polydimethyl siloxane liquid under test for this purpose. The Japanese National Railway System has used it for almost five years and ongoing field evaluation is under way in France, Scandinavia, and Great Britain.

Dow has assured the electrical industry that it will have the manufacturing capability to produce XFS-4169L at a 1-million-lb/yr rate during the first quarter of 1976. Should the fluid prove acceptable to the industry, Dow is willing to make a commitment to produce it in multimillion-lb/yr quantities by the end of 1976. ■

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Manufacturers

Substitute found for PCBs in capacitors

Polychlorinated biphenyls (PCBs) have been much in the news of late. Though widely used in electrical apparatus because of their nonflammability and low dielectric loss, PCBs have been under severe attack by environmentalists because of their extreme persistence and toxicity when they enter the food chain. As a partial answer to this problem, McGraw-Edison Co's Power Systems Div and Dow Chemical Co have announced jointly that an environmentally and electrically acceptable substitute for PCB in high-voltage power capacitors has been developed, and that McGraw-Edison will begin using it in commercial quantities by mid-1976. The new fluid—designated Dow XFS-4169L—has an alkylated chlorodiphenyl oxide (DPO) base, and will add less than $20 to the cost of a 200-kvar capacitor.

Herbert M. Appleton, president of McGraw-Edison's Electrical Systems & Service Group, says that, after examining results of tests performed at Dow's laboratories as well as evaluating experiences with its own equipment in hundreds of test samples over a three-year period, McGraw-Edison determined that the new fluid offers the same electrical performance as PCBs, or perhaps even better.

About 25% of all PCBs manufactured today are used in high-voltage power capacitors, so acceptance of the new fluid for this application alone would result in a significant cutback of PCB production and a corresponding reduction in hazard to the environment.

The three years of electrical testing by McGraw-Edison involved hundreds of samples and more than 18-million kvar-hr of service for full-sized units, as well as extensive testing of miniature units. The capacitors impregnated with the DPO-based dielectric demonstrated superior corona behavior and greater reliability than similar PCB-impregnated units. The units were subjected to accelerated life tests, with voltage stress and temperature ranges greatly in excess of those experienced under normal operating conditions.

Corona tests showed discharge inception voltage over the normal operating range to be 20-25% higher than for capacitors impregnated with PCB, and discharge extinction voltages were equivalent to those of PCB systems.

Dielectric loss as a function of temperature and stress also is equivalent in the two systems. The losses are as low as they are in PCB systems, from room temperature to about 90C.

The new dielectric fluid introduced by McGraw-Edison and Dow is technically a flammable liquid, using a standard flammability test. However, a comparison of flash and fire points shows that the new fluid has substantial advantages over mineral oil (see table).

Unlike distribution transformers in which the flash and fire points are often approached, capacitors are hermetically sealed, and the dielectric fluid normally

Flammability of insulants

	Flash deg, C	Fire deg, C
Mineral oil	154	167
PCB	166	316
XFS-4169L	174	199

attains maximum temperatures that are well below both the flash and fire points. Therefore, substantial energy is required from an arc to produce a fire.

The National Electrical Code allows installation of electrical devices in or on buildings without a vault if they contain less than 3 gal of a flammable liquid. The commonest-sized power capacitor—a 200-kvar unit—contains less than 3 gal of fluid—and is usually installed out-of-doors. Therefore, the flammability classification does not pose a serious drawback to use of the fluid in capacitors.

As a flammable liquid, the DPO-based dielectric offers at least one major advantage over the PCB it replaces. PCBs require incineration at temperatures in excess of 2,000F and under highly controlled conditions for environmentally acceptable disposal (EW, Sept 15, 1970, p 76). The new insulating fluid requires no special incineration, and no toxic residue is expelled or deposited in the stack.

The problem of disposal of PCB was called to the world's attention in 1966 when its residues were detected during studies of the retention of DDT in animal tissues. Pressure against use of PCBs built up so rapidly that, in 1971, Monsanto Industrial Chemicals Co, principal producer of the chemical in the US, announced that it would, thereafter, restrict sales to use in so-called "closed-cycle" systems, such as capacitors and transformers.

The US Food & Drug Administration allows up to 5 ppm of PCBs in fish, but the US Fish & Wildlife Service considers anything over 0.5 ppm in a fish egg as unacceptable. Despite current tight control of PCBs in aquatic life, readings of these values have been found in fish in extensive sections of waterways throughout the country.

The low toxicity of DPO has been demonstrated in a test on fathead minnows. Comparatively, the DPO-based fluid proved to be 20 times less toxic to fish after 96 hr than were PCBs. A concentration of only 0.7 mg/liter of a capacitor-grade PCB was lethal to 50% of the minnows, compared to 15.4 mg/liter of the DPO-based fluid. Further tests in the same series indicated an even greater difference in toxicity for longer exposures.

In tests for toxicity to mammals, the highest practical dosage of the DPO-based fluid did not kill rats. During a 90-day dietary feeding study, no significant differences resulted in control rats and rats fed up to 15 mg/kg/day. In a 110-lb person, this dose would be equivalent to 750 mg/day or 1,500 ppm if consumed in a daily portion of meat or fish.

Relative biodegradability of chemicals in the DPO-based fluid and in capacitor-grade PCB also shows a marked difference, according to the developers of the new fluid. Generally, DPO-based fluid chemicals biodegrade significantly faster than the chemicals in capacitor-grade PCB, at a rate comparable to many nonpersistent industrial chemicals.

Chlorodiphenyl oxide, the most-water-soluble component in the new dielectric fluid, biodegrades fast enough to be classified as "biotreatable" in wastewater-treatment plants, although the developers caution against using this kind of disposal as a recommended practice. Disposal of the DPO-based fluid should be performed as with any other low-hazard chemical.

The new fluid is intended for use in capacitors, and is not directly applicable to transformers. Dow, however, has a

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