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POB SUBSTITUTES - NEW DEVELOPMENTS IN MATERIALS AND APPLICATIONS

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BACKGROUND

Polychlorinated biphenyls were developed in 1929. Their excellent dielectric properties, including high dielectric strength, low water solubility, low flammability, high heat capacity, and stability were recognized almost immediately as having the potential to provide low fire risk indoor type transformers with the inherent advantages of liquid cooled efficiency and reliability. General Electric Company patented the electrical application of these fluids, and they were subsequently marketed as transformer askarels under such tradenames as Pyranol (General Electric), Inerteen (Westinghouse), Chlorextol (Allis Chalmers), etc.

The use of these fluids in transformers, and their excellent service record, led to their acceptance for indoor use without additional fire protection by major insurance underwriting firms, and to their inclusion in the National Electrical Code, provided that either gas absorption devices or external venting were used.

Polychlorinated biphenyls also found wide usage in capacitors because of their relatively high dielectric constant, although fire risk was not considered to be a major consideration in their selection as capacitor fluids.

In the late 1960s, it became apparent that PCBs had entered and contaminated the environment (primarily from non-electrical applications). Investigation into the long range effect of this contamination demonstrated that, although the acute toxicity of PCBs was low, its resistance to biodegradation and its tendency to bioaccumulate could create situations where levels of concentration would be harmful to man and his environment.

Manufacturers instituted voluntary restrictions on the sale and use of PCBs except in closed electrical equipment. Federal and State agencies took steps to minimize or eliminate the addition of PCBs into the environment.

The Toxic Substances Control Act (Public Law 94-469) specifically singled out polychlorinated biphenyls and effectively eliminated their future use while establishing a requirement for the promulgation of rules relative to the disposal of the material and its operation in totally enclosed systems. The act also provided for the development of programs to examine new chemicals for their toxicological and environmental effects which will hopefully prevent a "PCB problem" from happening again.

The Environmental Protection Agency estimates that there are presently approximately 140,000 transformers in service containing about 25 million gallons of PCBs and approximately 900 million capacitors in service (includes small appliances and fluorescent light ballasts) containing about 50 million gallons of PCBs.

SUBSTITUTE PRODUCT DEVELOPMENT

With the ultimate demise of PCB materials apparent, manufacturers of equipment utilizing PCBs and users of this equipment began pressing for the discovery and development of adequate replacement materials. It was obvious that a replacement fluid must avoid the type of problem which occurred with the PCBs. Basic development criteria included the following desirable characteristics.⁽¹⁾

1. It should be nontoxic or very low in toxicity.
2. It should be biodegradable.
3. It should be nonbioaccumulating.
4. It should exhibit low flammability characteristics.
5. It should have good heat transfer capabilities.
6. It should possess good dielectric properties.
7. It should have a long life and be compatible with the other materials of construction.
8. It should be readily available and reasonable in price.

The techniques for studying such factors as toxicity, environmental impact, heat transfer, dielectric properties and compatibility were well known. Techniques for assessing risks relative to life and property were not established. The acceptance of askarels had simply grown into existence by virtue of their excellent service record, and they had never been "listed" or "approved" by any nationally recognized laboratory.

In 1974, RTE Corporation conducted a series of tests designed to simulate the catastrophic explosion of a transformer. Tests were conducted on conventional transformer oil, transformer askarel, transformer silicone oil, and RTEmp fluid. The results of these tests have been reported elsewhere.⁽²⁾ At the same time, work was proceeding which culminated in revision of the National Electrical Code in May of 1977 and the addition of a new definition and code section for "high fire-point liquid insulated transformers". Factory Mutual Research Corporation did additional developmental work on test procedures in the fall of 1976 and between March and October of 1977, accepted for indoor use RTEmp fluid as manufactured by RTE Corporation, as well as the silicone products of Dow Corning, General Electric, Union Carbide, and SMS, and synthetic hydrocarbon materials manufactured by Uniroyal and Gulf Chemical Corporation. Research work is continuing at Factory Mutual in an attempt to develop rational "approval" standards.

LEGAL STATUS

Article 450-23 of the National Electrical Code has been revised and reads as follows:

"Transformers insulated with a non-propagating liquid approved for the purpose, having a fire point not less than 300°C, shall be permitted to be installed indoors or outdoors. Such transformers installed indoors and rated over 35,000 volts shall be installed in a vault. For the purpose of this article, a non-propagating liquid shall be one which, when subjected to a source of ignition, may burn but the flame will not spread from the source of ignition."

All of the materials accepted by Factory Mutual meet the requirements of this section of the code. The code section was written in such a way that it would not preclude the development of other economical solutions to the problem.

OSHA has issued Program Directive #100-68 which reads essentially the same as the 1978 National Electrical Code Article 450-23. The only difference is in OSHA's definition of the word "approved". In order to be approved by OSHA the material must be accepted by a nationally recognized testing laboratory. The materials which have been accepted by Factory Mutual therefore meet the OSHA requirements.

The Toxic Substances Control Act, and the Office of Toxic Substances, have phased out all manufacture of PCB containing devices. They are not legally in a position to "approve" any replacement materials, but conversations with the EPA have indicated that, although silicone oils are not biodegradable, there appears to be no adverse toxicological or environmental affect from their use in transformers. Since RTBp fluid is less toxic and more biodegradable than conventional transformer oils, there is virtually no concern about this type of material as a class.

To the best of our knowledge, insurance companies are writing insurance on installations of transformers insulated with both the silicone and hydrocarbon replacement materials with no increase in premium. Some insurance companies may choose to require some type of liquid containment as well as current limiting fuses on the primary side of the transformers, but these are insurance underwriting requirements and not legal requirements.

APPLICATIONS

Transformer askarels have historically been used in areas where safety, fire risk, or external environmental conditions precluded the use of conventional mineral oil-filled transformers. They have also been used historically in areas where maintenance was very difficult because they were felt to provide a lower maintenance situation (little or no sludging) as compared to conventional mineral oil-filled transformers. With the development of PCB substitute materials, a number of additional applications appear to be practical. A discussion of some of these follows.

1. Indoor Transformer Applications. Both the silicones and the hydrocarbons appear to be very satisfactory replacements for transformers either located indoors or immediately adjacent to buildings where substantial fire risk is involved. Transformers using these materials have been

in service for some time, and experience to date indicates that properly designed transformers can be used in unit substation applications and free-standing transformer applications without additional fire protection. Some manufacturers are recommending external venting on silicone transformers because of the potential for the accumulation of hydrogen gas.⁽³⁾

2. Higher Voltage Applications. Transformer askarels have been primarily limited to a high voltage of 35 kV because of some of the characteristics of other insulating materials impregnated with the askarels. Since RTEmp fluid performs as well or better than conventional transformer oil as a dielectric medium, we see no reason why it cannot be used at any voltage which is applicable to oil-filled transformers. There are some indications that the silicones can also be used at higher voltages. Of course, additional work must be done in this area before these fluids become universally applicable to the high voltage arena.
3. High Temperature Operation. There are indications that the replacement fluids add to the thermal stability of the cellulose materials used as insulation in transformers. Testing is going on at this time which may ultimately lead to the use of higher operating temperatures for transformers impregnated and cooled with the new PCB replacement materials.
4. Switching Applications. One of the deficiencies of askarels was poor performance as load break switching fluids. RTEmp fluid has substantially better arc suppression characteristics than conventional transformer oil, has superior lubricity and better fundamental dielectric characteristics. Preliminary testing in load break switching devices and in liquid poor circuit breakers indicates that its performance is somewhat better than conventional mineral oil with the added advantage of a much higher degree of fire safety. Switching devices specifically designed to utilize the unique characteristics of RTEmp fluid may provide further economies and operating advantages. The silicone oils appear to be better than the askarels in this regard but their lack of arc suppression capability and lubricity may tend to limit their use in this type of application.
5. Retrofilling Of Askarel Transformers. Primarily for environmental reasons, a substantial number of askarel transformers have been retrofilled with other materials. Among these are RTEmp fluid, conventional transformer oil and silicone oils. The immiscibility of silicone fluids with askarels, their lack of lubricity, and their higher cost, are problems which must be considered in a retrofill situation.⁽⁴⁾ However, as stated above, a substantial number of transformers have been successfully retrofilled with silicone and are operating properly today.⁽⁵⁾ Conventional transformer mineral oil does not have the immiscibility or lubricity problems of the silicone fluid, but transformers retrofilled with conventional transformer oil must have additional fire protection if they are in an indoor location or immediately adjacent to building openings. RTEmp fluid has the miscibility and lubricity advantages of conventional transformer oil. It is priced substantially above conventional oil, the price being approximately half way between conventional oil and silicone. When used in transformers not specifically designed for their characteristics, both RTEmp and silicone fluids are slightly less effective as coolants. However, as indicated

in paragraph 3 above, this may be more than compensated for by their high-temperature stability.⁽⁶⁾

6. Retrofitting of Conventional Oil-Filled Transformers. In past years, conventional oil-filled transformers in specific locations suffered changes in their risk environment due to plant expansion, etc. These transformers were sometimes retrofilled with askarel. While this situation still occurs, the traditional askarel solution is no longer available and the transformers must either be relocated, contained in fireproof vaults, or retrofilled with a high-fire-point liquid. Being a hydrocarbon material, RTEmp fluid is uniquely suited to this application. The only concern is that the residual mineral oil content be low enough to not adversely affect the fire point of the RTEmp fluid. Generally, a residual oil level of less than 2% is satisfactory and techniques are available to reach a satisfactory level.⁽⁶⁾
7. Makeup Fluid for Askarel Transformers. Many owners of askarel transformers wish to maintain them in their present condition for as long as possible. However, it is occasionally necessary to "top off" askarel transformers with some liquid in order to bring the liquid level up to the proper point.

Since the chlorobenzenes have been used in varying percentages over the years as fillers in the manufacture of transformer askarels, they can generally be added in reasonably small quantities without any particular problem. However, they are under suspicion of being carcinogens and the benzenes may not continue to be available. RTEmp fluid is fully miscible with transformer askarel; in any combination with askarel the fire point never falls below the fire point of the RTEmp fluid, and the dielectric characteristics will not fall below those of the askarel. Therefore, it makes an excellent topping off fluid which may be easily handled without the potential environmental or toxicological problems of tri or tetrachlorobenzene.⁽⁷⁾

SUMMARY

The Governmental actions which have resulted in the elimination of askarel from the manufacture of new equipment and which have placed severe restrictions on the use of askarels in material already in service may yet prove to be a blessing to the electrical industry. Certainly the continued introduction of polychlorinated biphenyls into the environment could not be tolerated. As testing continues with the replacement materials, new applications continue to arise which broaden the scope of these materials well beyond that which was permissible or practical with askarel.

BIBLIOGRAPHY

- (1) "PCB Substitutes and Their Properties For Use in Electrical Equipment", John Olmsted, Margaret Piotrowski, paper presented at American Public Power Association, March, 1977.
- (2) "Proposed Substitute Fluids For Transformer Askarels", D. A. Duckett, paper presented at the Southeastern Electrical Exchange, 4-27-76.
- (3) "Installation and Maintenance of Silicone Fluid Transformers", page 10, Westinghouse Electric Corporation.
- (4) "Problems Associated with the Retrofilling of Askarel Transformers", L. A. Morgan, R. C. Osthoff, paper presented at Power Engineering Society, 1977, Winter Meeting.
- (5) "Silicone Retrofill of Askarel Transformers", T. O'Neil, J. J. Kelly, paper presented at Electrical Insulation Conference, September 28, 1977, Chicago, Illinois.
- (6) "Comments and Recommendations on Retrofilling of Transformers", J. Olmsted, RTE Corporation Research Publication, 10/31/77.
- (7) "Comments and Recommendations on Makeup Fluid for Askarel Transformers", J. Olmsted, RTE Corporation Research Publication, 11/15/77.