ADAPTING U.S. TECHNOLOGY TO INTERNATIONAL PCB REGULATIONS

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ABSTRACT

The United States Congress, in 1976, passed the Toxic Substances Control Act which specifically prohibited the manufacture, process and distribution in commerce of polychlorinated biphenyls (PCBs). The U.S. Environmental Protection Agency was empowered to enforce this Act, a responsibility which led to the promulgation of consecutive, ever more restrictive rules governing the use of this class of materials. These EPA rule makings were in response to the prevalent belief that PCBs are extremely toxic materials which, under certain circumstances, can degrade to even more toxic materials. While debate on the toxicity and environmental considerations of this class of chemicals continues, the U.S. owners of PCBs and PCB transformers must contend with an evermore restrictive barrage of regulations. This paper will outline the technological responses in the United States tailored to free the PCB transformer owner from the regulations and, at the same time, to remove PCBs from further contamination of the environment. The application of this technology to other international PCB regulations also will be discussed.

PCB HISTORY AND REGULATIONS

PCBs had been utilized in transformers as premium fluids, because of their physical characteristics such as long term stability, non-flammability, no flash or fire point, and biological stability. PCBs or askarels were considered to be the fluid of choice where fire characteristics were important.

The regulatory driving force for the U.S. PCB market had its origins well before the 1976 enactment, by Congress, of the Toxic Substances Control Act (TSCA) which prohibited the manufacture, process or distribution in commerce of PCBs. In the late 1960's, evidence began to mount that PCBs were accumulating in the environment. The Yusho Rice Oil Disease in Japan and similar events were the catalyst which galvanized public opinion against PCBs. The precise origins of this drive to eliminate PCBs from the environment are perhaps difficult to ascertain, but the Yusho incident appears to be the earliest major reference to the hazards of PCBs, relegating them to the classification of "toxic waste".

It is agreed that PCBs are environmental toxins, but the exact cause of PCB toxicity or whether PCBs are carcinogenic are matters of debate. PCBs are referred to as suspect human carcinogens, although no definitive link between PCBs and cancer in humans has been established. In fact, given the body of scientific information, it is entirely possible that PCBs may not be carcinogenic at all.

Several years after the Yusho incident, the more plausible culprits were identified - polychlorinated dibenzofurans and dioxins, possible degradation products of the askarels. These materials were present in the PCB contaminated rice oil at such trace levels that they could not be detected until further analytical capabilities had been developed by Dr. C. Rappe (University of Umea) and others. However, the damage to the future of PCBs had been done. The public perceived that the dangers in the continued, uncontrolled uses of PCBs were simply too great and called for the elimination of PCBs from the environment.

Taking its cue from the public, and with the empowerment from Congress, the U.S. Environmental Protection Agency (EPA), since 1976, has promulgated a set of ever-more restrictive regulations governing the usage of PCBs. While the TSCA ban on PCBs was intended to be all encompassing, an exemption for continued use in transformers was written into the regulations. Even so, EPA continued to further restrict this use of PCBs.

The various EPA regulations address certain specific conditions. Thus, the Food and Feed Rule specifies that those PCB transformers which were in or near food or feed lines had to be removed. The Electric Rule requires the installation of electrical protection for certain transformers. The Fires Rule requires that certain other transformers, most notably those in or near commercial buildings or installations, had to be removed, retrofilled or otherwise brought into compliance by October 1, 1990. The Spill Clean-Up Policy requires clean up of new spills down to a level below that of the background level in most cases.

Other rules ban the landfill of liquid PCBs, as it was apparent that PCBs could readily migrate from the state-of-the-art landfills of the time. To date, however, a ban on the landfill of PCB-contaminated solids has not been addressed. Such a ban would not be inconsistent with EPA's past practices and promulgations nor with Congressional desires. Indeed today, only a small percentage of U.S. landfills are permitted to accept PCB wastes. Further limiting the attractiveness of landfills, the Superfund legislation (CERCLA) provided for cradle-to-grave liability, in which the original PCB owner may be held jointly and severally liable for the entire cleanup of a toxic waste site.

Given the scope of the current regulations, one is drawn to the inescapable conclusion that total elimination and destruction of PCBs is the only wise course of action. Only with such destruction can one be assured that liability (either at a transformer site or in the future at a landfill site) will be eliminated.

EARLY TECHNOLOGY RESPONSES

The first option to eliminate PCBs was transformer retrofit - removing the PCB transformer and replacing it with a new, non-PCB transformer. Whereas the PCB liquid could be incinerated, the transformer carcass could not, usually ending up in a landfill. The removal of the transformer eliminated the liability on-site. The PCBs were gone, and no PCBs would mean no spills or releases to the environment as well as no conversion of PCBs to toxic by-products. However, the ultimate fate of the PCB contained within the transformer carcass was not addressed. Years or even decades later, the PCBs could escape the landfill either through outright breach of security or through diffusion into the underlying aquifer.

With the recognition that landfill is not the most desirable solution, efforts were directed towards identification of alternate possibilities. Removal of the PCBs from the transformer appeared to be the most viable option. This removal and replacement with non-PCB fluid was called retrofill, with reclassification of the transformer to non-PCB status (i.e., less than 50 parts per million of PCB) the desired outcome. Early on, EPA recognized the potential viability of retrofill and specifically allowed this concept in its regulations.

The first notable product to be introduced was "direct silicone retrofill" in which the transformer dielectric coolant (askarel) was changed out completely with silicone, a now preferred dielectric fluid. Any leached PCBs (from the core and coil assembly) were removed via carbon absorption. It was believed initially that non-PCB status could be achieved relatively easily. Unfortunately, significantly longer times than originally anticipated were required to achieve even PCB-Contaminated status (between 50 and 500 parts per million). Non-PCB reclassifications were not economically achievable in an appropriate time frame.

MODERN RETOFILL TECHNOLOGY

In the early 1980's, Union Carbide Corporation began to address the problem of PCBs in electrical equipment. It was apparent that the "direct silicone retrofill" technology was not effective. Silicone is virtually insoluble in askarel and does not diffuse into the askarel phase, while PCBs diffuse only slowly into the silicone phase. The lower molecular weight PCBs diffuse into the silicone preferentially, leaving a layer of high molecular weight PCB species (i.e., with a greater degree of chlorination) at the silicone/askarel interface. This highly viscous barrier further retards the already slow diffusion of PCB into the silicone such that PCB-Contaminated status could be achieved. Unfortunately, the residual PCBs made attainment of non-PCB status difficult.

Recognizing this fact, Union Carbide scientists and engineers developed a two fluid process in which PCBs are first removed from the transformer core and coil and replaced with a temporary dielectric fluid. This fluid satisfied certain specific criteria such as low molecular size, low viscosity, high solubility of PCBs, high mobility and ease of separation from the PCBs. Because the temporary or interim fluid and askarel are mutually miscible, PCBs diffuse out of the askarel phase as rapidly as the interim fluid diffuses in. The result is a rapid dilution and diffusion of the PCB from the transformer internals.

After sufficient diffusion has occurred, the fluid is changed to the final dielectric fluid. In the United States, this fluid is frequently silicone. No final fluid satisfies all selection criteria, and although other suitable final fluids exist, silicone appears to be preferred overall, matching the vast majority of these criteria. Because of interfacial and solubility phenomena, the interim fluids (and their contained PCBs) rapidly diffuse into the silicone phase. Like the case with the askarel/silicone interface, silicone does not diffuse into the interim fluid matrix, but the same type of high viscosity interface is not created. As a result, a high concentration gradient is maintained driving the diffusion. The use of silicone after preleaching with interim fluid results in rapid removal of any final residues of PCBs, providing for reclassification to low PCB levels.

The era of modern retrofill and reclassification technology started with the 1985 commercial U.S. introduction of RECLASS 50^{SM} Transformer Retrofill Service offered by UNISON Transformer Services, Inc. Utilizing the retrofill technology described above, UNISON has reclassified thousands of transformers to non-PCB status. For this service, PCB containing fluids (both interim and final silicone) are sent to a recovery center where the PCBs are first separated from the dielectric fluids and then sent to an incinerator for total destruction. The recovered non-PCB fluids are available for reuse. Thus, reclassification is achieved in an acceptable time frame and at an economically attractive cost (generally 40-60% of retrofit).

Since the introduction of this breakthrough technology, other similar commercial services have been introduced. These technologies differ in that PCBs are separated from the interim dielectric fluid by on-site separation technology, usually distillation, which is run continuously and unattended. The choice of one particular variation of the technology over others is based on individual preference. It is important to note that modern retrofill technology for reclassification of askarel transformers to non-PCB status exists as a viable option for the PCB transformer owner.

COMPLETE TRANSFORMER DESTRUCTION

The PCB liability concerns for most transformer owners are addressed by this modern retrofill and reclassification technology. However, retrofill is not a practical option under certain circumstances, such as at the end of a transformer's useful life, in the case of a failure, or in the event of a change or upgrade in transformer substation requirements. Such situations would require the removal (retrofitting) of a PCB transformer. As discussed above, past approaches to retrofit led to the ultimate landfilling of a transformer carcass containing upwards of 100 pounds of PCB. Note, a spill of only one pound of PCBs must be reported to various regulatory agencies in the United States. The Superfund legislation discussed above provides that the landfilling of askarel transformers (while legal) does not remove the PCB liability, nor does it remove the PCBs from the environment.

For these reasons, no PCB containing article (including transformers) should be landfilled. UNISON's search for technology to provide PCB transformer owners with an alternate to landfill resulted in the introduction of TRANS-END^{SM} Transformer Destruction Service. As the name implies, in TRANS-END^{SM} Service a PCB transformer is decontaminated, disassembled and totally destroyed in an EPA permitted facility. All PCB incinerable materials and liquids are incinerated, while the metals are first decontaminated to < 10 ug/100 cm^2 (consistent with the EPA Spill Clean Up Policy requirements for high contact surfaces) and then are smelted to further remove any contamination potential.

TRANS-END^{SM} Service was designed to minimize customer exposure to PCB liability. Specifically, prior to leaving the transformer site, the unit is drained of its askarel fluid. The fluid is sent from there to an EPA approved incinerator for total destruction. The transformer is shipped to a UNISON facility where any liquid residues are drained and likewise sent for destruction. After an initial cleaning, the core and coil assembly is removed. The cleaning sequence is repeated on the now empty transformer tank. After wipe testing to confirm that residual surface PCBs are removed to < 10 ug/100 cm^2, the tank is sent for smelting. The transformer internals are completely disassembled inside a containment area. The metallic parts - whether aluminum, steel or copper, are separated and placed in uniquely identified containers for secondary cleaning followed by total destruction. The wood, gaskets, paper and other incinerable materials are sent to an EPA approved incinerator for total destruction.

Throughout the transformer destruction process, various controls (part of the EPA permit requirements) serve to assure no PCBs are inadvertently released to the environment. The process was developed to remove any source of contamination, the major problem plaguing prior processes. Surfaces outside the containment area are monitored weekly to ensure no PCB surface concentrations exceed the 10 ug/100 cm^2 limit of the Spill Clean Up Policy. Industrial hygiene monitoring assures that worker exposure to PCBs and any process solvent in the air meet the standards defined in Section 1910.1000 of the Occupational Safety and Health Standard, 29 CFR Part 1910. Such monitoring prevents exposure levels from increasing with time as had been the case with prior attempts to commercialize a transformer destruction service. Finally, periodic employee health monitoring, including blood analyses, make it possible to determine if any employee has been exposed to significant levels of PCBs.

Recently, the U.S. EPA promulgated a set of regulations covering record keeping, reporting and manifesting to ensure the proper records exist to document the ultimate disposition of the PCBs. At the conclusion of any PCB transformer service, whether retrofill and reclassification, retrofit or transformer destruction service, Certificates of Disposal and original, signed manifests (required documentation) along with accompanying PCB tracking documentation are provided.

WORLDWIDE REGULATORY CONSIDERATIONS

The worldwide situation generally differs from that in the United States in terms of regulatory rather than technological factors. While transformer designs differ, the basic structure of a metal core insulated by cellulosics and askarel and contained within a metal tank remains essentially identical. Such transformers can, of course, be retrofitted and disassembled for transformer destruction to avoid landfill of significant quantities of PCBs. A demonstration program of modern retrofill technology, utilizing interim dielectric fluid followed by silicone, has been conducted successfully in European transformers. A brief synopsis of some international situations follows.

CANADA

At the present time, only Alberta has full destruction capability. A new facility capable of destroying PCBs is nearing completion in northern Ontario, with another planned for the southern portion of the province. However, Canadian provincial law prohibits the transport of PCBs across the boundaries, so that PCBs from, for example, Quebec cannot be shipped to Alberta for destruction. As the movement of PCBs across Canada is basically frozen, the PCB transformer owner must choose between maintaining the transformer in operation or removing and storing the PCBs at the transformer site. Such long-term storage poses the threat of severe environmental contamination via leaking drums, etc. With destruction capability available, the Canadian legislature must weigh the risks between transportation/destruction of the PCBs and their continued, long-term storage. Providing for the transport of the PCBs coupled with the available destruction capability would open up the full range of PCB transformer services described above.

GERMANY

Current German law prohibits the retrofilling of PCB transformers containing greater than 2,000 ppm of PCB. This law was intended to limit the generation and disposal requirements of large quantities of PCB containing waste. Older retro-

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fill technologies would have generated significant quantities of PCB containing waste. Modern retrofill technology, however, limits the quantity of waste for destruction to essentially pure PCB by separating and recycling the interim dielectric fluids. Barring a change in this law, the retrofill option for transformers containing greater than 2,000 ppm of PCBs does not currently exist in Germany. Currently for PCB transformers, only the retrofit option followed by transformer carcass disposal in a salt dome is permitted. Salt domes may be superior to traditional landfilling, but the solution is only a temporary one.

FRANCE

Of the European countries, the current circumstances in France are perhaps the most favorable for the full range of PCB remediation technologies. Adequate incineration capacity exists such that France is willing to accept PCBs from other countires for destruction. This is an enlightened position, as the PCB burden from another country which may not have destruction capability could clearly affect the environment of countries such as France which do have such capabilities. France also has the capability to incinerate the entire transformer to eliminate PCBs. However, recycle of the metal content is not routine.

UNITED KINGDOM

The U.K. is similar to France in that sufficient incineration capacity exists such that it is willing to accept PCBs from other countries.

BELGIUM

Adequate incineration capability exists within Belgium, although importation of PCBs for destruction is not allowed. No other regulations are currently known which would prohibit the full range of PCB transformer remediation services.

The situation in most other European countries is characterized by the near total lack of destruction capability

With the advent of the 1992 European Community, a coordinated, multinational effort to eliminate PCBs from the environment utilizing modern technology is possible. With the full range of services offered, the PCB transformer owner would be better able to make the correct, site-specific decision for eliminating the PCB threat to the environment and its corresponding liability.