A Non-Sodium Process for Chemically Decontaminating Mineral Oil Dielectric Fluid

C. L. Coccio
Mgr. - Power Delivery Programs
GE Power Delivery Services
1 River Road, Bldg. 2-525
Schenectady, NY 12345

M. J. Maltoni
GE Power Delivery Services
1 River Road, Bldg. 2-525
Schenectady, NY 12345

ABSTRACT

As early as 1979, scientists at GE's Corporate Research and Development Center, Schenectady, NY recognized that PCB contaminated mineral oil transformer dielectric fluid could be chemically treated to reduce PCB content to non-detectable levels. This led us to develop and patent a chemical decontamination process in 1981 using metallic sodium. Because of the potential difficulties in handling sodium (sodium and water produce hydrogen which can be explosive), we embarked on a research program aimed at identifying a safe, economic means of reacting PCB in transformer oil that would reduce PCB levels to below the U.S. Environmental Protection Agency (EPA) 2 part per million (ppm) upper limit for chemical destruction. To be successful, this process would be safe, efficient, and economical and would not require the use of sodium.

CHEMICAL DESTRUCTION OF PCBs IN MINERAL OIL

EPA disposal regulations require destruction of PCB dielectric fluids, by thermal or "alternative" destruction methods. Although a number of "alternative destruction methods" have been tested, this category principally includes PCB chemical destruction systems.

Most of the currently permitted sodium chemical destruction systems can decontaminate fluid containing PCBs up to 5,000-10,000 ppm. However, because chemical costs increase with the PCB level treated, sodium based chemical systems are usually economic up to about 3,000-5,000 ppm. Beyond that level, incineration becomes more economical when transportation costs are equal. Besides being economical for the low contamination levels, chemical decontamination systems can be trailer mounted. Additionally, these systems produce a non-PCB fuel oil with a high BTU content, or after reprocessing the oil can be reused in transformers.

Because of the above advantages, many owners are now selecting chemical destruction as the preferred method of destroying PCB in mineral oil.

THE NON-SODIUM PROCESS

We found that PCBs in transformer oil react with polyethylene glycol (PEG) and potassium hydroxide (KOH) under relatively mild operating conditions [1,2]. Destruction of PCBs occurs by mixing heated transformer oil with small amounts of PEG and KOH in a stirred vessel. Both PEG and KOH are non-proprietary chemical substances commonly used in industry and do not pose any unusual risks. Complete reaction of PCB occurs quickly producing decontaminated transformer oil and a non-PCB byproduct. The small quantity of byproducts produced are insoluble in transformer oil and are easily removed from the decontaminated oil by decanting.

While sodium based processes destroy PCBs by sequentially stripping away chlorine atoms from the biphenyl molecule over time, the non-sodium process destroys PCBs as a result of a simple chemical substitution of a glycol atom (from the PEG) for a chlorine atom in the biphenyl system. While multiple substitutions of chlorine atoms may occur, with the non-sodium process only a single substitution is needed to render the PCB product molecule insoluble in the transformer oil. This non-PCB product can be easily removed from the oil by simple decanting.

Dioxins are also reacted in the non-sodium process and can be removed from contaminated mineral oil along with PCBs.

Because of the simplicity of the process, PCB destruction is fast, efficient and highly predictable. Because the oil and chemicals are easy to handle, a trailer-mounted PCB decontamination unit can be built using conventional and proven process equipment. Because metallic sodium is not used, there is no possibility of explosive hydrogen production.

Unlike the sodium based processes, the non-sodium process is not particularly sensitive to water. Additionally, it is not necessary to precisely measure the amount of PEG and KOH added to the oil.

LAB EXPERIMENTS AND EVALUATION

Commercial development of the non-sodium process began in 1981 with a series of laboratory bench scale experiments using a variety of process conditions and reagents.

Following the extensive experiments which proved the effectiveness of the decontamination chemistry (PCBs were destroyed to less than 2 ppm per EPA's requirements), an engineering analysis was conducted to establish the feasibility of commercializing the process; to evaluate the effects of using different process parameters; and to obtain scaleup and design data.

The following parameters were found to be critical:

- Reaction Temperature
- Reaction Time
- Mixing Rate
- Amount/Type of Reagents

As a result of this laboratory evaluation. We concluded that a safe, economic, simple and efficient method of destroying PCBs in mineral oil had been achieved without using sodium. PCBs were destroyed quickly in a simple reaction under mild operating conditions. The non-PCB reaction products were easily separated from oil.

PRODUCTION OF A TRAILER-MOUNTED PCB DECONTAMINATION UNIT

Based on the success of the laboratory experiments, We commenced process design and engineering of a PCB decontamination system using the advanced chemistry.

Prior to beginning design of a full scale commercial unit, we established strict design criteria that would ensure proper operation and safety of the unit consisting of:

- Maximized Safety Features
- Fail-safe Design
- Computer Controls
- Maximized Daily Throughput
- On-line Data Acquisition System
- Proper Materials of Construction
- Use of Conventional Equipment
- Ease of Operation

Using the basic process configuration proven in the lab, we have designed [3] and built a trailer-mounted PCB decontamination unit with three vessels operating in a batch type process. Batch processing was selected over continuous because of its operating simplicity, higher reliability and fail-safe features. The simplicity of the chemistry enabled us to select commercially available components and to provide for automated operation using a programmable logic controller (PLC). The PLC automatically controls the chemical process from the control room and provides the operator with continuous on-line process information and periodic status reports for critical process parameters.

PCB contaminated oil from storage is pumped through a filter to the effluent heat exchanger where the incoming oil is partially heated by exchanging heat from the previous batch of decontaminated oil. In the electric heater, the oil reaches the reaction temperature before entering one of the three reactors.

KOH added to the feed hopper is fed in the required amount to the reactor via the KOH feeder. PEG from the feed tank is metered and pumped to the reactor where the oil, PEG and KOH are mixed for the required reaction period. The reactor is blanketed with nitrogen during the reaction to prevent oxidative degradation of the oil. Any excess nitrogen and vapors are passed through an activated carbon bed where hydrocarbons are absorbed.

The reactor contents are pumped out through the heat exchanger, thereby heating the next incoming batch of oil. From the heat exchanger, the decontaminated oil and reaction products are pumped to a decanting tanker where the oil and reaction products are easily separated.

The entire sequence of filling, reacting and draining of the three reactor loops is accomplished automatically by the PLC which also provides the operator with process and equipment status, reports, and any alarm conditions.

All equipment and components are mounted in a specially designed 48 foot long air ride trailer which includes separate process and control room areas.

Design of the equipment and trailer includes many safety features, such as an integral spill pan, air ride suspension, halon fire protection system, trouble alarm system, automatic system shutdowns, emergency exits, safety shower, eye wash and air emissions control system.

SITING AND OPERATING CONSIDERATIONS

The decontamination unit is designed to be operated in multiple shifts either at a fixed location or in a mobile environment.

Operation requires two operators, one of whom is skilled in PCB product analysis. Prior to and following decontamination, the oil and products are tested for PCB content. These tests are performed using an electron capture gas chromatograph.

SUMMARY

We have developed and proven, through extensive laboratory experiments, that the non-sodium process is a safe, economic and reliable method of chemically decontaminating mineral oil containing PCBs. PCB levels are reduced to less than 2 ppm, thereby meeting EPA's destruction requirements. The process offers a number of significant advantages over sodium-based process including:

- No Chance of Hydrogen Production
- Insensitivity to Water in the Oil
- Precise Amount of Reagents Not Critical
- Fast Turnaround

Laboratory and scaleup tests have shown that the process can effectively decontaminate transformer mineral oil containing up to 10,000 ppm PCB and 50 - 80 ppb Dioxin.

The simplicity of the process supports the use of conventional chemical processing equipment in a trailer-mounted unit with a large volume of PCB destruction capacity.

References:

(1) Burnelle, D.J.; Mendiratta, A.K.; Singleton, D.A. "Reaction/Removal of Polychlorinated Biphenyls from transformer Oil: Treatment of contaminated Oil with poly(ethylene glycol)/KOH", *Environmental Science & Technology*, Vol. 19, Aug. 1985.

(2) Burnelle, D.J.; US Patents 4351718, 4353793, 4410422; 1982

(3) Mendiratta et all, US Patent 4781826, 1988