include: a specification to the type of equipment in which PCB's could be used (1977); the overall ban of the importation or manufacture of new equipment containing PCB's (1980); prescribing the maximum concentration of PCB's in new equipment sold in Canada (i.e. 50 ppm) (1984); and the restriction of the quantity of PCB's that can be released into the environment (1984).

Another very important piece of legislation is the Transporation of Dangerous Goods Act (TDGA). The TDGA was passed in 1985 to regulate the documentation, handling and control of dangerous goods for all interprovincial and international transport. Due to the spill of PCB's near Kenora in 1985 the TDGA was ammended to include specific requirements for the packaging of PCB material. As well, each province has legislation, of varying severity, restricting and regulating shipment of PCB material within its' own jurisdiction.

The combination of the enactment of this legislation with the increasing media reports on "CRISIS" situations has led to a general belief that the only thing that can be done with PCB waste material in Canada is to "SIT ON IT". This, however, is not the only option which is available.

Currently we, in Canada, have been presented with basic options for the P.C.B. problem:

1. Maintenance of the Status Quo
2. Removal and Storage
3. Removal for Destruction

Maintenance of the Status Quo

This option, although seemingly static, is in fact rather progressive within a limited framework. It encourages the proper care of all PCB equipment still in operation. To do this it is now necessary to adhere to all legislated guidelines pertaining to the containment and maintenance of this apparatus. In addition to this, various Provincial Departments of Labour have issued guidelines for the education and training of operating personnel as well as the recommandation for the formulation of contingency plans to allow for prompt and proper reaction to a P.C.B. release.

At its best, however, this option represents only a stopgap measure. It certainly does not address an ever more common scenario of an owner of such apparatus facing increasingly stringent requirements to qualify for liability insurance coverage with the underlying threat of total disqualification in the future. This option is designed to maximize public safety while waiting for a more satisfactory and, hopefully, permanent solution to the problem.

Removal and Storage

This option constitutes the next step to the status quo solution. Jurisdiction over P.C.B. waste falls within Provincial legislation. For this reason Provincial Guidelines have been issued to allow for the storage of out of service contaminated equipment at an approved storage location. These storage sites would be presented in two forms. They could either be an "on site" location or a general public storage compound.

"ON SITE" storage constitutes a location set up according to the Provincial Guidelines which would still be within the same property lines as when the equipment was operational. A public storage location, on the other hand, would involve transportation to an approved location specifically designed for long term storage of P.C.B. waste.

Simple sounding solutions with only one drawback. As of today there

not one public storage site within Canada which is able to accept P.C.B. waste material from any or all concerned. There are a few in the planning stages - but none are within two years of being able to accept waste material. Because there are no public facilities available if you wish to store a spent transformer or capacitor bank it will be necessary to do so "ON SITE". Once again, as with the Status Quo option, this response will not alleviate the owners of this apparatus of their obligation to protect the public as well as their property from exposure of P.C.B. emission. For this reason, this too, remains as an interim and not at all satisfactory solution.

Removal for Destruction

As with the storage option the destruction process can be carried out either "ON SITE" or at an approved destruction facility. Recent technological advances now would allow for the destruction of low level (i.e. below 6000 ppm) liquid waste material on an "ON SITE" basis. This destruction could be carried out with either the Westinghouse Mobile Plasma Arc System or by Chemical Decontamination using a Sodium Filtration process, such as the unit being developed by Ontario Hydro. Extensive studies are being conducted as to the accuracy and reliability of these two processes. The time frame for full implementation of these technologies appears to be approximately two years away.

The final option would be to remove P.C.B. contaminated equipment and transport it to an approved destruction facility. Unfortunately, as in the storage option, Canada does not have an approved destruction facility. There is a site located at Swan Hills in Northern Alberta scheduled to commence operation in late 1987, however, the acceptance of P.C.B. waste material will not be allowed until possibly 1989 and then probably on an "Alberta First" program. This program would see PCB waste materials from the Province of Alberta given priority over similar material from other Provinces. It would appear therefore that access to this facility, for the purpose of P.C.B. destruction, on a Canada wide basis would not be available for several years past the 1989 schedule. There have been hints of other proposed destruction facilities being planned for Ontario and Quebec but, once again, there have been no firm dates given for their opening.

The only other option for destruction would appear to be transport to

e destruction facility outside of Canada. As of this date the Unite States are not available to Canada due to a lack of a reciprocal agreement on P.C.B. waste management. Under present legislation transportation of P.C.B. waste material to an overseas destruction site is possible although the process for approval is complicated. Not only must the owner meet all requirements under the TDGA but also the accepting site must fall within the Guidelines as set out by the ECA and those of the various Provinces involved. Under no circumstances would a shipment be allowed for storage purposes only. It would appear, therfore, that if the option of destruction is deemed the most acceptable by the owner of contaminated equipment to limit their increasing liability, the only immediate relief would be to ship their equipment to an approved overseas destruction site.

Having listed the options the question must now be asked: why does Canada not have an operational destruction facility for P.C.B. waste materials? Given the technology available today why can't a decision be reached?

To formulate an answer to these questions an understanding of the Canadian public is necessary. Canadians can be just as reactionary as any other group of people. Therefore, when constantly bombarded with headlines such as:

> "Hit by Cancer, worker claims major cover-up over PCB's"
>
> "Mother's milk still safe for babies despite traces of PCB's, expert says"

their kneejerk response is to call for an immediate solution. However, historically speaking, in situations such as this, when presented with a seemingly satisfactory solution we tend to be very conservative in our approach. An example of this would be the announcement in April of this year of the creation of a P.C.B. destruction facility in Tracy, Quebec (just outside of Montreal). On the surface this is what everyone had been asking for, however, within 72 hours, the Honorable Clifford Lincoln, Minister of the Environment for Quebec, had to retract his statement and cancel plans for this facility. Local pressure was applied by the citizens because they did not want the solution to be implemented in their backyard. This is the type of response which should be expected by every Ministerial suggestion

a destruction facility. Because of this expectation, Federal and most Provincial, Ministries have taken the long, slow route to ascertain what the best technology and locations are for such a technology and locations are for such a destruction facility. Public input into this process is invited and in fact encouraged. Therefore, when a site does appear to be possible the chances for approval and general public acceptance are greatly enhanced.

To conclude, it would seem that we, in Canada, have assumed the long, slow, plodding process for a solution despite growing external pressures for an immediate response. Taking all factors into account this would appear to be the most satisfactory approach as well as the one which will ultimately lead to a permanent solution without fear of having to start over from scratch. In the meanwhile, legislation is in place to assure the safe, ongoing operation of such equipment as well as provisions being given to accomodate those owners who, due to growing liability pressures, can not wait for a long term solution within Canada.

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3. Environment Canada, Manual for the Management of Wastes Containing Polychlorinated Biphenyls (PCB's), February, 1987.

4. Ontario Ministry of Labour, Occupational Health and Safety Division, Guidelines on the Prevention and Control of Occupational Exposure to Polychlorinated Biphenyls (PCB's), July, 1986.

PART 2:

RETROFILL AND OISPOSAL

AUTOMATED PCB TRANSFORMER FLUSHING AND SOLVENT RECOVERY SYSTEM

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ABSTRACT

An operating system is described for flushing (and soaking) the interiors of distribution transformers scheduled for disposal or servicing. The system has practical application in utility transformer and equipment repair centers and in similar contractor service operations. Mineral oil dielectric PCB concentrations can range from 499 ppm to 50 ppm or less. For dielectrics having 500 ppm PCB or more, or of the Askarel type, the system automates the 18-hour solvent-soak requirement. The flushing solvent is recovered for reuse by a PCB-separation process. In addition, salvageable transformer parts, i.e. bushings, and contaminated hand tools can be recovered in an optional decontamination-cleaning chamber. This chamber is a satellite unit as is supported by the main system.

Major system features include recovery of the flushing solvent, minimum labor requirements for operation, and reduced worker exposure to PCB's and solvents. Reuse of the flushing solvent results in significant reduction of waste volume requiring disposal.

APPLICATION BACKGROUND

A utility serving a major metropolitan area can typically replace from one to ten thousand distribution transformers annually[1]. Thesa transformers are predominantly pole-mount types with a smaller proportion being pad mounted units. While the replacement transformers are PCB-free, some units being replaced contain various concentrations of PCB's in the dielectric fluid. Most concentrations are below 500 ppm PCB[2]. The transformers removed from service may be scrapped outright, rebuilt, or serviced depending on size, value, condition, and PCB classification.

A transformer's PCB classification governs servicing and salvage options and carcass disposal requirements. Under the Toxic Substances Control Act (TSCA) the U.S. EPA has established transformer PCB classifications and disposal requirements for carcasses. These are:

- Non-PCB: mineral oil dielectric contains less than 50 ppm PCB; carcass disposal not regulated under TSCA*.

- PCB contaminated: mineral oil contains 50 ppm to 499 ppm PCB; transformer to be drained of all free-flowing liquids; carcass disposal not regulatad under TSCA*.

- PCB: dielectric contains 500 ppm or greater in mineral oil or is Askarel; the transformer is to be drained of all free-flowing liquids, filled and soaked with solvent for 18 hours, then thoroughly drained; TSCA regulates carcass disposal to chemical waste landfill or incinerator.

*These drained carcasses (non-PCB and PCB-contaminated) must be disposed of in accordance with other applicable federal and state regulations.

REGULATORY TRIPWIRE

The PCB disposal requirements under TSCA do not exempt transformer disposers from actions or liability under other environmental laws. A triggering event could be spillage or leakage of residual dielectric, containing detectable PCB's, from carcasses at a salvage or disposal site.

SYSTEM DEVELOPMENT

Several utilities were surveyed and responded that lacking secure and commercially viable disposal alternatives, potential environmental liability could be mitigated by first flushing the interiors of transformer carcasses (to remove residual dielectric) prior to approved landfill or other disposal options[3]. The flushing operation could be performed by a utility itself or available from a service contractor. Further, for transformers scheduled for detanking (servicing or rebuild), a prior flush would mitigate potential employee health and safety concerns regarding exposure to PCB's.

SYSTEM DESCRIPTION

Figure 1 depicts a system designed for use by utility repair centers or contractor service operations. The system is designed to solvent flush one or more distribution-type transformers (<500 ppm PCB) simultaneously, and recover the solvent for reuse. Solvent flushing effectively removes free surface and residual dielectric liquids from the interiors of transformer carcasses. For transformers with 500 ppm or more PCB or Askarel dielectric, the system automates the 18-hour solvent-soak processing requirement, prior to regulated carcass disposal.

The flushing system is composed of six major components: (1) a 1500 gallon solvent supply tank containing less than 2 ppm PCB, (2) apparatus for the solvent filling and draining of transformers, (3) a control panel, (4) a 1500 gallon contaminated solvent tank, (5) a solvent recovery (PCB seperation) subsystem, and (6) a 150 gallon holding tank for the separated PCB's and dielectric liquids. Solvent recovery (<2 ppm PCB) is achieved using a physical separation process or distillation. Recovery rate is a nominal 60 GPH. No form of PCB destruction occurs in the system.

Figure 1 shows two pad-mount transformers being flushed using an auto-stop filling nozzle and connections to the drain valves. Smaller pole-mount units (lacking such access ports) are filled and drained using a wand attachment inserted through a hole punched in the top cover.

Not shown is an optional cleaning chamber (24"W X 18"D X 24"H) used to remove PCB contaminants, oil, grease, and dirt from salvageable transformer parts and power and hand tools. The chamber is of the sealed glovebox design, thus completely isolating the operator from contaminants, solvent and vapors during operation. Cleaning action is a jet spray of pressurized (100 psi nominal) solvent and is directed by a hand-held spray gun. This satellite unit is completely supported by the main system.

APPLICATION CONSIDERATIONS

This system is designed to mitigate potential environmental liability by providing an economical means to remove dielectric residues from distribution transformers prior to carcass disposal or salvage action. While this measure does not entirely remove the basis for potential liability associated with carcass disposal, it should be viewed as an interim option until secure and commercially viable transformer salvage (metal recycle, PCB destruction) operations are widely available. Nevertheless, the system makes solvent flushing affordable by providing a means to

recover flushing solvent for reuse. Avoided incineration costs are significant, since solvent disposal volume is reduced 50:1 or more when compared to non-recovery approaches.

To operate the system, a permit is required from the U.S. EPA and perhaps other regulatory agencies. Current U.S. EPA regulations require permit approval since the PCB separation process used is considered an alternative to the required incineration of PCB contaminated flushing solvent. The system has received operating permit approval at one or more locations.

The flushing solvent is Freon® 113 or TF, a liquid at room temperatures. In addition to its ideal application properties, it was selected primarily from a health and safety viewpoint. The solvent is three to four times higher in cost than other solvents and may incur a surcharge for its disposal. However the system was designed to minimize solvent losses to the atmosphere and as a still bottom. Operating data shows solvent losses are within design criteria.

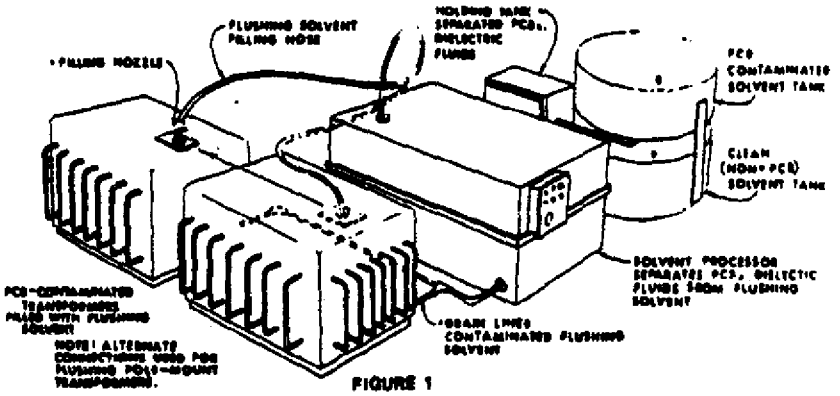

FIGURE 1

TRANSFORMER FLUSHING & SOLVENT RECOVERY SYSTEM ISOMETRIC

OPTIONAL PARTS CLEANING CHAMBER NOT SHOWN

ACKNOWLEDGMENTS

The author wishes to acknowledge the Electric Power Research Institute, Florida Power and Light Company, Georgia Power Company, Hydro Quebec, Potomac Electric Power Company, and the General Electric Company for their support and cooperation.

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PCB RESIDUE IN ASKAREL AND CONTAMINATED OIL-FILLED TRANSFORMERS

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ABSTRACT

The elimination of PCBs from electrical equipment is of considereble concern today. This report discusses the results of measurements made to charecterize the amounts and locations of PCB residues in transformers during end after disassembly.

Several askarel transformers were drained, fillad with trichlorotrifluoroethane (R113) for eighteen hours, drained again and the core-coil assemblies were untanked. The clamps were removed, the core laminations were separated, and the coils were unwound. The materials in the various substructures were accumulated separately and the metallic and ceramic parts were separated from the cellulosic and other polymeric parts wherever possible. The weights of tha various components were measured during disassembly and wipe samples for PCB analysis were taken from surfaces such as the tank wall after the R113 soak, the separated core laminations, and the unwound high and low voltage conductors. Samples of core laminations and conductors were saved for further cleaning and samples of insulation components were set aside for later measurement of PCB content and porosity. In some cases, the remaining laminations, conductor lengths, insulations, etc were soaked separately in weighed amounts of R113 which were later analyzed for PCBs. The retained metallic components were cleaned by immersion in an R113 degreaser for up to two hours and wipe samples were taken.

"PCB contaminated oil"-filled units were torn-down following this sama procedure, but with two differences. Initial R113 soaks and the last cleanings of metallic parts were omitted. Three companion units were refilled with fresh PCB-free oil and allowed to stand, one loaded continually to a top oil temperature in excess of 50°C and one energized. The three were regularly sampled to compare the buildup of PCBs to the amounts of residue estimated from the tear down results.

The weights and analytical results were used to reconstruct the distributions of PCBs in the verious substructures as the tear-down progressed. These distributions are presented and tha implications of these results to disposal and retrofilling of transformers conteining PCBs are discussed.

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PCB Contaminated Distribution Transformer Reclassification Study

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ABSTRACT

In August, 1986, a study with the following objectives was begun:

1. Determine what effect, if any, the loading of transformers has in the process of removing PCB from the core and coil of a drained, flushed and refilled distribution transformer.

2. To determine the loading required to achieve the 50°C oil temperature specified in 40CFR761.30a.2.V.

3. To determine whether the use of temperature sensitive labels on the tank is an adequate method to monitor oil temperatures.

INTRODUCTION

In order to conduct the study, 12 transformers, in for repair, were selected. All 12 units were General Electric; 6 were 15 kVA and 6 were 25 kVA. Their original PCB content ranged from 62 to 245 ppm. The transformers were handled routinely in so far as the draining of the old oil, flushing the core and coil and refilling with new oil.

The transformers were delivered to a substation yard for testing. Six of the transformers (3-15 kVA and 3-25 kVA) were mounted on poles and six were placed on the ground beneath. Test reference numbers P1 thru P6 (on poles) and G1 thru G6 (on ground) indicate their locations. In order to monitor transformer temperatures, thermocouples were used.

In October, 1986, the transformers were energized as follows:

P1 thru P6	Primary and Secondary at rated voltages 7620V and 120/240V respectively
P1, P3, P4 and P6	Primary and Secondary at rated voltages with 80% full load current circulated
G1 thru G6	Not energized

In order to achieve the 50°C specified, current was raised from 80% load current to 120% load current on December 3, 1986. Attached is a diagram of the circuit used. The circuits were metered as shown in the diagram. A record of the meter readings was kept.

Oil samples were drawn weekly (at first) from the transformers. Samples were drawn using the following procedure:

1. Yard was de-energized and 480/240V supply switch was opened.

2. Transformer tank hend hole covers were removed.

3. Samples were drawn from top oil using disposable plastic pipettes.

4. Pre-labeled disposable sample bottles were used to deliver samples for in house PCB analysis by gas chromatography.

Results of the PCB analysis are included in graphic form. The results thus far indicate very little change in PCB concentration. Items of interest to note.

1. The PCB contamination of Transformer G4 seems to be somewhat outside the normal distribution although it has to this point remained below the 50 ppm level.

2. Two individual sample concentration (G5 on day 102 and P3 on day 42) appear to be anomalous.

Temperature data for the air ambient as well as the top oil temperatures of transformers P3 and P6 have been included. Tha data is reported in the form of a graph of the 24 hour average temperature. It should be noted that four transformers (P1, P3, P4 and P6) did achieve temperatures in excess of 50°C. Also, all twelve transformers have maintained PCB levels well below the 50 ppm specified. As a result, four transformers (P1, P3, P4 and P6) hava met the criteria specified in 40 CFR 761.30a.2.V for reclassification as Non-PCB transformers.

On January 14, 1987, (Day Number 102), the even numbered transformers were exchanged (P2 was deenergized and placed on the ground, G2 was put on the pole and energized. Likewise, P4 and P6). This exchange was done to reveal whether the loading will increase the PCB levels in G2, G4 and G6. Results indicated that PCB levels did not change significantly.

After consultation with the EPA, it was decided to bring in a larger sampling of transformers. As a result, six transformers of various manufacturer and size, labeled X1 thru X6 were drained, flushed and refilled with new oil. These transformers were used to replace some of those transformers that had already met the reclassification requirements. On May 15, 1987, transformers X1, X3, X4, X5, and X6 were energized at full load along with G2. All of the transformers have already reached the 50° C requirement. Again, the results to date do not show significant increases in the level of PCB in the transformer oil. As of this date the complete results of these transformers are not available.

Conclusions

1. To this date there have been no significant differences between the change in PCB levels in the various units regardless of the transformers loading. That is, all of the units have remained well below the 50 PPM level.

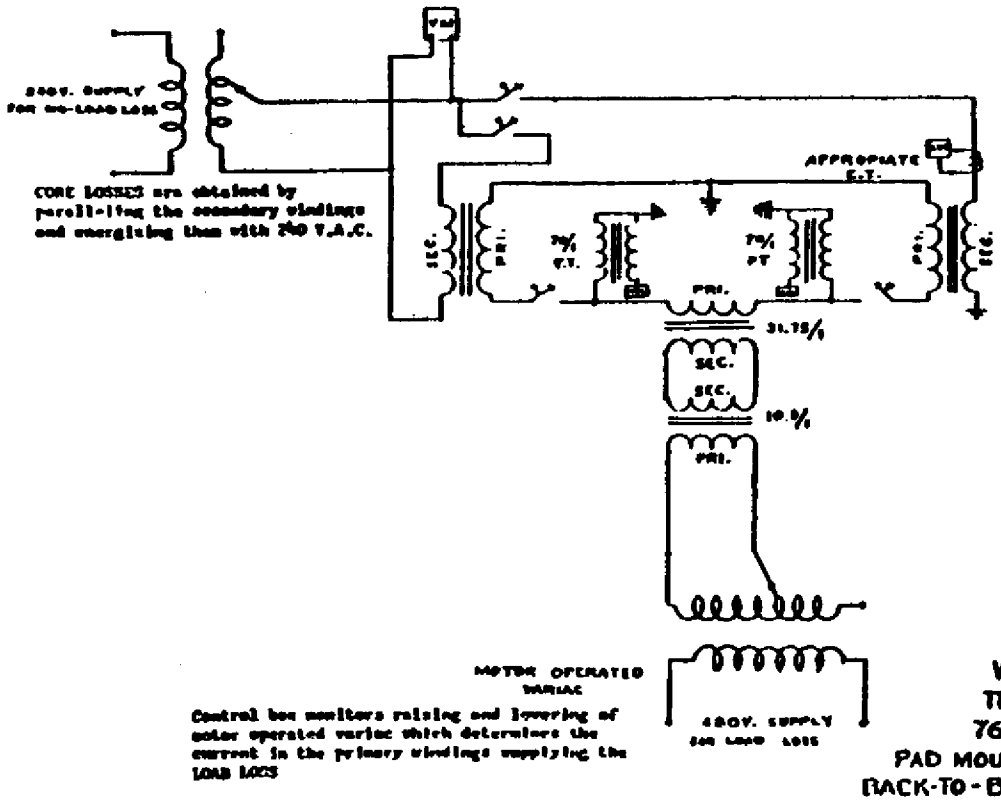
   By inference the experiment has proven that no large quantities of PCB lie hidden in the transformer core and coil. Logic dictates that where ever the PCB molecules travel, the oil solvent used in the flushing process may also enter. In my opinion this indicates that the "leaching" process is more or less the straight forward result of mixing two solutions of different concentration. It is also my opinion that in view of the above conclusions, the regulations

should be modified to allow for the reclassification of PCB-contaminated transformers on the basis of the draining of the oil, a flushing of the unit with new oil (0 PPM PCB), and refilling the unit with new oil.

2. This experiment was extended from the fall of the year through the summer. In general the results indicated that the tranformers experience approximately a 50°C temperature rise over ambient at approximately 100% full load. This is what would be expected.

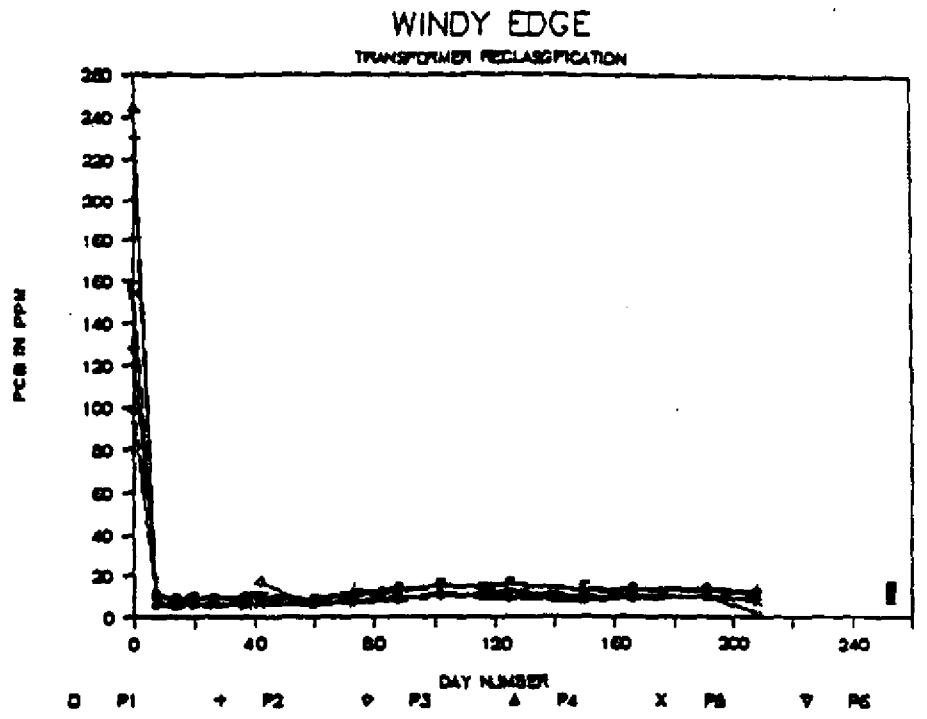
3. The use of temperature sensitive labels proved adequate.

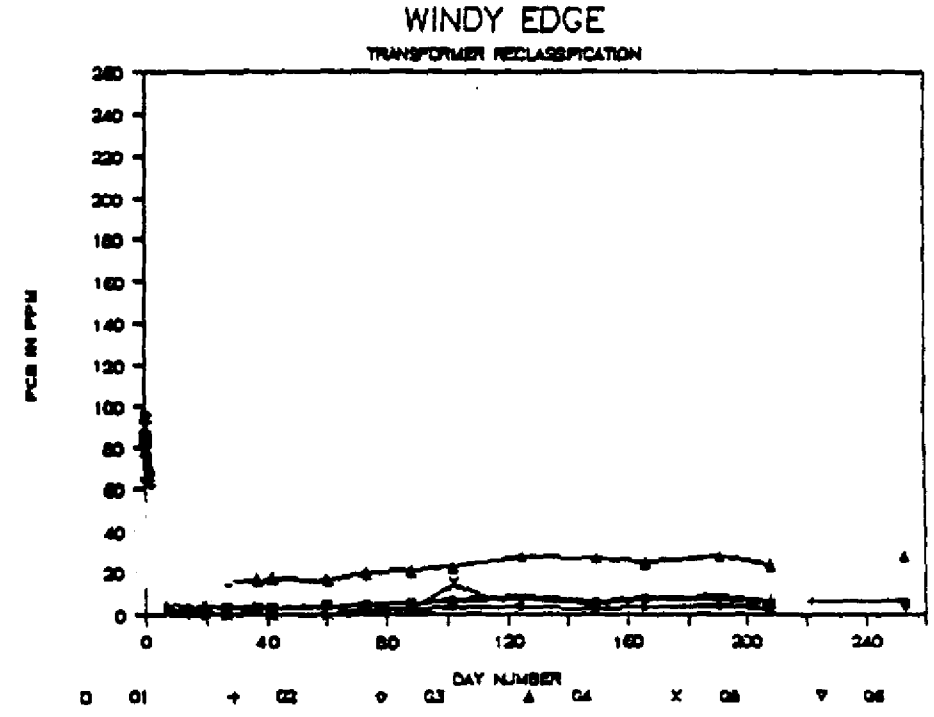
Revised 7/16/87

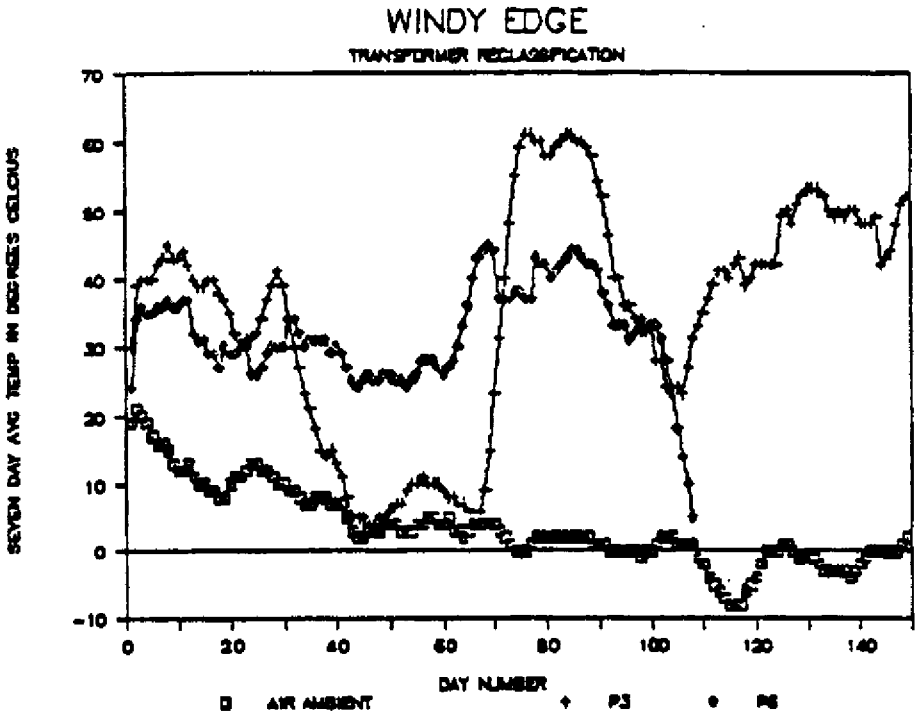


WINDY EDGE
TEST CIRCUIT
7620-120/240 V.
PAD MOUNT TRANSFORMERS
BACK-TO-BACK LOADING METHOD

MONS 217195


WINDY EDGE
TRANSFORMER RECLASSIFICATION
PCB IN PPM
DAY NUMBER
P1
P2
P3
P4
P5
P6


WINDY EDGE
TRANSFORMER RECLASSIFICATION
PCB IN PPM
DAY NUMBER
01
02
03
04
05
06


WINDY EDGE
TRANSFORMER RECLASSIFICATION
SEVEN DAY AVG TEMP IN DEGREES CELCIUS
70
60
50
40
30
20
10
0
-10
0
20
40
60
80
100
120
140
DAY NUMBER
AIR AMBIENT
P3
P6

MONS 217197

CONTINUOUS COLUMN TREATMENT OF PCB CONTAMINATION IN MINERAL OIL EQUIPMENT

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ABSTRACT

One of the biggest problems in re-classifying transformers to non-PCB status is achieving and maintaining a PCB concentration of less than 50 ppm after 90 days of service. Current technologies require repeated flushings and fluid replacements over an extended period of time to reach the 50 ppm goal.

IT has available a variety of technologies for the electrical power distribution industry. One of these is a technology that removes PCBs from mineral oil fluids continuously and destroys the PCBs. It was originally developed and tested by an electrical transformer service company in Italy and is now licensed by IT for use in the U.S.

The continuous treatment technology is based on an adaptation of patential and proprietary reagent formulations that use phase transfer technology to destroy the PCBs. Phase transfer components in the reagent facilitate transfer of the PCBs from mineral oil to the reagent where they can react and be destroyed.

The continuous treatment of PCB contaminated fluids is achieved by circulating the fluid through a cartridge containing the reagent in a solid form. The reaction by-products remain in the reagent phase. Use of the reagent in this mode enables simple equipment to be used. Treatment can either be done continuously or periodically to remove PCBs from individual transformers.

Pilot scale developmental testing of this technology has been performed. Mineral oil containing 1800 ppm Aroclor has been treated by circulating it through a one kilogram bed of reagent for approximately 90 hours. At the end of the run the Aroclor 1260 concentration in the mineral oil was reduced to less than 10 ppm. Trichlorobenzene was also reduced to <100 ppm.

systems have been designed for use in treating individual transformers. After connecting the solid reagent system to the transformer drain, the contaminated mineral oil is circulated through the reagent until the PCBs are reduced to the desired concentration. The system is simple in design and requirss little operator attention.

Treatment costs are expected to be less than one-half the cost of transformer replacement.

DESTRUCTION AND SALVAGE OF LARGE PCB TRANSFORMERS TO END OWNER LIABILITY

by

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ABSTRACT

Disposal of replaced transformers has long presented the owner with a dilemma. Current EPA regulations allow for landfill of PCB transformers in TSCA landfills, but only after draining and an 18 hour rinse. Although landfill is authorized, this disposal method is not without substantial potential for long term liability. The carcass can still contain up to 2% of its nameplate volume (20 to 100 lbs) soaked within its internals and the original owner remains responsible, jointly and severally, under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA or "Superfund"). Owners may attempt, by contractual means, to receive indemnifications from, or transfer title to, persons who have arranged for such disposal. Contractual indemnifications, title transfer and legal disposal are not allowable defenses in Superfund actions and will not prevent the original owner from being held liable.

TRANS-END℠ Service, introduced by UNISON Transformer Services, Inc. (a subsidiary of Union Carbide Corporation) solves this dilemma by thermally destroying transformer components and liquids in EPA authorized destruction facilities. Since the transformer and all PCBs are destroyed under controlled conditions by a EPA permitted destruction process, they no longer exist. Therefore, all future liability ceases and risk reduction has been complete and permanent.

The technology, developed by G & L Recovery Systems, Inc. of Ashtabula, Ohio, under R&D Authorization from EPA Region V, has been demonstrated on hundreds of askarel and PCB-contaminated oil transformers. A TSCA Operating Permit is expected by September 1987 and full commercial operation is planned to begin in the fourth quarter of this year.

BACKGROUND

Concern in the late 1960s and early 1970s about potential PCB environmental hazards, coupled with its long-term stability, resulted in the 1976 U.S. Congressional ban on PCB manufacture and use. Today, over ten years later, liquid cooled transformers remain as the largest single source of PCB exposure and as a result, the U.S. Environmental Protection Agency (EPA) has promulgated several sets of rules which severely regulate and restrict the use of electrical transformers containing PCBs.

To avoid the publicity, liability and costs associated with continued use of PCB containing transformers and maintaining compliance with these rules, there are only two viable options either retrofill or replacement. While retrofill of existing equipment is the least costly and easiest to option implement, for oil and askarel transformers, it may not be suitable in all cases. Transformers in poor condition, or which have failed, or changes in electrical systems require replacement and disposal of the removed carcasses.

Recent regulatory and congressional initiatives have been to encourage more permanent disposal technologies. In its interpretative guidelines to the EPA following the 1984 Hazardous and Solid Waste Amendments, Congress explained that these new provisions were necessitated by its finding that "land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment should be the least favorite method for managing hazardous waste". Thus, it is understandable why many owners of PCB transformers, particularly those with the deepest pockets, have been hesitant to replace and landfill transformers.

TRANS-END℠ Service was developed to process economically and safely the larger distribution class equipment of 100 to several thousand KVA in size. TRANS-END℠ Service is conducted with numerous controls, a rigorous QA/QC program, and extensive analytical protocol to monitor the progress and status of each transformer throughout the process. Liquid and incinerables (paper, linen, wood, etc.) are sent to one of several permitted PCB incinerators for destruction, while the metals (tank, laminations, windings, etc.) are solvent washed cleaned until each is shown by wipe samples to be PCB-free.

Disassembly and decontamination of an average 750 KVA transformer is achieved in less than eight hours. Analytical results needed to classify metals as PCB-free are available the next day. The Salvage Policy adopted by the US EPA in 1976 allows PCB-free metals to be sent to a smelter and recovered. This metal value offsets the additional costs of destruction over burial. Thus, TRANS-END℠ Service quickly, economically and safely loses transformer identity in a an authorized manner with analytical documentation provided.

Current EPA regulations require a TSCA permit and numerous controls to disassemble and decontaminate transformers greater than 500 ppm PCB (i.e. PCB transformers). Transformers less than 500 ppm PCB (PCB-Contaminated), however, can be decontaminated without a TSCA permit. While decontamination of PCB-contaminated transformers is legal, uncontrolled practices have led to the contamination of many scrapping operations in the past, making them potential Superfund cleanup sites and again exposing the transformer owners to further liability. Therefore, it is recommended that both PCB-contaminated and PCB transformers be destroyed through EPA authorized processes such as TRANS-END℠ Service because of the controls and extra assurances such authorization and permits provide.

LEGAL PRINCIPLES REGARDING LANDFILLING PCB

The public, Congress and regulatory agencies are moving increasingly to end landfilling of substances such as PCBs. Arguments against landfilling toxic chemicals have often been made by expert scientific groups and EPA.

MONS 217201

The comprehensive 1983 report on controlling hazardous waste by the Congressional Office of Technology Assessment (OTA) noted, for example, that "...and disposal, even if in compliance with RCRA,

probably poses some preventable risks both in the near term and for the future." OTA concluded, giving PCBs as an example, that "some untreatable wastes are so highly toxic that land disposal should not be used." This position was echoed by the National Research Council (NRC), which concluded that "..the use of landfills should be minimized since constituents will very likely migrate over long periods (more than 100 years) into groundwater."

Persons responsible for sending PCBs to landfills have been named as defendants in lawsuits at numerous Superfund sites. Although persons who transport carcasses to landfills may take title to the carcasses, such actions do not prevent the original owner from being held liable for the cost of cleanup should the disposal site be involved in a Superfund action. CERCLA holds both the original owner of the wastes and the transporter liable.

A transformer owner may also obtain, by contract, indemnification from persons who have arranged to dispose of the transformer carcass. Such contractual indemnification, however, is not a defense to government Superfund actions. Indemnification can be used only to seek reimbursement from the contracting party for any such Government-imposed liability. Moreover, some indemnification contracts covering transformer carcass disposal are narrowly worded in a manner that may lead to indemnification being denied. Indemnification limitations are exacerbated by the difficulty of obtaining insurance for liability for gradual release of toxic chemicals from landfills. Due to the massive liabilities now being levied for landfill disposal in the past, the insurance industry is often no longer willing to insure companies who dispose of toxic chemicals against long-term liabilities.

TRANS-EO℠ SERVICE

Transformer coolant is drained on-site and sent directly to an incinerator for disposal. When the drained carcass is received, remaining liquid residues or drainings from the core and coil assembly are removed prior to processing.

In the first step the transformer cover and bottom valves are removed and a small hole cut into the tank floor. The intact transformer then is hoisted into a primary cleaning tank and solvent washed. After completion, the transformer is evacuated, removing solvent from the transformer and its internals.

Next, the dry transformer is removed from the primary cleaning tank, transferred to a teardown area and completely disassembled. Metallic components are segregated by type and placed into containers for further cleaning. Embossed metal tags with transformer ID numbers are attached to each container for positive identification. Combustible solids (papers/gaskets/pressboard, etc.) are collected for incineration. The now empty can/tank and structural steel is reprocessed through the primary cleaning cycle until decontaminated. Entry and exit procedures,

housekeeping standards and dedicated equipment/tools are used within the teardown area. Contamination during disassembly, which has plagued other processors, is largely avoided by operating the primary cleaning stage in a manner which essentially removes all liquid residues and provides a dry transformer during teardown.

In the third step, the metallic parts are processed through several cleaning stages where surfaces are thoroughly cleaned. This method has enabled decontamination to exceptionally low levels; considerably below that established by the EPA Region V for PCB-free metal (less than 10 ug/100 cm^2).

After secondary cleaning, the containers are removed to a holding area, a yellow tag affixed, and wipe samples taken of all surfaces. When analytical results are received the next day, a green tag is affixed indicating all records and certifications have been received, satisfying EPA requirements for PCB-free, and the metals are now ready for smelting.

Over one hundered askarel and mineral oil transformers have been processed under two successive R&D permits to demonstrate and develop the TRANS-END^{SM} Service. Results of decontamination are shown in Table I. We have found all manufacturing types, sizes, and core and coil configurations can be processed successfully, generally with standard procedures. Only three construction features have required extra labor or effort. These have been: (1) welded tops, (2) ribbon-wound laminations, or (3) a failed winding.

With askarel transformers, greater than 75% of the windings are either kraft paper or linen wrapped with no impregnation used. Oil transformers of the size and voltage class processed, on the other hand, are typically wrapped with either paper or linen and impregnated with varnish. In all cases, the impregnated windings have been sufficiently brittle that complete stripping was easily accomplished.

The metals recovery realized with TRANS-END^{SM} Service makes full destruction competitive with disposal by burial and more attractive than burial when the elimination of long term liabilities is incorporated into the risk evaluation and decision process.

TABLE I

	ASKAREL TRANSFORMERS (400,000-900,000 PPM)	10 C OIL TRANSFORMERS (580-13,000 PPM)
Transformer Sizes Processed KVA	5-2000	45-1000
Average PCB Residual ug/100cm^2:		
Transformer Can	2.2	less than 0.1
Laminations	0.9	"
Windings	1.1	"
Range PCB Residuals ug/100cm^2:		
Transformer Can	01. - 4.5	less than 1.0
Laminations	0.1 - 2.5	"
Windings	0.1 - 2.7	"

OPTIONS AVAILABLE FOR ASKAREL TRANSFORMERS

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ABSTRACT

PCB transformers containing askarel fluid are typically used for indoor substation applications for critical power distribution within a facility. With the current EPA regulations, managers are faced with deadlines by which decisions must be made to solve the PCB dilemma.

This paper will discuss the motivating factors facing the manager and the current solutions available to make the proper decision for the best method to be employed. The active solutions available would include the retrofill method to reclassify the PCB transformer to NON-PCB status or the elimination of the PCB by a removal and replacement project. There are optional methods available for either approach, but cost effectiveness must be weighed against environmental concerns before a final decision can be reached that will satisfy EPA regulations.

OPTIONS AVAILABLE FOR ASKAREL TRANSFORMERS

The solutions available for the reclassification to NON-PCB status of askarel transformers have expanded to provide alternatives for the various types of substation installations. The particular installations, electrical characteristics, loading conditions and corporate policies as they apply to each transformer will dictate which option will provide be the best "risk management" decision for the PCB dilemma.

A distinction must be made that clearly differentiates contaminated mineral oil from askarel. Mineral oil, if containing PCB, could reach concentration levels as high as 20,000 parts per million. Askarel is typically in the range of 400,000 - 800,000 parts per million of PCB concentration. The PCB concentration in askarel transformers varied by manufacturer. Certain brand names such as: Pyranol, Inerteen, Chlorextol and Askarel indicate transformers that contain a fluid that is essentially "pure" PCB. All of these

brand names became generically known as askarel. The focus of this paper will be on these "pure" PCB transformers. There are three major options available for askarel transformers:

- Management and Containment
- Retrofill and Reclassification
- Replacement and Disposal

Initially, your company must determine whether the PCB problem will be handled in a passive or active manner.

The passive approach entails staying within the EPA guidelines and managing the PCB risk through a Management and Containment program. This course of action is the least expensive. In the case of companies with limited financial resources, it is usually the option of choice; and the passive approach is also chosen by companies whose facilities can not accommodate the extended outage that may be required for the retrofill method or the replacement of the PCB transformers. In cases such as these, Management and Containment programs are a viable temporary solution to the PCB problem. If the Management and Containment solution is chosen, the company may wish to implement a long-term program that will eventually eliminate the problem over a designated period of time.

The Management and Containment program is the broadest area of the three options and should include:

- Labeling of the transformers.
- Inspection of the transformers.
- Record keeping.
- Maintenance.

The four steps listed above should always be implemented even when an alternative solution is chosen some time in the future.

In cases where the Management and Containment approach has been chosen for the long-term, several risk-reduction techniques can be implemented in high-risk areas. Some of these techniques are:

- Diking for Spill Containment.
- Vaulting or Enclosing the Transformers.
- Current-limiting Fuse Protection Systems.
- Temperature Alarm or Trip Systems.
- Liquid-level Alarms or Trip Systems.
- CO_2 or H_2O Fire Extinguishing Systems.

- Air Isolation Valves on Air Handling Systems or Exhaust fans.

- Floor Sealers to Stop Penetration if a Spill Occurs.

- Wall and Ceiling Sealers to Stop Penetration if Fire Occurs.

- Periodic Oil Quality Testing Program.

There are several motivating factors which encourage companies to become active in dealing with their PCB problem:

- EPA Regulations have motivated many companies into action. The Food and Feed Industry was targeted by the EPA to eliminate PCBs by October, 1985. Some commercial office buildings have a target date of 1990. Other industrial facilities are not effected by the EPA regulations and could choose to continue to use their present electrical equipment.

- The Insurance Industry has also moved groups into action by increasing costs or by cancellation of catastrophic or accidental coverage.

- Risk Assessment and Company Policy have played large roles in the movement to remove PCBs. Corporate image, right-to-know movements by employees and exposure to risk by the presence of PCBs have also contributed to the movement.

- Leaking, Overloaded, and Poorly Maintained Transformers have encouraged system changes. Increased need for capacity or system upgrades have helped to reduce the PCB problems.

- Location of Transformers has been a factor in many cases. High-profile transformers overhead or on gratings above employee work areas or walkways may be good candidates for replacement activities. Units next to waterways or sewer systems may also need attention.

- Time will eventually move more and more companies into action.

- Cost will motivate commercial and industrial facilities into the active role of allowing funds to meet certain deadlines.

The active approach to solving a company's PCB problem would be to either retrofill to reclassify the transformer to NON-PCB status or replacement with a new transformer and disposal of the PCB transformers.

The materials inside the transformer: the laminated core steel, the paper insulation and the wood spacers have been immersed in PCBs for many years. The PCBs have impregnated into every crack and crevice within the core and into the porous paper and wood materials. Over a period of time, the PCB level is reduced by certain procedures to leach the PCB out of the transformer until it is reclassified to NON-

PCB status. The EPA requires that the PCB level remain below 50ppm at the end of a 90-day reclassification period.

Retrofilling for reclassification involves draining and disposing of the askarel. This process immediately reduces the PCB level; and there are processes available that will, in time, reduce the level of PCB to less than 50ppm for the 90-day period and ultimately reclassify the transformer.

The most popular--and currently available--ways to reclassify askarel transformers are the series retrofill method and the external "black box" method.

With the series retrofill option, the process takes place as follows:

- The askarel is drained and disposed of.
- The transformer is usually regasketed.
- The unit is flushed.
- Interim fluid is used to operate the unit.
- Over a period of time, PCBs leach out into the fluid.
- The unit is shut down so that interim fluid can be replaced.
- The process is repeated three to seven times as needed, depending upon warranty and operating conditions.
- The unit is reclassified as non-PCB.
- Final fluid is placed in the transformer for operation--usually silicone or RTEmp.

This process typically takes from 12 to 24 months to complete.
With the black box method, there are two processes:

- Filtration System
- Distillation System

After draining and disposal of the askarel fluid, regasketing is performed as required. The black box is then installed at the transformer location. The transformer is filled with a special dielectric fluid for a period of time that will continually remove PCBs from the fluid by circulation through the black box. This fluid will remain in the transformer with the system operating until the rate of change in the concentration of PCBs has maintained a relatively constant level. At this time, the process is stopped for reclassification and tested to determine if the levels will remain below 50 ppm after 90 days. If successful, the black box may or may not be removed depending upon warranty terms. A final replacement fluid may or may not be installed. Most systems use silicone or RTEmp; however, in certain cases, transformers can operate with the intermediary dielectric fluid as the final replacement fluid. This process typically takes 6 to 18 months.

The initial outage time may range from 12 to 24 hours, and 6 to 12 hours for each required outage for the series retrofill method. The block box method may require only a single initial outage for installation.

Many issues surround the retrofilling for reclassification choice. The company has to thoroughly investigate many factors, some of which are:

- Number of outages -- interruption of service.
- Amount of fluid handling and transportation.
- The characteristics of the interim fluid and final fluids. These characteristics must be determined both <u>environmentally</u> because some are hazardous chemicals; and <u>electrically</u> because NEC Code may have other requirements, such as diking or fusing, based on dielectric strength and flammability.
- Time of completion - reclassification.
- Duration of guarantee (1-to 5-year terms).
- Potential derating of transformers.

Replacement and disposal includes the removal and disposal of a PCB transformer, and the installation of a new transformer. Replacement allows the company to assess and evaluate the current load situation today and can thus plan for the future. Over a period of years, a company may have added or removed a great deal of equipment that has affected the load on the transformers. As a result, a company now would have several possibilities to consider:

- Down size transformers (from 1500 to 1000).
- Remove three single-phase units and replace with one three phase.
- Take out three similar units in the same location and put back only one unit.
- Replace three - 1000 kVA units with one - 1500 kVA unit with new switchgear.
- Evaluate your load losses and buy high-efficiency, low-loss transformers. Sometimes losses become a very important issue in choosing a replacement. (Losses are the energy cost to operate a unit. The lower the losses, the lower the operating costs.)

There are a variety of replacement transformer manufacturers that can offer dry-type transformers or transformers filled with a less-flammable fluid such as RTEmp or silicone.

The downtime required for each transformer is typically 8 to 24 hours for a replacement project.

PCB transformer disposal involves incineration of all PCB fluid and then disposal of the PCB transformer carcass. The most common method for the carcass disposal is landfilling. This is accomplished by first decommissioning the transformer through an EPA approved flushing procedure, and then, burial of the carcass at an EPA approved landfill.

As technological advancements procead within the environmental control industry, more options for the final disposition of the transformer carcasses may be available. An option that could be available to the replacement market in the near future is the scrapping or the recovery of salvaged metals by detoxification of an empty carcass. However, this system is labor intensive and the costs will have to be weighed against the potential liabilities of landfilling.

Other pertinent factors when considering the retrofill versus replacement option are the various conditions effecting the transformer's operation and the customer's needs. These factors might be:

- Age. Transformers in use are typically 10 - 50 years old. Newer units between 10 and 20 years old may be good candidates for retrofill. Older units (30 to 50) may be better candidates for replacement. The transformers that are in the mid range should be carefully evaluated to determine retrofill or replacement.

- Load. Transformers by application are loaded very differently. Some have constant load while others have a very cyclic, variable load.

  In retrofilling where the final fluid may be a less-flammable fluid like silicone or RTEmp, there may be derating of the transformers. Transformers with heavier loads typically have quicker leach back rates associated with a faster retrofill reclassification. The units that are lightly loaded many take more time to achieve reclassification. Lightly loaded transformers may also be good candidates for replacement.

- Size-Volume. Transformers by design vary in the number of gallons required to cool them. For example, a 1000 kVA transformer may very from as few as 130 gallons to as many as 650 gallons of PCB fluid. The retrofill costs for transformers with higher volumes of fluid may be as much as, or more than replacement costs.

- Outages. Transformers that may not be easily accessible or are extremely difficult to remove may be a better retrofill candidate. Units that are required to operate seven days per week and 24 hours per day may be replacement candidates because only one outage will be required for the new installation.

No one solution is the "least expensive" all of the time. Some PCB transformers may be cost effective to retrofill and other PCB

transformers will be more cost effective to replace.

When a company expends time, effort and money to evaluate these options and then to prepare a suitable plan to meet the goals within a limited mesos, the decision should encompass: the costs associated with the options available, risk assessment for each installation, corporate policy and current and future EPA regulations.

In conclusion, a company's available options from a risk management perspective would be the "do nothing" policy, retrofill for reclassification to NON-PCB status, or total elimination of on-site PCBs by replacement.

We feel that there is no ONE solution for all cases. Please contact the Sun Environmental Company for the services to develop a program for evaluating the circumstances pertaining to each transformer at all of your company's facility locations.

Our goal will be to help the responsible manager make a cost effective and environmentally conscious decision for the company to comply with the current EPA regulations.

SUCCESSFUL FIELD PROCEDURES IN THE RETROFILL OF EUROPEAN-DESIGNED TRANSFORMERS

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ABSTRACT

Successful retrofill of transformers and associated equipment requires a sound technical approach, safe and effective dielectric fluids, and a considerable amount of field planning and servicing resourcefulness. European-designed transformers, different in configuration from their U.S. counterparts but broadly exported around the world, emphasize the importance of field retrofill flexibility and ingenuity. The unique design of transformers in each country, such as conservator-type transformers, add to the need for very detailed field planning and execution. It is a mistake to generalize on field retrofills procedure without taking into account such differences by country. Field modifications to the transformer and equipment may be necessary and appropriate in conjunction with the retrofill itself. This paper will describe and list the lessons learned from the author's experiences in retrofilling hundreds of transformers in a number of European and international countries.

INTRODUCTION

In my present position at Grosvenor Transformers Services, Ltd., I have, over the last decade, planned, supervised and participated in the retrofill of over 500 transformers of various designs in countries as diverse as the United Kingdom, Holland, France, Italy, Ireland, Belgium, Singapore, Hong Kong, Bahrain and Saudi Arabia to name but a few. As can be imagined, the diversity of transformer design, service requirements and physical settings can be astonishing and even frightening considering the political situations around the world. For example, we were involved in the retrofill/servicing of transformers in Singapore under the watchful eye of heavily armed Gurkha Guards. To be in such a situation, unable to communicate easily with the men at the other end of the guns can be disconcerting, to say the least.

In the same vein, working at the site of a major transformer/PCB incident caused by a car bomb planted at a power substation can also set the nerves on edge. In this case, the bombing, motivated by political sentiments, was intended to cause maximum visible damage. Probably unintended was the major problem encountered when a wall from the substation fell on some transformers, shattering them and releasing significant quantities of PCB fluids. This PCB material flowed down several levels of a car park and into the water sump at the bottom. Contamination was massive and compounded by the fact that the fire brigade used water to control the resultant fire, thus spreading the contamination further. Whether dioxins or furans were released in this incident is unknown but very likely. Release of such information in most European countries has been less likely to occur than in the United States due to official restraints and the desire not to panic the public. We were involved in the cleanup which was conducted under the utmost and unusually tight security and secrecy. Some of the personnel at the site during cleanup were even armed!

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As in the States, many have in the past attempted to handle their PCB situations by burying the problems (Out of sight, out of mind, one concludes). Such a foolhardy approach only invites difficulties which surely will occur sooner or later. As a case in point, we were involved in the cleanup of a significant PCB spill in a container ship from a Middle Eastern country which had sailed into a European port city. In a large cargo hold, two containers with transformers were located on top of a score of other containers. During the transport, the transformers (not designed for such movement) ruptured, spilling their contents and contaminating the entire hold, contents and all. A significant and costly decontamination of the vessel and its contents thus was required. Fortunately, such incidents no longer are necessary because transformer replacement and landfill are not the only methods for eliminating PCB transformers. New retrofill technology, successfully commercialized in the United States, is being demonstrated on European designed transformers in operational plant settings in France and Italy, with my participation.

EUROPEAN SITUATION

PCBs in Europe and the rest of the "developed" world are at least as common as in the United States. In some areas, particularly France and West Germany, the concentration of PCB transformers is significantly greater than in the States. It has been estimated that France alone has approximately the same number of PCB transformers as the United States, with Germany having perhaps half that number. Other major PCB containing countries are Italy and Japan. As one can imagine, the concentration of PCB transformers is related to the population density of the industrial world. This should come as no surprise considering PCBs (Pyrene, Pyroclor, Chlophen, Kanaclor, etc.) were considered to be the best transformer dielectric fluid for use in those situations where fire hazards were of paramount concern.

PCB Regulatory Climate in Europe- Until recently, sentiment supporting PCBs was universally held in Europe, which continues to lag the United States in PCB regulatory matters. In fact, until recently, PCBs continued to be manufactured and placed in new transformers in France, to the continued amazement of Americans. If the regulatory climate in the States is considered to be confusing, the situation in Europe and elsewhere is orders of magnitude worse due to widely differing regulatory climates in the various countries. Holland, for example, was the first country to encourage PCB removal by granting subsidies to spur industry forward. Such subsidies (recognising the value of maintaining and existing transformer in place via retrofill rather than replacement) are greater for retrofill than the other option. France, due mainly to major PCB incidents in Reims in 1985 and Lyon in 1986, is moving towards rigorous control and regulation of PCB and PCB containing equipment.

Other countries are now beginning to address the situation. Germany for example does not have a national policy per se. However, state legislation on transportation, storage, destruction and processing of PCB wastes is severe and restricts movement of the material. Italy (still effected by the specter of Seveso) has specific regulations under development. Finally, Japan has perhaps the worst possible situation imaginable; PCBs seem too dangerous to move or handle. Such material and contaminated equipment should remain untouched and unmoved from current locations until some future date and identification of a national policy for addressing the total problem. This leads to the situation where contamination of the ecosystem is continued. However, once a policy (one would expect banning environmentally unacceptable landfill) is approved, the Japanese can be expected to move rapidly to correct the situation (Apparently no one wants to risk another "Yusho" incident).

A major, though completely unpublicized, PCB incident involved a major excavation project in Europe, now abandoned. A site substation containing 2 PCB transformers leaked over 200 gallons of PCB material, which ultimately reached the sea. The site was not cleaned up at the time due to the tremendous cost associated with decontami-

nation and remains contaminated. Events like this, Reims, Lyon and Seveso should cause more countries to address the situation by stricter environmental laws modeled after the U.S. EPA regulations. In addition, insurance carriers in Europe (such as ASEA, Allians and La Littorale) are now recommending removal of PCBs, thus putting increasing pressure on the regulatory agencies to enact stricter controls.

EUROPEAN DESIGNED TRANSFORMERS

There are many significant design differences in European designed transformers (often found in such far afield places as Singapore, Bahrain, etc.) that to enumerate them all would take more space than allowed here. These transformers, like their U.S. counterparts, are sized for the power requirements for a particular application. Thus, it would be impossible to discuss differences in average KVA per transformer, other than to state that the average PCB transformer is about 1,000 KVA. However, it seems true that European designed transformers are more conservatively designed than the U.S. transformers, (that is, they have a higher gallon to KVA ratio than in the States). This would be particularly true for those transformers which were installed in tropical environments where the greater air ambients require increased cooling capacity. Aside from these minor differences, unusual equipment with respect to the U.S. market is often encountered which must be taken into consideration during the successful retrofill servicing procedures.

Conservator tanks are rather like a reservoir fitted on the top of the transformer and used for the expansion of oil in the transformer as it comes up to operating temperatures. In addition, the conservator decreases the surface area of oil in contact with the atmosphere, reducing the potential for moisture contamination in these free breathing transformers. Such units pose, in the author's opinion, the greatest difficulty towards the successful retrofill operation. This is true basically because drainage of the conservator is not straightforward. A standpipe within the conservator and connecting it with the transformer tank extends about 5 cm up into the conservator. As a result, about 20% of the conservator volume is undrainable, yet can appear to be totally empty of its PCB contents. Compounding this is the fact that the conservator has a drain plug with no valve. In such a situation, removal of the undrainable PCBs in the conservator can be accomplished by removing the conservator itself, an action which can cause PCB to spill. Alternatively, the drain plug may be utilized, but at the risk of experiencing an uncontrolable flow of PCB material. Grosvenor Transformer Services has developed procedures for resolving this situation on a routine basis.

Fluid changes from PCB to silicone (for example) pose absolutely no problem with respect to the successful retrofill of conventionally designed transformers which can more than handle the minor differences in expansion of the various acceptable fluids. This, in general also is true for the conservator tank transformers in Europe because of sufficient capacity within the conservators. For those instances where the capacity of the conservator is insufficient, the knowledgeable retrofill service technician can easily overcome the problem by either changing or expanding the conservator, with both operations exhibiting their own particular set of difficulties. In both cases, careful examination by the technician is required to identify the materials of construction of the conservator (mild steel, stainless steel, steel with brazed ends, etc.), and to utilize compatible materials for the modifications lest different metal expansion characteristics result in cracking of welds and occurrence of leaks. Our experience demonstrates that fluid expansion and conservator design pose no insurmountable problem barring the successful implementation of retrofills.

Buchholz Relays, fitted on conservator units, serve as protection against fluid loss or as a fault detector triggered by rising gases caused by a fault. As in the case of the conservator itself, the Buchholz relay can retain a certain amount of fluid within its sump after the transformer unit has been drained of its contents during

the retrofill procedures. The floats of the fluid level gauge, designed for certain coolants, may require changing for proper gauge functioning.

Fully Integral Filled Transformers are hermetically sealed units which, in contrast to the conservator design, are non-breathing units. Fluid expansion is taken up by the expanding fins of the cooling radiators, and care must be exercised when changing fluids in this type of transformer lest undue pressure result. Careful choice of replacement fluid or installation of sealed conservator tanks or sealed pressure type vessels are some of the options available to overcome this minor difficulty.

Gasketing Materials often are composed of materials not compatible with both PCB and silicone dielectric fluid. As in the United States, standard operating procedures should call for regasketing with silicone compatible materials prior to introduction of the silicone dielectric fluid. In some European designed transformers, the core and windings of the units are attached to the main cover. Regasketing requires the use of a lifting gantry, making regasketing more difficult, but clearly not impossible. Alternatively, the use of specially developed sealants may be indicated.

ONE COMMON APPROACH

Like their American counterparts, all European designed PCB transformers (whether located in Europe or in other, more exotic locations) have one common problem. Simply stated- THEY CONTAIN PCBs. Except for the long term risk to the environment posed by the PCBs, nothing about these particular transformers suggests that they have anything but a long life of efficient operation ahead of them. Why then should the transformer owner want to eliminate such a valuable asset when technology to successfully retrofill and remove the PCB from the transformer exists today? The solution to the problem of removal of PCBs from a transformer requires the complete removal of the PCBs from the core insulation materials (cellulosic in nature in both Europe and abroad). One common approach will suffice for all these various transformer designs. That approach requires the rapid and total removal, via diffusion, of the PCB from the transformer core. Older technology directly utilizing silicone oil failed miserably in this respect when the silicone actually blocked the diffusion of the PCBs from the cellulosic material. New technology, recently pioneered in the United States, is now being applied to European designed transformers of the types listed above. Further, contrary to unfounded claims, silicone in my experience worldwide, exhibits no detrimental effect on formerly PCB containing transformers.

CONCLUSIONS

A. Europe faces the same dilemma regarding PCB transformers as in America, but is somewhat behind in regulations/control versus the States.
B. PCBs are common in Europe and other industrialized nations.
C. European designed transformers exhibit several differences from the U.S. units, including high gallons/KVA ratio, conservators, hermatically sealed tanks, etc.
D. Such differences pose their own set of service problems, but do not in any way rule out the utility of success of retrofill procedures.
E. Field modifications need be routine and a detailed knowledge of many transformer designs is required, necessiteting the use of specialized contractors.
F. Successful retrofill can best be accomplished with special dielectrics which maximize removal of PCBs from the transformer internals.
G. Ultimate retrofill with silicone is acceptable worldwide and does not adversely effect the operation of previously PCB containing transformers.
H. In Europe, old things- even transformers- are treasured, not discarded.

IN-SERVICE RECLASSIFICATION OF ASKAREL FILLED TRANSFORMERS PROGRAM UPDATE

Murray D. McMahon and Thomas C. Venable
Westinghouse Electric Corporation

ABSTRACT

EPA regulations restricting continued use of PCB transformers has caused most owners to seek the most efficient and cost effective means for minimizing PCB risk. PCB risk reduction programs should include risk surveys, remedial action and long-term plans for replacing or reconditioning PCB transformers. PCB transformer owners do have some choices in this program. PCB contaminated transformers may be retrofilled or replaced. Pure PCB (askarel) transformers have traditionally been replaced. The askarel is incinerated and the carcass is buried in a secure chemical waste landfill. Until recently industry could not offer a means to clean an askarel transformer so that it could be reclassified to non-PCB status.

Westinghouse offers a field-proven process by which pure askarel transformers may be reconditioned with guaranteed reclassification to non-PCB status of less than 50 PPM. Commercially owned transformers that have been reclassified at PCB levels as low as zero to 17 PPM following a few months of processing and ninety days of in-service waiting period required by EPA regulations 40 CFR 761 will be discussed.

Westinghouse TransForm^{tm} was introduced in early 1986 and has already resulted in more than 60 commercial transformer reclassifications. The process, extensive test program and actual case history results will be discussed.

^{tm}TransForm is a registered trademark of the Quadrex HPS Corporation

IN-SERVICE RECLASSIFICATION OF ASKAREL FILLED TRANSFORMERS PROGRAM UPDATE

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Westinghouse Electric Corporation

TEXT-INTRODUCTION

The 1979 enactment of EPA regulations restricting the continued use of PCB transformers and furtner revision of tnese regulations through 1985 has caused most PCB equipment owners to seek the most efficient and cost effective means of minimizing the PCB risk now confronting them. The degree of this risk depends upon the PCB concentration (PPM), which determines the risk category, and upon the equipment location, which may increase risk of exposure to the environment or possible fire. Equipment age and condition, of course, are contributing factors. It is beyond the scope of this paper to explore in depth the EPA regulations as they are defined in 40 CFR. The reader is advised to refer to 40 CFR 761 and to his own legal and environmental council for interpretation of the regulations.

In general, the current regulations define three categories of PCB devices:

> 500 PPM - PCB
> 50 but < 500 PPM - PCB Contaminated
< 50 PPM - Non-PCB

PCB contaminated devices (> 50 PPM but < 500 PPM) have long been remedied by simple "retrofill" or replacement of contaminated fluid with new fluid. Mineral oil devices, contaminated to even greater than 500 PPM have been easily remedied in the same manner. Many owners of PCB devices have elected to perform a complete changeout of the device, replacing it with a device of like kind and thus eliminating the immediate PCB risk. PCB fluids are incinerated in approved PCB

[tm]TransForm is a registered trademark of the Quadrex HPS Corporation

incinerators and carcasses are buried in EPA approved landfills. Retrofill and turnkey replacement services are available from several reputable service suppliers.

Industry has sought an acceptable procedure by which pure askarel transformers could be reconditioned in some manner to permanently reduce the PCB concentration to below 50 PPM while the transformer remains in service, as is permitted by the regulations. Several attempts have been made to achieve this goal in the past. Certain methods attempted to filter or absorb PCB's from the transformer; others attempted to reduce PCB concentration by multiple retrofill actions over long periods. Varying degrees of success (or lack of success) have been achieved. Residual PCB, leaching from the core and coils, untenable frequent power interruptions and lengthy processes have been frequent barriers to complete success and acceptability.

In early 1986, Westinghouse Electric Corporation introduced TransForm^{tm}, a PCB reconditioning process which guarantees reclassification of askarel filled transformers to non-PCB status (below 50 PPM) quickly and with only two short power interruptions. This paper will functionelly describe the proprietary process, the extensive test program and results, which are impressive. Although just introduced at the American Power Conference in April, 1986, the TransForm^{tm} process was turning out reclassified transformers by the fall of 1986 and by mid-1987 more than 50 customer owned commercial transformers have been certified non-PCB. Many more are currently being serviced or are in the 90-day reclassification period. Actual case history results will be described of in-service askarel transformers, many of which were processed in six months or less and reclassified at levels of zero to 17 PPM. It now appears that transformer size, as well as other variables such as manufacturer and internal configuration, may slightly effect processing time. Data will also show that leaching was insignificant over one year after reclassification.

PROCESS

The TransForm^{tm} process was jointly developed by Westinghouse and Quadrex HPS, Inc. starting in 1984. This process allows decontamination of operating transformers that were originally designed to be filled with askarel, a non-flammable transformer dielectric of the 1930's to 1970's specifically suited for indoor

transformer applications. The process is not intended for mineral oil filled transformer designs, which can be remedied by the simpler retrofill method.

Not all askarel transformers are considered candidates for TransForm[tm] or any other reclassification procedure. We recommend that potential candidates be scrutinized carefully as the decision is made for turnkey replacement, recondition or "do nothing", including an evaluation of:

Electrical Test
Fluid Test
Physical Condition
Age
Physical Location (ease of removal)
Cost of Replacement
Owner's Plans and Concerns

Following this evaluation with our clients, and once the choice is made to proceed with TransForm, the project schedule begins with a scheduled transformer de-energization for a period of less than 48 hours. Askarel fluid is drained from the transformer into tankers or barrels for disposal by incineration in an EPA approved PCB incinerator in full compliance with all EPA regulations. Gasket materials are always replaced during this initial outage. The transformer is then filled with a proprietary dielectric fluid, TDR-3. A TransForm[tm] processing unit is connected to the transformer via small teflon hoses with safety features such as stainless steel braided shield, quick disconnects, locked panels, and solenoid operated valves at each end to close in event of a problem. The process is designed for orderly shutdown of the processor in event of malfunctions, without disrupting the transformer operation. The transformer is then re-energized and processing occurs during normal, full-load operation.

The TDR-3 dielectric fluid is an excellent medium for PCB removal which readily extracts PCB from the transformer internal components. The unit processes a continuous flow from the transformer, removing the PCB's from the fluid and returning cleaned TDR-3 to the transformer. The TransForm[tm] unit is interlocked in such a manner that the liquid level in the transformer is maintained at the proper level. All parameters of the TransForm[tm] unit which can affect operation of the transformer are monitored and interlocked to assure that the transformer remains

within the normal operating range. TransForm™ is designed to run automatically during the servicing period of approximately 4 to 5 months or less. Remote interrogation via telephone modem is available. Servicing and inspection visits are made at two to three week intervals. The extracted wastes are removed from the site for incineration.

As the conclusion of the processing period is recognized from test sample data, the TransForm™ unit is disconnected from the transformer and the 90-day in-service period for reclassification to non-PCB status (below 50 PPM PCB content) in accordance with EPA regulations 40 CFR 761 is started. After reclassification, the transformer is scheduled to be out of service for approximately 8 to 24 hours, during which the TDR-3 fluid is removed from the transformer and handled in accordance with EPA approved procedures. The transformer is retrofilled with the dielectric fluid of the customer's choice. Candidates are mineral oil, silicone, R-temp, etc. TDR-3 remains the property of Westinghouse and is not intended to be a permanant replacement dielectric fluid.

Using TransForm, transformer owners can achieve guaranteed non-PCB status without having to replace existing equipment. TransForm™ is particularly well suited for units that are expensive, difficult and costly to remove or have long remaining useful life.

TESTING PROGRAM

During the initial testing program, a number of transformers were processed in accordance with the above procadures. The specific testing variables and results are discussed in detail in C. Claiborne's and C. L. Vacher's paper, "A Process for In-Service Reclassifications of Askarel Filled Transformers", presented at the Annual Meeting of the American Power conference April 14-16, 1986. (1)

During this testing program, monitoring of the contamination level indicated that the PCB level in the transformer fluid is reduced rapidly to below 50 PPM and held there for the remainder of the processing period. Figure 1 shows typical curves for contamination as a function of time during initial processing for units with original PCB levels ranging from 300,000 to 700,000 PPM. Obviously, PCB concentration in the dielactric is reduced drastically just by removal and replacemant with new fluid, but even with careful flushing procedures this

reduction may create a false image since leaching from the core coils and other internals would cause rise back to thousands of PPM. The TransForm[tm] process continuously extracts PCB's, hence, the fast reduction to the lower level. The completion of the processing period is determined by monitoring the rate of PCB removal from the transformer.

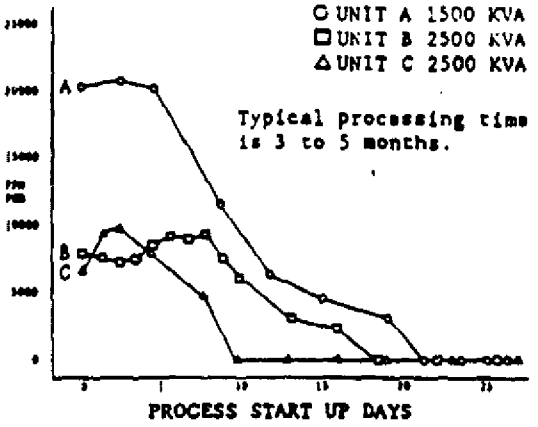

Figure 1: PBC level during process start-up.

As part of the test program, the leachback rate during and after reclassfication of two of the units continues to be monitored. Test data sheets 1 & 2 show the results of this monitoring. Both transformers were drained, retrofilled with silicone and returned to the customer.

After the completion of exhaustive electrical tests, other units have been untanked, disassembled and evaluated. No evidence of any effect upon the transformer material and minimal PCB residuals were found.

FIELD EXPERIENCE

The success revealed by the test program using customer owned transformers in the Westinghouse Lansing, Illinois facility, lead Westinghouse to confidently offer the TransForm[tm] process for general field applications. We were confident that askarel transformers could indeed be serviced and reclassified to non-PCB status (< 50 PPM) in the anticipated short period of time and that concerns of material degredation, leaching in the early or long-term stages, etc., have been overcome. Test results were discussed previously and are shown in figure 1 and on test data sheets 1 and 2. The TransForm[tm] process was now ready for field introduction, and was officially announced at the American Power Conference, Chicago, in April 1986.

Test Data Sheet 1

Unit [illegible]

Manufacturer	Westinghouse	KVA	[illegible]
Serial No.	[illegible]	Prim. Voltage	[illegible]
Yr. of Mfg.	[illegible] (Placed in service)	Sec. Voltage	480Y/277
Dielectric	Inerteen	Gallons	[illegible]

Transform Processing Completed	[illegible]
Processing Time	less than [illegible] days
Reclassification Date	November [illegible] 1985
PCB Content at Reclassification	[illegible] PPM

Follow-Up PCB Content Tests:

Date	[illegible]	PPM	[illegible]
Date	[illegible]	PPM	[illegible]
Date	[illegible]	PPM	[illegible]
Date	March 86	PPM	Returned to Customer Service
Date	[illegible]	PPM	[illegible]

Test Data Sheet 2

Unit [illegible]

Manufacturer	General Electric	KVA	[illegible]
Serial No.	[illegible]	Prim. Voltage	[illegible]
Yr. of Mfg.	[illegible]	Sec. Voltage	480Y/277
Dielectric	Pyranol	Gallons	[illegible]

Transform Processing Completed	[illegible]
Processing Time	less than [illegible] days
Reclassification Date	[illegible]
PCB Content at Reclassification	[illegible] PPM

Follow-Up PCB Content Tests:

Date	[illegible]	PPM	[illegible]
Date	[illegible]	PPM	[illegible]
Date	[illegible]	PPM	[illegible]
Date	March 86	PPM	Returned to Customer Service
Date	[illegible]	PPM	In storage

Customer orders were developed, based on the successful pilot programs, ranging from major utilities committing their entire system to small industrials with two or three transformers. One of our early commitments, a utility company opted to have its 2500 KVA transformer containing 1060 gallons of askarel processed in our Chicago facility rather than on-site. This large transformer processing was initiated in November, 1985, and completed August 7, 1986. The unit was certified non-PCB at a level of 17 PPM following the 90-day in-service period. It is significant that this large unit was processed under simulated load conditions, with special approval of the EPA. This procedure can be used to process askarel units that are not readily energized such as spares. One client has chosen to bring his transformers to a central facility for processing to minimize public attention and vault congestion. The client is reporting on this procedure to E.P.R.I.

Simultaneously, orders were received to process a multitude of types, sizes, ratings, manufacturers and ages of askarel transformers. Transformer ratings from 500 KVA to 7500 KVA with volumes from 150 to 2500 gallons of askarel are being Transformed. Ages range up to 30 years or more. Manufacturers of the askarel

units include Westingnouse, General Electric, ITE, Pennsylvania, Maloney, Niagra, Allis Chalmers, and others. A few of these certainly deserve mentioning and are tabulated in Figure 2.

One major midwestern utility company chose Westinghouse to recondition the remaining 68 askarel units of its Transmission/Distribution and Power Plant systems in a very tight time period. This has been discussed in greater detail in papers by our client. (2) Suffice to say here that the commitment is being met and the units began receiving reclassification certificates in November, 1986 following five months or less of TransForm[tm] processing. Reclassification levels of zero to six parts per million following the 90-day period are not uncommon as shown in Figure 2.

ASKAREL TRANSFORMER RECLASSIFICATIONS

TRANSFORMER	MANUF.	KVA	PRIM. VOLT	SEC VOLT	FLUID GALLONS	RECLASS TIME	PPM RECLASS
A	W	1500	12KV	480Y/277	410	120 days	7.8
B	GE	2500	12KV	480Y/277	400	100 days	8.5
C	W	2500	13.2KV	480	1060	8 mo.	17
D	W	1750	13.2KV	480	250	5 mo.	0
E	W	1500	13.2KV	480	221	5 mo.	6
F	W	1500	13.2KV	480	221	5 mo.	5
G	ITE	1500	6900V	480/277	300	5 mo.	6

Figure 2: Typical Case History Results

Another Midwest utility achieved reclassification of its 1500 KVA, 300 gallon transformer at 6 PPM following five months of TransForm[tm] processing and 90-day in-service period. Many more transformers for industrial, commercial and utility customers have completed their processing and are currently in the 90-day waiting periods. Many, many more are currently in process in major commerical buildings, hospitals, universities, dairies, chemical plants, paper mills, steel mills, utility power plants and distribution systems.

Transformers having a broad range of KVA's and liquid volumes have been and are now being processed. Some are very old and are being reconditioned due to the owners reluctance to landfill the units coupled with high replacement costs of some special units and the interest in repair in event of ultimate failure. As long as the unit passes the electrical and fluid acceptance test, successful processing and reclassification is achievable. It does appear from these experiences that larger transformers such as the 1000+ gallon variety may require slightly longer processing time, but that desired results are readily achievable. Fast reduction of PCB risk is a reality.

BENEFITS

The askarel transformer owner can now retain selected units within his system as non-PCB transformers with minimum disruption to his power supply and production schedule. The immediate economic savings is an obvious benefit. The resulting non-PCB classified transformers which are no longer regulated and can be repaired if they should fail are probably the most popular advantages. The reclassified transformers can legally be disposed of as non-PCB devises at the end of their useful life. It is not uncommon for TransForm^{tm} reconditioning of an average 2500 KVA transformer, where "in and out" costs will be significant, to render a savings of 40% over turnkey replacement. Obviously, site conditions greatly affect the difficulty to remove and replace transformers and each must be evaluated on its own merits.

CONCLUSIONS

This paper does not intend to promote or recommend indiscriminate reconditioning, or retrofilling, of askarel transformers. Nor does it intend to recommend indiscriminate changeout or replacement. It is the intent of the paper to recommend that the owner's entire PCB system be carefully evaluated from the standpoint of risk; that the identified deficiencies be immediately remedied; and that a carefully evaluated long-term PCB program be implemented to retrofill, recondition or replace each PCB or PCB contaminated device as is most appropriate from a service and economic standpoint. Askarel transformers that are small, easily accessible and inexpensive to purchase are usually better candidates for turnkey replacement. Similarly, askarel units that are "old" or that are in poor physical or electrical condition should usually be replaced. The PCB program may

also give added opportunity for replacement of askarel transformers that no longer accommodate the owner's electrical needs. In this case, a power system study is often recommended to determine the client's current power requirements before specifying a replacement program.

It is the primary intent of this paper to report that askarel transformer reconditioning through an approved servicing procedure, TransForm^{tm}, is field proven and available for fast reclassification with minimum power interruptions and that, for selected PCB applications, such reclassification is practical and economically feasible.

For any of these PCB risk reduction procedures, a reputable, total service supplier is recommended to assure an unbiased evaluation of each option and, thereby, achieve maximum risk reduction per dollar spent, with less disruption to your business operation.

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SYSTEM 50℠ PROCESS FOR RETROFILLING AND RECLASSIFICATION OF ASKAREL TRANSFORMERS

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The following is a report on experience gained in the retrofilling and reclassification of approximately 40 PCB transformers using System 50℠ technology. Experience clearly demonstrates that PCB transformers can be cleaned and reclassified to a non PCB status with a single interruption of transformer service of less than 24 hours and at costs which are fully competitive with transformer replacement. Cleaning is complete and permanent with essentially no intrusion into transformer operations.

SYSTEM 50℠ TECHNOLOGY

System 50℠ technology consists of a proprietary coolant/dielectric fluid and a proprietary fluids processor. In an initial maintenance phase of System 50℠ servicing, a transformer is (a) de-energized, (b) bulk askarel is drained from it, (c) the transformer is regasketed, (d) a System 50℠ fluids processor is attached to the transformer, (e) System 50℠ fluid is introduced into the transformer, and (f) the transformer is re-energized. As residual PCB's leach from the transformer into the fluid, the fluid is cleaned in the System 50℠ fluids processor and returned to the transformer. Such processing continues until essentially all residuals have leached from the transformer and have accumulated in the System 50℠ fluids processor. Processing is then stopped and PCB concentrations in the transformer are monitored for 90 days. Once the PCB concentration is demonstrated to remain below 50 ppm over this period of time, the transformer is declared reclassified and all PCB labels are removed. Under a basic service warranty, transformer PCB levels are then monitored for one year and adjusted to less than 5 ppm at the end of that time.

System 50℠ coolent/dielectric fluid is a Factory Mutual Approved nonflammable fluid. Its coolant capacity is twice that of askarel and its dielectric properties are comparable. Accordingly, System 50℠ fluid is an excellent permanent replacement for askarel in PCB transformers. Its use reduces transformer shutdowns to one and eliminates any necessity for the derating of transformers. Its use actually extends the useful life of transformers.

System 50℠ fluid processors are compact, rugged, reliable and effective. They are 2 feet square, less than 5 feet tall and weigh less than 500 lbs (see Figure 1). They sit immediately adjacent to the transformer and operate virtually unattended for the entire duration of a transformer servicing in environments ranging from severe outdoor winter conditions to transformer vaults as hot as 130°F.

RANGE OF TRANSFORMERS CLEANED

As illustrated in Table 1, System 50℠ cleaned transformers have ranged in size from 50 KVA to 2500 KVA and contained from 30 to over 700 gallons of PCB fluid. They have encompassed the full range of PCB arochlors in initial concentrations from 500,000 to over 800,000 ppm. Transformer locations have included operations outdoors, in power generating stations, in public buildings, and in industrial manufacturing facilities.

Transformer loading patterns have spanned the complete spectrum from continuous, fully loaded units to lightly loaded units with extreme cyclic patterns of use. Ambient conditions under these loads have included extreme cool dust, subzero temperatures, rain and snow, and elevated temperatures of up to about 130°F. System 50℠ fluids and fluid processors have performed well over the complete range of conditions tested.

PATTERNS OF TRANSFORMER CLEANING

Real PCB risks are mitigated almost immediately with System 50℠. PCB concentrations in bulk transformer fluid fall rapidly as soon as System 50℠ processing begins. As shown in Figure 2, concentrations typically fall below 500 ppm within a couple of weeks and below 50 ppm within about six weeks. They remain at or below these levels for the duration of the cleaning.

[redacted]tal cleaning time varies with transformer operating conditions. As shown in Figure 3, units operating continuously under full load clean within 3 to 4 months. Lightly loaded units and units under highly variable load or having low ambient temperatures can require from 6 to 12 months to clean (see Figure 4). Such units typically have low but persistent PCB leaching rates for much of the cleaning period. In these cases, cleaning times can be shortened by raising the temperature of these transformers.

COMPLETENESS OF SYSTEM 50 CLEANING

System 50℠ cleaning permanently eliminates the PCB leaching capacity of a transformer. This is illustrated in Figure 5, which shows PCB concentrations in a System 50℠ cleaned transformer during and after reclassification. PCB concentrations are substantially less than 50 ppm at the completion of reclassification. When this residual PCB level is then cleaned with the System 50℠ processor, the transformer shows essentially no further capacity to leach PCB's. This is verified by detailed dismantlement and inspection of the contents of a System 50℠ cleaned and reclassified transformer (see Figure 5). In analytical studies performed by a reputable independent laboratory, total measured residual PCB's in a reclassified transformer constitute an equivalent of only 7 ppm of PCB's if all residuals were dissolved in that transformer's coolant fluid.

TABLE 1

Partial List of System 50 Transformer Cleanings

TRANSFORMER INFO

Unit No.	KVA Rating	PCB Arochlor	PCB's PPM	Transform Manuf.	Volume (Gal)
10151	2500	1260	859,000	GE	720
10141	2500	1260	655,000	GE	720
10171	500	1260	754,000	GE	295
10211	750	1242	870,000	GE	130
10161	500	1260	694,000	GE	295
10201	2500	1242	700,000	GE	440
10051	2000	1260	760,000	GE	635
10241	1000	1254	540,000	GE	154
10251	1000	1254	540,000	GE	154
10221	500	1260	760,000	GE	300
10231	750	1260	460,000	GE	265
10121	2500	1254	619,000	GE	390
10061	1500	1242	NA	GE	225
10111	2500	1254	748,000	GE	390
10131	2500	1254	622,000	GE	390
10071	750	1260	NA	W	361
10091	750	1260	813,000	W	361
10081	750	1260	NA	W	361
10101	750	1260	813,000	W	361
10021	2000	1242	811,000	GE	300
10031	2000	1242	836,000	GE	300
10041	750	1242	867,000	GE	167
10181	750	1254	700,000	GE	215
10191	750	1254	800,000	GE	215

FIGURE 1

SYSTEM50 FLUIDS PROCESSOR IS COMPACT

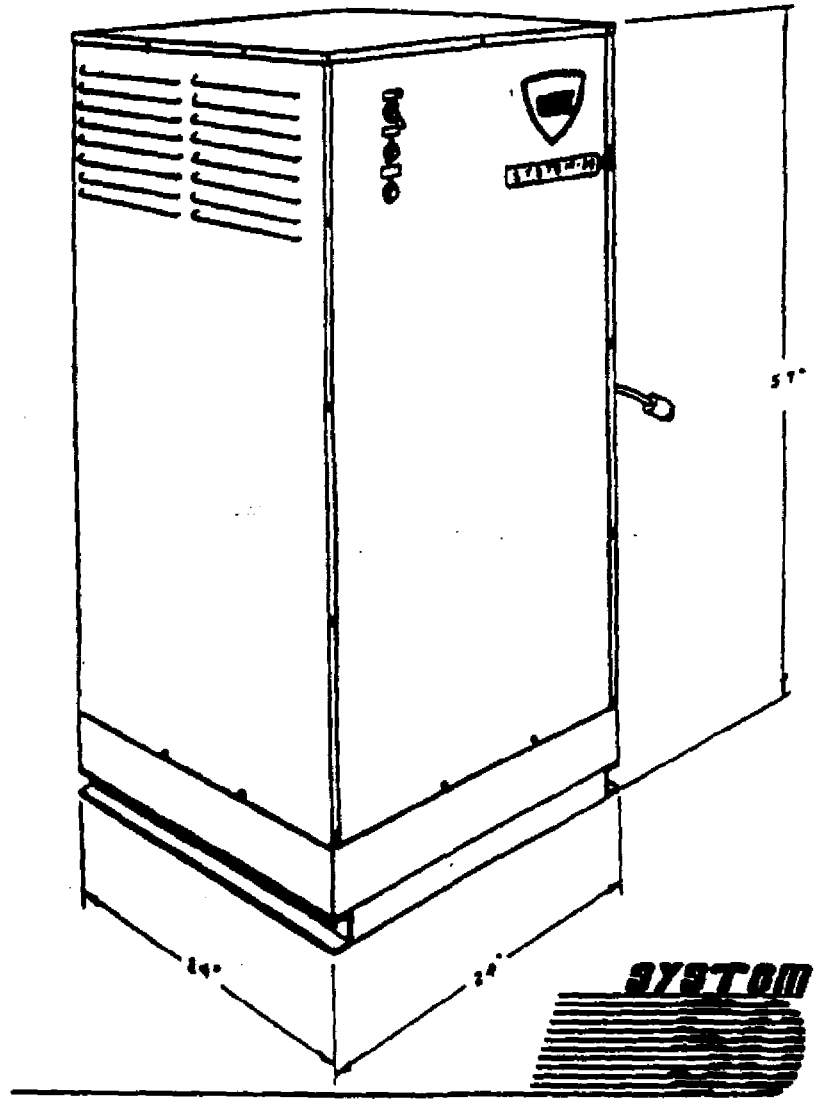

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FIGURE 2

SYSTEM 50 CLEANING REDUCES FLUID PCB CONCENTRATIONS RAPIDLY AND PERMANENTLY

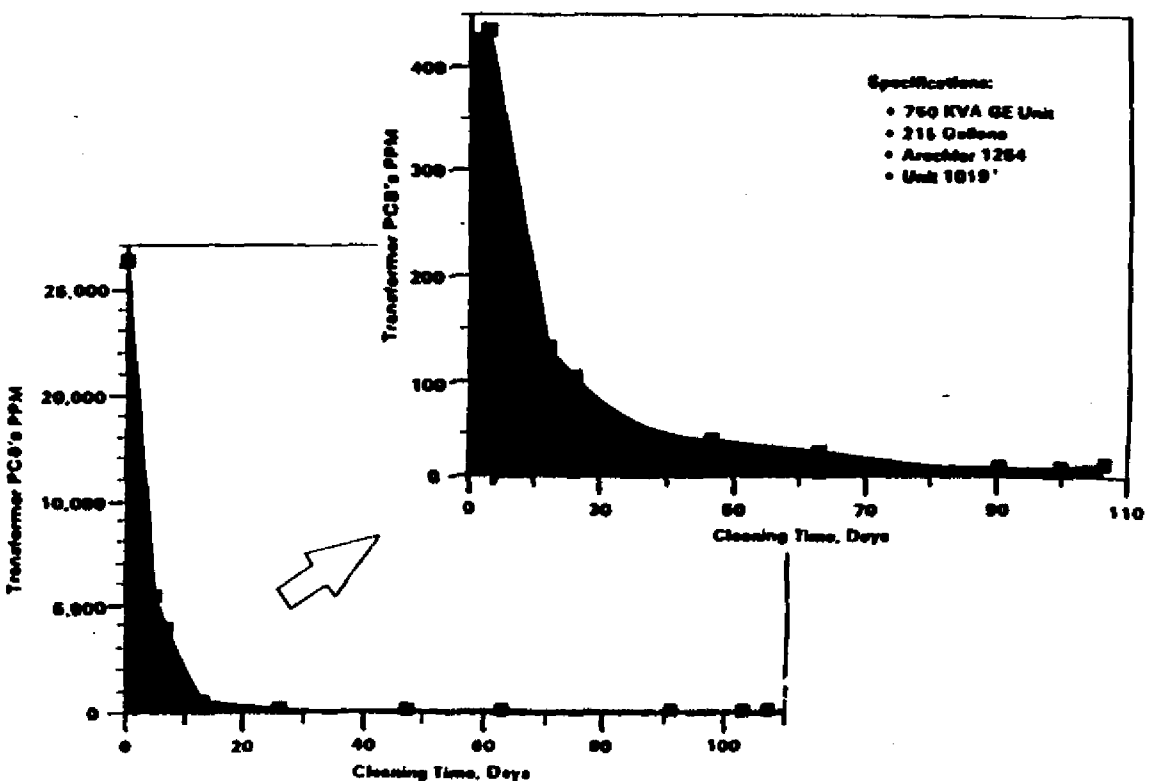

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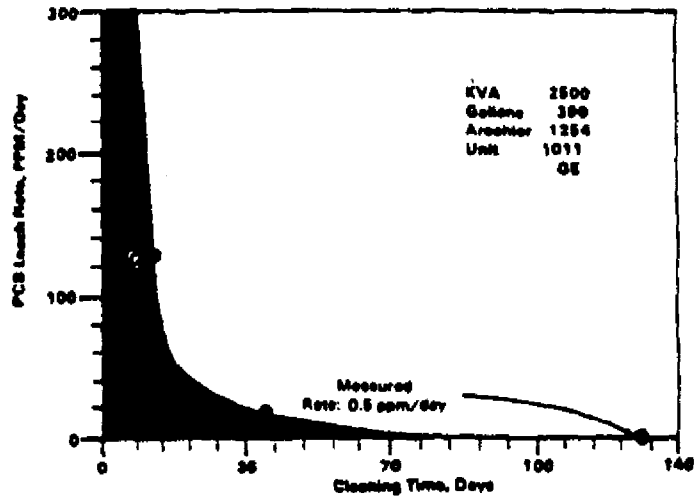
FIGURE 3

LARGE IN-SERVICE TRANSFORMERS CAN BE CLEANED QUICKLY AND COMPLETELY



ASKAREL TRANSFORMER RECLASSIFICATION

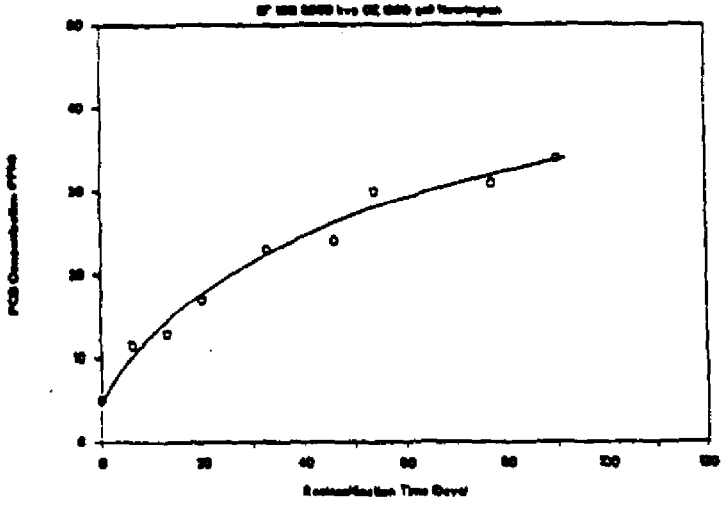


FIGURE 4

LOW LEVEL RESIDUAL PCB LEACHING CAN PERSIST FOR 6 TO 12 MONTHS ON TRANSFORMERS WITH LOW LOADS AND FOR LOW AMBIENT TEMPERATURES

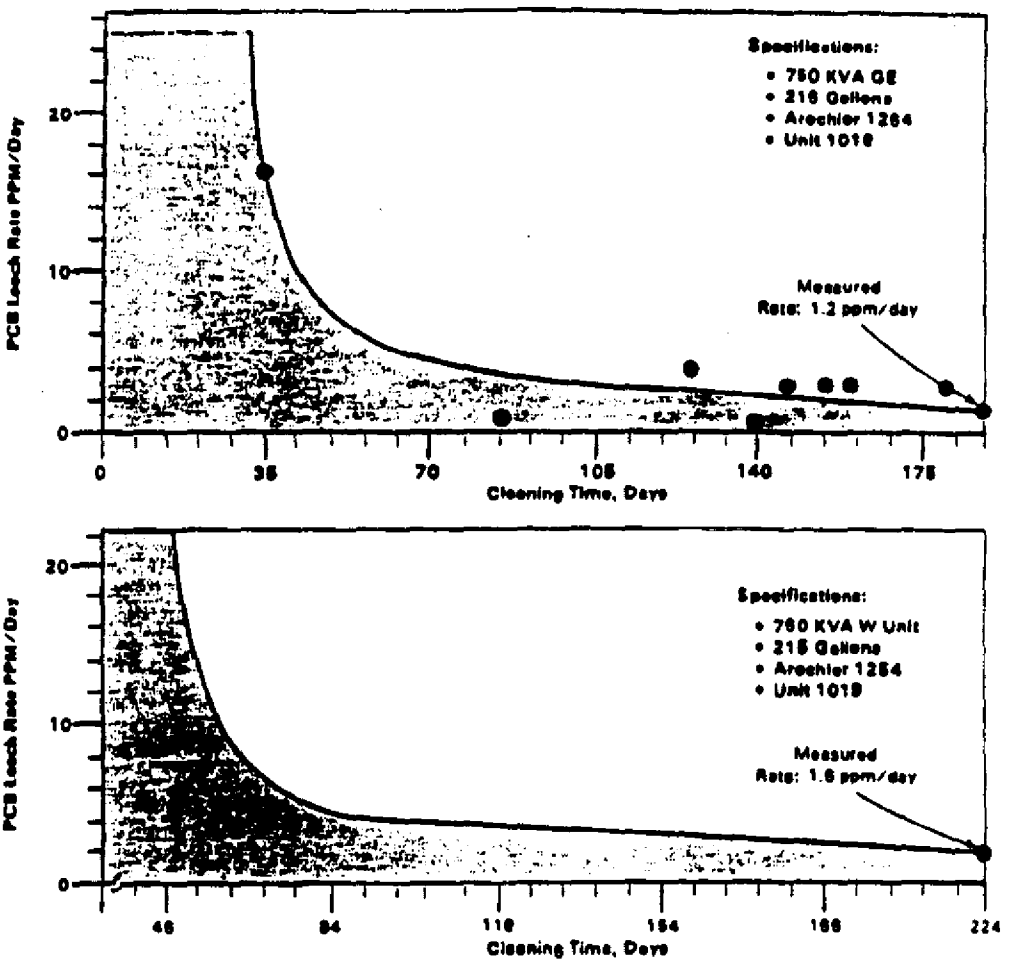
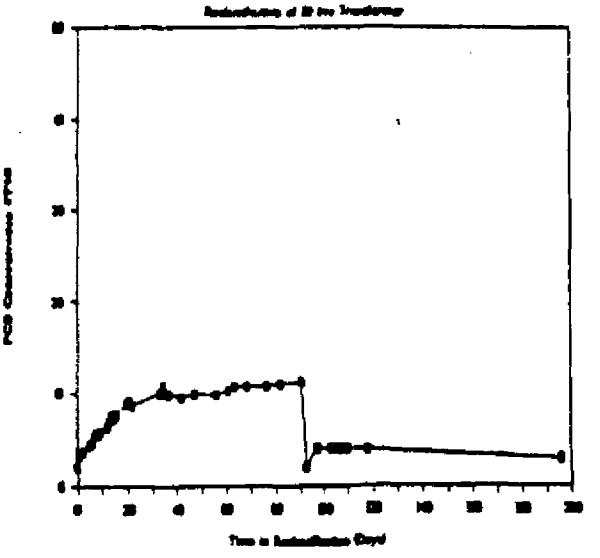


FIGURE 5

SYSTEM50 CLEANING IS COMPLETE AND PERMANENT



MEASURED RESIDUAL PCB IN SYSTEM50 RECLASSIFIED TRANSFORMER

Vessel Surfaces	< 0.5 ppm
Core Steel	3.7 ppm
Windings, Wood, Cellulose	2.0 ppm
Copper Conductor	0.9 ppm
Miscellaneous	< 0.8 ppm
Total	< 7.9 ppm

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Problems Associated With Reclassified PCB Transformer Disposal

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ABSTRACT

The "Fire Hazard Rule" issued in July 1985 provided new restrictions on certain types and applications of transformers with the basic deadline for modification, removal or reclassification in October 1990. Retrofill services as offered by various companies may be able to effect reclassification by the EPA definition, thus allowing the owner to continue operating the unit. The questions which should be answered are - How much PCB remains in the transformer after retrofilling and what actions should be taken by the owner of a retrofilled transformer? The cradle-to-grave responsibilities of the original owner could require him or her to remedy any contamination resulting from the residual PCB in the retrofilled unit.

A study was performed to determine which solvents were suitable for use as retrofill fluids. Diffusion studies and mathematical modeling were then performed for the most likely retrofill solvents. The results of this investigation suggest that significant amounts of PCB remain in the internal structure of the transformer after reclassification to PCB-contaminated or non-PCB regardless of the retrofill process used.

INTRODUCTION

By 1990, PCB transformers in commercial installations will have to be modified with high and in some cases low current fault protection equipment and certain PCB network transformers will require reclassification or replacement (1). The choice can sometimes be difficult for the owner of the transformer. If the owner chooses the transformer replacement option, he must remove the PCB transformer and replace it with a suitable environmentally acceptable non-PCB transformer. Despite these efforts, he remains responsible indefinitely for the contaminated carcass.

Retrofill services seemingly alleviate the potential liability by removing and ultimately destroying the PCBs. Those who choose retrofill may believe that a reclassified unit is equivalent to a unit that was non-PCB originally and can be disposed of in a like manner. The present EPA regulations allow units reclassified to non-PCB transformer status to be disposed of as non-PCB units. Two important questions remain - How much PCB remains in the retrofilled transformer and what liability can be incurred in the unregulated disposal of these PCBs?

There is nothing magical or mystical about the removal of PCBs from transformers. The process involves draining the PCB fluid from the transformer, replacing it with another dielectric fluid that is also a solvent for PCBs, and waiting a sufficiently long time for the PCBs to leach out of the internal structures. As the PCBs diffuse into the bulk fluid, they can be removed either by periodically changing the fluid or by continuously removing a fraction of the fluid, separating out the PCBs and returning the fluid to the unit.

This cleaning process, since it is strictly a diffusional process, can be characterized by transformer structural information and the mobility (diffusivity) of PCBs in the various transformer components. Typical transformer materials include paper insulation, wood, phenolic material, copper and aluminum windings and 8 to 14 mil thick sheets of steel used as the magnetic core. Herein is presented information regarding retrofill with the three most suitable solvents-tetrachloroethylene (TCE), trichlorobenzene (TCB) and silicone fluid. The information presented strongly suggests that a significant amount of PCBs remain in the transformer components after the retrofill process is complete, even though the transformer may meet the reclassification requirements as presently specified by EPA.

EXPERIMENTAL RESULTS AND DISCUSSION

Fluid Volumes

The amount of PCB fluid held in the internal structures of the transformer after it has been drained is an important piece of information for the modeling of the retrofill process. A 10 KVA oil-filled pole-top transformer was disassembled and each of its components was solvent extracted. The extract was collected and the solvent evaporated allowing determination of the amount of fluid trapped in each component. The amount of fluid extracted was a function of the degree of fragmentation. Samples that were extracted, then chopped to smaller pieces and re-extracted yielded considerable volumes of oil with the second extraction. The nominal size of the extracted fragments was 0.5 inch. The internals of the transformer held 3.3% of the original volume of fluid that filled the transformer. See Table 1 for a more detailed breakdown of the fluid volumes.

Independent of whether the transformer had been filled with 10C oil or PCB fluid, the volume of fluid trapped in each component would have been the same. While there are some structural differences between an oil-filled pole-top unit and a pyranol unit, the above information indicates the magnitude of the fluid trapped in the internal structure of a transformer.

Diffusivity Measurements

The above work defines the amount of PCB in the transformer at the start of the retrofill. The other piece of information necessary for the modeling is the rate at which the PCBs leach out of the structures. This is characterized by the diffusivity (D, cm^2/s) of the PCB in the materials. Diffusivity is the mass transfer analog of thermal conducitivty and is a function of the solvent as well as the medium in which the diffusion is occurring.

The molecular diffusivity of biphenyl in TCE and TCB was measured at 23°C using the method of hydrodynamic stability (2). The molecular diffusivity describes the mass transport through a homogeneous phase (stagnant film of fluid), not a porous structure. A porous medium, by providing resistance to diffusion, decreases the

effective diffusivity. The molecular diffusivities determined here can be viewed as upper bounds to the rate of diffusion in the various transformer components. Biphenyl provided for an easier analysis of the data since it is a single compound, unlike the PCBs used in transformers that were complex mixtures of similar chemical species. The transport properties of PCB and biphenyl are similar. The diffusivity of a PCB (polychlorinated biphenyl) can be easily estimated from the biphenyl value by accounting for the differences in molal volume at their respective boiling points (3). The estimation of diffusivities at temperatures other than the temperature of measurement is also straightforward (4). See Table 2 for the measured diffusivities of biphenyl along with the estimates for hexachlorobiphenyl (HCB) at 23°C and 60°C. Hexachlorobiphenyl (6 chlorine atoms out of a possible ten on the molecule) is the "average" constituent of Aroclor 1260 since Aroclor 1260 is 60% chlorinated.

The diffusivity of PCB in silicone fluid is substantially lower than in TCE or TCB as a result of its higher viscosity. Because of the lower diffusivity and partial miscibility with askarel, silicone fluid would be considerably less effective at PCB removal than either TCE or TCB. As a result of the lower leach rate, silicone fluid could be used to increase the likelihood of the reclassification if used as the dielectric fluid during the reclassification period. The silicone fluid would retard the leaching of the PCBs from the transformer internals resulting in a lower PCB concentration in the bulk fluid but higher PCB residuum.

MATHEMATICAL MODELING

The system chosen for the modeling of the retrofill process is a 500 KVA PCB transformer filled with 300 gallons of fluid that is 50% by weight Aroclor 1260 and 50% TCB (tri- and tetrachlorobenzene, a typical askarel mixture). The modeling is specifically of the transformer coils because these represent the most difficult structures to render PCB-free. The core, the other major constituent of the transformer, has spaces between he laminations that are large compared to he dimensions of a PCB molecule and the diffusion path out of these laminations is not tortuous (straight-line). Thus, the mode of diffusion out of the laminations is molecular, not hindered as is the case in the coil insulation. The level of PCB residual predicted here, modeling only the coils, is an under-estimate; because, there are likely to be considerable residual in the fiberboard and the maple in addition to what remains in the coils.

A conservative estimate of the amount of PCB material contained in the three coils of the 500 KVA transformer before retrofill is 4 kg based upon the fluid volume experiments described earlier. The actual amount could be as high as 16 kg. The diffusivity parallel to the paper windings is several orders of magnitude greater than perpendicular to the paper (5). Therefore the diffusion was modeled in one dimension parallel to the paper. THe length of the coil in the direction of greater diffusivity was 30 cm.

In Figure 1, the amount of PCB remaining in the coils after 6 months of diffusing into a solvent with zero PCB concentration (the maximum driving force for diffusion) is plotted against values of diffusivity/diffusion-length^2 (D/L^2). Curve A depicts the results for the conservative 4 kg fluid mass estimate while curve B depicts the results for the 16 kg estimate. D/L^2 is an indication of the rate at which the concentration of PCBs in a medium decreases. The dependence upon the length-squared is significant. A large transformer with larger internal parts could take very much longer to achieve the same degree of PCB removal than a smaller unit.

Only 56 g of PCB is necessary to raise the concentration of the 300 gallons of transformer fluid to 50 ppm. This quantity can be calculated by multiplying the total weight of transformer fluid by 5×10^{-5}. To be sure that the transformer fluid never exceeds the 50 ppm level, the PCB residual must be reduced to less than this quantity. For the transformer modeled here to remain under 50 ppm PCB (residual < 56 g) indefinitely, the D/L^2 value must equal or exceed 2.6×10^{-8} s^{-1}. The higher diffusivity of PCB in TCE makes this the solvent most likely to effect the desired cleanup. The highest value of D/L^2 (using the molecular diffusivity upper limit) possible for TCE at 60°C is 1.8×10^{-8} s^{-1}. Thus even TCE at 60°C with no impedence to diffusion from the coil materials is insufficient to clean the coils well enough to guarantee under 50 ppm concentrations indefinitely. Any reduction in the diffusivity resulting from the diffusional resistance of the insulation will substantially increase the residual level.

from curves A and B in Figure 1, it can be seen that kilograms of PCB are likely to remain in the coils. With the possibility of additional material in the fiberboard and wood, the values in Figure 1 are under-estimates of the total PCB remaining in the transformer after retrofill. The large PCB residuum does not imply any difficulty with reclassification. The leaching rate, particularly if silicone is the final fluid, is sufficiently low that the bulk fluid concentration would remain under 50 ppm for 90 days. The significant criterion that the transformer owner should use to evaluate the success of a retrofill process is the reduction of the PCB residuum to below the level necessary to guarantee under 50 ppm indefinitely, not the ability to meet the present reclassification requirements.

CONCLUSIONS

Retrofill services utilizing a good solvent may effect the desired reclassification by meeting the 90 day requirements set by the EPA for the dielectric to contain less than 500 or 50 ppm PCB. This does not mean that the transformer is truly PCB-free. Kilograms of PCB likely remain in the coils, fiberboard and maple wood. By opting for retrofill instead of retrofit, the owner risks the possibility of the reclassified transformer becoming a PCB-contaminated unit, or worse a PCB unit, as a result of the slow leaching of the remaining PCB. The owner, upon discovery of the increased level of PCBs in the replacement fluid, is subject again to EPA requirements as determined by the PCB concentration. His options may then be limited to replacament only, depending on the type, location and application of the transformer, or he may ba able to again retrofill.

Potentially more serious would be the discovery of the increased PCB concentration after a spill, leak or fire involving the transformer. As the EPA focuses more attention on transformer scrapping operations, the possibility increases for becoming involved in site remediations due to the disposal in a scrapyard or landfill of an EPA classified non-PCB or PCB-contaminated carcass containing significant amounts of PCB. The financial risk can be substantial as noted by several recent cleanups directed by EPA.

The rectrofill and reclassification of a transformer might initially be less costly than retrofit, but there are potentially higher future costs and significant risk that should be taken into consideration before a decision is made between the two choices.

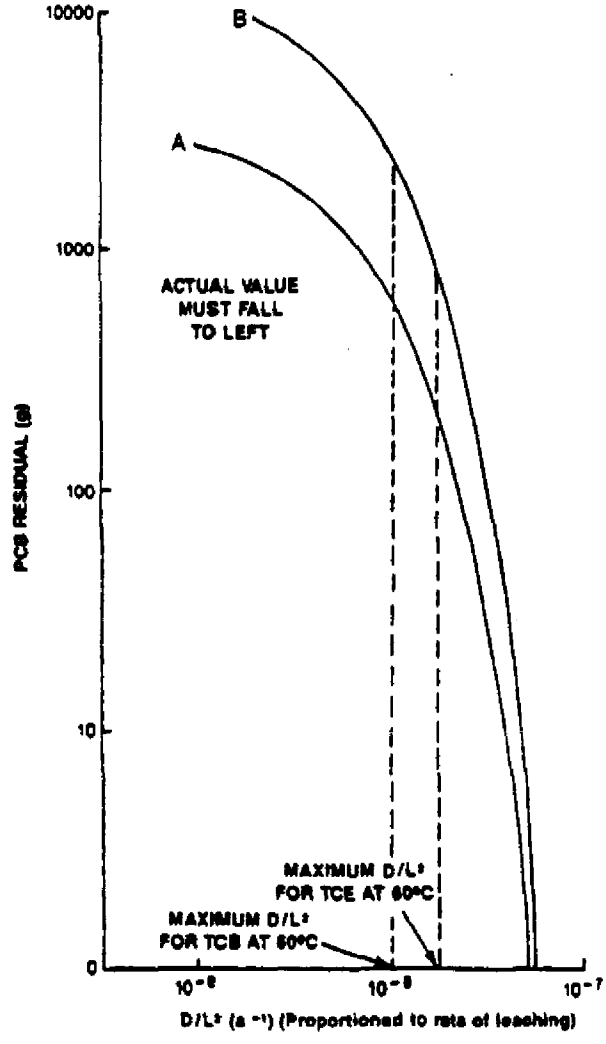

Figure 1. Amount of PCB remaining in coils versus D/L^2; A- conservative estimate, B- upper estimate.

Table 1

Breakdown of Transformer
Fluid Volumes

Structure	Fluid Volume (In Milliliters)	Percent of Total Volume
Core	270	0.8
Coils (2)	650	2.0
Fiberboard	177	0.5
	1097 ml	3.3%

Total Transformer Fluid Volume - 33 l

Table 2

Diffusivity (cm^2/s)

Solvent	Biphenyl (23°C)	HCB (23°C)	HCB (60°C)
TCE	1.4×10^{-5}	1.0×10^{-5}	1.6×10^{-5}
TCB	6.6×10^{-6}	4.8×10^{-6}	9.1×10^{-6}

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MONS 217242

MONS 217243

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TITLE AND ABSTRACT

Retrofill in a Remote Location of Network Transformers Using the Westinghouse System: The PCB transformers that are the subject of this paper present some special conditions. They are located in vaults beneath the sidewalks in downtown Cedar Rapids.

Cedar Rapids is a city of about 110,000 persons and a trade area for additional thousands. The downtown area, as you can imagine, as a well-established, traditional shopping and trade neighborhood. It is high-traffic for both automobiles and pedestrians.

Network transformers in the area present for our utility a typical low-probability, high-risk condition: the chances of a problem affecting utility customers and the public are very low. Should a problem occur, however, the risk is potentially very high.

Many of you have been, or are now, confronted with the same situation.

What do you do? Do you leave things as they are, changing to non-PCB equipment as it ages, fails, or becomes economically inefficient in the natural course of events? Or do you, as many have done, replace the PCB apparatus as quickly as you can? That is the safest way. Also, the most expensive. All companies cannot follow the replacement course because of budgetary limitations. There is an added cost factor in replacement, too. That is the cost of disposal and destruction. Retrofill is a middle course that many are following. It is the course Iowa Electric decided to follow for its downtown Cedar Rapids network transformers. This decision was carefully and thoughtfully made. It was reached after careful evaluation of all the factors--public and customer welfare, system efficiency, cost, and impact on overall operation.

Retrofill will cost somewhat less than replacement. We do not know just what that cost savings will be as yet. But costs of retrofill now appear to be two-thirds

to three-fourths those of raplacing existing units with naw apparatuses. This savings of 33 to 25% of replacement includes the avoidad cost of disposal and destruction.

Iowa Electric personnal made tha ratrofill deciaion after careful evaluation. To data, that decision seems to be a good ona. So far, our experiance has baan good and wa axpect to continua to have good experience. We are now working with the retrofill of four of the transformers--and fully axpect that we will continua with this retrofill proceas for an additional 10 to 15 transformers. When Iowa Electric decided to retrofill, our technicians were concerned about the impact retrofill might have on customers and tha public as they watched us work in high-treffic downtown.

We rightfully falt that work in downtown vaults might cause unusual comment and concern among customers and tha public. Heavy vehicular and padestrian treffic could raise more questions about the ratrofill procedure than tha procedure itself would answer. As you all know, the presence of PCBs in electrical equipment is wall known to the public. The public has no trouble perceiving PCB dangers. At the same time, the public in ganaral has little perception of PCB's actual dangers to human health and welfare. The general public has not been able to realistically evaluate the low level of PCB risk. Thus, Iowa Electric welcomed a retrofill process which allowed the company and its contractor to carry out the transformer process in a remote location.

In this setup, the transformer is removed from its place in the network vault and trucked a mile and a half to a facility the company owns. The transformer is replaced with a spare one from the company's inventory. The transformer taken to our remote facility for the transformer process has, of course, been carefully evaluated for age, projected remaining useful life, and general condition. Only good candidates for relatively long remaining useful life are selected for TransForm. Units which do not meet criteria are removed from service and are replaced either with transformers from inventory or with new apparatuses.

At the transform facility, this procedure is followed: PCB fluid is drained, gasket materials are replaced, and the transformer is filled with a proprietary dielectric fluid called TDR-3. Then a processing machine is connected to the transformer and the transformer is re-energized. This first stage is expected, by Westinghouse, to not exceed 48 hours. Experience indicates that under most circumstances not more than twelve hours are required.

The processor then operates with the transformer in service for duration of the treatment--usually four to nine months. When tests and completed processing time

signal the end of this stage, a second stage begins. The processor is disconnected from the transformer and the TDR-3 is drained from the transformer. The transformer is then vacuum-filled with the dielectric fluid of the owner's choice. It could be mineral oil, silicone oil, or other material. The choice is based on the owner's choice and code requirements applicable to the permanent location of the transformer.

The building in which the TransForm process is carried out is in a commercial/residential area in Cedar Rapids. We now have four transformers in TransForm process. While the facility is not manned continuously, it is monitored continually with sensors which activate telephone equipment if and when a glitch occurs and the processor automatic equipment shuts down the operation without affecting the transformer. Thus, monitoring is carried out by Iowa Electric Operations personnel or by Westinghouse technicians. Iowa Electric personnel are only a few minutes away. To date, the automatic shut-down and telephone sensing devices have operated very well.

The Westinghouse TransForm process is a single-treatment reconditioning service. We are guaranteed reclassification of the transformers to non-PCB status. As you know, non-PCB status is less than 50 parts per million. At the end of the processing period, the transformer is disconnected and a 90-day in-service period is begun. Then, the TDR-3 fluid is removed and replaced with the final fluid. In our case, that fluid will probably be silicone.

(Results of our TransForm experience through September 30, 1987, will be presented when the paper is read.)

MONS 217247

EXPERIENCES FROM RETROFILLING ASKAREL TRANSFORMERS

A TWO YEAR SERVICE DATA PROGRAM

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ABSTRACT

Since RECLASS 50^{SM} Servicing was first offered in July of 1985, it has been accepted by more than 200 major clients. Over 3,000 askarel servicings have been completed with no evidence of incompatibilities or other problems having been observed. In general, the vast majority of askarel equipment has been found, upon examination, to be in excellent condition, dry, lightly loaded and operating at oil temperatures of less than 50°C.

The results of a Servicing Information Data Program are summarized. The data include most types of 15KV equipment (including rectifiers, voltage regulators, and grounding transformers), over 23 different manufacturers, and network and radial electrical configurations.

A common question for existing transformers is the condition of the equipment and how much useful life remains. The mean age of equipment under service is greater than 25 years. Age alone, however, has not been a reliable indicator. Transformer inspection, electrical testing, and coolant analysis can be helpful. Askarel coolant has been observed to be quite stable and inhibitory towards internal degradation. The vast majority of coolant in transformers have tested low in water with correspondingly high dielectric insulating strength (indicative of tight gaskets and bushings.)

Transformers in the Data Program differ greatly in design and electrical characteristics but have been constructed from similar porous materials and thus are observed to be responding similarly with respect to PCB removal. The dominant parameters influencing PCB removal rates and methods for tracking progress are discussed.

ENVIRONMENTAL ALTERNATIVE TO LANDFILLING PCB TRANSFORMERS

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ABSTRACT

In order to eliminate the "lingering liabilities" associated with the landfilling of PCB transformers, S. D. Myers, Inc. has developed a process which will decontaminate the internal metallic parts of the unit. The cellulosic materials, along with the askarel fluid, will be incinerated. (For fluids contaminated up to 3300 ppm PCB, the PCBs will be chemically destroyed using the PCB-Gone Mobile Process.) The end product will be that the natural resources are recovered for reuse, the PCBs are destroyed, and no trace of the transformer will exist.

Since the advent of Superfund, it is no longer possible to place toxic or hazardous substances into a landfill and assume that the problem has been solved. Despite the Constitutional prohibition of retroactive laws (ex post facto), Congress decided that they can pass laws in the present that may affect actions of the past. Therefore, disposal methods which are legal today may turn into tomorrow's extraordinary costs.

EPRI recognized this when it spoke about the "lingering liability" associated with the landfilling of PCB transformers. Since the owner of a PCB transformer bears responsibility for disposal of the PCB transformer at its end of life, and landfilling may not constitute "end of life," landfilling could subject the generator to possible future liability should any number of things happen (e.g., leaching, leaks, improper disposal, poor record keeping, changes in the laws, etc.).

Development of the disposal process discussed in this paper (the details being highlighted in the accompanying slides) began as a research project to retrofill askarel transformers. Experiments with cleaning tightly packed laminations to below 10 ug/100 cm^2 revealed the difficulty of such a feat. Then, when we found 144 pounds of askarel soaked hardwood together with over 60 pounds of paper in a 200 gallon askarel unit, it was decided that this was a very difficult, if not impossible, proposition. The fact that we are not aware of any company claiming to retrofill askarel units to non-PCB status, and the guaranteeing that they stay non-PCB for one or two years without any servicing after the 90-day wait period, points towards a high probability that it cannot be done.

S. D. Myers, Inc. therefore developed our disposal process, now in the midst of commercial scale-up, that relieves the transformer owner of his PCB liability and eliminates the need for landfilling any transformer, PCB or not. The process

involves, in the case of askarel units, first draining and flushing the unit to remove gross amounts of PCBs. After this, the transformer core and coils are untanked, all porous materials (paper, wood, gasket material) removed from the metal parts, the laminations separated and all the metal parts rinsed until the PCBs have been removed. This is done under EPA authorization, and health and safety issues have been addressed. The case is then separately rinsed both inside and out to ensure that the PCBs have been adequately removed.

The waste streams and materials are then handled as follows: All porous materials are sent out for incineration. All PCB-free metal parts are sent to smelters. The solvent used for rinsing is distilled for reuse, and only the still bottoms collected for incineretion. Thus, nothing exists that can, in any imaginable way, be traced back to either the generator or the disposer.

PCBs have been adequately removed, according to the EPA, when less than 10 ug/100 cm^2 of PCBs are detected on a wipe sample. Region VII EPA considers 10 ug PCB/100 cm^2 to be the limit of detection for wipe samples. Region V EPA, under whose authority we have been working, considers less than 10 ug/100 cm^2 to be the goal of such clean-up activity.

We believe that good reason exists to justify that the 10 ug/100 cm^2 is the environmentally safe level for clean-up that should apply for this operation. First, the April 2, 1987, "TSCA PCB Spill Clean-Up Policy Rule" uses less than 10 ug/100 cm^2 as its level for clean-up of "high contact solid surfaces." Second, the EPA allows PCB contaminated transformers to be drained and the core, coils, and case (with the porous materials still attached) sent to a smelting operation. These transformer parts often contain more than 10 ug/100 cm^2. This being the case, it would be illogical for the EPA to require stricter clean-up levels for disposal of PCB transformers than they do for disposal of PCB contaminated transformers. Third, if the 200 gallon unit previously mentioned had all its metal parts cleaned to 9 ug/100 cm^2, the total amount of PCBs remaining would be 0.8 gm for a 99.9999% removal efficiency.

The goal in developing this process was to eliminate the "lingering liability" of PCB transformer owners in an economical fashion. While this goal has been realized, other benefits also accrue with this process; namely, valuable natural resources are recycled for use, the amount of waste generated is reduced, and the generator can say, "I have selected the method of treatment, storage or disposal currently available to me which minimizes the present and future threat to human health and the environment."

PART 3:

MISCELLANEOUS

THE FATE OF PCBs IN SOIL AND WATER

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Until recently, there existed two contradictory perceptions regarding the behavior of PCBs in the general environment. One was that the commercial PCBs (Aroclors) were essentially indestructible, and would persist indefinitely at spill sites unless removed by some form of remedial action. The other was that the analytical gas chromatograms of PCBs recovered from environmental samples rarely matched those of either individual or mixed Aroclors, so that various arbitrary conventions were needed in order to report environmental PCB analyses in terms of "Aroclor" compositions. The chromatographic mismatch was attributed to "weathering" of the PCBs.

During the past four years, we have been studying the composition of environmental PCBs with high resolution capillary gas chromatography and mass spectrometry in order to better characterize the PCB "weathering" phenomenon and identify its origins. It is now apparent that it includes at least four different types of PCB alteration processes: partitioning into a mobile phase, oxidative biodegradation, reductive biodegradation (dechlorination), and photolysis by sunlight (1-6). These four processes, their environmental requirements, their recognition features, and their influence on PCB fate will be described in turn.

PARTITIONING INTO A MOBILE PHASE

There are at least four purely physical mechanisms by which PCBs can be removed from contaminated soils or sediments. These are (a) evaporation into the atmosphere, (b) extraction into a body of water by true, molecular solution, (c) extraction into the water by dissolved organic colloids (facilitated solution), and (d) flushing of suspended droplets or particles by a water stream. Process (d) requires an appreciable current velocity, and hence represents an important PCB transport mechanism in rivers, but not in most lakes, estuaries, or groundwater. It can be distinguished from (b) and (c) by filtering a sample of the water and analyzing the filtrate and suspended particulates separately for PCB content. Processes (a) and (b), unlike (c) and (d), result in changes (actually, very similar changes) in PCB composition. These occur because the various individual PCB congeners differ considerably in volatility and water-solubility. Since these properties are closely related to mobility on a gas chromatographic column, if either evaporation or water-extraction of an environmental PCB specimen has occurred, its chromatogram will show a general weakening of the early peaks that becomes more marked the earlier the retention time, but with no marked alterations in the relative

intensities of neighboring peaks. The extent of such evaporative or extractive loss is probably best estimated by comparison with Aroclor standards that have been allowed to evaporate to known extents of weight loss in the laboratory. Such estimates indicate extensive (20-80%) PCB losses from the surface layers of soils and sediments at Aroclor 1242 spill sites, and sometimes even significant evaporation from Aroclor 1260. This loss mechanism, however, is obviously improbable for PCBs that are more deeply buried or sedispersed, as in landfills.

OXIDATIVE BIODEGRADATION

Soils, sediments, and surface waters contain complex populations of aerobic microorganisms that are capable of oxidatively biodegrading all of the naturally occurring chemical constituents of organic matter, and also many PCB congeners. PCB-degrading bacteria have been detected in every soil and sediment that we have examined. To date, over two dozen strains of PCB-degrading bacteria have been isolated (1). These vary widely in PCB-degrading activity: some can attack only a few mono- and dichlorobiphenyls, others can attack almost all of the lower congeners, many of the pentachlorobiphenyls, and even a few hexachlorobiphenyls. They also vary in congener selectivity pattern: some (the majority) can tolerate the presence of chlorine atoms in both para (4,4'-) positions but are inhibited when chlorine atoms occupy two ortho (2,2'- or 2,6) positions, or positions 2,5-, while the others can tolerate 2,2'- substitution more easily than 4,4'- (1,2). The levels of the individual strains in soils and sediments are probably low and probably not increased in the presence of PCB contamination, since none of the PCB-degrading aerobes can actually grow on PCB.

In environmental PCB samples the occurrence of oxidative microbial biodegradation may be distinguished from that of evaporative or elutriative loss by the appearance of selectivity in the congener removal pattern. Instead of an indiscriminant loss of all lower congeners in proportion to their volatility, one usually sees losses of those lower congeners that carry only one ortho chlorine in preference to those of the symmetrically di-ortho (2,2'-) substituted type, and those in preference to those of the unsymmetrically di-ortho (2,6-) substituted types. We have seen these sort of alterations most clearly in samples of groundwater, and those of riverwater that had contained most of the PCB in true solution; in aerobic soils and sediments losses of lower congeners by aerobic biodegradation are often overshadowed by those arising from evaporation or elution.

A biochemically different form of oxidative biodegradation (that is, a form mediated by monooxygenase rather than dioxygenase enzymes) form occurs in birds, mammals, crustaceans, and some kinds of fish (3). As a result, in environmental PCB specimens derived from such sources, rather than from soils, sediments, water, or molluscs, the alterations in PCB congener distribution produced by either physical partitioning or environmental bacteria can be overridden by those effected by monooxygenase (i.e., P-450 cytochrome) metabolism. This type of metabolism removes essentially all PCB congeners except those that are di-para substituted, and particularly those carrying chlorines in positions 2,4,5, and 4'.

REDUCTIVE BIODEGRADATION (DECHLORINATION)

The most recently discovered form of environmental PCB biodegradation consists of reductive dechlorination in aquatic sediments (4,5). Evidences for the

occurrence of such processes have now been found in sediments or fish from the waters of Fort Edward, NY; Pittsfield, MA; Waukegan, IL; Sheboygan, WI; Massena, NY; Albany, NY; New Bedford, MA; Escambia Bay, FL; and New York City. The process has been duplicated in the laboratory by incubating PCBs with unsterilized sediments under anaerobic conditions, but is stopped by sterilization, indicating that a biological agent is involved. Available evidence indicates that at least 9 different environmental agents, presumably all different strains of anaerobic bacteria, are responsible for carrying out the observed dechlorination processes. We also believe that these bacteria use the PCBs as terminal electron acceptors in their metabolic processes. Thus, these anaerobes, unlike the PCB-oxidizing aerobes, may be able to derive a competitive advantage from their PCB-degrading activities, and therefore produce extended colonies of a single species in areas where they have managed to seed a PCB spill site. At any event, patterns of higher congener depletion and lower congener formation tend to be sharply defined and quite consistent from sample to sample within a single spill site, but demonstrably different in different sites. Characteristic recognition features of environmental PCBs that have undergone reductive dechlorination include depressed levels of most higher congeners, particularly of those containing 3,4-, 3,4,5- or 2,3,4-chlorophenyl groups; and sharply increased levels of certain lower congeners, which may be those carrying either 2-, 3-, 2,6- 3,4- or 3,5-chlorophenyl groups, depending upon the particular dechlorination system involved. Thus far, we have usually seen reductive dechlorination in the heavily contaminated sediments from the immediate vicinity of spill sites, and in the less heavily contaminated regions around the periphery of such sites, but usually not in the lightly contaminated sediments from remote areas.

The significance of reductive dechlorination is three-fold. First, by reducing the degree of chlorination of the PCB molecules it makes them more easily removed from the site by either partitioning into air or water or by oxidative biodegradation. Second, by removing the congeners carrying 3,4-, 2,3,4-, and 3,4,5-chlorophenyl groups reductive dechlorination also removes the potential for chloracnegenic toxicity, and by removing other chlorine atoms from para (4-) positions, as well the potential for PCB bioaccumulation in warm-blooded animals. Thus, the biological dechlorination also accomplishes detoxification. Third, by sharply altering the congener distribution in the Aroclor, it can provide unusual PCB compositions whose movements through environments contaminated with PCBs from other sources can be traced.

PHOTOLYSIS BY SUNLIGHT

Laboratory and modeling studies (6) have shown that PCBs in solution may be photodegraded by solar ultraviolet, the products being mostly those of reductive dechlorination, along with some of photo-assisted solvolysis. The photochemical dechlorination, in sharp contrast to the microbiological, has a strong preference for removing ortho chlorines, and thus yields PCB mixtures consisting predominantly of mono-ortho and non-ortho substituted congeners. We have not yet seen any such compositions in water, fish, or sediment samples from inshore or inland locations, nor does theory predict their existence. However, modeling results suggest that they might appear in off-shore specimens, such as mid-ocean plankton collections. Photochemical dechlorination should improve PCB susceptibility to elution and oxidative biodegradation, but in the early stages would increase rather than decrease chloracnegenic toxicity.

Putting these processes together, it would appear that the ultimate fate of PCBs released on land will be a partial biodegradation by aerobic soil bac-

terie on site accompanied by a gradual transport via meteorological and hydrological processes to large lakes or oceans where destruction will occur by a combination of photochemical and aerobic microbial processes. For those PCBs released into waterways and those taken up by the sediments, anaerobic microbial dechlorination will permit a considerable acceleration of the processes of detoxication and mobilization, and give products that will be more rapidly destroyed by photolysis and oxidative biodegradation in the surface waters of rivers, lakes, and oceans. The extent to which these processes of transport and transformation have occurred at any one site will obviously be dependent upon local environmental factors, particularly those affecting the levels and activities of both aerobic and anaerobic microbial populations. At present, such factors are not well understood, so that their net effect upon PCB fate at any specific site has to be determined through a detailed chromatographic analysis of the residual PCB composition.

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MONS 217256

PCB-RELATED ACTIVITIES AT EPRI, 1986-1987

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ABSTRACT

Research activities concerning polychlorinated biphenyls (PCBs) are currently being conducted in three technical divisions of the Electric Power Research Institute. In the Electrical Systems Division, activities are focused on the decontamination of utility fluids, decontamination and destruction of PCB-containing capacitors and transformers, PCB fires, and substitutes for PCB. Projects in the Coal Combustion Systems Division address remedial action for PCB spills. Environment Division research is concerned with risk assessment for PCB exposure, risk management for utility PCB equipment and PCB-contaminated sites, and analytical methods development for polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) in PCB matrices.

ELECTRICAL SYSTEMS DIVISION

In the last year, most of EPRI's PCB-related research has been managed by the Electrical Systems Division. A 500,000 gallon per year plant for the decontamination of mineral oil has been constructed in the Georgia Power Company system at Atlanta (Research Project 2028-13,14). Research permits were received in autumn 1986 and shakedown runs and instrument calibration began in October 1986. PCB runs have been conducted, problems in the extraction section have been corrected, and problems in the solvent recovery section are being addressed. The facility is scheduled to begin operation again in June 1987. This is expected to be the final EPRI research effort toward decontamination of mineral oil.

Studies investigating the pyrolysis and combustion of PCB as a contaminant (RP2028-4) have shown that PCDF formation in PCB-contaminated fluid is proportional to the PCB concentration. With tri/tetrachlorobenzene replacing PCB as the contaminant, at concentrations as high as 5000 ppm, neither PCDF nor PCDD is found following pyrolysis or combustion. Pyrolysis and combustion of pentachlorophenol-contaminated insulating oils are currently being examined. As part of this project, the flat-cell bioassay technique is being developed to measure PCDF/PCDD-like activity in pyrolysis or combustion products in a PCB matrix. This should serve as a simple screening technique for emergency uses.

An improved analytical method based on gas chromotography/mass spectrometry for measurement of individual PCDF/PCDD species in utility fluids has been developed (RP2028-5 through -10) and tested through a laboratory round-robin. Both the Electrical Systems Division and the Environment Division participated in this project. Agreement between the five laboratories participating in the round-robin testing was generally within a factor of two, which was considered satisfactory. In general, results indicate that the method represents a significant advance in analytical technique for measurement of PCDF/PCDD in utility fluids, and no additional research is planned in PCDF/PCDD analysis.

A DC arc furnace for destruction of PCB-capacitors is being constructed at a field site in Model City, New York (RP2701-1). Permits have been received from the New York State Department of Environmental Conservation and the U.S. Environmental Protection Agency and initial tests on non-PCB surrogate materials have been planned for the second quarter of 1987. Tests with PCB materials will follow in 1987. This will be the final EPRI research project in askarel destruction.

EPRI has been evaluating options for rapid and economical methods to retrofill or scrap askarel transformers to meet EPA requirements (RP2028-19), seeking a method for cleaning drained transformers so that they would not require disposal in special landfills. EPA permits have been received for the experimental work, and experiments are underway to detank and clean metal parts, followed by incineration of PCB-saturated cellulosic materials. The economics of such a process will require careful study. Under the same contract, a material balance and analysis is being done on the residue remaining in contaminated mineral oil transformers after careful draining. The objective of this work is to gain background information for possible simplification of analytical requirements for reclassification of retrofilled transformers as non-contaminated.

COAL COMBUSTION SYSTEMS DIVISION

In EPRI's Coal Combustion System Division, PCB-related activities have addressed remedial action for PCB spills, including PCB analysis and spill cleanup. In 1986, phaseout of PCB-related activities was begun in the CCS Division.

A portable PCB analyzer (PCBA-102 gas chromatograph) was developed under EPRI contract (RP1263-9); extensive laboratory and field testing has now demonstrated that accurate and precise measurements can be made by experienced operators using rigorous quality control procedures (RP1263-23). The field instrument has been modified and ruggedized as a result of the field tests and is now commercially available from the developer.

Pilot scale tests have been conducted of a soil-washing system for PCB remediation (RP1262-15) and have demonstrated successful volume reduction of hazardous materials using a proprietary solvent. PCB-contaminated soil (up to 4000 ppm PCB) was cleaned to below 2 ppm and the solvent could be recovered for reuse leaving a PCB-solvent residue for disposal. Field demonstration indicated the need for additional development of the mechanical system for soil-washing. EPRI is currently pursuing options for additional development of the soil-washing process by the commercial sector.

Mobility of PCBs on soils is currently being investigated (RP1263-22); sorption uptake equilibria and release rate studies are being conducted for three PCB congeners on typical and low organic carbon soils. Examination of the effect of aqueous surfactants on PCB release, toward development of an aqueous soil-washing process, is planned.

In-situ vitrification of PCB-contaminated soils has been demonstrated on the engineering scale (RP1263-24). Opportunities for further development and demonstration are being discussed with EPRI member utilities. In addition, use of in-situ vitrification for immobilization/destruction of mixed radioactive and hazardous wastes and use of vitrified barriers for waste containment are being considered as future project areas.

ENVIRONMENT DIVISION

The Environment Division at EPRI is developing analytical tools and information to help utilities to assess and manage risks from PCBs. A PCB Spill Exposure Assessment Model has been developed to include exposure assessment for PCB-contaminated mineral oil and askarel. Components of the PCB exposure assessment methodology include release mode, transport and fate mode, and exposure mode. After release, a number of processes act to transport the PCBs in air, water, and soil. The transport and fate component of the methodology contains several models: a spill-site model called POSSM, PCB On-Site Spill Model, and several off-site models, which are established air, surface, and groundwater models.

Once a PCB spill occurs, a number of key hydrologic and transport processes come into play, depending on whether the spill is on soil or asphalt/concrete. From soil, PCB may volatilize and enter the atmosphere, leach through soil into groundwater, or migrate overland to surface water. If PCB spills on concrete, the compound may volatilize and/or migrate overland to surface water. POSSM can consider the influence of these processes on two types of spills: relatively pure chemical spills (e.g., capacitor spills) and spills of a mixture of two chemicals that are relatively insoluble in water (e.g., PCB-contaminated transformer oil spills). When applied to the second type of spill, POSSM simulates the impact that each component in the mixture will have on the volatility and solubility in water of the other component.

The off-site models are a Gaussian plume dispersion model, an analytic surface water transport model and an analytic groundwater transport model. These models predict PCB fate as the compounds migrate through the air, surface water, or groundwater.

Exposure can occur by three routes; inhalation, ingestion, and dermal contact. Population distribution and activity patterns determine contact. The exposure model, EXPOSE, includes a general exposure analysis framework for estimating exposure levels for each route. The framework is currently used by EPA. In addition, software for uncertainty analysis has been produced. The software will establish the variance of the predicted values of concentration in air, water and soil over time. It will also aid in estimating the probability of exceeding a given standard and so can replace worst cast scenarios.

The computer models ASK and COIL have been developed to help utilities manage their economic risks from PCB equipment (RP2595). The models are designed to help utility staffs to develop and explain policies to manage dollar risks to the utility and its ratepayers from two sources: PCB equipment in power plants and contaminated mineral oil transformers in the distribution system. Health risk management of PCB or contaminated mineral oil equipment is addressed in a separate model also developed in RP2595, the Transformer/Capacitor Risk Management Model (TRIM). All three models operate on IBM PC-compatible computers.

ASK is designed to analyze the alternatives for managing economic risks from PCB equipment in power plants. A PCB spill or fire in a power plant poses the risk of extensive cleanup costs, the cost of replacement power if the plant must be shut down, and possible legal liabilities. ASK helps the analyst to compare the costs of possible PCB incidents of varying severity versus the costs of management alternatives to prevent or limit such incidents.

COIL is designed to analyze alternatives for managing the economic risks from PCB-contaminated mineral oil equipment in utility distribution systems. A spill or fire in such equipment poses the risk of cleanup costs and legal liabilities.

COIL helps the analyst compare the risk of incidents against the costs of policies to manage those risks. An important aspect of this problem addressed by COIL is deciding whether a program to go out and sample mineral oil equipment in operation, for PCB content, is worth the effort.

A series of case studies was conducted to field-test ASK and COIL and to demonstrate how the models might be used. Write-ups of the case studies describe the structure of the analyses, the major input assumptions and the results. COIL was applied at two utilities; one was large and urban, the other was small and rural. ASK was applied in analyses of different types of transformers in five different power plants: two coal, one lignite, one gas, and one nuclear. The seven write-ups of the case studies are available now. Later they will be available as part of the ASK and COIL documentation.

A computer model called SITES has recently been developed to help utilities to manage their risks from PCB-contaminated sites. SITES addresses two problems in site remediation: determining the extent of site investigation to perform and evaluating the effectiveness of remedial actions in reducing health and economic risks. SITES has been applied to two manufactured gas plant waste sites, and EPRI is currently seeking host utilities to apply SITES at PCB-contaminated locations.

Updates on PCB research activities are available several times per year as the PCB technical report from EPRI.

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TRANSFORMER LIFE EXPECTANCY

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ABSTRACT

This paper comprehensively analyses transformer life expectancy. Conclusions are presented in terms of transformer type and dielectric fluid utilized. A rationale is provided in support of vigorous pursuit of policies by transformer owners which maintain existing transformers in service.

INTRODUCTION

Transformer life expectancy is a subject of critical concern to all transformer owners. The concept of scheduled replacement before a transformer has failed often is practiced in the hope of minimizing forced outages and other disruptions of service. However, reliability surveys have also shown that the majority of transformer failures are caused by factors not related to normal deterioration from age. Pressure changeout may result in a poor allocation of resources and may in fact cause more transformer failures than would be experienced if the old transformer were left in service. Accelerated replacement of transformers due to environmental risks associated with PCB as coolant is not only counterproductive with regard to failure rate analysis but is also extremely cost ineffective. Proper transformer replacement requires an understanding of transformer failure causes as well as evaluation of transformer life including both adverse and positive factors such as preventative maintenance and retrofill options.

TRANSFORMER FAILURES

Failure Rates Transformers are reliable, trouble-free pieces of equipment, resulting in an unobtrusiveness which makes failures both unexpected and difficult to predict. In an effort to more precisely define and categorize transformer failures, several surveys by IEEE, Doble, the U.S. government, and others have been undertaken[2,3]. For this paper, a "failure" is defined as an unplanned or unanticipated event which results in any of the following to occur: 1) partial or complete shutdown, or below-standard operation; 2) unacceptable performance of user's equipment; 3) operation of the electrical protective relaying or emergency operation of the electrical system; 4) de-energization of any electrical circuit or equipment.

In such surveys, an effort was made to identify the initiating component failure as well as the contributing cause of that failure, discussion limited here to liquid filled units due to the greater amount of available historical data. A comparison of the IEEE 1973-74 and 1978 total failure rate surveys reveals an increased failure

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rate of 50% in just six years. This suggests that newer liquid filled transformers are not as reliable as their older counterparts. Confirming this are the data for liquid filled transformers between 300 and 10000 kVA which show that the failure rates for units aged 1-10, 11-25 and greater than 25 years were 0.0072, 0.0053 and 0.0060 respectively. New transformers suffer from high "infant mortality", middle aged transformers display greatest reliability and only a slight indication of decreased reliability is seen with the oldest age group. This behavior, the "Bathtub curve" [4] holds that the ideal decision point for scheduled replacement is the point where the failure rate for an existing in-place transformer equals the failure rate of a new replacement unit. Replacement prior to this point will actually result in a higher overall failure rate for any given system.

Failure Modes Examination of failure modes allows a transformer owner to judge the risk that any given transformer is subject to and determine if and when a scheduled replacement should occur. It is clear from the IEEE survey that the majority (59%) of failures result from some type of insulation breakdown. Most interesting is that in only 13.3 percent of the failures was normal deterioration from age cited as a contributing cause, the remainder caused by either unpreventable outside cause or by preventable abuse, misuse or inadequate maintenance. These statistics call into question the very concept of scheduled replacement and indicate that the most sound policy to minimize transformer failures is a comprehensive preventative maintenance program to retain dependable transformers in service. A further justification for this premise is the widely held belief[5] that older transformers were built with design excesses which resulted in minimum stressing of conductors and insulation.

FACTORS AFFECTING TRANSFORMER AGING

Insulation Life Most transformer failures can be related to a short coming of the cellulosic insulation system, often described as an electrical system, a chemical system or a mechanical system. As an electrical system, the dielectric strength of the oil impregnated paper is the critical parameter and is most affected by contamination of the oil by water. As a mechanical system the cellulosic insulation must maintain its tensile strength to withstand the stresses which occur with overvoltage surges. Dictating both of these properties is its chemical integrity, i.e. its ability to withstand detrimental chemical transformations, which has lead to the development of the currently accepted rational for thermal insulation aging as an application of the Arrhenius rate equation.

The Arrhenius equation allows performance of accelerated functional life testing under controlled conditions. As early as 1942[6] and continuing until 1972 industry standards for evaluating both power and distribution transformer life expectancies at and above nameplate rating were base solely on laboratory measurements. The "end of life" point was arbitrarily chosen as the time to decrease the insulation's tensile strength to 50% of its original value. During the 1950's and 1960's a series of tests (published as ANSI C57.91 (1969)) were performed by the AIEE on small distribution transformers (15kVA) which showed that the published life span information based solely on insulation aging was conservative.

The time-temperature relationship for existing power transformers based on insulation aging studies is also unnecessarily conservative and should be confirmed by studies on entire units. This research has not been performed to date, and plans[7] are now being implemented calling for development of a laboratory test model which will more closely simulate entire units. When this research is performed one can expect that the life expectancy curves for power transformers will be likewise shifted upward.

Transformer Vintage The change in the design philosophy over the last 50 years had allowed the manufacture of units which do not possess the built in safety factor resulting from more conservative design practice. Design differences in modern

transformers of particular concern are lower Basic Insulation Impulse Levels (BILs), higher number of volt per turn, reduced impedance and reduced oil content per kVA. It is difficult to foresee the result of such changes when the unit is stressed beyond its intended use, the situations where most failures occur. One case in point is the epidemic of through-fault failures which began to appear in the 1970's[8] due in large measure to the reduced BILs and their correspondingly reduced impedance rating. The increased electromagnetic forces created during short circuit current surges created excessive movement and resulted in winding insulation rupture. Currently spring loaded clamping has been adopted to correct this design flaw and through-fault failures are beginning to decline. These data lend credence to the proposition that the only true measure of reliability is field experience. the exact same field experience which is present in a unit which has been flawlessly operating for 30, 40 or more years.

Transformer Oil Just as in any chemical system, the environment (dielectric) in which a reaction (deterioration) is performed will determine the outcome of the reaction. Mineral oil has been used in the overwhelming majority of transformers to date. In certain transformers, Askarel was the oil of choice until the 1978 ban on the manufacture of PCB. Since that time silicone has generally been used for applications requiring flame retardance. The owners of the more than 150,000 Askarel transformers extant today are faced with the choice of removal of the PCB fluid or premature replacement of the entire transformer. The question that must be answered is -is the cellulosic insulation in my Askarel transformer deteriorating more or less than its mineral oil counterpart?

Degradation Pathways The primary agents of cellulosic degradation are oxygen and water, with heat accelerating the reactions. Additionally, various oil degradation products will act as catalysts for this deterioration. Various data[9,10] indicate the solubility properties for mineral oil and Askarel vis a vis oxygen and water are not markedly different, and equivalent amounts of degradation reactants will be available. Any differences in aging characteristics of the cellulosic will be attributable to the presence of any catalysts or differences in heat transfer in the cellulosic matrix. Conduction of the heat out of the cellulose is dependant on the thermal conductivity of the fluid, with Askarel having the advantage over mineral oil. Heat transfer due to convection is a complex function of Viscosity, Density, Thereal Conductivity, Heat Capacity and Coefficient of Thermal Expansion. On balance, Askarel is more effective in convective heat transfer. An additional factor which greatly favors Askarel is the total absence of sludge formation. Mineral oil is prone to sludge formation which is very deleterious to convective heat transfer from the core. As a result, many utilities have instigated a policy of mineral oil "polishing" at least once every five years to remove sludge buildup.[11]

The final factor in cellulosic degradation is the formation of acidic residues which act as catalysts. The important difference between the acidic residues is that Askarel forms HCl while mineral oil forms relatively weak, but more deliterious, carboxylic acids. Strong acids can be trapped by neutral acid scavengers while the less reactive organic acids cannot. For these reasons, the insulation will age more gracefully in an Askarel unit than in its mineral oil transformer counterpart. The same conclusions are reached with regard to silicone oil transformers. Silicone oil exhibits superior (with respect to Askarel and mineral oil) conductive heat transfer, does not form sludge and is chemically incapable of degradation to acidic residues. For these reasons, silicone oil has become the standard dielectric coolant for virtually all new liquid filled, indoor transformers.

Because of various factors, de-tanking and core examination studies have been limited essentially to mineral oil transformers. One such study[12] involved fifty oil filled transformers which had been in continuous operation at Bonneville Power Administration for approximately 25-27 years. Several conclusions were drawn from this study:

1. Only a nominal loss was observed in such dielectric properties as impulse, switching surge and low-frequency voltage strength in transformers over a 25 year period.
2. Only low to moderate thermal degradation of the cellulosic insulation was observed. Further, little loss in cellulosic tensile strength was observed.
3. Mechanically, substantial useful life remained in these transformers (transformers at their stated, installed life expectancies).
4. These 25 years represent NOT MORE THAN 20 PERCENT of the expected lifetimes with such projections. 125 years may be possible.
5. An additional twenty-five or more years of useful service life (roughly twice the installed life expectancy) can be expected from such transformers.

Another study by Public Service Electric and Gas Company[13] concluded "that transformers of older construction have an average expected failure life of around 60 years," supporting the conclusion that older transformers have a life expectancy of two or three times the installed expectancy. In addition, PSE&G concluded that "today's mass production methods have resulted in many cases of faulty workmanship and marginal designs that are not uncovered by factory inspection or testing, resulting in a higher failure rate during the first three years of service. This is in contrast to the craftsmanship of yesterday with its pride in a perfect product."

These two comprehensive studies conclude that the average life expectancies of older transformers are far longer than the originally stated expectancies. Given the superior properties of Askarel and silicone fluid, the life expectancies of the older Askarel units when retrofilled and reclassified to non-PCB status via Reclass-60℠ Transformer Retrofill Service, likewise, are expected to be far greater than originally stated, thus augmenting the risk reduction value of retrofill and reclassification to non-PCB status.

SUMMARY AND CONCLUSIONS

1. Transformers, particularly Askarel transformers, were significantly overdesigned pieces of electrical equipment with exceptionally long life expectancies.
2. History has shown that such transformers have true life expectancies of fifty, sixty, seventy, or even eighty years or more.
3. Viable, commercially proven technology exists to retrofill that transformer and reclassify it to non-PCB status per EPA regulations.
4. The life expectancy of any transformer is dependent on the care with which that transformer has been maintained.

UNISON Transformer Retrofill Services, Inc. has, during the past two years, initiated in excess of two thousand transformer servicings. These Askarel transformers are exceptionally well built pieces of equipment, well worth saving. A summary table of anticipated transformer life expectancies of installed equipment is the following:

Year Placed in Service	Minimum Life Expectancy	Maximum Life Expectancy
Askarel (or Silicone Oil)		
Prior to 1970	50	65
Since 1970	40	60
Mineral Oil		
Prior to 1970	45	60
Since 1970	25	35

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ASKAREL TRANSFORMER RETROFILL - AN ANSWER TO COMMON MISCONCEPTIONS

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ABSTRACT

With the commercial introduction of technology to successfully retrofill transformers and reclassify them to non-PCB status, the transformer owner for the first time has a real choice of options for dealing with his or her PCB transformer problems. The choice should be made only after consideration of all the factors which might have a bearing, including risk reduction and management, near-term and long-term liabilities, transformer life expectancy and safe operation. Although technology to successfully reclassify transformers to non-PCB status was introduced to the market in 1984 by UNISON Transformer Services, Inc., the safe use of silicone as a retrofill fluid has been demonstrated for many years. Even so, a number of questions concerning the advisability of utilizing silicone in askarel transformers have been posed. This paper will enumerate and discuss these subjects in view of available scientific information.

INTRODUCTION

With the development of the RECLASS-50sm Transformer Retrofill Service by Union Carbide Corporation and UNISON Transformer Services, Inc., reclassification of askarel transformers to non-PCB status became a reality. This technology directly addressed the problem of leeching the PCB out of the insulation, and utilized a proprietary interim coolant, TF-1, to accomplish this task. During the leaching with TF-1 to remove PCBs, the transformer may be operated under normal conditions. Following the TF-1 cycles, during which virtually all the PCBs are removed from the transformer core, any of several possible permanent dielectric coolants may be used, the most desirable of which, would be silicone oil. Doubts about silicone's utility, though unfounded, when circulated throughout the electrical industry can cause anxiety. It is the intent of this paper to resolve these uncertainties, by restating the questions and then factually resolving the issues.

POINTS OF CONCERN

ARE SPECIAL FLUSHING AGENTS NECESSARY TO CLEAN OUT AS MUCH ASKAREL AS POSSIBLE PRIOR TO RETROFILL OF A TRANSFORMER? Special flushing agents, such as perchloroethylene or Freon™, are not required in order to achieve non-PCB status via retrofill. While superficial askarel is removed this brief flushing technique does nothing to solve the fundamental problem of retrofill - diffusion and removal of deeply imbedded askarel. The surface cleaning advantages do not outweigh the risk of transformer damage by these strong solvents. UNISON's RECLASS-50sm Transformer Retrofill Service is designed to enhance the natural diffusion mechanisms which leach out the deeply imbedded askarel. UNISON's TF-1 accomplishes the same task in an acceptable time frame and also without damaging the transformer.

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Retrofill processes have been proposed which recommend thorough flushing with strong solvents, followed by retrofill with silicone oil, rather than an intermediate leachant such as TF-1. However, silicone oil preferentially leaches out whatever diluents (askarel co-solvents) may be present, thus and reducing PCB leachability. Consequently, leeching askarel with silicone oil tekes years, even if strong solvent flushing agents are utilized.

WILL RETROFILL COOLANTS BE COMPATIBLE WITH ANY TRANSFORMER? In this instance, compatibility means the absence of deleterious chemical or physical interections. The coolant should not dissolve, degrade, or otherwise modify the insulation, its adhesives, saalants or the insulating lacquers used on many transformer windings. Coolants which are recommended by UNISON at this time are its proprietary TF-1, silicone oil, and mineral oil.

TF-1 is a low viscosity coolant, totally miscible with askarel, and compatible with the materials used in askarel transformers. Its use will enhanca diffusional leaching of PCBs from askarel transformers, but will not affect the integrity or electrical characteristics of the insulation. TF-1, however, is not always compatible with transformers designed for mineral oil. Other fluids and procedures need be utilized in these cases.

Silicone oil is noteworthy for its innocuous interaction with other types of materials. It will not dissolve or degrade the insulation or lacquers in either askarel or mineral oil transformers. With respect to interaction with silicone, gasketing materials are a special case. Most gaskets, whether silicone rubber or neoprene, will be swollen by askarel or mineral oil. Such swollen gaskets can deswell and possibly leak after retrofill with silicone oil. Accordingly, all gaskets need be replaced with Viton or other gasketing materials at the appropriate time. Mineral oil is considered to be compatible with askarel transformers, and can be a final coolant if the transformer is located such that the flammability of mineral oil is not a hazard.

IS THERE DANGER OF EXCESSIVE TRANSFORMER PRESSURE DUE TO THE HIGHER COEFFICIENT OF THERMAL EXPANSION FOR SILICONE? The erroneous fear that excessive transformer pressure can develop when a transformer is retrofilled with silicone is based on a common misconception as to a suggested "excessive" thermal coefficient of expansion of silicone oil. Exaggerated values as high as 0.00106cc/cc°C have been claimed. In actuality, the value for silicone oil is 0.00092cc/cc°C, while those for askarel and mineral oil are about 0.0007 and 0.00086cc/cc°C, respectively. Thus, for a 65°C rise in temperature, silicone oil would expand 6.0% vs. 4.6% for askarel a mere 1/2 inch difference for a 350 gallon case, not a large difference, but one which UNISON has considered, particularly where the transformer may have been designed with insufficient head space or is hydrostatically designed to be gas free.

IF MY ASKAREL TRANSFORMER IS RETROFILLED WITH SILICONE OIL, WILL IT NEED TO BE DERATED? This is a complex subject which deserves detailed discussion. First, however, it must be noted that for most transformer owners, this is an academic question because most transformers are used well below their rated capacities and there is no reason to consider derating. For those few transformers that run at capacity, derating is not a major issue. Oil temperature is used by many as a gauge on transformer insulation life. However, winding tempertures are more likely to correlate to the insulation and transformer life than the fluid temperature. The actual electrical windings are surrounded by cellulosic materials for electrical insulation and spacing. Such materials are also thermal insulators unless they are saturated with a fluid, such as askarel or silicone fluid, which provides thermal conduction. The thermal conductivity of silicone is higher than that of askarel (0.036 vs. 0.023 sec [°C/cm], respectively) and accordingly, silicone is more efficient in this phase of heat transfer. Data generated by Dow Corning,

from two identical pancake type transformers (2500 KVA 13.8 KV HY Delta 450 LV WYE) filled with askarel and silicone show that temperature rises for the high voltage and low voltage windings are 3-4°C lower for the silicone filled transformer than for the askaral transformer. Thus, the temperature rise for the transformer windings and the surrounding cellulosic materials is lower for a silicone retrofilled transformer than for the corresponding askarel filled transformer.

Regarding top oil temperatures, the effectiveness of heat transfer by convection is a complex function of: viscosity, density, thermal conductivity, heat capacity, coefficient of thermal expansion. The last three favor silicone. On balance, the thermal transport due to convection is marginally slower for silicone, and bulk top oil temperatures can be expected to be slightly higher (only five degrees or less) for silicone than for askarel. Even for transformers run at electrical capacity, the top oil temperature rise for silicone filled transformers should be less than the rated degree rise, and derating is of no concern.

Taking into account the top oil temperature rise and the winding temperature rise, it is apparent that the temperature of the cellulosic winding insulation in a silicone retrofilled transformer is essentially the same as the temperature in the corresponding askarel transformer. The transformer life is, to a major extent, determined by the life of the cellulosic winding insulation, and the essentially identical temperature of a silicone versus askarel filled transformer corresponds to identical transformer lifetimes.

In summary, as stated above, for most transformer owners, this is all academic, because most transformers in fact are used well below their rated capacities. However, for those who do run at capacity, it is comforting to know that a slightly higher top oil temperature does not necessarily signify the need to derate. Those wishing a greater, though unnecessary, margin of safety in top oil temperatures should consider derating the transformer by one to not more than five percent maximum. However, while we may expect a slightly higher top oil temperature rise with silicone fluid, we will encounter lower winding or hot spot temperature rises, and the transformer does not need to be derated.

IF MY ASKAREL TRANSFORMER IS RETROFILLED WITH SILICONE OIL, WILL ADDITIONAL PRECAUTIONS BE NECESSARY TO INSURE THE SAFE OPERATION OF NO-LOAD (DE-ENERGIZED OPERATION) TAP CHANGERS?- Silicone fluid in no way affects the standard operation of no-load tap changers which set and allow changes in the voltage ratio of a de-energized transformer without breaking the transformer seal. Tap changers are generally set during the initial commissioning of the transformer, and once the transformer is placed in service, the tap changer requires no attention and rarely, is changed from its initial position.

A tap changer consists of stationary conductive elements and movable conductive elements which frequently are tin plated copper. Prior studies show that silicone fluid is a good lubricant for tin on tin. Thus, it is unlikely that the drive shaft, which controls the movement of the movable elements, would break and lead to or cause a misalignment of the tap changer. In the unlikely event that the drive shaft would break, the cause would undoubtedly be improper movement or handling of the drive shaft rather that the presence of the silicone fluid. If the drive shaft should break, the absence of any high torque region during tap changer movement would be e clear indication that a problem exists within the changer. At this point, it would be a relatively easy task to replace the tap changer.

If the tap changer were to fail on energizing due to improper positioning of the contacts, tha failure would occur regerdless of the fluid contained within the

[redacted]ansformer. Failure would occur due to arcing across the contact elements, and [redacted]uld be severe enough to compromise the integrity of the transformer itself. It [redacted]clear that THE TAP CHANGER MUST BE IN THE CORRECT POSITION TO INSURE PROPER [redacted]ERATION, SUCH POSITION BEING THE CENTER OF THE HIGH TORQUE REGION.

[redacted]It is true that redesign of tap changers occurred in parallel during the time [redacted]period that silicone was replacing Askarel as the transformer fluid of choice. [redacted]Such redesign occurred to counter a design deficiency of the then existing units [redacted]rather than in response to a problem caused by silicone. It was determined that [redacted]the voltage ratio of many transformers was being changed more often than the [redacted]designers of the tap changers had anticipated. Failure due to improper positioning [redacted]of the drive was occurring, albeit rarely. As a result, the tap changer design was [redacted]changed to provide for both easier movement of the mechanism and easier, proper [redacted]placement of the contacts.

[redacted]IF MY TRANSFORMER IS RETROFILLED WITH SILICONE, WILL BASIC IMPULSE LEVEL (BILs) REQUIRE REDUCTION DUE TO DIFFERENCES IN POSITIVE POLARITY IMPULSE CREEP STRENGTH BETWEEN SILICONE AND ASKAREL? Assuming a transformer has been properly maintained and is protected by suitable lightning arresters or other fault protection equipment, there are no reasons BIL's should be reduced.

With the advent in the early 1980's of silicone retrofill technology (whether reclassification had been achieved or not), and the corresponding availability of silicone retrofilled askarel transformers, data became available which show that transient voltage surge induced faults are no more likely to occur with a silicone retrofilled askarel transformer than with the askarel transformer itself.

An additional support for this conclusion is the building of transformers with reduced BIL's, a trend that has become an usual original equipment manufacturer (OEM) practice. At the present time, the industry accepted norm for most new transformers is a BIL range of 45-60 KV, with previous designs for older transformers being 90-125 KV. Simply stated, this translates to assembling transformers with reduced insulating materials, effectively lowering the manufacturing costs of the transformers. If the reduction in insulation capability of pressboard impregnated with silicone were to cause problems or faults through transient voltage surges, then the current OEM practice of building transformers with a reduction in insulation materials and concomitant reduced BIL's would also present a problem. Since the latter obviously is of no concern, the former (any suggested but clearly not evident reduction in insulation character due to lower positive impulse polarity creep strength of silicone) likewise presents no problem. This clearly supports the widely held belief that older transformers were overdesigned and, correspondingly, are superior to modern transformers in reliability and performance under stress; making them assets well worth preserving.

CONCLUSIONS

In summary, questions have been posed regarding the retrofill and reclassification option for dealing with a transformer's PCB risk. Such questions or doubts, posed by a few individuals, can cause the transformer owner a great deal of anxiety even though such doubts are based only on supposition. When answered in the face of available, scientific evidence, however, such doubts vanish. This leaves the transformer owner free to concentrate on more important factors such as risk reduction and elimination of long-term liabilities associated with PCBs. With the demonstration that RECLASS-50℠ Transformer Retrofill Service offers a viable retrofill technology which does not adversely affect the transformer, the transformer owner finally has an option for eliminating his or her PCBs and their associated risks, forever.

PART 4:

DESTRUCTION

SMALL-SCALE DESTRUCTION OF PCB FLUIDS BY ELECTRICAL DISCHARGE PLASMAS

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ABSTRACT

A process which uses high-voltage, ac discharges as a reaction zone to decompose oils has been developed and patented. The system is unique in that the discharge plasma is confined to the interface between the oil being decomposed and water. The temperature of the discharge region is of sufficient magnitude to cause fast pyrolysis of the oil. The water helps prevent carbon buildups via a shift reaction which produces hydrogen and carbon monoxide. The water also allows soluble catalysts to be introduced to the reaction zone, and reaction products to be removed. For example, the chlorine of chlorinated hydrocarbons is converted to HCl, then neutralized to a metal salt which is withdrawn from the water phase. The gaseous products of the decomposition are withdrawn as hydrocarbon vapors.

Fluids contaminated with PCB's have been tested on a limited basis. These and other preliminary tests on waste agrichemicals and other hazardous industrial wastes indicate that the geses evolved are free of hazardous or toxic components, while precipitates are condensed carbon structures and inorganic salts. Projected advantages are low capital costs and the ability to be scaled to small or large sizes without loss of efficiency.

Processes to destroy PCB's continue to be of high interest both nationally and internationally. A recent international meeting in Vienna addressed this topic as well as a multitude of other problems involving the management of hazardous and toxic wastes (1). The concept of "waste minimization" appears to be the goal for future control efforts. Meanwhile, efforts to develop acceptable technology for the treatment of existing hazardous wastes continues to go forward. With respect to PCB's, on-site clean ups have always been an attractive feature for developing technologies (2). This feature is particularly agreeable with the electric power industry which acknowledges the potential hazardous condition of widely scattered transformers containing PCB's. Such transformers are distributed throughout most populated geographical areas. They represent a multitude of small volumes, 250 liters (60 gal.) which can contain anywhere from pure askarels to ppm concentrations of PCB's in the dielectric fluids (3). As such, they represent potential high risks for causing environmental insult should accidental spills occur.

Progress is being made in the removal of these PCB containing fluids from active service. Incineration is an accepted technology. It is effective and can be regulated by governmental agencies. However, most incineration processes are large

scale and necessitate that the hazardous fluid be transported to the disposal site; a process which also can have a high liability risk associated with it if an accidental spill occurs. The more preferable on-site technology for treating the PCB fluids has centered on both physical and chemical treatment processes. Physical processes utilize distillation or extraction techniques with proprietary solvents (2). Chemical treatments use alkali metals or molten salt baths to actually change the PCB molecular structure. These processes are successful in many instances, but can be expensive, may require repeated applications due to diffusion controlled phenomena, and are still dependent on incineration to treat by-products which are formed. For these reasons, on-site disposal of fluids containing PCB's remains a competitive area of technology. This paper will describe a new technology being developed which may perhaps find a niche in the removal processes for PCB's on site.

PROGRAM OBJECTIVES

The technology to be discussed in this paper was developed over the last four years as a process for generating fuel gases from waste or low cost liquid hydrocarbons. A patent covering this technology has been applied for and will issue to Al-Chem Fuels, Inc. (Dimmitt, TX) this year. Only within the last year has the application of this technology been directed towards the treatment of hazardous or toxic chemical wastes (4, 5, 6). Moreover, it has only been during the last six months that serious attention has been given to the problems associated with PCB disposal. Therefore, many pertinent questions pertaining to the technology remain to be answered.

In our initial approach to PCB disposal several program objectives were established. These included the following: (1) to develop a capability of completely destroying PCB molecular structures without creating new hazardous wastes (i.e., dioxins); (2) to attempt small-scale, on-site disposal (i.e., 200 liters/day (50 gal/day) with minimal utility requirements) and; (3) to strive for a cost competitive process. The technology being developed appears to be progressing towards achieving these objectives. The discussion which follows offers data and evidence as to how this is being achieved.

ELECTRICAL DISCHARGE PROCESS

The discharge of electricity between two electrodes is known to contain electrons at temperatures in excess of 15000K. This level of temperature is sufficient to dissociate most chemical bonds and create lower molecular weight species which are thermally more stable. Thermal cracking and pyrolysis processes on an industrial scale are examples of such thermally induced changes. The technology used in this process makes use of the elevated temperatures associated with repetitive electric arc discharges to destroy the PCB molecular structure. Not only is the PCB structure destroyed, but also that of the mineral oil, silicone oil or any other solvent in which the PCB's are dissolved. Hence, the process is not one of resource recovery and recycle, but one of total destruction.

The physical structure requirements of the process which will be discussed here are depicted in Figure 1. As shown, a metal electrode is immersed in an insulating oil phase and brought into the proximity of the interface formed with a conducting water phase. The water phase acts as an electrode during operation. A high voltage potential is created between the tip of the metal electrode and the conducting water phase. As this potential is increased, a point is reached at which the nonconducting oil phase breaks down and an electrical discharge is created through the gap between the electrode tip and the water interface. By using an alternating power source, multiple arcs can be struck over a period of time as the polarity of the electrodes cycles between the extremes of positive and negative potentials. Generally, the potentials involved are in the kilovolt range while the current

densities are a function of the potential drop squared and the inverse of the cube of the distance between the electrode tip and the water interface. Hence, moving the electrode away from the interface can cause cessation of the discharge process. Similarly, an increase in the electrical conductivity of the insulating oil phase can reach a level at which discharges are eliminated and ohmic conduction and heating are created. To be effective therefore, an arc discharge must occur. It must be repetitive to the point that it is continuous. If this can be accomplished and controlled, then the arc becomes the destructive mechanism for all molecular species drawn into the plasma zone.

Plasma treatment processes are not new technology for waste treatment. Freeman discussed two plasma processes that have reached demonstration stages (7). One unit is offered by Pyrolysis Systems, Inc. and the other by Applied Energetics, Inc. The Pyrolysis Systems' technology is based on a plasma torch concept developed at the Pittsburgh based Westinghouse Electric Corporation (8). It has been described as a mobile unit capable of treating up to six tons of waste per day with a one hundred percent conversion efficiency. Gases produced by the plasma torch must be scrubbed to remove hazardous constituents.

These examples of the proven ability of electrical discharge plasmas to destroy chemical structures are offered as supportive evidence for the technology developed by Al-Chem. The unit being developed by Al-Chem also utilizes the destructive potential of a hot, ionizing electrical discharge. However, it differs in several significant ways: (1) it is a much smaller plasma zone; (2) the discherge occurs at a water interface; and (3) it has a built in gas scrubbing mechanism. A fourth feature is that it is capable of utilizing the fuel gases produced to offset the power requirements of operation.

In order to put a scale of size on Figure 1, it should be noted that the plasma arc created by the discharge rarely exceeds an elliptical shape whose major axis is 0.5 cm in length. The volume of plasma region is therefore somewhat less than one tenth of one percent of the volume of liquid oil and water in the vicinity of the discharge. Therefore, it is possible to maintain a steep thermal gradient between the thousands of degrees centigrade within the arc and the less than one hundred degrees of the bulk fluid. The gases produced by the electrical arc are thereby quenched and scrubbed by the surrounding oil and water within seconds of their formation. The large volume of fluids relative to the discharge zone also helps prevent spurious discharges of electrical energy which can arise as carbon deposits build in the oil phase. This carbon buildup is the direct result of the pyrolysis caused by the high temperatures within the arc and carbon-rich deposits represent a by-product of the cell's operation.

The presence of the water interface and the actual use of water as an electrode is necessary in order to prevent an excessive buildup of carbon deposits. Unlike the insulating oil, the more conductive water is actually drawn into the reaction zone by the forces of the high electrical potential. The chemical analyses of the gases produced suggest that because of this participation of the water in the reaction chemistry, solid carbon is shifted to molecular hydrogen and carbon monoxide. Therefore, depending upon the type of oil being destroyed, a quasi-steady state level of carbon rich precipitates are formed. The level of condensed carbon structures can be further reduced by the introduction of water soluble catalysts. Finally, the water phase acts as a highly adsorbtive medium for the removal of any acidic gases which are formed (i.e., HCl, SO_x, NO_x, etc.). It is well known that these inorganic mineral acids are many times more soluble in aqueous solutions than they are in organic fluids. Moreover, if the aqueous phase contains mineral bases of high pH, then soluble or insoluble salts can be formed. In this way the offending anions of the hazardous waste can be removed expeditiously without the need for auxiliary gas scrubbers.

The schematic shown in Figure 2 indicates how the gases produced could be scrubbed by caustic water if it were deemed necessary. Also shown in this figure is the manner in which the fuel gases produced by the Al-Chem device can be used to power or at least co-fuel the unit. The efficiency of this type of system will be discussed later, but generally light hydrocarbons to serve as fuel must be brought to the site if the twenty-five percent efficiency of the internal combustion engine is to be overcome. However, the electrical energy needed to run the Al-Chem unit can come directly from an electrical power source if it is available on site.

EXPERIMENTAL APPROACH

The experimental approach used in this study is the same as that used in similar prior studies which involved fuel gas generation. This is detailed in other publications (4, 5, 6) and only a summary of the procedure is repeated here. The reaction container was a glass vessel (3.8×10^{-3} m^3 or 1 US gallon). The glass provided a visual display of the electrodes during operation and for photographic purposes. However, stainless steel containers and carbon steel units have been assembled on a pilot scale.

A 110-120 volt power source was used with the one gallon glass reaction vessel. Here again a 220-240 volt, three phase power source has been used with larger units. The 110 house voltage was connected to two electrodes within the cell through a proprietary electronic circuit. This allows power consumption by the unit to be monitored and provided some diagnostic assistance. Gases produced were collected in metal sample bombs or vented through a laboratory hood. In some cases samples of residual liquids and precipitated solids were collected for analysis.

In most cases, the small-scale, two electrode device is run on a semicontinuous mode for from six to ten hours. Both water and hydrocerbon fluids are added during operation to maintain a proper level of the interface. Most of the data collected have been from runs with tap water and three hydrocarbons; n-heptane, diesel fuel, and toluene. A silicone oil used as a viscosity standard was also run. For this particular study, a transformer oil containing 550 ppm of Aroclor 1242, and a blend of 100,000 ppm of a PCB in diesel ware tested. Concentration levels were determined with HPLC using EPA approved guidelines. Similarly, all analyses of gases which were produced were performed on a series of chromatographs with programmed elution. This particular GC system could identify permanent gases and hydrocarbons below C_5 to the nearest 0.01 percentage, although all report values were rounded to the nearest 0.1 percent (1000 ppm). The carbon sludges which formed were subjected to elemental carbon, hydrogen and oxygen analysis.

EXPERIMENTAL RESULTS

Although a large number of experimental runs with various different feed materials have been conducted, only three runs relate to the PCB trials. The experimental results are shown in the following tables. Table 1, for example shows the variation in composition of the gases produced during a series of three, six hour runs in which the organic phase contain a low level of PCB's (550 ppm); a rather high level of PCB's (97,000 ppm); and one without any PCB's (pure diesel). The diesel was selected because we have amassed a considerable amount of run time during test procedures with diesel fuel, and because it appeared to mimic the performance of the mineral oil used in the transformer fluid which contained the 550 ppm PCB's. Also shown in Table 1 are the theoretical heating values expected for the gases produced each test run.

The data given in Table 2 show the various types of information obtained before and after six hours of run time. These data include PCB concentrations in the initial and final periods for all three of the phases. With the pure diesel oil, more specific data concerning mass and energy balances were also obtained. In general,

The total mass balance was closed to within three to five percent. The elemental balance was much more difficult to close, however.

DISCUSSION OF RESULTS

Gas Production

Based on the data shown in Table 1, it would appear that the mineral oil in the transformer fluid (Run A) behaves much like the pure diesel fuel (Run C) when subjected to the arc discharge. Both fluids decomposed to produce essentially the same gas phase composition. The slight increases in carbon monoxide and acetylene may be due to differences between the mineral oil and the diesel fuel, or it may well be due to the presence of the PCB's. A comparison between Run B and Run C, in which the only difference is the presence of PCB's, would seem to indicate that the contaminant has an effect. Based on other experiments not reported in this paper, it appears that halogens can act to enhance acetylene formation and, in some cases, carbon monoxide as well. This is thought to be a Lewis Acid catalytic phenomenon in which the halogen combines with metallic ions, such as iron, from the electrodes to produce Lewis acids in the aqueous phase. In the other experiments, fluorine was introduced to the system through the water phase and found to double the fraction of acetylene produced.

One surprising result was the comparatively high level of carbon dioxide in Run A. It was assumed that the presence of calcium hydroxide and the higher pH would effectively remove any acid gases which formed including carbon dioxide. This had been the case with other experimental runs in which sodium hydroxide was used to increase the pH of the aqueous phase. In fact, it was possible to remove all carbon dioxide from the product gases by using sodium hydroxide. In Run A, however, the calcium hydroxide appeared to be ineffective. Rather, it appeared that the divalent calcium ion was participating in the formation of a greater fraction of solid precipitates. Since the calcium ion can form structured soaps or greases which are less soluble than the sodium ion structures, this may well have been what occured. In any event, it is evident that the inorganic ions, anionic or cationic, introduced through the aqueous fluid can indeed change the overall reaction chemistry and, tharefore, deserves more attention in future studies.

Finally, the theoretical heating value of the product gases produced are shown in Table 1. These data should be interpreted only on a relative scale, since the calculated theoretical values can change significantly by the addition of small amounts of heavier hydrocarbons (C_3+). In fact, the two to five percentages of gas compositions not shown in Table I, were indeed hydrocarbons greater than C_3 and most of which appeared as unsaturated hydrocarbons. An average heating value aquivalent to pentane was used for this fraction in calculating the values shown in Table 1. In all three runs, the heating value was in the mid range of fuel values of known commercial fuel gases. Moreover, the heating value of the gases produced can be significantly increased by spiking the organic phase with a light hydrocarbon (C_6-C_7) and operating the unit at an elevated temperature. The higher temperature causes the light hydrocarbon to distill out of the organic phase as a vapor component. As will be shown, this can be used advantageously for on-site destruction of waste fluids.

Liquid and Solid Residuals

The data in Table 2 deal with the chemical changes in the liquids fed to the unit and with the organic sludges produced. During the three, six hour runs, the PCB concentration dropped, indicating that it was indeed being destroyed in the plasma arc. The destructive nature is more dramatic at the lower PCB concantrations where the six hour operation resulted in nearly a fifty percent decrease of the PCB level. It should be kept in mind that during that six hour period, less than five percent

of the bulk organic phase was consumed. Hence, if both oil and PCB contaminant were being consumed at equal rates in proportion to their concentration, then a fifty percent drop in PCB concentration would not have been predicted. At the much higher PCB concentrations which were used in Run B, this is more nearly the case. That is, six percent of the PCB's were destroyed during which approximately five percent of the oil was also destroyed.

In both Run A and Run B, the PCB's were found to contaminate both the residual water phase and the sludge which formed. In the latter case, it appears as though the PCB's in the sludge are associated with the organic fluids it retained, since the PCB concentration is nearly the same in both. This is in keeping with the hypothesis that this plasma process is not a "vis breaking" phenomena. That is, the molecular structure of the oil phase is not successively reduced to lower and lower molecular weights. Rather, whatever material is drawn into the plasma arc is rapidly pyrolyzed to gases and solids. The bulk fluid remains essentially unchanged. Since hazardous wastes in either the oil phase or the aqueous phase are more sensitive to the alternating electric field potentials that develop prior to discharge, they are more likely to be drawn into the discharge region. It is important therefore to develop techniques which enhance this effect, i.e., perhaps modify the frequency of the alternating current.

An elemental analysis of the sludge produced during processing of the diesel fuel indicates that rather condensed carbon structures are formed. It is interesting that oxygen from the water also participates in this chemistry. It is expected that other divalent anions, i.e., sulfur, nitrogen, phosphorous, etc., will do the same. The sludge has not yet been analyzed for chlorine, but these monovalent halogens may also be part of these condensed structures. The approximately four percent of unknown, shown in Table 2, is suspected of containing iron atoms from the electrodes. This is based on the magnetic properties exhibited by the sludges which were produced over longer experimental test runs.

Finally, Table 2 offers the observation that the organic phase is consumed at approximately twice the rate of the water phase on a mass basis. Moreover, the electrical energy input to the system produces a nearly equal amount of chemical energy as fuel gases which can be drawn from the system. This latter point is important to on-site waste treatment. Ideally, it is desirable for four units of energy to be produced per unit of electrical energy consumed. This ratio was observed only when n-heptane was used in the organic phase under thermal conditions which caused some of it to be volatilized. In this instance, some of the input electrical energy was used as a heat source for the latent heat of vaporization of the heptane as well as for the pyrolysis chemistry. This effect will be discussed later.

UNIT OPERATING CHARACTERISTICS

Figure 2 depicts schematically the field operation of the Al-Chem technology in which the fuel gases generated are combusted in an IC engine. The engine powers a generater which produces electricity and which in turn is used to generate more gas. The actual hydrocarbon fuel for the internal combustion engine comes from the waste oil being decomposed or from a utility source as required. If the efficiencies of the various components are known, then an energy balance can be structured to indicate at what point the gases produced from the waste hydrocarbon are sufficient to power the system without assistance from an auxiliary gas source. One solution to this energy balance relationship is shown in Figure 3. This figure depicts the ratio of (1) chemical energy produced as fuel gas from the waste to (2) the electrical energy consumed, as a function of the thermal efficiency of the internal combustion engine. The region to the left of the curve indicates that an auxiliary fuel gas source is needed. The region to the right and above the curve implies that the equipment is being operated in such a manner that more fuel is produced than

that which is required to sustain the operation. Since internal combustion engines have thermal efficiencies of twenty-five percent or less, then the electrical discharge device must produce something in excess of four energy units of fuel gas for every unit of electrical energy consumed. A ratio of four or more to one is possible only when volatile light hydrocarbons are used as a diluent in the waste organic phase. In another sense, this is the fuel required for a double incineration of the hazardous waste; once in the plasma discharge and once in the combustion chamber of the engine.

Although nearly all the experimental data were obtained on a single pair of electrodes, sufficient longer term runs with multiple electrodes have been undertaken so that estimates of cost information could be made. These data are given in Table 3. At this point it is difficult to compare these costs with those reported in the literature (7, 9) although they appear to be competitive. As suggested, the operating costs can be reduced by making use of the fuel gases produced to offset the cost of electrical energy. However, what is not shown directly in Table 3 is the low capital investment required. The unit in Table 3 has been scaled as small size by the standards of most waste disposal systems. Because of this small scale, the unit is expected to cost somewhat under fifty thousand dollars per unit. This means that a producer of small quantities of hazardous wastes (200 liter/day) could afford to treat his own wastes on site. This would not only eliminate expensive transportation charges, but also remove the potential risks involved with an accidental spill in transit to a central disposal site.

ACKNOWLEDGMENTS

The authors wish to thank Fina Oil and Chemical for assistance in chemical analyses.

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TABLE 1

GAS CHROMATOGRAPHIC (GC) ANALYSIS OF OFF GASES FROM THE TREATMENT OF PCB CONTAMINATED HYDROCARBON LIQUIDS

Gaseous Components	Description of Liquid Feeds For Each Run Is Shown Below Run A Vol. Percent	Run B Vol. Percent	Run C Vol. Percent
Hydrogen (H_2)	63.3	61.4	63.9
Carbon Monoxide (CO)	21.0	21.1	17.0
Acetylene (C_2H_2)	6.7	9.6	6.3
Carbon Dioxide (CO_2)	4.1	1.5	3.2
Methane (CH_4)	2.3	2.6	2.5
Ethylene (C_2H_4)	1.3	2.1	2.3
	98.7	98.3	95.2
Heating Value of Gas Kilojoules/mole (BTU/SCF)	409 (491)	470 (564)	500 (600)

Run A Transformer oil containing 500 ppm PCB's and water with $Ca(OH)_2$ and 11.9 pH. Six hours of run time.

Run B Diesel spiked with 97,000 ppm PCB and tapwater, pH 7.8. Six hours of run time.

Run C. Pure diesel and tap water, pH 7.8. Six hours of run time.

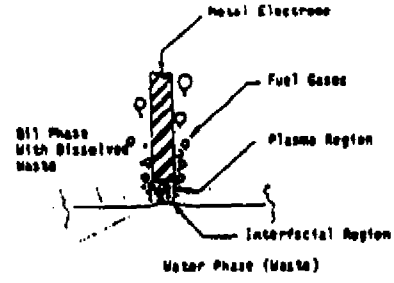

FIGURE 1. ELECTRICAL DISCHARGE PROCESS OF WASTE TREATMENT UNIT

TABLE 2

DATA OBTAINED FROM THE THREE EXPERIMENTAL RUNS WITH PCB'S

Parameter Being Monitored	Description of Each Run is Given in Table 1 Run A	Run B	Run C
Initial PCB's in Oil	550 ppm	97,000 ppm	-NA-
Final PCB's in Oil (6 hrs.)	287 ppm	91,000 ppm	-NA-
Initial PCB's in Water	-0-	-0-	-0-
Final PCB's in Water (6 hrs.)	1 ppm	849 ppm	-NA-
PCB's in Sludge Formed	247 ppm	----	-NA-
Composition of Sludge Formed--Atomic Percent			83.52% C 7.37% H 5.19% O 3.92% UK
Ratio of Diesel:Water Consumption by Weight	----	----	2:1
Ratio of BTU Electricity In: BTU of Fuel Gas Out	----	----	1:0.9
Gas Production Rate Liter/Hour (STP)	----	----	15.84

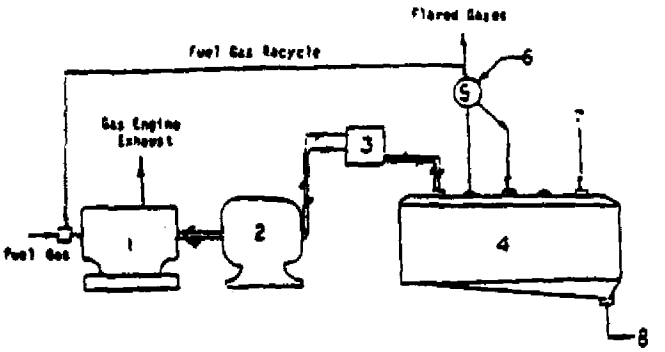

FIGURE 2. SCHEMATIC DIAGRAM OF ON-SITE WASTE TREATMENT UNIT

1. Internal combustion gas engine
2. Generator
3. Electronic control box
4. Electric arc reaction chamber
5. Heat exchanger (scrubber)
6. Water (aqueous waste)
7. Waste organic (transformer oil)
8. Solid precipitate withdrawal

TABLE 3

HYPOTHETICAL COST ESTIMATES

Basis:

Organic waste is a transformer fluid containing 1000 ppm PCB's

Processing rate	150 liter/day (40 gal/day)

Reactor System:

Number of electrodes: 1300

Volume: 5 m^3 (180 ft^3)

Operational Utility Requirements:

Water: 75 liter/day (20 gal/day)	negligible cost
Electricity: 110 or 220 AC, 60 Hz	
(a) Power line, $0.07/killowatt hr	$2.65/gal
(b) Natural gas engine and generator $6.00/$10^6$ BTU	$2.58/gal.
(c) Co-fueled with product gases	$1.93/gal.

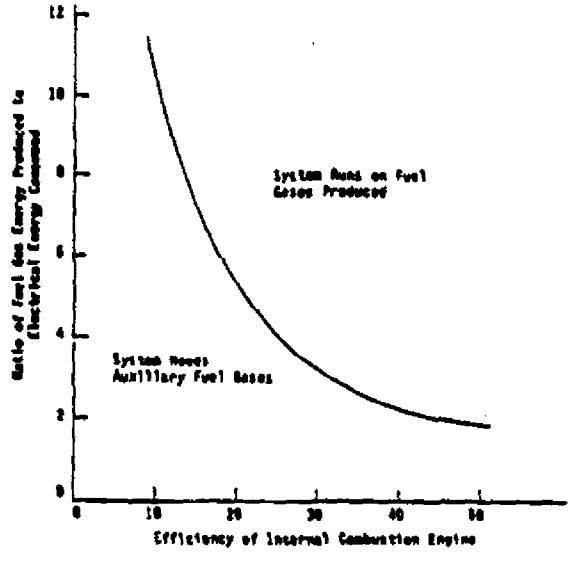

FIGURE 3. USE OF FUEL GASES PRODUCED AS ENERGY SOURCE

MONS 217282

TESTING OF TSCA INCINERATOR FOR DESTRUCTION OF PCBs IN URANIUM CONTAMINATED WASTES

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ABSTRACT

A Toxic Substances Control Act (TSCA) incinerator for environmentally safe destruction of PCBs and hazardous organic materials contaminated with low level radioactive wastes from seven DOE facilities has been constructed at the Oak Ridge Gaseous Diffusion Plant, and has undergone performance testing with PCB surrogates. The system incorporates state-of-the-art off-gas treatment, a highly instrumented kiln, and secondary combustion chamber, and an inert atmosphere solids handling feed system. Release of organic during an upset event, which triggers opening of the secondary combustion chamber relief vent, will be prevented by maintaining excess oxygen in the kiln and a high temperature in the secondary combustion chamber with an operating burner. Mixtures of chlorinated benzenes used in performance testing to simulate destruction of PCB, worst case studies to satisfy regulatory concerns, and implications of performance test results will be discussed.

RCRA/TSCA MIXED WASTE INCINERATOR DESCRIPTION

In the past, no incinerator facility was available with licensing to handle both toxic, hazardous, and low-level uranium contaminated waste. With the addition of this facility, all backlogged stored wastes along with currently generated waste from seven DOE facilities under the direction of the Oak Ridge Operation will be disposed in a safe manner. About 75 to 80 percent of these wastes will be from the Oak Ridge complex.

Design

The DOE-ORO incinerator was custom designed to meet the needs of this facility and was manufactured by International Waste Energy Systems, Inc. of St. Louis, Missouri. The design incorporates a highly instrumented rotary kiln, mixing chamber, and secondary combustion chamber (SCC) combined with a state-of-the-art off-gas treatment system to insure that the incinerator meets or exceeds all regulations. Off-gas from the SCC is pulled through a quench chamber, variable throat venturi scrubber, packed bed, cross-flow scrubber, and two ionizing wet scrubbers in series by an induced draft fan to remove particulates and acid gases before discharge to a stack.

Incineration Process

Nonvolatile waste materials remain inside the kiln for 1 to 1-1/2 hours at temperatures

of 1500 to 1800°F. Solids passing through the kiln fall into a water basin, where a drag link conveyor continuously removes the solids to a collection hopper. Combustion gases from the kiln enter a mix chamber and from thence travel through a secondary combustion chamber at 1900 to 2200°F. The SCC provides a gas retention time of four seconds, twice that required by federal regulations.

Technology Advances

This project has three specific areas in which the state of technology was advanced.

Drummed Solids Handling. This is the first incineration facility to provide automatic handling of 30, 55, and 85 gallon drums in an inert atmosphere.

PCB Surrogate. PCB's are not permitted to be destroyed in an incineration facility until the facility enters its licensing tests. To enhance the probability of passing the licensing test, the Energy Systems Quality & Technical Services Division developed a mixture of chlorinated benzene compounds to simulate the atomic composition and difficulty of destroying PCB mixtures at Oak Ridge. These chlorinated benzene mixtures were used in performance tests.

Assurance of Organics Destruction in Incinerator Upset Conditions. The Oak Ridge incineration facility implements a new EPA requirement in that during emergency shut down, in which the induced draft fan and gas scrubbing system is shut down and the SCC thermal relief vent is opened, the Oak Ridge design provides at least 25% excess air for combustion of residual unburned solids while maintaining operation of the auxiliary SCC burner to assure high enough temperatures for destruction of organics when the relief vent is open.

Effluent Management

Liquid scrubber blowdown and wet ash will be collected and analyzed prior to release. If excessive levels of organics are present the scrubber blowdown will be passed through a carbon column to remove organics, and wet ash will be recycled to the rotary kiln.

INCINERATOR TESTING

Construction of the incinerator system was completed in October 1986. A functional test was carried out during November 1986 to determine system inadequacies, and performance testing was carried out during July 1987 to determine if the incinerator meets performance standards established by procurement specifications.

Test Results

All EPA requirements under RCRA were met by the functional test with perchloroethylene as POHC and by the performance tests. Average DREs > 99.99991% for trichloromonofluoromethane and carbon tetrachloride at RCRA temperatures and for liquid polychlorinated benzenes as surrogates for PCB at TSCA temperatures were obtained in performance tests, and results indicated that the incinerator is able to meet all procurement specifications. In the functional test sulfur dioxide, from combustion of sulfur fed to the kiln, was oxidized to sulfate and sorbed in the scrubber for a removal efficiency of 99.96%. Results from a special test between RCRA and TSCA phases of functional tests indicated that the TRV stack draft should be sufficient to meet the new EPA requirement for 25% excess kiln air while maintaining an SCC tem-

[redacted]ature > 1832°F and a sufficiently negative pressure to prevent a sustained positive pressure at the kiln face plate for more than 15 seconds during a TRV opening event. Supplemental test involving feed of coal at a rate of 8.2×10^6 BTU/hr, prior to a simulated emergency TRV opening will be conducted during trial burns to verify achievement of the required excess air, kiln vacuum, and minimum SCC temperature.

[redacted]

Problems. Problems needing correction which were revealed by the functional test included: (1) strength and operation of mechanical systems; (2) air inleakage; (3) erratic quench flow; (4) instrumentation; and (5) discrepancies between Orsat and stack instrument readings for CO_2 and O_2. Although problems with quench flows and discrepancies between Orsat and stack CO_2 and O_2 values persisted, during performance tests the most serious problems were: (1) an unexpected chemical reaction of components in a carbon tetrachloride-methanol-isopropyl alcohol-polydimethylsiloxane feed solution with severe corrosion of the steel mix tank; (2) loss of eight type K thermocouples in the secondary combustion chamber due to overheating and corrosion, and (3) failure of demister components with scrubber plugging during test 1 because the components were fabricated from Noryl plastic rather than the specified FRP material. Other problems encountered were fugitive emissions which caused field blank samples to contain more POHC than stack samples, and detection limits for chlorobenzenes which were not low enough to determine whether or not the required DRE of 99.9999% was achieved in test 7 which involved a small feed of chlorobenzenes with solids.

Principle Organic Hazardous Constituents (POHCs)

The first four performance tests at RCRA temperatures used trichloromonofluoromethane or carbon tetrachloride for POHC's since a 50:50 mixture of these chemicals will be used in Trial Burns. Trichloromonofluoromethane was used because it is the most difficult to incinerate Appendix VIII constituent according to EPA's incinerability ranking because of its low heat of combustion. Carbon tetrachloride, which was added as a second POHC at the request of EPA, Region IV, is the fourth most difficult to destruct on the EPA list. Tests 5, 6, and 7 were intended to demonstrate the probable destruction efficiency of PCB's by destruction of polychlorinated benzene mixtures as surrogates for PCB's. To be acceptable the combustion mixes for use in the performance tests had to be homogeneous, have the required average heat of combustion, have the required chlorine content, and yield the required ash content. These requirements were met by mixtures of the POHC's with varying amounts of dimethyl malonate, methanol, ethylene glycol, isopropyl alcohol and polydimethylsiloxene.

PCB Surrogate. Polychlorinated benzene mixtures were selected for testing which had the same chlorine content, same average heat of combustion, and approximately the same distribution of temperatures required for 99% thermal degradation in two seconds in a dry gas stream as the average of PCB wastes at K-25 for runs 5 and 6, and Aroclor 1260 for test 7.

RCRA Trial Burns

Test 1 will use maximum feed rates for all waste feeds, and minimum heats of combustion of 7,000 BTU/lb. for the kiln and 10,000 BTU/lb. for the SCC with kiln temperature from 1400 to 1600°F and an SCC outlet temperature of 1832 ± 50°F. Methanol will be mixed with the CCl_3F-CCl_4 mixture to obtain the 7,000 BTU/lb. heat of combustion for kiln feed, and ethanol will be mixed with the CCl_3F-CCl_4 mixture to obtain a mean H_c of 10,000 BTU/lb. for the SCC feed. The second RCRA trial burn will involve waste feed to the SCC while the kiln is shut down to demonstrate the capability to operate the SCC alone.

TSCA Trial Burns

TSCA test 1 will be conducted by feeding organic liquids with a heat of combustion of 7,000 BTU/lb., aqueous waste, sludges, soils and shredded capacitors containing PCB's at maximum rates to the rotary kiln, while also feeding at a maximum rate PCB organic liquid with a heat of combustion of 10,000 BTU/lb. to the SCC. This test will demonstrate the incinerators ability to burn all forms of PCB wastes, and will also establish maximum allowable feed rates and thermal duties. TSCA test 2 will be conducted feeding only non-liquid PCB materials to the incinerator. The objectives of this test will be to establish minimum temperatures acceptable for proper destruction efficiency when PCB liquids are not being fed to the incinerator. Anticipated kiln and SCC temperatures are expected to be 1700-1900°F and 2150-2250°F respectively. For TSCA test 2 the expected kiln and SCC temperatures are 1400-1600°F and 1750-1850°F respectively.

Shakedown Testing

Shake down testing of the incinerator is planned to begin during the latter part of October or first of November, and will precede Trial Burns. However, before any wastes containing uranium or other radionuclaides can be burned a permit must be obtained from NESHAP.

CONCLUSION

Although some problems remain, pre-trial burn test results indicate that the DOE-ORO RCRA/TSCA incinerator should meet all regulatory requirements during trial burns, and is expected to be permitted to destroy all hazardous wastes including dioxins which have a heat of combustion greater than that of trichlormonofluoromethane.

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ARC PYROLYSIS PROJECT
A Progress Report

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ABSTRACT

A high temperature DC arc furnace for the destruction of capacitors containing polychlorinated biphenyls (PCB) has been permitted for test at the SCA Model City site of Chemical Waste Management. This prototype research and development furnace is being developed with major funding by EPRI. The technology is based upon the utilization of a direct current arc impinging on a molten metal bath. The system is designed so that initial decomposition takes place in the molten bath and the resultant gaseous products are passed in the vicinity of the high temperature arc. The system reduces PCBs to HCl, CO, H_2, and particulate carbon. Solids added to the system melt to produce the molten metal bath in the furnace.

Construction and permitting of the facility was completed in September of 1987. Testing of the system has begun and will continue through November of this year.

BACKGROUND

At the 1983 EPRI PCB Seminar, a paper describing the concept for this project was presented. At that time, completion of the project was projected to be completed within three years. At the conference, it was anticipated that the furnace was to be sited in California at a utility site. In the intervening years, the project progressed but not in California. Difficulties in permitting a "green field" site were found to be insurmountable for this new and alternative technology. After Arc Technologies Company was formed by Chemical Waste Management and Electro-Pyrolysis, Inc., existing hazardous waste sites were evaluated for the location of the furnace. In addition to the site, the process required adequate electric power and water. The Model City site in western New York met all of these requirements.

PERMITTING

Dual permitting was required under Federal TSCA regulations as administered by the United States Environmental Protection Agency (EPA) and New York State regulations

which are administered by the Department of Environmental Conservation (NYSDEC). The New York State Regulation Part 373 Application supplies detailed organizational and operational information such as a waste analysis plan, a contingency plan, a financial assurance plan, a closure plan, and a demonstration plan. The Part 201 Permit Application contains assurances that the facility can and will operate in full compliance with all applicable air emissions regulations. The Part 361 Application was a Request for a Certificate of Environmental Safety and Public Necessity and the Supplemental Draft Environmental Impact Statement. This application was submitted to both NYSDEC and a special siting board appointed by the governor which was charged with reviewing the project. Both the siting board and NYSDEC required public hearings.

The Federal permit application was submitted in April 1985 and the permit to conduct the test was received in January 1987. The New York State applications were submitted in May through June 1985 with additional information being supplied during the next year. A completeness determination was rendered prior to the public hearings which were held in June 1986. With no major public opposition, the hearings proceeded smoothly. The Draft Permit and the Permit to Construct was issued in November of 1986. Construction was started and continued through September 1987. During this period, additional documents were submitted to the State as required as special conditions in the Draft Permit. The final permit to start up was issued on August 17, 1987.

FACILITY DESCRIPTION

The facility is an integrated system capable of taking the smallest to the largest utility capacitor and destroying them under pyrolytic conditions in the sealed arc furnace. The facility consists of a capacitor handling area, DC arc furnace, gas handling system, metal tapping facility, and control house. DC power is supplied by a three phase AC full wave solid state diode rectifier having AC and DC reactors on the input and output of the power supply.

The capacitor handling area consists of a building in which capacitors will be uncrated and cataloged. The capacitors will be loaded on a semiautomatic conveyor system and elevators which will load them and feed them into the furnace.

The capacitors are fed into the furnace through a sealed three-door automatic loading system. The first step in the charging sequence is to open the first door and load the capacitor into the first chamber. The first door closes, but before the second door opens, the first chamber is purged with nitrogen. The second door opens, allowing the capacitor to drop into the second chamber. In the second chamber, the capacitor is punctured by several steel prongs. The third door then opens, and the capacitor is pushed into the furnace chamber.

Once in the furnace chamber, which is controlled at 1600°C., the steel case and ceramic bushings melt into the molten bath. At the same time, the PCBs and capacitor core pyrolyze, decomposing into carbon monoxide, hydrogen, and hydrogen chloride gas. The small volume of gases produced during pyrolysis pass through the 6000°C. plasma zone. Exiting upward through the 30 inch diameter hollow electrode, the gases flow through a sealed duct, constructed of steel, lined with a refractory material, into the gas handling system.

In the gas handling system, the gases will be quenched by evaporative cooling. Two spray nozzles supply recycled scrubber liquid and one nozzle supplies cool fresh water. In a portion of the quench chamber, additional cooling takes place by means of a noncontact jacket of cooling water.

Next, the dry separator receives gases saturated with water vapor from the quench chamber. Here, excess water droplets are removed by gravity, draining to a sump in the bottom of the separator and into the scrubber recycle tank.

The cyclone separator receives the gases next. It removes the medium sized carbon particles. The hopper, or cone shaped receiving vessel on the bottom, stores the collected particulates. A sealed solids collection system has been installed on the bottom of the lower hopper for solids removal.

Gases travel from the cyclone separator into the second phase of the gas handling system, where they enter the venturi scrubber. Some of the hydrogen chloride gas will be removed in this chamber, along with the smaller sized particles. The operating liquid for the venturi scrubber is also recycled scrubber liquid.

Following the venturi scrubber, the gases pass into two packed tower sections. Here, the hydrogen chloride in the pyrolysis gas will be removed with a minimum efficiency of 99.9%. Scrubber liquid will flow in the opposite direction of the gas flow, draining into the underlying scrubber tank.

From this point, the gas flows into the afterburner section of the gas handling system. The afterburner will burn the remaining hydrogen and carbon monoxide, converting them to carbon dioxide and water vapor, gases we humans exhale. The afterburner is a 60 foot stack with an inside diameter of 30 inches. The combustible gases flowing into the afterburner will normally burn without additional fuel. When required, propane gas will be used to maintain the minimum required combustion temperature.

Gas exiting the top of the stack will be common carbon dioxide and water vapor.

Approximately every 8 hours, the furnace will be tapped using standard furnace operating procedures. The molten metal will be tapped into mold cars sized to hold the approximate 1 foot of molten metal and slag which accumulates on the furnace hearth.

A 10,000 CFM blower and baghouse control the emissions during tapping.

The system is controlled from a control house which includes the motor control center, continuous stack gas monitoring equipment, and furnace and feed chamber controls. Two multichannel data acquisition systems record more than 35 points of data continuously.

An annunciator panel indicates and alarms over 79 functions for the fail-safe operation of the system.

Power for the furnace is supplied from a 115 KV line on Niagara Mohawk's system. The power is rectified by a diode rectifier utilizing both AC and DC reactors to provide continuous smooth power to the arc.

The design philosophy used in the system provides for redundancy of all functional systems. The control system operates on 24V DC with battery backup. In case of power loss, all systems return to a fail-safe condition. A 150 KW emergency generator is designed to pick up the power load of all equipment except the DC arc itself.

In addition to redundant water cooling pumps, an emergency water system using city water has been provided. Due to the nature of the facility, the concern for the city water system dictates our use of both double backflow preventers and a water break.

Other auxiliary equipment required on site consists of two 28,000 gallon blowdown storage tanks, liquid nitrogen storage, and propane storage. All hazardous materials are stored in areas designed to contain the volume of the material plus 110% of the rainwater from a 100-year storm.

We are about to start a two phase start-up and test program to demonstrate the six nines Destruction Removal Efficiency (DRE) capability for the furnace system to destroy PCBs. The first phase program consists of seven tests to check out all aspects of the system's operation prior to feeding PCBs to the furnace.

Test I	Furnace lining cure
Test II	Mixed metal
Test III	Metal and ceramics
Test IV	Metal, ceramics, polyethylene
Test V	Metal, ceramics, film and paper
Test VI	Metal, ceramics, PVC and paper
Test VII	Non-PCB filled capacitors

Phase II consists of feeding PCB filled capacitors at feed rates of 3000, 4500, and 5500 pounds/hour. Each test will be run in triplicate.

An extensive test plan will check all byproducts including stack emissions, ingots, blowdown liquid, and collected particulates for PCBs, dioxins, furans, volatile and semi-volatile organics, PP + 10 (Priority Pollutants), metals, cyanides, chlorides. The plan currently provides for a long-term health risk assessment to be provided to both New York State Department of Environmental Conservation and New York State Department of Health. Results are to be submitted by December, receipt of public comments by February 1988, and commercial operation in April - June 1988.

ULTRASONIC PROCESS FOR THE DESTRUCTION OF PCBs IN OIL AND SOIL

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ABSTRACT

The use of ultrasonic radiation to promote chemical reactions has been studied for many years. The literature is replete with references to many different chemical reactions including dechlorination of both aliphatic and aromatic hydrocarbons, cleavage of aromatic molecules, promotion of catalytic reactions, etc.

Ultrasonic radiation promotes chemical reactions by means of high energy generated in the cavitation zone created in liquids. It has been observed that accoustically generated cavitation causes the rapid formation, growth and implosive collapse of vapor filled vacuoles. This sequence generates short lived, localized "hot-spots" where peak temperatures of 3000^{0} to 10,000^{0}K and high pressures of 300 to 1000 atmospheres have been reported. The time cycle for the formation, growth and implosive collapse of the gas vacuoles is reported to be of the order of nseconds.

Cleavage of chemical bonds in molecules can occur by increasing the vibration frequency of the bonds by high temperatures or the physical action of high frequency vibrations. It has been suggested also that cavitation energy can create organic radicals through ion generation at the surface of the vacuoles. The formation of organic radicals promotes chain reactions.

It is well known that PCBs are considered to be chemically very inert. However, they will react with certain chemicals under very high temperature conditions. For example, PCBs react with sodium hydroxide at elevated temperatures. PCBs can also be destroyed by combustion with the formation of hydrogen chloride.

Despite its relative inertness, a number of processes have been proposed for the destruction of PCBs. These include incineration, extraction with solvents, photolytic irradiation, gamma radiation, reaction with a sodium organic complex under anhydrous conditions, etc. Of these, the ones that have been studied most and developed for commercial use are incineration and reaction with a sodium organic complex.

In the case of incineration, when the equipment is properly designed and operated, the process has a destruction efficiency of 99.999% of the PCBs fed. However, there are some inherent problems. First, dioxins can be formed in the combustion process. Second, portable incinerators are difficult to design and operate at peak efficiencies. Third, it is not possible to decontaminate liquids by burning only the PCBs. Fourth, if the contaminated material is non-combustible, then fuel costs can become quite high.

The processes using the sodium organic complex reactant were designed to recover contaminated liquids. However, the preparation of the reactant requires handling metallic sodium, a very reactive and hazardous substance. As a result, the process

must be conducted under anhydrous conditions. Reaction times for these processes have been reported to require several hours to complete.

The ultrasonic process developed by Hazardous Waste Management, Inc. for decontaminating various liquid and solid substrates containing PCBs represents a novel approach to the PCB problem. The process is based on the fact that under extreme conditions of temperatures, such as are obtained in the cavitation zone generated by ultrasonic action, PCBs will react with other chemicals resulting in breaking carbon to carbon and carbon to chlorine bonds.

The HWM process for detoxification of substances by utilization of ultrasonic energy is described in U.S. Patent No 4,477,357. It consists of irradiating PCB containing material in the presence of an alkaline material with ultrasonic energy of sufficient intensity to destroy the PCBs. The alkaline substances are added to remove any chlorine or chloride ions and permit the reaction to go to completion.

A series of experiments are described demonstrating the feasibility of the process. One series subjected a transformer oil containing 93 ppm of Aroclor 1242 to different reaction parameters. As a result, the PCB concentrations in the oil were reduced to as low as 35 ppm.

Another series of experiments were made on a heavy sludge obtained from a waste disposal site. This sludge contained about 2.6% Aroclor 1242 and about 3.3% Aroclor 1260. After subjecting the sludge to the HWM ultrasonic process, analyses showed that about 99% of the Aroclor 1242 and 63% of Arcolor 1260 were destroyed. Reaction times of about 5 minutes were used.

To date, the experimental work has been done using a commercial 350 watt ultrasonic generator operating at 20 Kiloherts. Plans have been prepared for additional work to optimize operating conditions, evaluate flow patterns through the generator and test continuous flow ultrasonic units.

An economic analysis of the process indicates that overall costs to decontaminate liquids are of the order of $1.50 to $2.00 per gallon, based on current information It is estimated that a portable ultrasonic decontamination unit can be built for between $200,000 and $450,000 capable of processing as much as 50 gpm of contaminated fluids.

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THE USE OF LIQUID REAGENT FOR IN-SITU TREATMENT OF PCB'S IN CONCRETE AND ON SURFACES

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ABSTRACT

This peper describes a new development in PCB concrete and other surface decontamination through the use of a liquid treatment reagent. The reagent, developed in Europe specifically for treatment of chlorinated hydrocarbons, is applied in a heated liquid form and allowed to either penetrate porous surfaces or coat non-porous surfaces. The technique provides a significant advantage in many instances; for concrete it allows destruction of PCB in place without concrete removal, while on metal or other non-porous surfaces it can be used to reduce or eliminate the need for PCB disposal of decontamination residues. The technique has also been used successfully for treatment of dioxin and dibenzofurans, and provides an initial response tool in PCB transformer fire incidents involving significant levels of these compounds.

INTRODUCTION

PCB spill and fire cleanup projects require expertise in a variety of decontamination technologies, given the similar variety of surfaces and materials that require decontamination. While improvements in technology have resulted in cost savings and efficiencies through the use of recyclable cleaning solvents and low volume cleaning techniques, decontamination of concrete continues to be one of the most difficult problems facing utilities and decontamination contractors. Traditional methods of washing or otherwise removing portions of concrete is well documented. These methods alone can account for the most significant portion of a decontamination project cost.

International Technology Corporation (IT) licensed a patented reagent process in 1986, designed to be used in a solid or liquid form to dechlorinate PCB. After reviewing and confirming some of the initial field results from the European use of the reagent, IT applied for a TSCA research permit in January, 1987 and received permission from USEPA to proceed with field scale demonstration of the technology in May. IT has completed its first field trial of the reagent, and has plans for several additional tests in the next six months. Field research will focus on a variety of surfaces, levels of contamination, aroclor types, penetration effectiveness, and dibenzofuran destruction.

CHEMISTRY

The IT reagent is based on phase transfer catalysis chemistry, in which one of the chemicals to be reacted is transferred from a phase in which it is relatively unreactive to one in which it can be reacted. In the IT reagent, the reactive chemicals in the formulation are an alkali metal alkoxide or peroxide and a polyglycol of varying molecular weight. The high molecular weight glycols are solid at room temperature, but liquids at the reaction temperature range of 60 to 90°C.

The liquid reagent is prepared by suspending the alkoxide in the liquid polyglycol (low molecular weight) at elevated temperature. The mixture is then heated and applied to the surface to be treated. The material remains in intimate contact with the contaminants for days or weeks until the reaction proceeds to completion. Experimental use of ultraviolet light has also been conducted to enhance the free radical formation association with the reaction.

TEST RESULTS

The liquid reagent has been applied to commercial surface decontamination in Europe on sever l projects involving PCB, dibenzofurans, and dioxins (Ref. 1). These field scale demonstrations have shown the liquid reagent to be an effective destruction agent in as little as one week. Because of differences in spill cleanup standards and approaches, however, these projects do not provide sufficient information for ready technology transfer in this country.

In July, 1987, IT conducted the first U.S. test of the reagent technology at a transformer fire site in Shreveport, Louisiana. Results of the Shreveport test will be available just prior to the presentation of this paper.

PERMITS

Because spilling PCB liquid constitutes illegal disposal as interpreted by USEPA, destruction of PCB in place constitutes an alternative to conventional disposal and must therefore be permitted. IT received a TSCA Research and Development permit from USEPA in May, 1987, allowing for the demonstration of the technology at several active PCB decontamination project sites. The first such demonstration was conducted in Shreveport on an emergency basis, where the state and EPA region waived notification requirements in order to proceed expeditiously with the test during normal decontamination.

Attempts to permit the technology for commercial application will hinge on the results of the first several field demonstrations, all scheduled this year. While the reagent is known to be effective for surface or shallow contamination, the optimum reagent recipe and application parameters are not sufficiently known to guarantee commercial success. Any degree of technical success in the initial field demonstrations could result in an application to

EPA for a commercial permit, although such a permit would likely be limited to the only specific type of successful application associated with the demonstration. The USEPA permitting process clearly did not anticipate the advent of this type of technology, therefore requiring fairly stringent USEPA testing requirements, thorough permit review, and narrowly defined permit conditions.

PLANS FOR DEVELOPMENT

The liquid reagent technology has several obvious applications in industrial PCB decontamination, including the following:

1. Treatment of contaminated non-porous surfaces, such as metal cabinets and machinery.

2. Treatment of porous surfaces such as concrete and wood.

3. Initial response treatment of furan/dioxin contamination following PCB fire incidents.

The technology has been proven effective in situations like 1 and 3. Successful field confirmation of the European results will result in commercialization of a viable emergency response technology for PCB spills and fires, as well as a means of decontaminating industrial equipment contacted with PCB during years of use. Successful use in decontaminating concrete and wood, and the biggest problem, would perhaps provide the most dramatic improvement in technology due to the primitive nature and high cost of technologies currently available.

ACKNOWLEDGMENTS

The authors would like to acknowledge the active participation and support in IT Technology Development by Dr. Jurgen Exner, Vice President, and Mr. Robert Fox, Director. The authors would also like to acknowledge the assistance of EPA management and staff, particularly Mr. Edward Anna, for their patience and cooperation in the development and review of the permit applications associated with this novel technology.

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PLASMA ARC DESTRUCTION OF HAZARDOUS WASTES

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ABSTRACT

The Westinghouse Plasma Systems PYROPLASMA waste destruction unit destroys liquid organic materials by breaking the molecular structure of chemical wastes and changing hazardous wastes into nonhazardous, potentially useful substantes. The highly efficient mobile destruction process is based upon the concept of pyrolyzing waste molecules using a thermal plasma field.

DESCRIPTION OF TECHNOLOGY

The Pyroplasma process is based on the concept of pyrolyzing waste molecules using a thermal plasma field. The heart of the destruction system is a plasma torch which was designed by Westinghouse Electric Corporation and Pyrolysis Systems Inc. Similar torches have been used commercially for years in practical applications ranging from blast furnaces and boiler ignition to the testing of atmospheric reentry heat shields by NASA and development of Mach 6 aircraft engines.

The Pyroplasma unit is entirely contained in a 48-foot tractor trailer and requires only power, water, and sanitary sewer discharge lines. The power requirements are 4160 volts, 3-phase. Domestic water supply and access to a sewage treatment plant (STP) are the only addition external requirements other than a waste source. Only a matter of a few days are required for complete system mobilization to the point of actual operation. There are currently two commercial size units available: a 1-gallon per minute (GPM) unit operating at 350 kW and a 3 GPM (1 ton/hour) unit operating at 750 kW. Mobile units may be designed with throughout capacities as high as 6 GPM and still be contained in a single trailer. While current emphasis has been on the design of mobile units for reasons of lower environmental risk and greater public acceptance, the construction of fixed facilities is possible in the event that higher throughput capacities are required.

FIELD TESTS

Preliminary field testing of the Pyroplasma mobile unit was completed in early 1986 as part of the contract between Pyrolysis Systems and New York State. All tests were observed by both federal and state authorities from the Unite States, as well as federal, provincial and local Canadian authorities. Chemical analyses of both gas and water effluent streams were performed externally by Zenon Environmental (Burlington, Ontario) and stack testing was conducted by GGA Corporation of the U.S. and IMET Incorporated of Canada.

Mechanical operation of the mobile plasma pyrolysis stream was first verified by processing a nonchlorinated blend of MEK/MeOH (1:1 volume). Following this, three, one-hour carbon tetrachloride runs were conducted to demonstrate i) the destruction efficiency of the plasma process with a difficult to destroy chlorinated compound, ii) the stability of the system upon exposure to high concentrations of chlorine, and iii) the effectiveness of the scrubber for HCl removal. The carbon tetrachloride was blended with MEK/MeOH/H_2O and fed at a rate of one kilogram of CCl_4 per minute. Destruction efficiencies were greater than 99.99995% for all three runs based on measured residuals in all effluent streams. Stack emissions for CCl_4 were analytically nondetectable.

After completion of the CCl_4 runs, seven tests were performed using a blend of Askarel (Aroclors 1254 and 1260 in trichlorbenzene) in MEK/MeOH to determine the PCB destruction capabilities of the process. Three one-hour, one two-hour and three five-hour tests gave destruction removal efficiencies consistently greater than 99.99999%.

TECHNOLOGY ADVANTAGES

The Westinghouse Plasma Systems mobile Pyroplasma unit provides unique advantages over other conventional technologies. The most important of these is the very low emissions resulting from the high destruction efficiencies combined with the low PIC formation. The technology itself is pyrolytic in nature and does not require tha large volumes of air needed for combustion. The lower gas volumes and thus lower quenching and scrubbing water volumes land themselves to a small, compact process which is easily made mobile.

CATALYTIC HYDROGENATION OF POLYCHLORINATED HYOROCARBONS

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ABSTRACT

The UOP Decontamination process employs catalytic hydrogenation technology which converts the chlorinated compounds,producing hydrogen chloride and a petroleum derivative. Typically, the petroleum derivative is a reusable product of such value that it offsets the costs to treat the waste material. Depending on the source of the waste oil, its economic value can be recovered by using it as a source of energy (fuel oil); recycling it as a refined intermediate (lube base stock); or, upgrading it as a specialty product (chlorinated benzene to cyclohexane).

As well as an economic means of converting contaminated waste oils into reusable products, a properly designed catalytic hydrogenation process unit eliminates the possibility of releasing products of incomplete conversion into the environment. Process units are designed and constructed to allow certification of products before they are released from the treatmant facility.

PROCESS ADVANTAGES

Catalytic hydrogenation as practiced in the UOP Decontamination process is a safe and efficient means of treating PCB-contaminated oils when designed and operated pursuant to the standards of the petroleum refining and petrochemical industries. Basic hydroprocessing technology is found in most modern day refineries and petrochemical plants, and is used to reduce the contaminant levels in virgin oils of such heteroatoms as sulfur, nitrogen, oxygen and metal complexes. Most importantly, the UOP Decontamination process offers a method of treatment for a wide range of hazardous materials converting chemical waste streams into hydrocarbon products that have value as petrochemical charge stocks, solvents, lubricants and fuels.

Based on pilot plant runs employing PCB-contaminated waste oils, UOP has demonstrated that undesirable side reactions involving the hydrocarbon matrix of the waste oil can be minimized. The formation of partially oxidized materials such as chlorinated dioxins and furans which can be formed by oxidative processes such as incineration is chemically impossible with the hydrogen reducing environment of the process [1,2]. Further, when compared with other chemical reduction processes, such as those based on sodium technology, the final product from catalytic hydrogenation is a more valuable oil since it is not contaminated with tha sludge-like material formed from polymerization raactions during reduction by metallic sodium.

PROCESS DESCRIPTION

The unit process design is based on the waste oil composition, the and product specification, the regulatory requirements, and the desired operational flexibility so that any constraints on utilizing the technology are economic, not technical, in nature.

Along with catalytic hydrogenation, the UOP Decontamination process utilizes unit operations such as phase separation, extraction, adsorption, evaporation and distillation for pre-treatment of the waste oil to remove solids, metal contaminants, or catalyst poisons and post-treatment of the products to meet requisite effluent specifications.

In the UOP hydroprocessing scheme, after pre-treatment, the waste oil is heated and combined with a hydrogen-rich gas stream before entering the reactor catalyst bed, refer to Figure 1. The UOP catalysts utilized by the process react hydrogen with the waste oil halogen contaminants at temperatures and pressures exemplary of those found in the petroleum refining industry:

- Operating Pressures, psig 200 - 1000
- Operating Temperatures, ^{o}F 150 - 700

The reactor effluent is cooled and neutralized with an aqueous solution containing a basic compound. UOP has engineered a unique system to ensure intimate contacting of the reactor effluent and aqueous solution in order to cool, neutralize and purify the reaction products. The technique along with proper selection of metallurgy minimizes the corrosivity of the product streams caused by the presence of HCl.

Within the same unique system, the neutralized reactor effluent is next separated into three phases. A hydrogen gas stream is recycled to the reactor section to provide a large excess of hydrogen in the catalyst reaction zone. Hydrogen gas is added during the operation to balance its consumption. An aqueous fraction leaves the plant as a solution of non-hazardous salts and the decontaminated organic fraction is recovered as final product. The overall objective of waste minimization is applied to each specific design case.

PILOT PLANT TEST RESULTS

PCB Waste Streams

Pilot plant test results support the application of the UOP Decontamination process to a broad class of hazardous waste types, such as transformer oils, still bottoms, waste solvents, cutting oils and used lubricating oils. PCBs have been chosen as the principal focus to illustrate the capabilities of this treatment technology. The following waste streams were continuously processed to demonstrate the feasibility of the technology in this service:

- Diala AX transformer oil contaminated with 1400 ppm PCBs as Aroclor 1016.
- Waste lubrication oil obtained from a contaminated oil recycling site. The material was contaminated with 270 ppm of Aroclor 1260 and 750 ppm of lead.

In both cases, the waste oils were processed without dilution in a pilot plant designed to evaluate catalytic activity, stability and selectivity. Demonstration data were obtained using a recycle gas flow configuration to eliminate scale-up assumptions.

Analytical

Both the product liquid and gas streams were subjected to a variety of detailed analyses to quantify pollutant conversion, hydrogen consumption and hydrocarbon product quality. Reduction in metals, ash, sulfur and other undesirable compounds was measured using a combination of ASTM, UOP and USEPA derived tast methods Monitoring the waste oil's PCB concentration was by a gas chromatogaphy/electron capture detection method (GC/ECD)[3].

The objective of catalytic hydrogenation is to remove the chlorine atoms from the PCB molecule. Thus, the typical Aroclor pattern used to detect the PCB level in the waste oil feed is eliminated from the final product. When measuring the final product PCB content, the GC/ECD detector's response to other constituents tends to interfere with low levels of PCBs. Therefore, measurement of the product oil's PCB concentration was with either a HP 5987 GC/MS system or a HP 5890 GC equipped with a HP 5970 MSD detector. The final product PCB concentration was further confirmed by an outside laboratory, Battelle Laboratories.

Results Summary

High conversion levels of contaminants were acheived for the waste oils processed in the pilot plant. In addition to reducing product PCB concentrations to non-detectable levels, other contaminants, such as lead and sulfur were also converted, further improving the quality of the final product. Table I is provided as a comparative summary of the waste oils and the corresponding final product.

Transformer Oil.

The PCB-contaminated transformer oil was processed for approximately 30 days under an accelerated stability/activity test program. A final product PCB content of less than 2 ppm was the operating basis throughout the pilot plant run. As the analytical results show in Table I, the level of PCBs in the final product oil was reduced to the limits of detection (~0.5 ppm) thus demonstrating a complete conversion level for PCBs greater than 99.9%. Over the same period, the concentrqtion of sulfur heteroatoms in the transformer oil was reduced reflecting a sulfur removal of 97.5%.

Waste Lubrication Oil.

The waste lubricating oil treatability was examined over an 8-day test period. Catalytic hydrogenation of the waste oil produced a final material which was measured to contain less than 2 ppm of PCBs at each level of chlorination (per Battelle). The oil's lead content was reduced from 750 ppm to less than 10 ppm. Desulfurization of the oil was 73%. Hydroprocessing the waste oil retained tha excellent viscosity characteristics of the starting material as evidenced by comparing the Viscosity Index of the raw oil with the final product. Thus, as illustrated in Table I, once the undesirable contaminants were removed, tha oil became an excellent candidate for reuse as a lube base stock.

PROCESS ECONOMICS

While the discussion here has focused upon converting PCB-contaminated waste oils into reusable oils, a wide range of waste streams can be treated in a similar fashion. UOP's current pilot plant experience includes trichloroethylene-contaminated still bottoms from a solvent recycling operation, highly chlorinated waste oils (circa 60 wt-% chlorine), and both chlorinated and non-chlorinated waste solvents.

Pro forma economics for the UOP Decontamination process have been prepared assuming annual on stream factors of 70%, although 90% or greater is readily achevable. The payback calculations summarized in Table 2 are based on a plant size of 10,000 gpd and conservative assumptions with respect to capital costs and operating costs. The positive contributions utilized in determining the simple paybacks arise from avoidance of external disposal costs and from final product credits; both of which were based on current competitive values in the United States.

In all of the waste oil cases reviewed, the payback on the installation of a new UOP Decontamination process was favorable; less than 2 years in all cases. In certain applications, such as treating Askarels or highly chlorinated waste oils, the paybacks are less than 1 year. As might be expected, the rapid paybacks are directly attributable to the ever increasing costs to dispose of waste oils off site.

COMMERCIAL STATUS

State-of-the-art processing technologies coupled with over two dozen proprietary hydrogenation catalysts provide a firm basis for offering the UOP Decontamination process to the waste management industry. The highly qualified engineering staff at UOP make possible the custom design and supply of treatment plants to satisfy a wide variety of environmental and industrial needs. Joining the knowledge to design, engineer and construct treatment facilities with UOP plant start-up, operator training and troubleshooting activities provides waste oil generators a fully supported single source option to finding solutions to today's waste treatment problems.

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FIGURE 1

UOP DECONTAMINATION PROCESS

HYDROGENATION SECTION

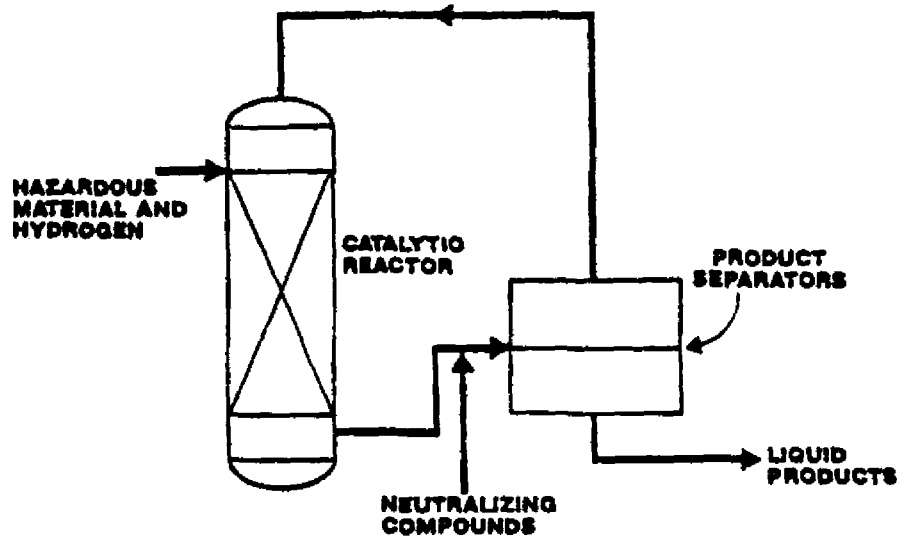

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Table 1

Pilot Plant Waste Oil and Final Product Analyses

	Transformer Oil		Waste Lube Oil	
	Waste Oil	Product	Waste Oil	Product
Analyses				
PCB Concentration, ppm	1400	ND	270	<2
Aroclor Type	1016	--	1260	--
Specific Gravity	0.886	0.878	0.887	0.875
Distillation Range, °C				
IBP	222	220	163	122
50% Over	327	329	416	405
FBP	522	493	485	545
Residue, vol%	--	--	20	1
Sulfur, wt-ppm	700	17	4900	1300
Nitrogen, wt-ppm	1	--	600	250
Metals, wt-ppm				
Lead	--	--	750	5.5
Zinc	--	--	285	1.7
Vanadium	--	--	2.9	<0.1
Nickel	--	--	3.8	2.6
Viscosity Index	--	--	128	126

Table 2

Payback Economics of UOP Decontamination Unit

Waste Type	Payback (yrs)
Waste Lube Contaminated with PCBs	1.8
Askarel	<1.0
Chlorinated Still Bottoms	1.9
Spent Halogenated Solvent	<1.0

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PART 5:

HEALTH EFFECTS AND RISK ASSESSMENT

PCB TRANSFORMER FIRES:
THE RISK IN NUCLEAR POWER PLANTS

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One of the more valuable assets any utility company possesses is its nuclear power plant. For that reason, if one of these plants is out of commission for any period of time due to a PCB fire it can be very costly. The average down time cost for a nuclear power plant is between 2 to 4 million dollars a week, per unit and many plants have multiple units. It is estimated that one-half of the present nuclear power plants operate with PCB filled transformer equipment.

A study performed in 1984 for Nuclear Mutual Limited and Nuclear Electric Insurance Limited addressed the risk potential for PCB fires at nuclear generating facilities. The study was performed by the National Economic Research Associates, Inc., in conjunction with M&M Protection Consultants and Clayton Environmental Consultants. The report identified conditions where PCB filled transformers were located in close proximity to major oil hazards beneath turbine generators. Because of the large quantities of lubricating oil required in these facilities, a fire in a power plant is not uncommon. A classic example of this was a fire that occurred under the turbine at the 30 megawatt Pickway Generating Plant in Columbus, Ohio on June 23, 1951. Fire damage was extensive and included collapse of the plant roof. Of course, there was no fire protection system at the plant.

Another incident occurred approximately 15 years ago when a fire at the Browns Ferry Nuclear Power Plant caught the attention of the utility industry. Apparently an employee checking for leaks in seals between the containment building and the auxiliary building accidentally set fire to some insulating material. The fire spread under the control room and severely damaged cable runs to the point where the plant was shut down for an extended period of time. This incident is what prompted the NRC to require certain fire protection in all nuclear power plants. Probability estimates relating to the frequency of this type incident can never be accurate; however, it is possible to establish fairly accurate estimates of potential clean-up costs and down time.

In an attempt to obtain better estimates of clean-up costs in a nuclear power plant under reasonable loss scenarios, a study was commissioned. This study was a joint venture between Bleckmon-Mooring Steamatic Technologies, Inc., (BMS-TECH) and M&M Protection Consultants (1). This joint study was conducted at a typical pressurized water reactor plant consisting of two 1000 megawatt units. Three specific scenarios were selected and analyzed for this typical power plant. These scenarios were: 1) an electrical failure of a transformer in an isolated switch gear room; 2) a transformer exposed to a 55 gallon transient combustion oil fire in the auxiliary building; and 3) a PCB transformer involved in a major turbine lube fire in the turbine building.

In the first scenario, it was assumed that the switch gear room could be completely isolated and that contaminants from the fire would be contained within that room.

Damage was estimated to be at approximately $500,000. Although this isolated switch gear room was used only in case of emergency, the NRC clearly stipulated that they would not allow the plant to operate unless the equipment was in working condition. Because of this, it was anticipated that the plant would be shut down during the entire 10 weeks required for the decontamination and clean-up. However, because this was a two unit nuclear plant it was assumed that only one of the units would be affected.

In the second scenario a 55 gallon drum of oil was being transported through an area of the auxiliary building when it accidentally spilled and the oil ignited next to a transformer containing PCB's. Because of the open construction of the auxiliary building (between floors and within each floor), soot fallout could be expected to spread throughout this structure. The cost for the clean-up and decontamination effort was estimated at approximately 79 million dollars. It was estimated the entire plant would be shut down, including both reactors for a period of approximately 8 months.

In the final scenario a PCB transformer was engulfed in flames caused by an accidental turbine lube oil release. This time the transformer was located in a open area of the turbine building beneath the turbine operating floor. Again because of the vast openiness of the turbine building, and the positive air flow from this area into the auxiliary building, it was deemed highly probable that the turbine building as well as the auxiliary building would be contaminated. Clean-up and decontamination costs for the third scenario were estimated at approximately 98 million dollars. Both reactors were expected to be shut down for the approximate 9 months the clean-up operation would require.

In all of the scenarios no additional damage was assumed to have occurred to equipment exposed to the fire or the combustion by-products. Also, no estimate of damage to the transformer was included. The only regulatory delays anticipated in the clean-up estimates were approximately 2 weeks to negotiate with the health officials concerning the acceptable level of decontamination necessary. Significant regulatory delays caused by the NRC, EPA, OSHA, etc., could extend the outage significantly beyond the estimates included in this report. Another factor that must be included as a cost but was not in this study would be the purchase of replacement electricity during the time the plant was shut down. As stated earlier, the average down time cost for a unit is estimated to be between 2 and 4 million dollars a week.

In general, a clean-up at a nuclear power plant would be more difficult than a clean-up in an ordinary office building contaminated as a result of a PCB fire. Some of the reasons are as follows:

1. Both cleaning and handling of the residue from PCB's, related toxic compounds, and waste water would be complicated by the presence of radioactive material. Cleaning would require additional worker protection which would expand the clean-up time.

2. Waste handling and disposal could be more complicated and costly because both toxic chemicals and radioactive materials could be involved.

3. Negative air pressure, typically found in the containment building, designed to keep radioactive material from spreading to the auxiliary and turbine buildings would provide a vehicle to spread any transformer fire contaminants from the turbine building to the auxiliary building.

4. An additional regulatory authority, the NRC, would have to be added to the group of decision makers when it came to formulating clean-up criteria and operating procedures.

5. Health and safety programs would not only have to take into consideration the occupational physician's and industrial hygienist's normal concerns, but also would involve input from health physicists to deal with possible problems of

radioactivity.

Plant security which is typically exceptionally stringent in a nuclear generating facility, could slow the clean-up effort.

In performing decontamination at a nuclear power plant many of the procedures will be very similar to those used in other PCB fires, while others will be quite different . Some of the differences are as follows:

1. Air Filtration Systems used to evacuate air from contaminated areas must not only be able to remove the chemical contaminants but will also have to remove radioactive contaminents. It is probable that the air filtration system will adversely affect the plant's operating radioactive air contamination controls.

2. All waste water generated from the clean-up activity would first have to pass through a radioactive waste water treatment facility and then through a PCB waste water system. However, the capacity of most plants existing rad-waste treatment systems appears sufficient to handle the volume of liquid waste that would be generated by such a clean-up operation.

There were also several other factors that appear to affect cost and down time:

1. It is imperative that corrosion control procedures be implemented immediately after extinguishing the fire. The corrosive fallout generated from a PCB fire could cause extensive damage to unpainted metal surfaces. If these surfaces were left untreated the cost and down time would dramatically increase because equipment could be damaged beyond repair and therefore need to be replaced.

2. It was discovered, during the course of this study that if certain areas of the plant were isolated from each other damage could be minimized. Some items to be considered are as follows:

   A. The design of HVAC systems through negative pressure, smoke triggered exhaust systems, etc.

   B. The sealing of all openings between areas.

   C. The encasement of PCB transformers in vaults with separate ventilation systems.

3. The degree of cleanliness that a plant normally maintains with respect to radiation contamination can also effect clean-up costs and down time. If an area is contaminated with PCB and PCB by-products as well as radioactive contamination, the clean-up is further complicated. The worker normally is able to work for 8 hours in a PCB/PCDD/PCDF environment wearing proper protective gear but if the area is additionally contaminated with radioactive material it is possible that the work day could be reduced to two hours or less.

4. This type of loss generates complex wastes, making disposal more difficult.

5. Contingency plans covering these types of events should be implemented prior to the occurrance of an accident. How well an organization is prepared for such a catastrophic event can dramatically affect cost and down time.

The issue of frequency of transformer failures in a nuclear power plant was also addressed in this study. It can be expected that the rate of these incidents may be lower than in a commercial building due to better maintenance, surveillance, inner locks and operator action, etc. For these reasons it is estimated that the annual rate of 6 x 10-5 per transformer per year should be assumed. (2) These features should reduce the likelihood of electrical or mechanical failures. However, a major portion of the PCB risk is derived from transformers being exposed to external fires. Because of the fact that these transformers are normally located in open areas of the plants and/or exposed to potentially severe fires such as turbine lubricating fires, it is expected that contamination would be wide spread

in the plant.

Based on the results of the BMS TECH/M&M Protection Consultants study, the insurance carriers for this industry have implemented an adjustment in their rate structures for nuclear plants that have PCB equipment. It should also be noted that most nuclear power plants are self insured for the first 6 months of down time. Given the research that has been completed, and considering current techniques in decontamination and political as well as environmental complications that exist in the United States, the risk of a PCB fire in a nuclear power plant is not only significant but has catastrophic ramifications. This conclusion is based more on the severity of such a event rather than its frequency.

1. M&M Protection Consultants are affiliated with Marsh and McLennan, Companies

2. PCB Transformers - The Risk In Nuclear Power Plants, prepared by James M. Connally, P.E., - M&M Protection Consultants, November 24, 1986

[redacted]

RISK ANALYSIS OF PCB SPILL CLEANUP OPTIONS

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ABSTRACT

What residual concentration after a PCB spill cleanup is low enough to ensure public safety? How quickly should the spill be cleaned up? The fastest cleanup to the lowest levels will lead to the lowest risk, but at extraordinary, and possibly unnecessary, costs. The objective of this risk analysis was to develop a better understanding of alternative spill cleanup options by integrating information on potential incidents, environmental fate, human exposure and deposition, and human health affects. The study analyzed potential human health risks from PCB capacitor spills for each of several spill cleanup options. The cleanup options differ in the speed of the cleanup process and the final level of residual concentration achieved in the cleanup. The cleanup options were analyzed using the EPRI Contaminated Sites Risk Management System, SITES. SITES provided a comprehensive framework for comparing cleanup options in terms of the health and environmental effects and total costs. This paper will discuss the SITES methodology, and the data, assumptions, results, and conclusions of the analysis.

THE SITES MODEL

The EPRI SITES model is a decision support tool to help utility personnel manage contaminated, or potentially contaminated, sites. SITES can help rank potentially contaminated sites, decide on the best site investigation strategy, and, as is the case in this analysis, choose the appropriate cleanup or remedial action strategy. Its flexible structure allows analysis of risks due to a range of substances including PCBs, manufactured gas plant wastes, coal-combustion by-products, and petroleum products. The SITES model is an interactive, menu-based program which facilitates and guides the user through all steps of the analyses.

SITES provides a framework for comparing alternative cleanup strategies in terms of both health and environmental effects and total costs. The model tracks the contamination levels over time and computes exposure and effects for several different chemicals, locations, media, site investigation and remedial actions options. It can also evaluate other costs such as fines, legal liabilities, or future cleanup costs. A key feature of SITES is that it can explicitly represent uncertainty in several important factors. Figure 1 shows a shorthand representation of the decision tree structure of the SITES model. In the full decision tree, each successive node is connected to every endpoint of the previous node. The left-most square node represents the decision to select one of the cleanup strategies, or no cleanup at all. The circle nodes represent uncertainties in cleanup effectiveness, actual contamination level, exposure, and health impacts.

Using this decision tree structure, SITES can examine the sensitivity of the total risk associated with a site to the extent and nature of the contamination, the possibility of human exposure and environmental damage, the costs of testing and cleanup, and the size and likelihood of fines and financial liabilities. This permits the user to focus on the most important uncertain factors for each site. SITES allows the user to specify any single path through the decision tree to examine the detailed doses and effects based on that specific set of assumptions, or perform a tree

rollback to examine the expected impacts and costs of all the scenarios. The SITES model reports the dose that each receptor receives by chemical and exposure pathway, the health impacts resulting from these exposures, and the total costs associated with each cleanup strategy.

THE PCB SPILL ANALYSIS

The analysis was originally conducted in 1984 for the Utility Solid Waste Activities Group and formed the basis for their comments on EPA's proposed spill cleanup policies[1]. The analysis has since been updated to reflect current understanding of transport and fate modeling, exposure scenarios, and toxicological information. Table 1 shows the four alternative cleanup strategies following the spill of a pole-mounted PCB capacitor examined in the analysis. For all cleanup strategies, it was assumed that the spill site was restored to its original condition on the 30th day after cleanup.

The major data used in the SITES model represent (i) transport and fate (ii) exposure parameters, and (iii) health impacts. Concentration profiles and the impacts of the cleanup strategies were modeled using EPRI's PCB On-Site Spill Model (POSSM)[2]. Figure 2 shows an example concentration profile over time assuming a 14 day, 50 ppm cleanup. The exposure parameters were based on reasonable and accepted behavioral assumptions for adults and children in urban and suburban settings. For example, it was assumed that suburban adults could have fairly frequent soil contact at the site after cleanup (but before reclamation), with 870 cm^2/day of dermal contact on 100 days/year, with 1% absorption through the skin.

The health impact data for PCBs was originally estimated from an EPA Office of Toxic Substances report[3], and was subsequently reviewed and updated by the Washington Occupational Health Associates[4].

RESULTS AND CONCLUSIONS

The SITES model was used to first estimate the total doses of PCBs for the exposed individuals. Figure 3 shows the dose results; the population group of Urban Children receive the highest doses. The dominant exposure pathway is generally inhalation of volatilized PCBs.

The lifetime individuals risk of living near a PCB capacitor is estimated by multiplying the doses by a dose-response function, and multiplying this result by the probability of a spill incident occurring. Figure 4 shows the calculated lifetime individual risks.

The conclusions drawn from this analysis of the health impacts resulting from PCB capacitor spills, given the data and assumptions used, are:

- Lifetime risks faced by all potentially exposed individuals are small -- less than 10^{-8} when no cleanup is performed and less than 10^{-10} for all cleanup options considered.

---

1. The Utility Solid Waste Activities Group. Proposed Spill Cleanup Policy and Supporting Studies. October 15, 1984.

2. The Utility Solid Waste Activities Group. Proposed Spill Cleanup Policy and Supporting Studies. October 15, 1984.

3. U. S. Environmental Protection Agency. Carcinogenic Risk Assessments of Polychlorinated Biphenyls (PCBs). November 14, 1983.

4. Washington Occupational Health Associates, Inc. Review of Health Effects Documents Relevant to the EPA Proposed Rule on the Use of PCBs in Electrical Transformers. December 5, 1984.

- Increasing the speed of cleanup produces a greater reduction in potential health effects than does reducing the residual concentration.
- Restricting access to a spill site greatly reduces overall exposure.
- Inhalation is generally the dominant exposure pathway.

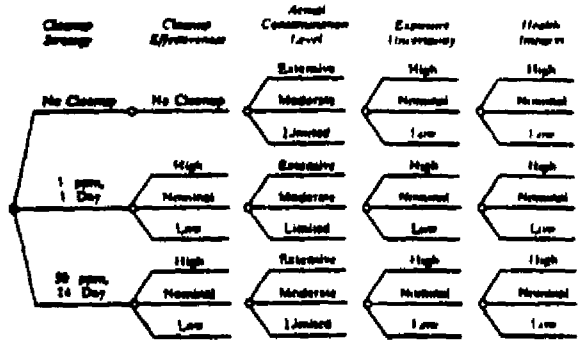

Figure 1. The SITES Model Decision Tree

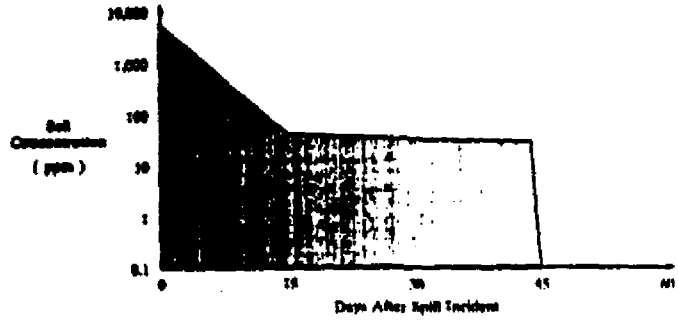

Figure 2. Soil Concentrations Assuming 14 day, 50 ppm Cleanup

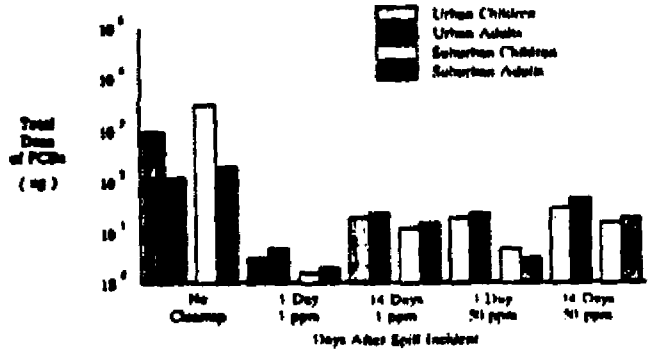

Figure 3. Total Dose of PCBs for Exposed Individuals

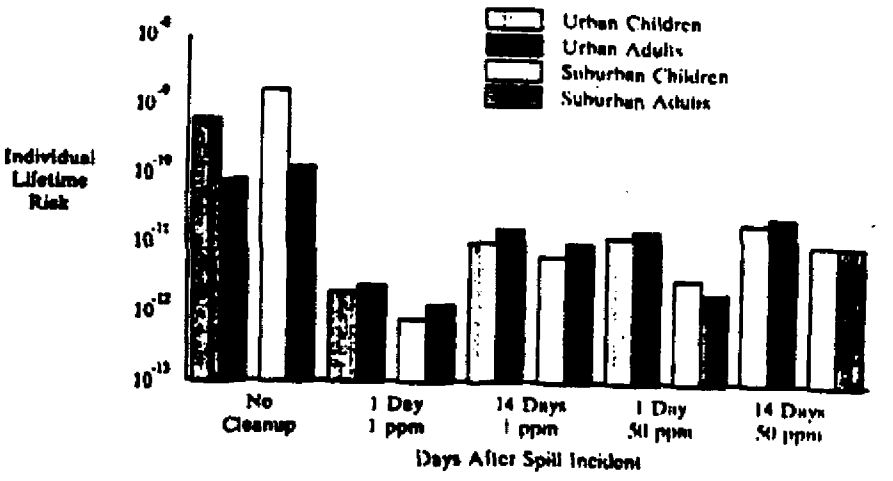

Figure 4. Lifetime Individual Risk

Table 1

PCB SPILL CLEANUP STRATEGIES

Strategy	Time to Cleanup (day(s))	Residual PCB Levels Soil (ppm)	Asphalt/Concrete ($\mu g/100\ cm^2$)
1	1	1	10
2	14	1	10
3	1	50	100
4	14	50	100

POSSM: A TOOL FOR RISK ASSESSMENT OF PCB SPILLS SITES

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INTRODUCTION

POSSM, the PCB On-Site Spill Model, was developed for the Electric Power Research Institute by Brown and Boutwell in order to assist electric utility personnel in understanding and evaluating the risks associated with spills of oil from electrical equipment (1). Spills of PCB or Askarel-type fluids such as from PCB cepacitors, as well as low concentration PCB contaminated mineral oil from distribution transformers can be evaluated using POSSM. The model utilizes spill information such as the volume of fluid lost, area of the spill, soil type, cleanup actions taken, soil concentrations, meteorological conditions, and other data in order to calculate the fate of the PCBs over time.

POSSM was used to conduct a human health risk assessment of two transformer oil spills and two PCB capacitor spills which occurred over the last three years in the Wisconsin Electric system. Site-specific data were used as POSSM input in order to determine the fate of the PCBs in the soil, air, and rainfall runoff. Initial PCB loadings to the soil and vegetation were calculated based on the volume and concentration of PCBs spilled. PCB soil concentrations measured after site cleanup were used as input data to the model for the time period following cleanup. Airborne concentrations of PCBs downwind of the spill site were calculated using the PTDIS gaussian dispersion model based on daily volatilization rates from the soil, vegetation, and solid surfaces at the site. Exposure pathways considered included inhalation for the substation spills; and inhalation, dermal absorption of soil, and ingestion of soil for the residential transformer oil spill cases. Exposure factors and chemical transfer rates are generally consistent with those used in the EPA PCB Spill Cleanup Policy.

SPILL SCENARIOS

Two 25 kVA distribution transformer oil spills which occurred in residential areas were used as input to POSSM. Specific details are provided on Table 1. A statistically based hexagonal sampling grid was used to characterize the soil concentrations following cleanup of both spills (2). Results of the soil sampling are shown on Figure 1. Both residential spill areas were grass covered. The Pewaukee soil consisted of a loamy soil whereas the Cudahy site contained a silt-loam soil.

Both PCB capacitor spills occurred in substations. Although several residences are nearby, the substations are considered as restricted access areas since each substation is enclosed by a secure fence and a second fence surrounds each

capacitor bank. A six inch layer of crushed stone overlaid a silt-loam soil base at each substation. Inhalation intake by nearby residents was based on a breathing rate of 20 cubic meter/day for an exposure period of 365 days a year for four years. A 15 percent wind direction frequency factor was used to account for the time the wind blows toward the house. No adjustment was made for indoor vs. outdoor concentration differences. PCBs were assumed to be absorbed at a 50 percent rate in the lungs. Lifetime health risks were based on a 70-year lifespan for a 70 kg adult. A PCB carcinogenic potency of 4.34 mg/kg/day was used based on an EPA health effects report for PCBs (3).

Dermal contact by children was assumed based on a 1000 cm^2 skin area and a daily soil deposition of 1 $mg/cm^2/day$. Soil concentrations were averaged for 12 cm of the soil profile. The exposure period was estimated at 120 days/year for six years. A site access frequency of 10 percent was assumed based on the probability that a child would be in the spill area. (The Cudahy spill area represented 5 percent of the accessible land for the residential property.)

Ingestion wes based on an average soil concentration in the 12 cm soil profile over a four-year period. Exposure frequency was estimated at 120 days/year for six years with a site access frequency of 10 percent as explained above. Soil ingestion was estimated at 0.6 grams/day with an absorption rate of 30 percent.

RESULTS AND DISCUSSION

The fate of the PCBs was determined by running POSSM for a four-year period for the residential spills and for a one-year period for the substation sites. Nearly all of the PCB was removed by cleanup activities, although a small amount was volatilized and an even smaller amount remained in the soil site. Specific data are shown on Table 2. Since none of the PCB migrated more than 6 cm in the soil, groundwater was not affected.

Health risks calculated indicate that of the four spill scenarios considered, none pose a significant health risk (see Table 3). The Waterford substation spill produced the highest numerical risk with a lifetime risk of 1×10^{-6} for inhalation. The Waukesha substation produced a health risk from inhalation of 3×10^{-9}. These data suggest that PCB spills in substations do not pose an unreasonable risk to human health, even when residences are nearby and the soil concentrations are relatively high (the Waterford substation soil contained an average of 20 ppm and a maximum of 150 ppm prior to the second cleanup). Perhaps the residential cleanup standard (10 ppm) now required by EPA for substations located within 328 feet of a residential area is overly restrictive.

The transformer oil spills also posed no significant health risk to nearby residents, even though exposure by dermal contact and ingestion were assumed. Overall health risks were less than 8×10^{-9} for both transformer oil spills. One major uncertainty often overlooked in conducting risk assessments of transformer oil spills in residential areas is the probability that a child will come into contact with soil in the spill area. In both spills examined, the area of the spill was small compered to the total yard area, and the spill areas were re-sodded following spill cleanup.

POSSM has provided a useful method to evaluate the environmental behavior of PCB spills end to calculate human health risks associated with those spills.

REFERENCES

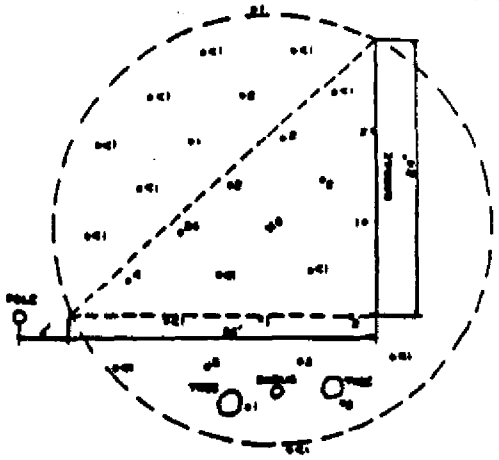
1. S. M. Brown and S. H. Boutwell, Chemical Spill Exposure Assessment Methodology (RP-2634-1), Electric Power Research Institute, Palo Alto, California, 1984.

2. B. A. Boomer, M. D. Erickson, S. E. Swanson, G. L. Kelson, Verification of PCB Spill Cleanup by Sampling and Analysis, EPA-560/5-85026, August 1985.

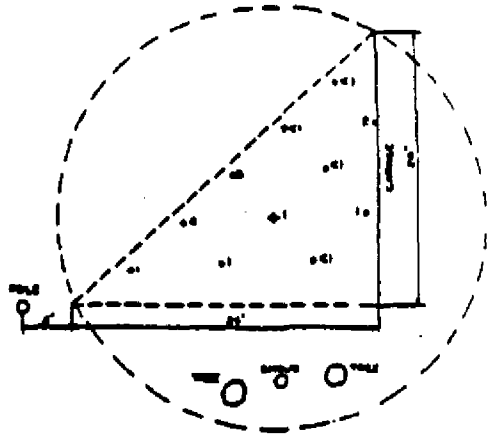
3. U.S. EPA, Health Effects Assessment for Polychlorinated Biphenyls (PCBs), EPA/540/1-86/004, NTIS No. PB86-134152, September, 1984.

FIGURE 1

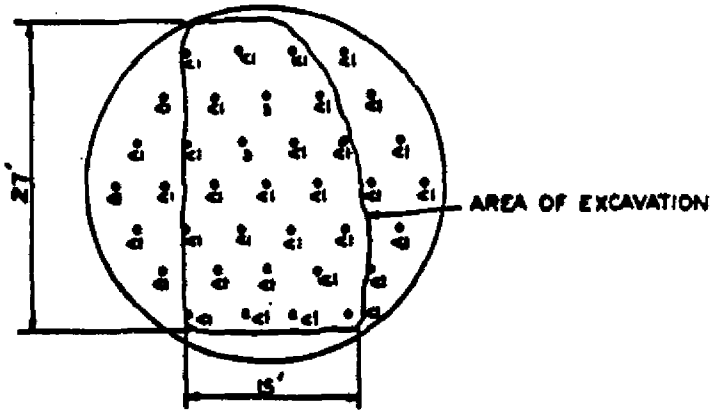
SOIL SAMPLING DATA



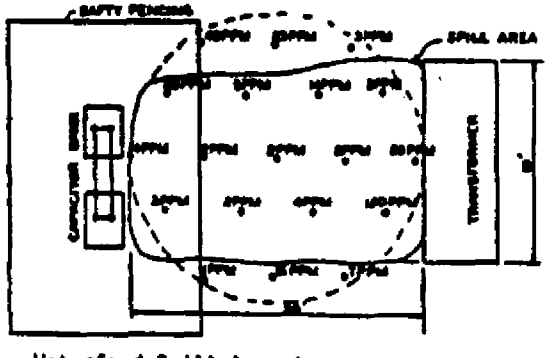
Cudahy Spill-before cleanup



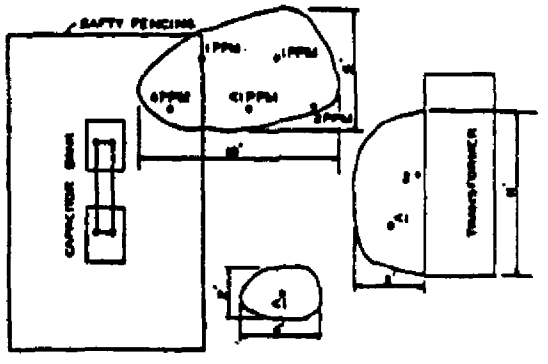
Cudahy Spill-after cleanup



Pewaukee Spill-after cleanup



Waterford Spill-1st cleanup



Waterford Spill-2nd cleanup

TABLE 1

TRANSFORMER AND CAPACITOR SPILL DATA

	Location Area			
	Waterford Substation	Waukesha Substation	Cudahy Residential	Pewaukee Residential
Equipment	PCB Capacitor	PCB Capacitor	kVA Transformer	kVA Transformer
Fluid Volume	1 gallon	1 quart	6.5 gallons	15 gallons
PCB concentration	100%	100%	100 ppm	180 ppm
Acoclor type	1242	1242	1254	1260
Mass of PCB	5216 grams	1304 grams	2.2 grams	9.0 grams
Date of spill	Mar., 1986	May, 1986	Sep., 1985	July, 1987
Area affected	260 sq. ft.	30 sq. ft.	312 sq. ft.	400 sq. ft.
Avg. soil PCB level				
1st cleanup	19.7 ppm	11.2 ppm	1.18 ppm	0.25 ppm
2nd cleanup	1.2 ppm	2.0 ppm		
Nearest Residence	92 feet	200 feet	50 feet	122 feet

TABLE 2

FATE OF PCBs

	Waterford	Waukesha	Cudahy	Pewaukee
Cleanup	98.8%	95.9%	65.0%	95.0%
Volatilized	1.1%	4.0%	3.3%	.005%
Runoff	0.0%	0.0%	0.2%	0.0%
Remaining	0.03%	0.03%	31.5%	4.9%

TABLE 3

HUMAN HEALTH RISKS FROM PCB SPILLS

Pathway	Waterford	Waukesha	Cudahy	Pewaukee
Inhalation	1×10^{-8}	3×10^{-9}	2×10^{-11}	5×10^{-14}
Ingestion			6×10^{-9}	3×10^{-9}
Dermal Absorption			2×10^{-9}	7×10^{-10}

EMPLOYEE BLOOD SCREENING FOR PCB EXPOSURE AT NORTHWESTERN RURAL ELECTRIC COOPERATIVE, INC.

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ABSTRACT

In early 1983, several employees at Northwestern Rural Electric Cooperative expressed concerns about their exposures to PCB contaminated mineral oils and the potential future health effects that may exist. Consequently, the management at the Cooperative established, with considerable help from a local hospital, a testing protocol that could be used to satisfy our employees' concerns as to the extent of body contamination. A representative sample of seven employees was selected and tested along with two hospital employees for comparison. This paper outlines the development of the testing protocol, the ensuing testing and the associated results analysis.

BACKGROUND

The process began in early 1983, when at a regular monthly safety meeting, several of the Co-op's linemen expressed a sincere concern about exposure to PCB contaminated mineral oils. As linemen, they have had direct contact with transformer and recloser mineral oils during their careers through various maintenance programs. These mineral oils had known PCB contamination of up to 200 parts per million (PPM).

The questions raised were generally as follows:

- How much body contamination has been the result of the exposures over time to PCB's?
- What short-term and long-term health effects does this contamination represent?

It became apparent that these concerns needed two different, yet interrelated solutions. The first being a procedure to determine accurately and reliably the level of body contamination of PCB's. The second relating to just what these results meant for the present as well as the future of our employees.

PROTOCOL DEVELOPMENT

Literature available at the time indicated that a blood serum test for PCB's was available, but drawing blood requires assistance from the medical community. Consequently, a contact was made with the Meadville City Hospital and a meeting was set-up with the Executive Director and several of his key staff people, including the Director of the Pathology and Laboratory Medicine Department.

The first meeting pointed-out that few in our local medical community knew about PCB exposures or the proper testing protocol needed for our employees. Fortunately, the director of Pathology and Laboratory Medicine took an interest in this project and proceeded to do an extensive literature search including contacting the Center for Diseases Control (CDC) in Atlanta, GA.

The CDC was most helpful and suggested the following protocol:

- Through job history, identify the most highly exposed individuals for the screening test sample.
- Utilize control samples of non-exposed individuals when possible.
- Use standard samples provided by the CDC to check the accuracy of the laboratory equipment.

The CDC also provided the names of several laboratories that would be suitable for the testing desired.

EDUCATION

While the testing protocol was under development by the hospital staff, a contact was made at the National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH, that proved to be very helpful. The Chief of Medical Section, Hazard Evaluation, and Technical Assistance Branch, Division of Surveillance, Hazard Evaluation and Field Studies, agreed to conduct educational seminars for both our Cooperative's employees and the physicians of City Hospital. This seminar was held in January, 1984.

We learned from studies completed by NIOSH[1] that very little correlation existed between PCB exposure and worker health. Extreme exposures have resulted in chloracne and signs of liver enlargement, but routine utility work rarely exposes employees to these levels.

The studies also indicated that the blood serum PCB level for utility workers appears to be very similar to the general public level which is that approximately 90% of all individuals have 20 parts per billion (PPB) or less (80 to 85% are less than 10 PPB).

These educational seminars helped to answer the question of short-term and long-term health effects of our employees as well as raise the awareness and knowledge level of PCB diagnosis for the local medical community.

TESTING AND RESULTS

The final protocol for our screening procedure was as follows:

- Five of our employees were selected who had the greatest exposure potential to PCB contaminated mineral oils based on their years service and job function.
- Two employees were selected who had little or no known exposure to PCB's.
- Two hospital laboratory employees were selected to provide further blind duplicate samples.
- Permission was obtained from each of the employees' physicians for the blood work.
- Blood samples were to be taken, prepared, and sent by the City Hospital Lab to the Rel-Tech Science Services Lab, Madison, Wisconsin, as per their instructions.
- Three standard samples, provided by the CDC, were sent along with the above mentioned samples as a way of measuring the precision of the testing. These samples represented PCB levels of 1.6, 9.9, and 22.2 PPB.
- In addition to the PCB testing at Rel-Tech, the City Hospital lab ran tests on the blood samples for liver enzymes (SGOT/SPGT) alkaline phosphatase and cholesterol levels to determine if any correlations existed with PCB levels as had been indicated in the literature on previous studies.

The blood samples were taken in early April, 1984, coded to eliminate names for privacy and sent to Rel-Tech for analysis. Table 1 outlines the results of the testing.

Employee sample #3, who had the highest PCB level of 25.2 PPB, had a slightly elevated liver enzyme level (SGOT) of 28 (normal range 7-23 units per liter).

Employee sample #5, who had a PCB level of 8.2 PPB, also had an SGOT level at the upper limit of the normal range.

Both employees were advised to see their family doctors for a follow-up exam to investigate potential liver damage. Follow-up blood tests a few weeks later indicated the liver enzyme levels to be back within the normal range for both employees. After examinations, they were each given a clean bill of health. It appears that a variety of factors can influence these enzyme levels temporarily. A correlation with the PCB level did not appear to be indicated in our tests.

COSTS

The serum analysis at Rel-Tech was approximately $100 per sample. The standard samples from the CDC were provided at no cost as were the chemical profiles at City Hospital. The only renumeration necessary for both organizations was the sharing of the data at the completion of the testing.

SUMMARY

The test results indicated to us that the employee serum PCB levels to be about as expected. Even the high reading of 25.2 could be considered about 20 PPB when the testing accuracy was taken into account.

Our employees were more than satisfied that their body PCB contamination was not significantly different from the general population, and that minimal danger existed for either short-term or long-term health effects. Both major questions were answered at this point.

With all risks considered, the best course of action for this particular problem was to meet the concerns of the employees head on.

ACKNOWLEDGEMENTS

Meadville City Hospital (currently the Meadville Medical Center), Meadville, PA 16335
Anthony J. DeFail, Executive Director, Dr. Jerry Marty, Director Pathology and Laboratory Medicine Department.

Center for Disease Control, Department of Health and Human Services, Toxicology Section, Atlanta, GA

NIOSH, Cincinnati, OH 45226
Dr. Alexander B. Smith, Chief of Medical Section, Hazard Evaluation and Technical Assistance Branch, Division of Surveillance, Hazard Evaluation and Field Studies.

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1. Alexander B. Smith, M. D., M. S., and David P. Brown, M.S. Polychlorinated Biphenyls in the Workplace. U. S. Department of Health and Human Services, Public Health Servite, Centers for Disease Control, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226, April, 1983.

TABLE 1

BLOOD SERUM PCB LEVEL TEST RESULTS

SAMPLE NO.	RESULTS (PPB)
EMPLOYEES - GREATER EXPOSURE	
#1	18.5
#2	8.2
#3	25.2
#4	9.7
#5	8.2
EMPLOYEES - LITTLE EXPOSURE	
#6	6.5
#7	7.3
HOSPITAL EMPLOYEES	
#8	7.7
#9	6.8
STANDARD SAMPLES*	
#10 - 1.6 PPB level	3.4(1st run); 2.0 (2nd run)
#11 - 9.7 PPB level	11.7(1st run); 15.5 (2nd run)
#12 - 22.2 PPB level	27.5(1st run); 30.2 (2nd run)

*The standard sample runs indicate the results to be as much as 10 to 20% higher than expected. A rerun was requested to provide a further accuracy check.

MONS 217326

PCB MANAGEMENT IN A MULTI-PLANT CANADIAN CORPORATION

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ABSTRACT

Domtar Inc., a Canadian Corporation, operates 75 plants in Canada and 25 in the U.S.. It is a diversified company, producing pulp and paper products, packaging, construction materials and chemicals. The Corporate Environmental Services Department established a program of PCB management to ensure compliance with Federal, Provincial and State regulations, and to develop and implement a plan to reduce Domtar's exposure to PCB related incidents.

The objectives of this program are being achieved by the execution of the following phases:

- Inventory of all electrical equipment containing or contaminated with PCB
- Technical audits and risk evaluation
- Analysis of options for action to reduce risks
- Action plan and implementation

INTRODUCTION

Inefficient management of PCBs could be disasterous to any corporation. PCBs have become the focus of more regulatory attention than any other compound in history. Recent clean-up and decontamination costs after a fire involving PCBs have reached millions of dollars. The cost of production loss and ensuing legal claims could be astronomical. Domtar initiated its PCB management program in 1985 in order to reduce its exposure to PCB related incidents and to minimize health, environmental and financial risks.

INVENTORY

An inventory of all electrical equipment containing PCB fluids in Canadian and U.S. mills and plants was carried out, followed by inventory of over 200 offices, warehouses and distribution centres. All electrical equipment containing or contaminated with PCBs, in service or in storage, were included. A questionnaire was sent to every location in a format which facilitated reporting to government authorities.

Due to the volume of information collected and the necessity to keep the information updated, it became evident that a computer was needed to process and

manage this information. A data base management system using DBASE-III program was implemented on an IBM-PC. Data manipulation and updating became an easy task. Inventory listing of any type of electrical equipment such as capacitors, PCB transformers or mineral oil filled transformers per Company Group, Division, Province, State, Country is available.

The inventory format was divided into six sections. It included PCB transformers, capacitors, contaminated mineral oil transformers and miscellaneous articles in service, PCB equipment in storage for future disposal as well as a list of all PCB equipment shipped out for storage. A complete description of every PCB equipment is provided, including its government label number, serial number, kVA, location, volume of fluid, and in the case of mineral oil transformers, the contamination level. For PCB equipment shipped out for storage, the shipping date, carrier, destination and manifest number is also included.

Following the completion of the inventory, all PCB filled capacitors, transformers as well as mineral oil transformers contaminated with over 50 ppm PCBs in Domtar's Canadian plants were labelled using stickers obtained from Environment Canada.

REGULATORY BACKGROUND: THE CANADIAN ENVIRONMENTAL CONTAMINANTS ACT

"Chlorophenyl Regulation No. 1" which became effective on September 28, 1977, bans the use of PCB equipment in any product, machinery or equipment manufactured or imported into Canada.

"Chlorobiphenyl Regulations No. 2 (Product)" prescribes a maximum permissible concentration of 50 ppm of PCB in electrical equipment which are imported, manufactured or offered for sale in Canada. Exceptions exist where the electrical equipment containing PCB in concentrations greater than 50 PPM is offered for sale as a necessary and integral part of a building, plant or structure which itself is offered for sale. To qualify for this exception the electrical equipment must be functional and operating. A further exception is PCB filled equipment sold for destruction or for storage awaiting destruction.

"Chlorobiphenyl Regulations No. 3 (Release)" prescribes 50 ppm by weight as the maximum concentration of PCB which may be released into the environment other than an application to a road surface, in which case the maximum permissible concentration is 5 ppm by weight. The maximum quantity of PCB which may be released into the environment from any PCB filled electrical equipment is limited to 1 gram per day. Offences under the Environmental Contaminants Act are punishable by a fine up to $100,000 per day or imprisonment for two years.

Chlorobiphenyl Regulations No. 2 and No. 3 became effective on May 15, 1985.

The major differences between Canadian and U.S. regulations are:

- Any electrical equipment in Canada containing over 50 ppm PCB is considered as a PCB equipment and is subject to chlorobiphenyl regulations 2 and 3.
- The U.S. regulations make provisions for PCB contaminated transformers, i.e. ones containing 50-500 ppm PCBs. A PCB transformer is one that contains 500 ppm or greater.
- Transportation of PCBs between the two countries is not allowed.
- The EPA has stricter regulations regarding registration of PCB equipment with fire departments, removing of combustible materials, inspections, location

restrictions, maintenance etc.
Destruction of PCBs is available in the U.S. but not in Canada. Mobile decontamination units for mineral oil filled transformers have recently been approved by most Canadian provinces.

TECHNICAL AUDITS AND RISK EVALUATION

A PCB auditing program is a necessary measure to ensure compliance with PCB regulations. It should also be the basis on which risk assessment is carried out and corrective measures taken. Domtar's PCB audits are carried out during the general environmental audits, which are conducted by Domtar's Environmental Technology Group. The auditors (including an Electrical Engineer) are trained in PCB regulations, spill and fire prevention measures, leak inspections, etc.

The purpose of these audits is to examine the physical condition of the PCB equipment and its installation and to evaluate risks of spills and fires. A checklist based on the guidelines published by Environment Canada is used by the auditors, which includes the category of the electrical equipment, its complete identification, the equipment condition and its layout, the presence of labels and records, evidence of spills, spill containment, fire risks, such as the presence of flammable material near transformers, the availability of protective equipment against spills and fires etc.

After the visit, a list of recommendations for prevention and containment are made. The audit report is then conveyed to the management of that specific location with recommendations for an action plan.

OPTIONS FOR ACTION

Since all PCB storage sites in Canada are filled to capacity, and there are still no approved PCB destruction processes in oparation, our choices remain very limited.
The options available for a company concerned with its PCB inventory in Canada are the following:

1. Do nothing.
2. Take all PCB equipment out of service and store on-site.
3. Retrofill all PCB equipment with non-PCB fluids and decontaminate. Store liquid on site.
4. Keep all PCB equipment in service and take proper safety precautions.
5. Replace structurally poor and high risk transformers at once and take preventive measures for securing others.

ANALYSIS OF OPTIONS

Option	Advantages	Disadvantages
1. Do nothing.	No capital outlay.	-High risk of spills and fires.
2. Take all PCB equipment out of service and store on site.	Exposure is low if adequately stored.	-Useful life of equipment is shortened. -Major capital outlay for new equipment. -Capital required for building storage sites. -Creates a PCB waste site.

3a. Retrofill PCB transformers with non PCB fluids.	Concentration of dioxins and furans will be less during PCB fires.	-Does not eliminate PCBs. -PCB levels will almost certainly be over 50 ppm. -May generate PCB waste 3 times the original volume.
3b. Decontaminate PCB contaminated equipment to below 50 ppm.	If successful, a PCB contaminated mineral oil transformer will be reclassified as a non-PCB equipment.	-Transformer could be downrated. -Applies only to mineral oil transformers contaminated with up to 500 ppm PCBs. -PCB concentration will increase within 6 months. -2 or 3 treatments may be required. -Generates small amounts of wastes which have to be landfillad. -Costs up to $20 per gallon.
4. Keep all PCB equipment in service and take proper safety precautions.	-Exposure reduced. -Maintain control over PCBs until such time when destruction facilities are approved.	-Some mills or plants may ignore safety precautions. -Capital expenditure required.
5. Replace all high risk PCB equipment with environmentally acceptable equipment.	-Minimum exposure. -Economically and environmentally sound.	-Additional servicing or replacement will continue to be necessary to minimize liability. -Will have to be monitored on a regular basis. -Will create PCB storage sites.

If a PCB transformer is in good condition and could be kept in service for an additional 10 or 20 years, efforts are made to secure that transformer and extract the maximum possible service as long as all precautionary measures are taken in order to minimize spill and fire risks.

Option 5, which is a combination of options 2, 3b and 4, allows for the gradual phasing out of the PCB articles and in the present Canadian context. It is an environmentally and economically sound option.

It is understood that implementing this option is not the final solution to the PCB problem and that replacing them is the ultimate aim. However, under the present regulatory environment and the non-existence of PCB destruction facilities in Canada, the above recommended route must be pursued.

CORROSION AND ITS COSTLY EFFECTS AFTER THE PCB FIRE

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When you walk into the mechanical room of the Binghamton State Office Building one obvious site is the massive amounts of corrosion apparent on all unpainted metal surfaces. All electrical switch gear, backup electrical generators, fire alarm systems, elevator switch gear, and massive amounts of electro-mechanical equipment will have to be replaced. The corrosive effects of the PCB fire have taken their toll on this equipment.

Although we have observed these corrosive effects at almost all PCB fire incidents little has been done to control it. It is known that the soot generated from the PCB fire is laced with corrosive gases such as hydrogen chloride (HCl) and chlorine (Cl). When these gases combine with moisture (Humidity) they form highly corrosive hydrochloric acid deposits. Another example of this occurred at the Air Force Wind Tunnel Testing Facility at Arnold Engineering and Developing Center in Tullahoma, Tennessee. Because the corrosion problem was not addressed in the early stages all electrical equipment, switch gears, controller equipment, and some manufacturing equipment will have to be replaced.

The cost of replacing this equipment and other equipment damaged by the corrosive effects of PCB fire incidents is staggering. Until now, this has received little attention. The corrosion may be primarily caused by the acid condition left by the fire incident; however, there are also several other factors that can accelerate the corrosive action. These include:

1. The presence of moisture
2. The absence of protective coating on the metal surfaces
3. The presence of air

There are certain items with which you should normally be concerned when evaluating the damage done by a PCB fire. They are as follows:

1. Electronics
2. Electro-mechanical equipment
3. Industrial machinery
4. Metal Structural items

As a factor in the PCB fire arena, the corrosion problem is relatively new. However, the field of corrosion control after disasters is not new. For years the by-products of fires and floods have left a corrosive atmosphere in facilities. Extensive research in this area has indicated that most losses caused by such corrosion can be averted with proper treatment.

The natural tendency once a PCB fire occurs is to test the building thoroughly to determine the extent of contamination. Unfortunately this takes time. Emergency corrosion control procedures should be performed within the first 24-36 hours after the incident. This work can be done very quickly even in maximum protective gear. The actual restoration work on the equipment can be done later. The key in most cases is the speed at which the proper treatment is initiated. There are basically two steps to corrosion control. The first is emergency treatment, which includes the steps taken to retard corrosion and slow its destructive force. The second step is the actual restoration or removal of all contaminants from the surfaces. In the initial emergency treatment several steps should be taken:

1. Control of humidity - In some cases this means simply removing the firemans' water and containerizing it. In other situations this could mean the placement of dehumidifying equipment or the use of air conditioners.

2. Isolating valuable equipment from the hostile environment - If the equipment cannot be physically isolated from the contamination or the high humidity, it might be possible to move the equipment to another area of the building.

3. All untreated metal surfaces should be sprayed with inhibitors as prescribed by a corrosion control chemist to reduce oxygen on the exposed surfaces and displace any moisture.

Electronic Data Processing (EDP) Equipment is particularly susceptible to the effects of corrosion for several reasons: 1) They operate on very low voltage so consequently any particulate matter settling on surfaces can have the potential to produce a stray signal resulting in equipment malfunction. 2) Very tight tolerances and multiple connectors make these items partially susceptible.

If the corrosion has progressed to the point where you can see it, normally it is too late to save the equipment. The emergency treatment of equipment slows the progress of the corrosion and buys the customer time for decision making. Normally during this time the building can be analyzed for the extent of PCB/PCDD/PCDF contamination and a clean-up and a decontamination plan can be formulated. As a part of the decontamination plan restoration of the EDP equipment should also be included. The metal surfaces should be tested to determine the nature of the contamination and its corrosive properties. Using information obtained from these tests, the corrosion control chemist will formulate a solution for each surface and component. Some methods that have been successfully used are as follows:

1. Ultrasonic - This innovation is particularly good for cleaning printed circuit boards, keyboards, and small parts. Special care must be taken to insure that sonic sensitive items are not placed in the ultrasonic baths.

2. Hand cleaning with a wash and rinse system - This process normally is used with a freon based cleaner.

3. Wash and bake operation - Components are normally dipped in a washing solution and then baked dry. Most manufacturers use a form of this cleaning method in the final stages of printed circuit board construction.

Once the unit has been thoroughly decontaminated, it must be recertified and placed under a proper maintenance contract, if applicable. In many cases the original maintenance provider for the equipment may not wish to continue the maintenance contract. Fortunately, there are many other reputable third party maintenance companies that are usually quite anxious to establish an acceptable program for the equipment.

Many times the most important asset requiring preservation by the company is its corporate media (company data base). It is very possible to have a $10,000 computer with a $150,000 worth of accounts receivable in its memory. This will normally be contained on tape or disk. Severe damage to disk read/write heads is possible. If an attempt is made to use the media when it is not clean, a "head

[redacted]rash" caused by a particle on the surface of the media will not only damage the drive but also result in a loss of data. In decontaminating the media it is important to keep all cleaners away from the drive head and the disk surfaces. The cleaning of disk packs, tapes, and floppy disks requires special techniques and should be done only by experienced personnel. In the event media is damaged by a head crash this does not necessarily mean that it is irretrievable. However, it does require the use of specifically configured disk drives with mechanically movable heads. Again, a service provided by a professional.

Industrial equipment is normally treated in a completely different fashion from the EDP equipment. In this case, even if this equipment is rusted it can often be brought back to a serviceable condition. Again, it is important that the emergency treatment be performed immediately. Although you may be able to restore the equipment if it goes untreated, the cost and the complexity of the restoration is much more difficult if the corrosion is not retarded in the beginning. Some types of industrial equipment are as follows:

1. Typewriters
2. Manufacturing machinery
3. Motors
4. Numerically controlled manufacturing equipment
5. Computer operated manufacturing equipment
6. Raw metal stock items

The emergency treatment usually consists of the use of inhibiting oils to restrict oxygen on the surface of the metals and displace any moisture present. Controlling the humidity is also an important factor. The restoration process normally begins with the stripping of rust from the surfaces of the metal. In this process the corrosion control chemist will prescribe either an acid or alkaline rust remover, depending on the contaminant. Many of these chemicals are heat activated, so often they are applied with the use of steam cleaners. Protective gear must be used to protect the employees' skin from the caustic effects of these chemicals. Next, the surface of the metal is neutralized, sometimes it is then pacified and then finally the proper protective coating is applied. Some examples of coatings are lubricating oils, phosphate coatings or possibly a primer coat of paint.

Although many of the landmark PCB fire incidents resulted in staggering losses due to the corrosive effects of PCB by-products on the equipment, today we know this need not happen. These excessive financial losses which have resulted from PCB fires can be substantially reduced in the future through the immediate use of initial emergency techniques followed by a methodical restoration program.

PCB-CONTAMINATED TRANSFORMER OIL SPILL EXPOSURE ASSESSMENT

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INTRODUCTION

A study was conducted to estimate potential human exposure levels associated with PCB-contaminated transformer oil spills following visible trace cleanup (1). This exposure assessment differed in two ways from those previously conducted by the EPA (2,3) in support of their recent Toxic Substances Control Act (TSCA) PCB spill cleanup policy rule (4). First, PCB concentrations and associated exposure levels were estimated for conditions representative of visible trace cleanup at transformer oil sites. Second, the presence of mineral oil and its effect on the environmental behavior of PCB were considered. The EPA exposure assessments assumed conditions typical of disposal sites, rather than spill sites, and did not consider potential PCB-mineral oil interactions.

APPROACH

PCB concentrations associated with transformer oil spills were estimated with the PCB On-Site Spill Model, POSSM, (5,6) and an EPA air dispersion model, PTDIS (7). POSSM is a chemical transport and fate model that simulates changes in chemical concentrations on a spill site and losses of chemical from the spill site via volatilization, runoff-soil erosion, and leaching to groundwater. PTDIS calculates chemical concentrations in air downwind from a point source of release.

POSSM was used to evaluate PCB losses from a 40-liter (10.6-gallon) spill of mineral oil containing 270-ppm PCB in the form of Aroclor 1242. Visible traces of the spill were assumed to cover an area of 0.0016 ha (170 square feet). These spill conditions represent the average spill volume, PCB concentration, and cleanup area for 60 spills from distribution system transformers.

Visible trace cleanup was assumed to occur one day after the spill resulting in between 65 and 95 percent removal of the PCB-contaminated oil. These two values

bracket the range of spill cleanup efficiencies observed by the utility industry. Spill site restoration through the placement of a clean soil-sod cover over the cleanup area was assumed to occur 30 days following cleanup. Cover thicknesses of 5 centimeters (cm) (2 inches), 10-cm (4 inches), and 25-cm (10 inches) were evaluated.

MCPOSSM (8), or Monte Carlo POSSM, was also used to determine the potential range of variability of estimated exposure levels. MCPOSSM was applied to the 30-day time period between spill cleanup and site restoration. MCPOSSM runs were conducted for two cleanup levels: 65 and 95 percent removal. Input parameter frequency distributions were developed to represent the variability of spill conditions based on utility data for 60 transformer spills, a broad range of soil types, and the range of PCB properties typical of Aroclor 1242.

Soil concentrations estimated with POSSM were converted into soil ingestion and dermal contact exposure levels using exposure factors consistent with those used by EPA (2). PCB volatilization losses were converted into downwind air concentrations using PTDIS. The resultant air concentrations were converted into inhalation intake rates using exposure factors consistent with those used by EPA (2).

RESULTS

PCB volatilization was found to be the most significant loss mechanism in all simulations. Losses via runoff-soil erosion and leaching were negligible compared to the volatilization losses.

The results indicate that dermal contact is the most significant route of exposure, particularly for the 65 percent cleanup level with a 5- or 10-cm cover thickness. This result is due to the assumption that the receptor comes into contact with soil to a depth of 25 cm; for the 5- and 10-cm-thick cover options, the 25-cm depth includes residual PCB remaining following cleanup. Estimated soil ingestion rates are a factor of approximately 3 lower than the dermal contact rates, and estimated inhalation intake rates are between a factor of 4 to 15 lower than the dermal contact rates.

Estimated intake rates for the 65 and 95 percent cleanup, with a 10-cm cover, show that inhalation intake could decrease by a factor of 6 if the more common 95 percent cleanup level were achieved. Soil ingestion and dermal contact intake could decrease by a factor of 9.

The MCPOSSM results indicate that inhalation intake rates can be highly variable. MCPOSSM results for the 30-day prerestoration period show that average intake rates could range over four to five orders-of-magnitude. The large range of variability is due to the large range of potential variability in spill conditions, soil properties, and PCB properties. Frequency distributions of inhalation intake rates for the 30-day prerestoration period show that a high percentage of the time (i.e., 90 percent) exposure levels are at the low end of the range of estimated values.

ACKNOWLEDGMENTS

This exposure assessment was supported by the Utility Solid Waste Activities Group, Edison Electric Institute, Washington, D.C. POSSM and MCPOSSM were developed by EPRI under RP 2634-1.

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PART 6:

SPILL CLEANUP

THE PCB SPILL CLEANUP POLICY OF 1987: SUMMARY AND IMPLICATIONS

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ABSTRACT

The purpose of this paper is to summarize and discuss the national PCB spill cleanup policy. The policy requires that all new PCB spills be cleaned up according to strict performance standards. All professionals responsible for PCB management should be familiar with this policy, since it once again changes the game rules for handling PCBs. This summary addresses and clarifies the PCB policy's requirements for spill reporting, cleanup, post-cleanup sampling, and record-keeping, along with some of the policy's problems and implications.

INTRODUCTION

On April 2, 1987, the U.S.EPA issued a final rule establishing a National PCB Spill Cleanup Policy (1). The policy became effective May 4, 1987, and significantly increases the requirements for reporting and cleanup of all new PCB spills. Spills are defined as intentional or unintentional leaks, spills, and other uncontrolled discharges of any quantity of PCBs running off or about to run off the external surface of the equipment or PCB source, as well as the resulting contamination. The scope of the policy covers most new spills of PCB fluids containing 50 ppm and above. However, spills directly into water, sewers, vegetable gardens, and animal grazing land are not covered by the policy but will be considered by the EPA regions on a site-by-site basis. Cleanup requirements for these types of spills are likely to be stricter than the policy requirements.

OVERVIEW OF REQUIREMENTS

The Policy addresses five basic aspects of PCB spill response. Generally, for most new spills of materials containing more than 500 ppm PCB, the following is required:

1. Reporting: To EPA within 24 hours of spill discovery
2. Cleanup: Completion within 48 hours of spill discovery
3. Performance Standards: Variable according to spill location and mass of PCBs spilled
4. Post-Cleanup Sampling: Statistically valid methodology and analytical techniques for verification
5. Record-Keeping: Certification and document retention for five years

Spill Reporting

The overall objective of the Policy is rapid PCB spill response. The Policy requires that all new spills of more than 10 pounds of pure PCB by weight be reported to the EPA regional office and National Response Center (NRC) (1-800-424-8802) within 24 hours after the spill has been discovered. Typically, this would cover any complete release of fluid from a single PCB capacitor or transformer. This requirement may be waived only in the case of adverse circumstances, such as tornado, hurricane, or civil emergency. However, responsible parties who delay reporting and cleanup due to an adverse circumstance must keep records documenting the circumstances precluding rapid response. Most spills of low concentration PCB (50-500 ppm) must be cleaned up, but EPA notification is not required. Spills of materials containing less than 50 ppm PCB are not covered by this Policy.

It is worth noting that the published policy does indicate that "spills exceeding 10 pounds of PCB material (generally one gallon of dielectric fluid)" must be reported to the EPA regional office. Consequently, the Utility Solid Waste Activity Group (USWAG) requested that the EPA clarify this reporting requirement since it would have unduly required the reporting of nearly all mineral oil transformer spills regardless of the mass of PCBs spilled. In a subsequent memorandum to USWAG, the EPA Office of Toxic Substances clarified that the specified reporting requirement only pertains to spills of 10 pounds of pure PCBs or more by weight and that the regional offices had been notified of this policy revision (2).

Cleanup Standards

The Policy imposes variable cleanup requirements based on the mass of PCBs spilled and the location of the spill.

I. For spills of PCB-contaminated material (50-500 ppm) containing less than one pound of pure PCB by weight, the following cleanup requirements must be completed within 48 hours of spill discovery.

- Solid Surfaces: Double wash/rinse with solvent
- Soil: Remove visible traces plus a buffer of one lateral foot
- Documentation: Provide cleanup certification

II. The following is required for all spills involving PCB materials over 500 ppm and PCB-contaminated materials exceeding one pound of PCB by weight:

1. Immediate Response: The following requirements must be satisfied within 24 hours of spill discovery:

- Notification: Contact EPA and NRC if over 10 pounds of PCB
- Barrier Protection: Restrict access to spill area plus a three foot buffer zone
- Eliminate Spillage: Stop flow with absorbent or plug
- Initiate Cleanup: Remove all visible traces of spill

2. Cleanup Standards: Spill cleanup must meet stringent performance standards. A summary of the spill cleanup performance standards is presented in Table 1. Within 48 hours of spill discovery, cleanup should be completed and achieve the specific standards for the listed locations. Post-cleanup sampling must verify that the standards for cleanup have been successfully achieved.

Post-Cleanup Sampling

The policy requires a statistically valid, reproducible, sampling methodology to verify the achievement of the cleanup performance standards for all high-level PCB spills or low level spills involving one pound or more PCBs by weight. The sampling scheme may consist of either random or grid samples. However, the sampling area must be the larger of either the area cleaned plus an additional one foot boundary, or an area 20 percent larger than the original spill boundary.

The number of samples collected can be as little as three or as many as 40; however, a sufficient number must be taken to ensure that areas of contamination of a radius of two feet or more within the sampling area will be detected. Additionally, the sampling scheme must ensure 95 percent confidence against false positives and include a calculation for expected variability due to analytical error.

Although any sampling methodology which achieves the above requirements may be used, the EPA recommends the use of the sampling scheme and verification techniques developed by the Midwest Research Institute for the EPA Office of Toxic Substances (3) (4).

Record-Keeping

The Policy requires that all spill cleanups be fully documented and that the responsible party certify the required site decontamination. All spill records, documentation, and pertinent data must be retained for at least five years and be made available to the EPA upon request. The records and documentation must consist of the following information:

- Identification of spill source (equipment)
- Estimated or actual date and time of spill
- Actual date and time of cleanup completion
- Description of spill location and nature
- Pre-cleanup sampling data
- Description of solid surface cleaning
- Approximate depth and amount of soil removed
- Post-cleanup verification sampling data and methodology
- Signed certification statement
- Estimated cost of spill cleanup (optional)

IMPLICATIONS AND PROBLEMS

The policy will prove costly to electric utilities. The EPA estimates that 620,000 pounds of PCBs are leaked or spilled from electrical equipment every year.

Based on available data, 38% of these PCBs are spilled in electrical substations and 68% are spilled in residential/commercial, rural, or industrial areas. Given the large quantities of spilled PCBs and the very stringent cleanup standards required by the Policy, the cost of PCB cleanup is certain to increase significantly. The cleanup of one PCB capacitor spill in a residential area is expected to cost on the order of $10,000. Based on EPA's cost estimates, U.S. industry can expect to pay over $100 million per year to clean up PCB spills. Not only is this Policy very costly, but it creates some very serious compliance problems for electric utilities.

Old and New Spills

Most electrical substations and other locations where PCB equipment is in use have been subject to historical PCB spills. Therefore, a residual PCB concentration may be expected at these locations. Once a new spill occurs in such a location, the prescribed decontamination standards must be achieved at that site. If the contamination from the new spill can't be distinguished from the historical contamination, the entire site may have to be excavated and cleaned to the prescribed standard. This scenario may easily increase EPA's original cost estimates. To solve this dilemma, it may be necessary for utilities to construct containment structures in all substations and areas where PCBs are currently in use in order to isolate all new spills from past spill environments.

48-Hour Requirement

Meeting the requirement of spill cleanup completion and restoration within 48 hours is also expected to cause compliance problems. In order to meet this requirement, the site must be cleaned, verification samples obtained, analytical results reported, and the site restored within two days. Needless to say, getting a turn-around time of one to two days for PCB analyses is atypical. There will also be a need for all PCB generators to have a reliable source of clean fill material ready for transport to any spill location for site restoration at a moment's notice. If a contractor is used for site cleanup and/or sampling, this requirement will substantially increase the costs.

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(4) U.S.EPA "Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup," EPA-560-5-86-017, May 1986.

Table 1. PCB SPILL CLEANUP PERFORMANCE STANDARDS

Mass of PCBs	Location	CONTAMINATED SOIL: Visible Traces + 1 ft. Lateral Buffer	CONTAMINATED SOIL: 50 ppm + notice	CONTAMINATED SOIL: 25 ppm	CONTAMINATED SOIL: 10 ppm + 10 inch Excavation	SOLID SURFACES: Double Rinse/ Wash	SOLID SURFACES: 100 ug/ 100cm^2	SOLID SURFACES: 100 ug/ 100cm^2 + cap	SOLID SURFACES: 10 ug/ 100cm^2
Low Conc. Spills 50-500 ppm <270 gal.	Indoor Residential Areas								X
	All Other Areas	X				X			
All High Conc. Spills >500 ppm and Low Conc. Spills >270 gallons	ELECTRICAL SUBSTATIONS		X	X			X		
	RESTRICTED ACCESS AREAS								
	Hi Contact Outdoor Lo Contact Indoor			X					X
	Lo Contact Indoor Nonimpervious			X				X	X
	Lo Contact Outdoor			X			X		
	NON-RESTRICTED ACCESS AREAS								
	All Indoor Hi Contact Outdoor				X				X
	Vaults Indoor Lo Contact Outdoor				X				X
	Lo Contact Outdoor Nonimpervious				X			X	X

Attenuation of Polychlorinated Biphenyls in Soils

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The ability to predict the long-term mobility of polychlorinated biphenyls (PCBs) in the soil-water environment is of particular interest to the electric utility industry and regulatory agencies because of the history of use of PCBs as a coolant-insulation fluid and their resistance to degradation. This paper describes the influence that adsorption/desorption has upon PCB mobility in soils and our current experimental work to 1) establish correlative relationships that can be used to estimate equilibrium sorption parameters from easily measured soil characteristics and well-established physical properties of PCBs; and 2) measure the release rates under non-equilibrium conditions of PCB congeners from utility soils containing Aroclor mixtures. The approach being used in this program to describe the role of sorption/desorption on PCB mobility in soils is also applicable to other hydrophobic organic compounds, such as the polynuclear aromatic hydrocarbons (PAHs), which are present in the soils at Town Gas sites.

INFLUENCE OF SORPTION ON PCB MOBILITY & TRANSPORT

In soil-water systems at low environmental concentrations, the sorption of a PCB congener "i" can be described by a linear sorption isotherm, where the amount sorbed (S^i) is related to the equilibrium solution concentration (C^i) by a constant (K_p^i) termed the equilibrium partition constant for that congener (1) and given by

$$S^i = K_p^i C^i \text{ or } K_p^i = \frac{S^i}{C^i} \qquad (1)$$

To illustrate the attenuation or retardation effect that sorption has on the transport of PCBs or other organic compounds (e.g., PAHs) away from their initial point of contact with the soil, consider the following simple example. Water is flowing at a steady hydrologic flow with an average velocity, v, through a soil of uniform porosity (n) that contains PCBs. Assume further that, the sorption reactions are fast relative to v, so that sorption/desorption can be described by equation (1), the water content of the soil is constant, and that dispersion effects unrelated to sorption are negligible. The rate of advancement (v') of the PCB front through the soil will be retarded relative to the rate of advancement of the water by an amount $v' = v / R_f$. The retardation factor R_f is defined as,

$$R_f = v/v' = 1 + \frac{\rho}{n} K_p, \quad (2)$$

where n and ρ are the soil porosity and density respectively (2).

Consider the retardation of the Aroclor 1260 congener 2,4,5,2',4',5' in a low organic carbon soil characterized by 0.05% (by weight) organic carbon (OC), 5% expandable clay minerals (CM), a porosity n = 0.5, and density ρ = 2.4 g/cm^3. Although a reasonably accurate "carbon-reference" model exists for calculating K_p and describing the sorption of organic compounds by soils containing greater than 0.2% OC (1,3), no such model has been established to describe sorption on soils containing less than 0.2% OC. Thus to estimate the retardation in this low OC soil we could only make the questionable assumption that OC still dominates sorption and K_p can be estimated using the carbon-reference approach. Based on a review of literature data (1), K_ps for the 2,2',4,4',5,5' congener for such low OC soils range from 36 to 1400. For sake of illustration K_p can be assumed to be 300, yielding a retardation factor of R_f=1440. With a water velocity of 50 cm/d, we would expect PCBs to require approximately 385 years to move 50 meters. This assumption neglects sorption by expandable clays; however, there is no "clay-reference" model from which we can estimate a K_p for the clay fraction of the soil. Based on our current lack of information in estimating a K_p value for this low OC, 5% clay soil, it is not unreasonable to postulate that the K_p used above could be in error by as much as a factor of 10. In this case, the 50-meter transit time could be as low as 38 years or as high as 3850 years. Thus, we currently have no basis with which to estimate the rate of PCB movement in low OC soils. Clearly additional information is needed on PCB sorption in low OC soils to define the role played by expandable clay minerals in sorption processes.

ESTIMATION OF EQUILIBRIUM PARTITION COEFFICIENTS FROM PHYSICAL CONSTANTS

Our current experimental program includes investigation of PCB sorption/desorption under equilibrium conditions for both typical (>0.2%) and low (<0.1%) OC soils. The objective is to derive a predictive equation or equations, based on a small but adequate set of experimental sorption data, which can be used to estimate equilibrium pertition constants (K_p') for a large number of individual congeners for which sorption experiments have not been performed. Experiments are in progress to measure K_ps for 2,4'; 2,2',4,4'; and 2,2'4,4',5,5' on 10 soils differing in their OC and CM content (0.05% < OC < 4%; 5% < CM < 53%).

For typical OC soils, regression equations of the form,

$$\log K_p = a \log K_{ow} + b - \log f_{oc} \quad (3)$$

have been extensively used in the literature, where Kow is the octenol-water partition coefficient and f_{oc} is weight fraction of organic carbon in the soil. A significant body of K_{ow} data exists in the literature (4-6) and f_{oc} is an easily measured quantity. The a and b correlation coefficients determined for various classes of hydrophobic organic compounds differ significantly (3,7-9). The coefficients for one class of compounds do not work for another class (3). These coefficients have not previously been derived for a series of PCB congeners.

Once the a and b coefficients and their limits of accuracy are established with data from experiments currently in progress, K_p values for congeners for which no

experimental data exist can be estimated from experimental (4) or calculated (5) K_{ow} values and the measured f_{oc} of the soil. Development of this information represents a significant advance because it is far easier to measure the foc for a soil and measure or calculate the K_{ow}'s for a series of congeners than to measure K_ps for a series of congeners on the soil.

MEASUREMENT OF PCB DESORPTION RATES FROM UTILITY SOILS

The partition coefficients described above treat the sorption process and retardation under equilibrium conditions, that is when the flow of water through the soil is sufficiently slow that local equilibrium conditions exist. When the flow increases to the point where local equilibrium is not attained, the sorption process is described in terms of the rates of sorption and desorption. In general both the K_ps and the sorption/desorption rates are required for a complete description of the retardation of organic compounds in field situations.

The utility industry is interested in soils that have been in contact with Aroclor mixtures for an extended period of time. Thus the practical question is, what is the rate of desorption once these contaminated soils are contacted by the waters percolating through them. To address this question we are utilizing gas stripping columns with Tenax resin traps (10) to simultaneously determine the rates of release of 16 to 25 congeners from a utility soil suspended in water. The Tenax traps are changed at regular intervals and the trapped PCBs are measured by gas chromatography. In this way the release rates from the soil can be determined for individual congeners. This follows because the rate of PCB exchange between the water and the gas, which is flowing up the column, is virtually instantaneous in comparison to the release rate from the soil which is diffusion limited. Thus the rate of change of PCBs in the Tenax resin trap is equal to the rate of release from the soil.

Gas stripping experiments have been conducted with a 1.5% OC utility site soil containing 1.5 ppm total Aroclor 1260 to determine whether this method for measuring release rates is applicable to Aroclor mixtures in soils. The results showed that the release of 16 congeners could be observed during the four-month term of the experiments and that a greater number of congeners could be observed if soils containing higher total PCB concentrations were used. The cumulative fractions released, when plotted against the square root of time, are approximately linear for those congeners present in sufficiently high concentrations. This linearity is consistent with the hypothesis that the release rates from soil particles are limited by diffusion from the interior of the soil particle (10). This follows because the boundary conditions existing in these experiments (e.g., zero aqueous PCB concentration) approximate those for which diffusion controlled release rates depend on the square root of time (11). During the four-month stripping experiment, 38%, 28% and 20% of the total quantity of congeners 2,2',4,5,5'; 2,2',3,5,5',6; 2,2',4,4',5,5' were removed from the one-gram sample of utility soil used. This represents the upper limit of the release which could occur from this soil under field conditions. Based on the success of these preliminary experiments, additional stripping experiments are planned for 1988 using several utility soils. These experiments will be conducted for longer times to quantitatively determine the release rates and how these release rates change with time. The release rates, determined in this way, represent the upper limit or maximum release rates that could occur in a soil-water system. This information directly quantifies the significance of a given spill site as a PCB source term for subsequent migration in soil-water or aquifer-groundwater systems.

SUMMARY

We have given a simple example of how sorption/desorption influences the mobility of PCBs in soils and described our experimental work to develop methods and data for quantitatively estimating sorption/desorption parameters, which can be used to describe PCB movement in soils using transport or risk assessment models. Specifically we have described correlation relationships that can be used to estimate equilibrium partition coefficients and experimental gas stripping techniques to measure maximum possible release rates. Finally, we pointed out that while PCBs are important compounds to the utility industry, the methods and approach described here for PCBs are applicable for the study of the attenuation of other hydrophobic compounds (e.g., PAHs) that may be of current or future importance to the utility industry.

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EVALUATION OF DECONTAMINATION OF SOLID SURFACES EXPOSED TO PCBs

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INTRODUCTION

Under the authority of the Toxic Substance Control Act (TSCA) the U.S. Environmental Protection Agency has recently established a uniform policy for decontamination of polychlorinated biphenyl (PCB) spill areas (1). Numerical decontamination standards, which define adequate cleanup in terms of residual PCBs, and performance-based standards have been established. Under a performance-based standard, cleanup in accordance with a specified procedure is considered adequate cleanup without post-cleanup sampling and analysis. Whether numerical or performance-based standards are specified is dependant upon the quantity and concentration of the PCB spill.

The optimal equipment and materials to successfully achieve either the numerical or performance-based standards for cleanup of PCB-contaminated solid surfaces have not been established. The need for appropriate measures for cleaning up residues of polychlorinated biphenyls (PCBs) on a variety of solid surfaces continues to be a high-priority issue confronting utilities and other PCB equipment owners. Recognizing the continued need for enhanced cleanup efficiency and the findings of other researchers on the subject, the authors designed a laboratory investigation to provide additional comparisons of promising solvents and cleansers (2).

METHODS

The laboratory tests were designed to evaluate cleaning materials commonly used for cleanup of both porous and non-porous surfaces by the sponsoring utility, Seattle City Light (Table 1). Bench testing entailed the application of spiked PCB-contaminated mineral oil (448 ug/g) onto clean surfaces to total approximately 1,000 ug/100 cm^2. The test surfaces were exposed to the PCBs for seven days at room temperature prior to cleanup. Each porous surface was cleaned by pipeting the cleaning agent (5 mL/100 cm^2) onto the test surface (surrounded by caulking), scrubbing with a metal brush, and then absorbing the wash water with a polypropylene absorbent pad. Three such wash iterations were

performed prior to sampling for residual PCBs. Each non-porous surface was cleaned by pipeting the cleaning solution onto a gauze pad and wiping the test surface. Three wash iterations were also performed on the non-porous surfaces prior to sampling for residual PCBs.

After three wash iterations residual PCBs were evaluated by collecting a wipe sample from each test surface. The wipe sampling was performed using a gauze pad saturated with hexane. To further evaluate the fate of the PCBs applied to the porous surfaces, a mass balance of the originally applied PCBs was attempted. The following samples were analyzed for PCBs to perform the mass balance: 1) Absorbent pads collected after each wash, 2) final rinsate from the metal brush and steel box used to contain wash water, and 3) the 100 cm^2 spiked surface (removed by chipping). Chips were collected in the following increments: 1/8-inch (surface), next 1/8-inch (depth 2), and final 1/4-inch (depth 3). All PCB analyses on the wipe and chip samples were performed by gas chromatography with electron capture detection.

RESULTS AND DISCUSSION

Cleaning agents, spike concentrations, and results from the wipe tests are listed in Table 2. One control sample was prepared for each type of surface by placing spiked PCB-contaminated mineral oil on the test surface and collecting a wipe sample after seven days without washing.

Concrete

The concentration of PCBs in the wipe samples collected after concrete washing ranged from 0.89 to 5.03 ug/100 cm^2. No significant difference in PCB cleaning ability was found among the three cleaning agents used for concrete washing, based on a one-way analysis of variance of the post-wash wipe tests. The control wipe result is significantly higher than all concrete post-wash wipe tests, but represents a recovery of only 2.5% of the originally applied PCBs.

The low recovery of PCBs with the control wipe sample indicates the PCBs either absorbed strongly enough to the concrete surface to prevent removal by the wipe test, spread to areas outside the test area, or penetrated deeper into the concrete. Chip samples collected from the concrete up to a depth of 1/2 inch after no cleanup recovered only 30% of the originally applied PCBs.

Concentration of PCBs decreased markedly with depth (Figure 1), indicating that nominal PCBs remained on the surface or traveled deeper into the concrete. To verify that PCBs had spread outside the test area, caulking surrounding one of the test areas was analyzed and found to contain 301 ug of PCBs, representing 30% of the originally applied PCBs. The spread of the PCBs into the caulking indicates that if there had been no barrier the PCBs would have continued to spreading across the surface outside the 100 cm^2 test area. The chips directly underneath the caulking contained no PCBs (less than 4 ug/g), indicating that the PCBs were preferentially absorbed by the caulking thereby inhibiting further spreading to outside or deeper areas.

Asphalt

The concentration of PCBs in the wipe tests collected after asphalt washing ranged from 1.20 to 38.1 ug/100 cm^2. Ranges and variability were much greater for the asphalt surfaces than for the concrete surfaces. As was found with concrete washing, no significant difference in PCB cleanup ability was found among the three cleaning agents used for asphalt washing. The control wipe test, which was collected after no cleaning of the asphalt, recovered 8.17 ug/100 cm^2 of PCBs from the surface. This is lower than four out of the nine wipe tests collected after cleaning, and is not significantly higher than the post-wash wipe tests.

Test results indicate that the poor recovery of PCBs with the asphalt control wipe test was due to strong absorption of the PCBs to the asphalt surface. This was further indicated by the mass balance analysis: recovery of the originally applied PCBs in the wash water and chip samples collected after cleaning was 67% to 97%. The largest proportion of the PCBs were collected in the chip samples collected from the surface of the asphalt (Figure 2), representing 30% to 40% of the originally applied PCBs. This high recovery of PCBs after washing indicates the strong affinity of the PCBs for the asphalt surface.

Painted and Unpainted Steel

The concentration of the PCBs in the wipe samples collected after washing the metal surfaces with each cleaning agent ranged from 1.53 to 4.02 ug/100 cm^2. Statistical comparisons, using a one-way analysis of variance, showed no significant difference among the cleaning agent abilities to clean painted or unpainted steel; nor could any significance be attributed to whether the steel was painted or unpainted. Unlike the wipe tests collected from concrete and asphalt, the variance in wipe test data collected from the painted and unpainted steel was low. Therefore, any large differences among the abilities of cleaning agents to clean non-porous surfaces would have been more readily detected.

Poor recovery of PCBs from the metal surface was obtained for the control wipe samples collected after no washing. Only 25% of the originally applied PCBs were recovered from the unpainted steel, and only 38% were recovered from the painted steel. The caulking surrounding the painted metal was found to contain 434 ug PCB which increased the recovery of PCBs from 32% to 77%. This indicates that a significant portion of the PCBs spread outside the test area decreasing the actual PCB content within the test area.

CONCLUSIONS

Based on the laboratory bench tests, designed to evaluate spills of low concentration (less than 500 ug/g) PCB contaminated-mineral oil, the following conclusions are made:

- PCB-contaminated mineral oil preferentially spreads laterally across uncracked surfaces of concrete. Over a seven-day period with less than 2 g/100 cm^2 of mineral oil originally applied to a concrete surface, PCBs were found to have spread outside the 100 cm^2 test area outlined by caulking. More PCBs were recovered from the caulking bordering the test area, than from chip samples collected from within the test area at a depth interval of 1/4 inch to 1/2 inch.

- Wipe testing after the cleanup of concrete surfaces indicated that all cleaning agents tested were capable of cleaning the concrete test surfaces to the level of cleanup required for all categories under the TSCA PCB spill cleanup policy. However, mass balance determinations during the bench testing on concrete indicated that a minimum of 65% to 82% of the PCBs in the test area remained in the concrete after cleaning. There is a need for additional research regarding the potential fate of the remaining PCBs, and the applicability of encapsulation to cleaned concrete.

- PCB-contaminated mineral oil absorbed strongly to asphalt, minimizing the spread of PCBs across the asphalt surface. The majority of the PCBs recovered after cleaning, when obtaining a mass balance of the originally applied PCBs, were in the chip samples collected from the asphalt surface.

- The strong absorption of PCBs to asphalt inhibited removal of PCBs by the cleanup procedures evaluated, and inhibited recovery of surficial PCBs during the wipe test procedure. Less than 10% of the PCBs were removed from the asphalt surfaces during the cleanup procedures. Wipe testing was highly variable, and a wipe test collected before cleanup was lower than several wipe tests collected after cleanup.

- No significant difference between the abilities of Penetone, TSP or hexane to clean up PCB-contaminated painted or unpainted steel could be detected. Based on wipe samples collected after washing, all the cleaning agents tested were able to clean up the metal surfaces to acceptable levels under the TSCA PCB spill policy.

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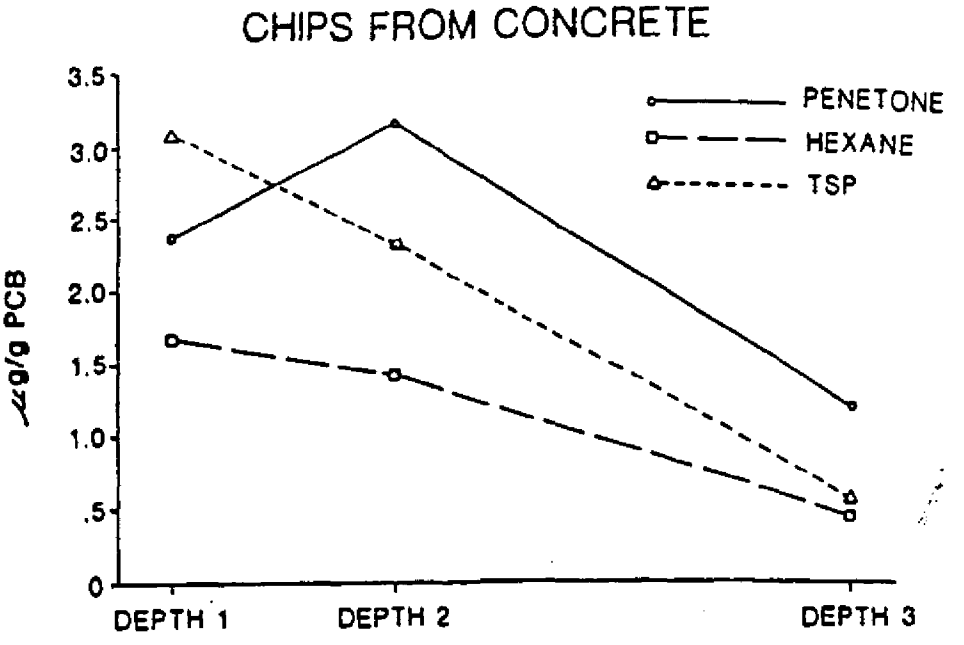

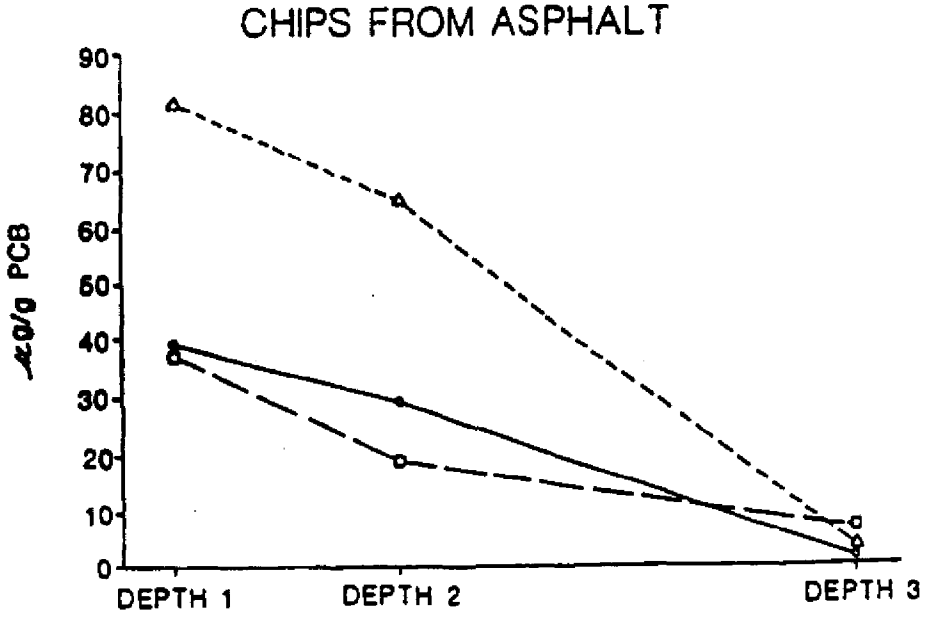

FIGURE 1 CONCENTRATION OF PCBS IN CHIPS COLLECTED AFTER CLEANUP

TABLE 1
MATERIALS EVALUATED
UNDER BENCH TEST CONDITIONS

Detergent/Solvent	Concrete	Asphalt	Painted Galvanized Steel	Steel
Penetone	a	a	b	b
Trisodium Phosphate	a	a	b	b
Hexane	a	a	b	b

a Test conditions were replicated three times to determine within-treatment variability. For each treatment, wash procedures were repeated three times, then final PCB content was determined for the solid surface by a wipe test. For one of each test condition the following samples were collected and analyzed to evaluate the fate of the applied PCBs:

- Absorbent pads collected after each wash.
- Final rinseate from the metal brush and steel box used to contain wash water.
- Chips from the test sample surface and two lower depths.

b Test conditions were replicated three times to determine within-treatment variability. For each treatment, the steel was washed three times, then a wipe sample collected and analyzed to evaluate residual PCBs.

TABLE 2
CLEANING AGENTS, SPIKE CONCENTRATIONS,
AND WIPE TEST RESULTS

Surface	Cleaning Agent	Average Weight of PCB Spiked ($\mu g/100\ cm^2$)[a]	Wipe Test Result ($\mu g/100\ cm^2$) Average	Standard Deviation
Concrete	Penetone	975.	2.82	1.63
	Hexane	980.	3.65	1.39
	Trisodium Phosphate	1009.	2.43	0.30
	Control[b]	1022.	25.4 (one sample)	
Asphalt	Penetone	970.	11.8	10.3
	Hexane	977.	3.35	1.56
	Trisodium Phosphate	971.	16.3	19.3
	Control[b]	960.	8.17 (one sample)	
Painted Steel	Penetone	954.	3.47	0.31
	Hexane	980.	2.98	0.70
	Trisodium Phosphate	965.	2.83	1.25
	Control[b]	979.	322. (one sample)	
Unpainted Steel	Penetone	967.	2.83	1.03
	Hexane	970.	2.89	0.45
	Trisodium Phosphate	968.	2.73	0.17
	Control[b]	980.	248. (one sample)	

[a] Test area spiked with mineral oil containing PCB Aroclor 1260 at 485 ug/g.

[b] Surface spiked the same as other test samples, but no washing performed before wipe test.

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