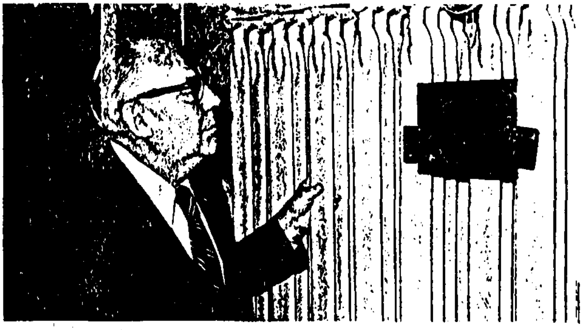
Askarel coolant, being fire-resistant, permits indoor installation of liquid-filled transformers and capacitors. Future of this polychlorinated biphenyl (PCB) is being questioned. The probable alternatives are outlined here by author W.C. Bloomquist, consultant with a rich background in industrial-power-system design and equipment application



Plant electric systems

What is the future for askarel?

After serving for years as a successful fire-resistant transformer and capacitor coolant and insulator, askarel has been labeled toxic. The designation goes back some years, but is getting a fresh appraisal by government, equipment manufacturers, fluid suppliers, and engineers responsible for transformer and capacitor selection. Here's where we stand today—along with meager data on possible alternative liquids and dry-type designs

By W C Bloomquist, PE, President, Industrial Power Systems Engineering Co

The term askarel describes a class of fire-resistant synthetic insulating liquids which industry and the lay press more accurately call PCBs– polychlorinated biphenyls. The prime reason for its use over the years is high fire resistance: The auto-ignition point of askarel is 1240F, while that of mineral oil is 680F. The sole manufacturer of PCBs in the US is Monsanto Chemical Co, which markets its product under the trade name *Aroclor*. When mixed with chlorobenzenes, the PCB fluid is labeled *Pyranol* by General Electric and *Inerteen* by Westinghouse.

Proven values. Askarel is among the best liquid man-made insulations. It is fire-resistant and chemically stable, and has high dielectric strength. Because of these plus characteristics, askarel has found many industrial and consumer-product applications since it was introduced over 45 years ago. Askarel use in the US today totals about 40-million lb annually, with about ⅗ of this being used in capacitors, ⅕ in transformers. Power capacitors use about 14% of the capacitor-use total, with most of the remainder spread among fluorescent-lighting ballasts, single-phase-motor capacitors, and TV and other electronic devices.

Fire resistance is the principal reason insurance companies and the National Electrical Code permit use of askarel-filled equipment indoors without further enclosure. Askarel-filled interrupter switches were used for years throughout industry; however, most have now been superseded by the air-type.

Ecology and health. Although askarel has been in use for close to a half-century, it is only in recent years that EPA has placed PCBs on its Toxic Pollutant List. Since askarels are chemically stable, they are not biodegradeable—a major environmental concern. PCBs are found widely dispersed on land and in our waterways. They were first clearly identified as a food contaminant in the mid-1960s, when they were found in fresh-water fish. Here the source ranged from polychlorinated biphenyls used in carbonless paper to food-packaging materials, where PCBs had migrated into the food product. It is unfortunate that suitable detection equipment was unavailable until recent years. It was a Dr Jensen of Sweden who, in 1966, referred to PCB as a "new pollutant."

Ecologists use a three-pronged approach in classifying PCB applications: *open, nominally closed,* and *closed*. The open classification spans the manufacturing of paints, plastics, and some adhesives; nominally closed refers to systems that include hydraulic, heat-transfer, and lubricating fluids. Both of these classifications are generally free of PCBs today, through voluntary banning. Closed applications—sealed transformers and capacitors- now account for our total domestic askarel consumption.

About five years ago, poultry and eggs in Minnesota and North Carolina were found to have large concentrations of PCB, and were destroyed. The PCB source was traced to a nominally closed system- a leaking heat exchanger in a fish-meal processor's plant. The fish meal, in turn, found its way into a commercial poultry-food product.

A federal task force was established in 1971 to coordinate governmental efforts aimed at understanding the family of PCB chemical compounds. Its report, now somewhat dated[1], reflects the posture of various governmental agencies at that time. On the basis of available information, the task force issued a nine-point report: four of the points are summarized here:

- PCBs should be restricted to essential or nonreplaceable uses that involve minimal direct human exposure, since they can have adverse health effects. Currently [1971] there are no toxicological or ecological data available to indicate that the levels of PCBs known to be in the environment constitute a threat to health. Additional tests are under way to evaluate the impact of long-term, low-level exposure to PCBs.
- Housekeeping is particularly important in the manufacture, use, and disposal of PCBs.

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Table 1: Flammability properties

	Silicone oil[1]	Transformer Askarel[2]	Mineral oil
Flash point, deg C	300	None	145
Fire point, deg C	310-370	None	160

[1]Varies with molecular weight. [2]Capacitor askarels do have flash points.

Flash point is the lowest temperature at which a liquid gives off sufficient vapor to form an ignitable mixture under standard conditions. Fire point is the lowest temperature at which an oil vaporizes rapidly enough to sustain burning after ignition. See ASTM Standards for details and test methods.

Table 2: Comparison of transformer types (1000 kVA range)

	Oil	Askarel	Dry types: Open	Dry types: Sealed gas C_2F_6
Relative price	1.0	1.25	1.25	2.0
Weight (lb) 5/15 kV [illegible]	5400	6300	4000/5400*	8300/9000
Fan cooled capability (NEMA)				
750-2000 kVA	+15%	+15%	+33⅓%	None
2500 kVA	+25%	+25%	+33⅓%	None
Basic Insulation Level (kV)	60/95	60/95	25/60	60/95
Sound level dB (NEMA)				
Without fans running	58	58	64	64
With fans running	67	67	67	not used

*[illegible] kVA ratings the open dry-type weighs more than liquid types

- PCB use should not be banned entirely. Continued use in transformers and capacitors, at least in the near future, is necessary because of the increased risk of fire and explosion—and the resulting disruption of electrical service—that might possibly result from an outright ban. Also, continued use of PCBs in transformers and capacitors presents a minimal environmental risk.
- More information is needed. The total exposure of a human to a given substance from all sources—air, water, and food—must be considered, and interactions of PCBs and other substances, within and outside the body, must be evaluated.

The report went on to state that the then-current body of knowledge gained from animal experiments was inadequate to allow reliable extrapolation to possible effects on man. Also, it said, the basis for interpreting such tests had to be improved.

Net results of this 1971 report was an uneasiness throughout industry about many of FDA's proposed rules. Some felt they were not practical or fell short on ecological fact. Example: Maximum recommended concentration of PCBs in fresh water is a meaningful number, yet the proposal was not supported by sound ecological data.

An EPA meeting held last fall brought together the latest data and experience to help clarify problems associated with PCBs. In one sense, the three-day conference served to update the 1971 task-force report. During the three-day gathering, there were reviews of laboratory and field studies, and reports on monitoring programs, human exposure and health effects, and impact on ecology. Also, there was an assessment of steps being taken to reduce problems associated with PCBs. Of direct interest were those reports on substitutes for askarel[2], which are highlighted here.

When questions about the effect of PCBs on the environment first surfaced, Monsanto Co.—the sole US manufacturer of PCBs—reviewed its product line and PCB applications. It stopped sale of PCBs for applications in the first two categories—*open* and *nominally closed*; this step cut PCB output by 50%. Today, PCBs manufactured by Monsanto and sold only to the electrical industry for use in closed systems as a dielectric and coolant in transformers and capacitors. While recognizing that there is some loss of the askarel fluid in service, remember that there is no fully acceptable substitute to date.

In recent years, evidence of PCBs have been found in fish in the upper Mississippi River, the Hudson River, the Great Lakes, and along the southern California coast. According to Russell E. Train, head of EPA, 300-million lb of PCBs are currently in use, and another 300-million in the air, soil, and water.

The picture today differs drastically from that of four years ago. Through elimination of the open and nominally closed applications, use of the PCBs has been halved. The impact on our waterways can be materially reduced through an educational program directed to users of PCBs, stressing proper handling and disposal. Housekeeping is of key importance in the manufacture, use, and disposal of PCBs. For current guidelines to handling and disposal, study references, 3, 4, and 5 listed at the end of this article.

What are the alternatives? Many are working on the problem of finding fluids having the attractive characteristics of askarel yet without its environmental and health drawbacks. Much work has already been done. In 1971, Monsanto introduced *Aroclor 1016* for capacitors, and it has found growing use. This fluid retains the high dielectric properties of traditional askarel, is fire-resistant and partially degradeable. Time may prove it to be sufficiently degradeable to remain in controlled use.

Others have announced potentially acceptable replacements for askarel in capacitors, even though they are not fully fire-resistant. Three are in the market development stage: General Electric's liquid for small capacitors is labeled *Econol*; Dow Chemical has an alkylated chlorodiphenyl oxide fluid—XFS-4169L; Monsanto has a fluid identified as *MCS-1238*.

Another liquid, potentially useful in transformers, is dimethyl siloxane, a silicone oil. This is made today by at least four US manufacturers, with Dow Corning and General Electric the two major suppliers. Bear in mind, however, that the silicone fluid has an auto-ignition point of 750F, only about 80 degrees above that of mineral oil.

Silicone liquids have many of the desirable electrical characteristics of askarel and are not toxic. The fine electrical properties of silicone fluids stem from their unique chemical structure[6,7]. As with all likely fluids, the electrical characteristics will be reduced by gross contamination or water.

Silicones are available with a range of viscosities and for many applications. Fluid suppliers have set 50 centistokes as a suitable viscosity for transformers. Transformer askarel has no flash point, while a 50-cs silicone fluid tests out at 300C. The silicone fluids have low toxicity and are classified as "physiologically inert." They have been cleared by the FDA, and are currently being used in a variety of medical and chemical applications. The fluids are not biodegradeable, but are nontoxic.

With the exception of silicone rubber, sometimes used for gasketing, the silicone liquids are compatible with materials found today in askarel-cooled transformers. Since the silicone fluids will ignite at 750F, they are not classed as fire-resistant; above that temperature they will burn. If the heat source is removed or fluid temperature drops below 750F, burning will cease. Thus, the fluid is self-extinguishing.

Underwriters Lab (UL) does not approve or reject liquids intended for electrical test equipment, nor will they test or list any liquid-filled electrical equipment. They do, however, provide a

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classification service of flammability ratings. Following is a typical comparison:

Fluid	Flammability Rating
Ether	100
Mineral oil (*transformer*)	10-20
Silicone oil (50 cs for transformers)	4-5
Askarel	2-3

Field experience with the silicones as transformer coolants is limited. Dow Corning has had several load-center transformers retrofitted with 50-cs silicone oil for several years. And silicone oil is slated for all of Dow's future plant transformers. If you want to consider changing transformers from askarel to silicone oil, first check with the transformer manufacturer. Few physical changes should be necessary. Transformer rating may be reduced 10% because of difference in fluid viscosity and heat conductivity. At present, insurance carriers have no formal policy covering the use of silicone oils. They have approved use in a limited number of cases.

The Japanese National Railway has used silicone fluid as the transformer coolant on its electric coaches for the past five years with good results. Here several design modifications were necessary.

Code-making bodies should consider a tentative approval or interim amendment of silicone-fluid applications in specified environmental and plant locations to obtain operating experience. Net result would be to determine if such transformers can replace askarel, under what conditions, and in which locations. Bear in mind that it generally takes two to four years for Code approval for such a basic change: The changing from a proven fire-resistant product to a nonfire-resistant fluid, for indoor use.

Cost can be a problem: Silicone fluids cost about twice as much as askarel. Thus, for a typical 1000-kVA load-center transformer, total transformer cost may increase 8-10%. The actual increase in cost is a *function of the specific design*.

Dry-type designs may be used in place of askarel if the user recognizes the inherent limits of dry-type transformers (Table 2).

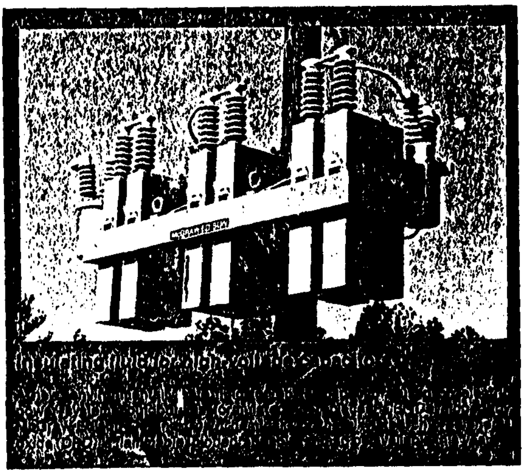
Failure testing. In recent years, a series of explosion tests were conducted in the US and Japan using mineral oil, askarel, and silicone oil. The fluids were tested in small tanks with a loose cover, and 'shot' with 4000-5000 amp at 4.8 kV. In each case, and with each fluid, the covers blew off. This was to be expected, since a high-current arc in any liquid-filled transformer will generate gas, followed by a pressure buildup. Such tests are not representative of actual operation. True, explosions do occasionally occur with pole-type transformers on outdoor utility systems. But they are rare indeed for industrial transformers located indoors and protected from lightning.

Transformer failures are generally turn-to-turn, and therefore carry limited fault current. This is a far cry from the magnitude of the tests outlined above. Manufacturers of industrial transformers offer sensors to detect incipient arcing faults and severe faults. I know of but one catastrophic occurrence—lightning struck an askarel transformer on the roof of a building. But there was no fire damage. Spot-checking with an insurance carrier confirms the rarity of such accidents.

Still other answers? It is possible that a new nonliquid transformer will emerge. Several European manufacturers, and at least one in the US, now offer an epoxy cast-coil design in the 100-500-kVA range. With more developmental work, kVA ratings may reach the currently popular transformer sizes. Another alternative lies in modification of present dry-type transformers. The present sealed-dry gas type is too large, too heavy, and too expensive for general use.

Unless EPA prohibits use of askarel, this fluid will continue to be used in indoor transformers and capacitors until an approved substitute is available. EPA may wisely restrict import of askarels to use only in closed systems, as is practiced by Monsanto domestically.

A new policy of indemnification by the buyer to the seller is one factor that may affect use of askarel-filled transformers. Wording of the indemnification contract may vary. The key lies in its application to any and all liabilities and expenses, including actions, suits, proceedings, investigations, instituted or issued by any government agency or body. The liability would include handling, possession, use, or disposition of askarels that may contaminate the environment. **JOC**



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