PCB ALTERNATIVES AND THEIR CHARACTERISTICS FOR AC CAPACITORS

March 1976

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ALTERNATIVES TO PCBs

Askarels provide favorable capacitor characteristics of long life, high reliability, and safe failure modes.

The proposed alternatives not only must provide these characteristics but in addition must not cause environmental problems.

Today there are no dielectric fluids available which can be considered as acceptable substitutes for PCBs in the broad range of AC capacitors.

Characteristic Requirements for Capacitor Fluid Impregnants

Physical characteristics of impregnants must include that: 1. the boiling point, the freezing point, and the pour point should be beyond the capacitor operational temperature range, 2. the flash point should be greater than 300°F, and 3. the vapor pressure at 100°C and low vacuum (better than 500 microns) should be negligible for ease of vacuum impregnation processing, and 4. the viscosity at 100°C should be 1000 centipoise or less for processing.

Electrical characteristics requirements include: 1. a dielectric constant greater than about 2 but smaller than about 10, 2. Volume resistivity should be in excess of 10^{10} ohm-cm in the capacitor operating temperature range, and 3. Power factor should be less than 0.1 percent and preferably less than 0.05 percent. 4. Dielectric strength greater than 30KV/.1 inch.

Chemical characteristics have to include: 1. Stability over the capacitor operating range (-35°C to +95°C) while under electrical stress, 2. Biodegradability and toxicity to prevent environmental or health problems, and 3. Non-corrosivity with other capacitor materials.

Discussion: The word"askarels"designates a synthetic, fire-retardant, insulating liquid which when decomposed by an electric arc evolves only gaseous mixtures of hydrogen chloride and carbon. These fluids are not subject to oxidation and provide significant freedom from chemical and electrical degradation. The basis for these beneficial properties and the detrimental lack of biodegradability in the environment is in part due to the fact that the compounds are chlorinated.

Candidate fluids which are more environmentally acceptable such as mineral oils create a concern of safety in the capacitor applications. Fire and explosion is an ever present hazard using these fluids because electrical failures may lead to conflagration and loss of life. Not only from the oil flammability may a problem arise but also from the gases formed upon decomposition of the oil by an electric arc.

The flammability of a liquid is usually indicated by reference to the flash and fire points. The use of these as an indicator of flammability is helpful but not completely satisfactory in evaluating the fire and explosion characteristics in applications. The flammability of condensed oil mists or sprays can be of equal or greater importance. Atomization may occur when internal pressure mounts as during an electrical failure and a small hole exists in the capacitor case. Such suspension of oil drops can propagate flame when ignited even though the liquid is essentially non-volatile and not capable of forming a flammable vapor mixture with air.

If flammable gases are evolved during arcing, high internal pressures may exist within the capacitor case, causing rupture and subsequent fire and explosion.

The electrical stress on a composite dielectric system, such as oil and kraft paper, divides inversely to the dielectric constants of the individual materials. Thus, as in an askarel-kraft paper system where the dielectric constants are nearly matched, the electric stress is divided approximately equally. However, if a fluid has a significantly lower dielectric constant than the kraft in the composite system, the fluid is stressed inordinately. As is typical of most proposed non-chlorinated dielectric fluids, the fluid will be the weakest link in the dielectric system because of its characteristics and it will have a substantially worse performance characteristic if it also has too low of a dielectric constant. The fluid which has a dielectric constant significantly higher (about 10) than the kraft paper, will frequently have ionic materials present acting as contamination causing excess heat development and reduced life.

Listed below is a summary of required characteristics of PCB alternatives:

TABLE I

CHARACTERISTIC	LEVEL
Boiling Point	Greater than maximum operating temperature (95°C)
Flash Point	Greater than 300°F
Freezing Point	Lower than minimum operating temperature (-35°C)
Pour Point	Lower than minimum operating temperature (-35°C)
Vapor Pressure	Negligible at approx. 100°C and low vacuum (better than 500 microns)
Viscosity	1000 centipoise at impregnation
Dielectric Constant	Greater than 2 but less than 10
Dielectric Strength	Greater than 30KV per 0.1 inch
Power Factor	Much less than 10 percent
Volume Resistivity	10^{10} ohm-cm
Biodegradability	Greater than 15% degradation per 48 hour cycle with semi-continuous activated sludge.*

*Based on Aroclor 1254 being found in the environment and food chain and the paper presented by James Mueire, Monsanto, Characterization of Polychlorinated Biphenyls, Table IV (Given at National Conference on Polychlorinated Biphenyls, Nov. 1975, Chicago)

TABLE I - Con't

CHARACTERISTIC	LEVEL
Acute Toxicity	No significant levels to humans exposed during processing capacitors
Chronic Toxicity	No significant effects on humans after long term exposures
Bioaccumulation and Bioconcentration	No significant build up in human food chain, if appreciable human chronic toxicity

TABLE II

PROPOSED CANDIDATES* FOR PCB SUBSTITUTION AND THEIR CHARACTERISTICS

		CANDIDATES				
CHARACTERISTIC	PCB (1016)	Substituted Aromatic Compound	Phthalate Esters	Synthetic Hydrocarbons	Silicone Oil	Mineral Oil
Boiling Point (°C)	>300	>300	>300	296°C	>300	>300
Flash Point/Fire Point(°F)	358/None	345/390	430/495	303/328	605/680	300/374
Pour Point (°C)	-19	-45	-45	-47	-50	-45
Vapor Pressure	Negligible	Neg.	Neg.	Neg.	Neg.	Neg.
Viscosity (CS)	2.1	-	4.3	2.0	20	3
Dielectric Constant	5.9	4.4	5.0	6.1	2.8	2.2
Dielectric Strengtn (KV/.1")	35	35	35	35	35	30
Power Factor (%)	1.0	1.0	2.5	2.0	0.05	0.1
Volume Resistivity	10^{12}	10^{12}	10^{12}	10^{12}	10^{14}	10^{12}
Relative Capacitor Size	1.0	1.23	1.03	.97	1.39	1.5(
Relative Capacitor Cost						

*The candidates are listed under their general classifications but this does not imply all variations of fluids within those classes will have the characteristics given.

MONS 045799