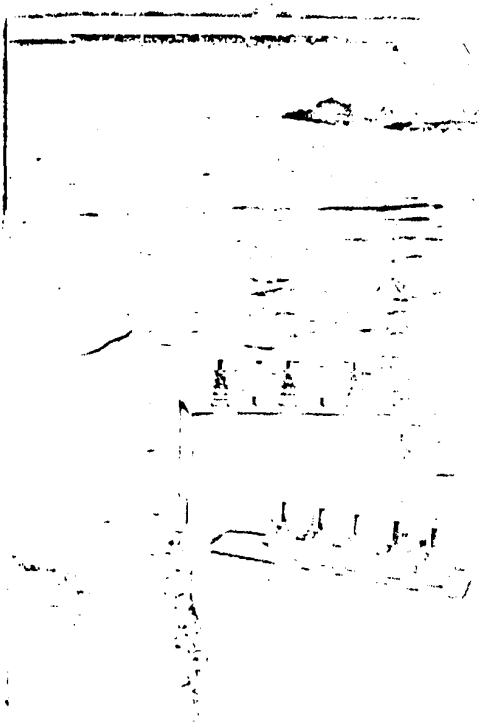
GENERAL ELECTRIC

TROL II

power capabilities



uncompromising performance from an environmentally compatible flight

MONS 073240



DIELEKTROL® II:

uncompromising performance from an environmentally compatible fluid

The challenge in developing a new dielectric fluid to replace PCB in General Electric power capacitors was to maximize performance and minimize risk to the environment. Many of the more than one hundred fluids GE tested were environmentally acceptable. And many of these fluids could even meet minimum product application requirements.

But the real challenge was to produce an environmentally compatible fluid with no sacrifice, no compromise in capacitor performance. General Electric met that challenge. The result is achieved with Dielektrol II liquid, an ester-based capacitor fluid that meets or exceeds PCB performance.

Early in the GE program, Phthalate ester-based impregnants emerged as the most promising candidates. Since 1972, GE has amassed millions of KVAR hours of field service experience with Phthalate ester impregnants in power as well as in component-type capacitors. These non-PCB capacitors have gone to customers who by choice or of necessity have avoided PCB impregnants. Results have been excellent, for example 500 power capacitor units which have been in service in Japan for up to 2½ years have led to only 2 reported field failures.

To assure that both environmental and performance criteria were met, GE conducted an exhaustive product testing program. Environmental testing has been and continues to be carried out by some of the top independent research organizations in the United States. Product performance testing is done primarily at the Capacitor Products Department in Hudson Falls, N.Y. More than 40 million KVAR hours of power capacitor testing has been completed to date. Additional testing continues.

These are the latest results.

Environmental compatibility: In acute toxicity tests, Dielektrol II capacitor fluid has demonstrated low toxicity to humans, fish, fowl and soil microorganisms in concentrations that can reasonably be expected to occur. Even at concentrations far in excess of those expected, Dielektrol II fluid exhibits a low toxicity comparable to many other commonly used industrial materials.

Acute Oral Toxicity — Rats: Rats are fed a single dose, then observed 2 weeks. Three dosage levels per test. Test is prerequisite to *28-day feeding study.*

Liquid	LD 50 (gm/kg body wt.)
DIELEKTROL II	4
Non-PCB A	4
Non-PCB B	>10
Brake fluid base	1.5
Glycerin	8
Benzene	3.5

Note: To calculate approximate lethal dose for a 70 KG (155 lb.) man, multiply any number by 70.

Dielektrol II fluid has not been found to be carcinogenic. The tests conducted to date reveal that Dielektrol II fluid degrades and metabolizes and thus will not persist in the environment. Preliminary test results also indicate there is no bioaccumulation problem.

Performance: Dielektrol II capacitor performance is equal to or better than that achieved with PCB. Partial discharge or corona start characteristics is one area where Dielektrol II capacitors are clearly superior. Power factor is another characteristic in which Dielektrol II units outperform the PCB impregnated ones throughout the *normal temperature ranges.*

Particularly significant is the high dielectric constant of Dielektrol II liquid. This key characteristic permits the capacitor unit size to be essentially the same as that of PCB impregnated units without raising the stress imposed on the impregnant to values higher than those consistent with past practices.

Through overall performance improvements, especially that of partial discharge, Dielektrol II units exhibit substantially greater reliability and life over equally rated PCB units in accelerated life tests. The same results are expected in the field.

Ratings/Case size: Dielektrol II unit ratings, configurations and case sizes are virtually unchanged from GE Pyranol units and can be substituted as direct replacements. They fit all standard NEMA rack structures and can be paralleled with previously installed PCB units.

Quality

Power capacitor design technology demands consistently high quality in all components and materials and little variance can be tolerated without affecting field performance. For this reason, General Electric believes that in-house processing of major capacitor materials, such as the liquid impregnant as well as polypropylene film and aluminum foil, provides a better quality and more predictable supply than purchasing these key materials *from outside vendors.*

In keeping with this philosophy, Dielektrol II is formulated and refined at Hudson Falls specifically for power capacitor use. By blending in-house and applying our own strict quality standards to the incoming chemical components and the refined blend, consistent product quality is assured.

Cost: Increased cost of the new Dielektrol II units has been held to a minimum as the new fluid is compatible with existing dielectric structures and requires only a few key changes in manufacturing processes.

Disposal: Unlike PCB capacitors, Dielektrol II units have no severe disposal limitations other than normal good industrial practices for chemical materials.

Suggested disposal methods are incineration or dry landfill disposal consistent with applicable regulations.

Availability: Dielektrol II units are available now. Contact your local GE sales representative or write to General Electric Company, Capacitor Products Department, Hudson Falls, New York 12839.

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ENVIRONMENTAL COMPATIBILITY:
the living proof

Every man-made substance makes some impact on the "natural" environment. The goal in developing Dielektrol II liquid was to produce a fluid that would constitute no significant hazard to life forms and neither persist nor accumulate in the environment. All data accumulated to date show this goal has been achieved.

To minimize the possibility that the new compound might have unknown and undesirable environmental characteristics, commodity liquids with a long history of use in substantial volume were chosen as the major constituents of Dielektrol II fluid. For example, Dielektrol II impregnant is composed of a Phthalate ester plasticizer mixed with a halocarbon widely used as a textile dye solvent. Because the components have been used extensively in the past, GE has been able to review environmental compatibility through standard toxicity data bases such as Chemline and Toxline. In essence, GE was able to "pre-assess" Dielektrol II fluid's environmental impact. No significant effects have been recorded.

Independent Confirmatory Testing

To confirm the environmental compatibility of Dielektrol II fluid, GE commissioned several independent research organizations to conduct a wide variety of experiments and gather more data. While some tests are not yet completed, the preliminary data consistently supports Dielektrol II fluid's environmental compatibility.

Toxicity

Toxicity experiments assess the effects of a single massive dose (acute) or smaller doses over periods of time (chronic). Data from acute toxicity tests show Dielektrol II fluid is far less toxic than PCB and approximately as toxic as many widely used industrial materials considered non-hazardous.

Inhalation: Rats were put in closed containers and made to breathe Dielektrol II liquid vapors for one hour. Result: No effect was found during 14-day observation period.

Dermal contact: Patches of rabbit skin were exposed by shaving and undiluted Dielektrol II fluid put on skin and covered for 24 hours. Result: During a 14-day observation period, slight irritation was found such as might be caused by some laundry soaps.

Eye contact: One dose of undiluted fluid was dropped into the eyes of rabbits. Result: No effect during a 72-hour observation period.

Ingestion: Rats were fed various concentrations of Dielektrol II fluid for 28 days. Result: Concentrations that might be expected to occur do not pose a hazard.

Fish (bluegill, fathead minnow) were placed in tanks with various concentrations of Dielektrol II fluid. Result: Dielektrol II fluid is approximately 5 times less toxic than PCB. It is unlikely to cause harm at concentrations which can be expected to occur.

Micro-organisms (4 different bacteria) were introduced to soil impregnated with Dielektrol II fluid. Result: Growth was not inhibited even at concentrations of 5,000 parts per million.

Birds (pheasants, ducks) were fed single doses at various concentrations of the fluid. Conclusion: It is unlikely to cause harm at concentrations which might be expected to occur.

Biodegradation/Bioaccumulation

Dielektrol II fluid biodegrades. In a river die away test major constituents of the fluid and the refined Dielektrol II fluid itself all produced results which indicate that Dielektrol II fluid will not persist in the environment.

Preliminary bioaccumulation test results suggest that accumulation of Dielektrol II fluid in tissues of fish tested is so low as to be insignificant.

Continued testing

Additional testing is currently under way. Interim results from chronic toxicity tests as well as further biodegradation and bioaccumulation studies are expected by mid 1977. Results will be available as tests are completed.

LC 50 Fish — 96 Hours Static Test

	Bluegill	Fathead minnows
Dielektrol II	11 ppm	16 ppm
*Non-PCB-A	8	9
*PCB-1254	NA	1

*Alternate fluids considered

Note: LC 50 test shows concentration in parts per million necessary to achieve 50% mortality of fish in the tank. Lower ppm figures indicate higher toxicity.

28-day Rat Feeding Study

	Highest concentration No effect	Liver effect level
Dielektrol II	250 ppm	1250 ppm
*Non-PCB-A	190	950
PCB 1016	>2.5	2.5

*Alternate fluids considered

Note: The 28 day feeding test shows concentrations in parts per million necessary to cause liver enlargements in rats. Lower ppm figures indicate higher toxicity.



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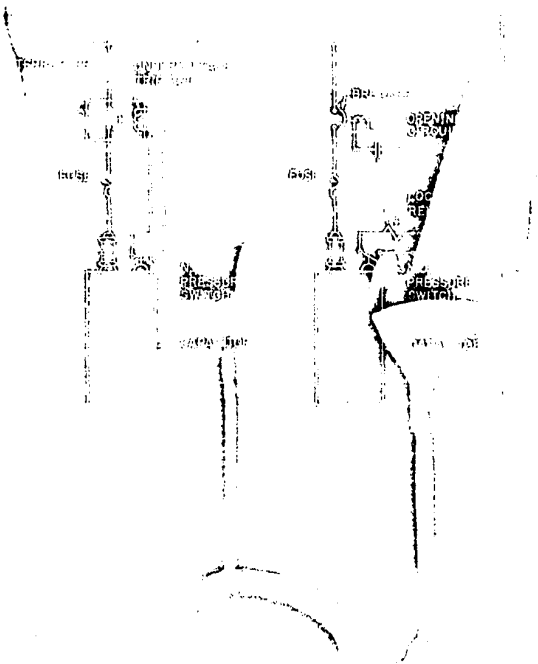

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FLAMMABILITY:
why a III B classification doesn't tell the whole story

Dielektrol II fluids, like all other non-PCB fluids developed to date, falls into the NFPA III B combustible category. But there's more to Dielektrol II liquid than the III B designation implies.

First, the NFPA classification of the liquid does not mean the capacitor is going to fail and burn. GE has shipped more than 100,000 castor oil, mineral oil, and "GECONOL" impregnated units (all III B's) and overall the 30-years of experience has produced results comparable to these achieved with PCB's. No fires occurred during Dielektrol II fluid's 40 million KVAR hours of accelerated life testing, testing that pushed many units to the end of life.

Dielektrol II Units Self-extinguish

During what is probably the most extensive case rupture study ever undertaken, GE deliberately failed 400 PCB, Dielektrol II, and other non-PCB impregnated units and caused them to rupture. High speed movies record the results and one thing was confirmed: Dielektrol II unit fires generally self-extinguish in seconds due to the high fire point, in excess of 250°C, of the fluid. Note: (See page 10) For comparison, other non-PCB units would often continue to burn after Dielektrol II units self-extinguished.

Dielektrol II Capacitor Fusing

Correct fusing minimizes the possibility of case rupture and fire.

Analysis of the case bursting data of several different KVAR and voltage ratings indicates no significant difference between the times to rupture of Dielektrol II and PCB units. Thus, present fusing practice will provide the same order of protection against case rupture with Dielektrol II capacitors as previously experienced for PCB units.

Supplementary Protection

Additional protection against case rupture and its attendant fire hazard can be furnished in the form of pressure sensors built into the GE capacitors. This optional protection feature can be used to operate capacitor switching devices, thereby protecting against low fault currents. Fusing tends to be least effective in low current fault occurrences.

For more information on environmentally compatible Dielektrol II Power Capacitors, contact your local GE representative or write to General Electric Company, Capacitor Products Dept., Hudson Falls, N.Y. 12839.

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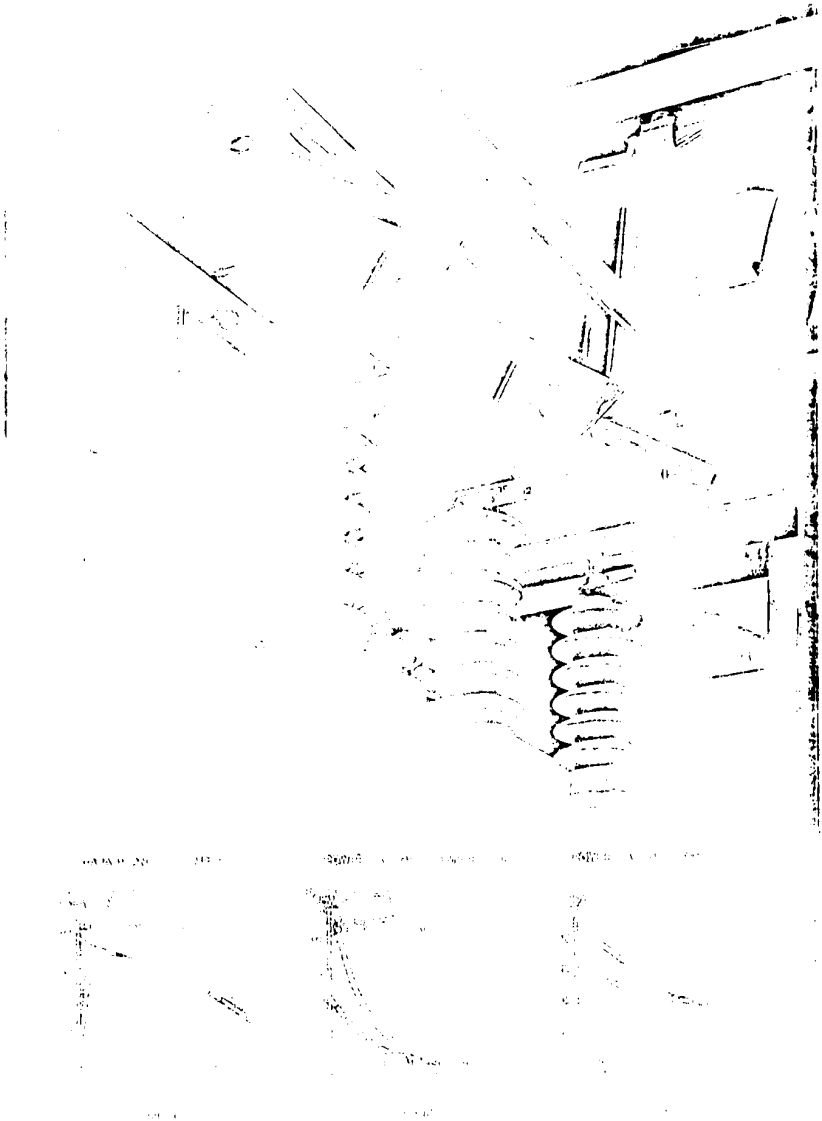


PERFORMANCE:
as good or better than PCB

Environmentally compatible Dielektrol II capacitors make no performance compromise. Overall charactenstics are as good as PCB and in some areas significantly superior. See for yourself. The results provided are the product of more than 40 million KVAR hours of testing.

Capacitance vs Temperature: Dielektrol II fluid outperforms PCB ... there is no loss of capacitance to −40°C. Average capacitance is better than rated throughout normal temperature ranges to 90° C. See Figure #1.

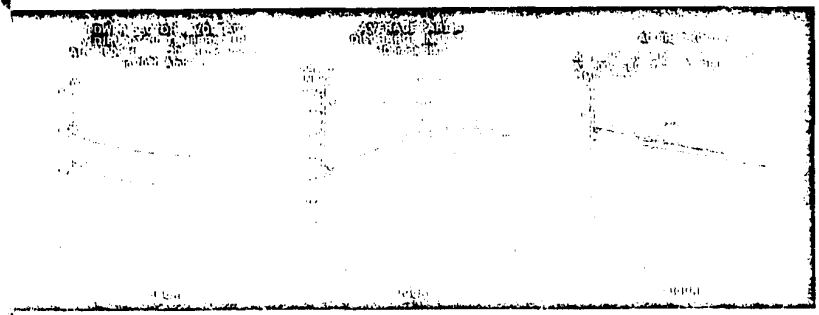
Power Factor vs Temperature: Better than PCB. Curve for Dielektrol II fluid is lower than PCB at typical operating temperatures with losses less than 0.5 watts per KVAR. Dielektrol power consumption will be less than for PCB units. See Figure #2 and Figure #3.

Power Factor vs Voltage vs Temperature: Excellent power factor stability with increasing voltage is shown in Figure #4. Dielektrol II fluid's long term power factor stability is confirmed by life tests at voltages in excess of twice rated.

Partial Discharge Inception Voltage (DIV): Clearly superior to PCB units. See Figure #5. A substantially higher DIV is experienced over the normal operating range. Measurements were made on individual rolls in full-size power capacitors. More reliable, longer lived capacitors are expected because of the greater margin between rated and partial discharge inception and extinction levels.

AC Breakdown: Individual capacitor elements consistently demonstrate AC breakdown values exceeding four times rated voltage. Even in applications subject to severe overvoltages and substantial transients, Dielektrol II capacitors are expected to deliver long-lived reliable service as a result of the high AC breakdown values. See Figure #6.

NEMA-ANSI Design Tests. *Dielektrol II units* exceed all requirements for DC dielectric strength, impulse withstand, thermal stability, RIV and voltage decay.



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PERFORMANCE AND RELIABILITY TESTING:

the foundation for confidence

Life Tests

Units are being tested at 120% to 225% of rated voltage in ambients from −40°C to 70°C. Result: Under all conditions, the Dielektrol II units meet or exceed the performance of PCB units. Many PCB units failed in less than 100 hours due to partial discharge damage. Most Dielektrol II units are still on test after more than 4,000 hours under conditions which are equivalent to 100 years of normal service.

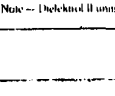
ACCELERATION % RATED VOLTS	AMBIENT TEMP	% DIELEKTROL II UNITS SURVIVING AFTER 50% OF PCB CAPACITORS FAILED
FULL-SIZE POWER CAPACITORS		
175	25°C	80
175	55	70
200	25	90
200	55	50
COMPONENT CAPACITORS		
150	70	85
150	25	90

Based on over 40 million KVAR hours of accelerated tests

Case Rupture Test

200 KVAR unit impregnated with Dielektrol II

Test conditions: 9 KV, 2500 Amp Rms Symmetrical Available

Movie Frame	Description	Time in Seconds
	Power On Unit bulged by internal gassing	.535
	Unit ruptured, initial fire ball	.666
	Fire at maximum intensity	.742
	Power off, fire starting to self-extinguish	.863
	Only sparks remaining	1.035
	Time to complete extinction	1.47

Note — Dielektrol II units tend to be self-extinguishing

Switching Tests

Demonstate ability to withstand duty in outdoor switched capacitor banks.

Low Temperature Switching Tests

Impregnant	Ambient	60Hz Voltage*
DIELEKTROL II	−20°C	120% to 180% rated
DIELEKTROL II	−40°C	120% to 150% rated

*All tests were started with units cooled to ambient temperature and switched on with a peak transient voltage equal to 170 to 180% of the peak 60Hz test voltage

Result: No failures to date after 8 sets of tests.

Design and Process Proof Test

Dielektrol II capacitors have passed type tests structured to establish the product's reliability. For example, the test which qualified the 7620 volt-200 KVAR capacitor was completed in December 1976. It is detailed below.

Design subjected to proof test — Cat. No. 58L107KC2

Design Issue Date: November 23, 1976

Wt. 103 Lbs. Size 5 x 13½ x 26¼

Design Parameters — Film/Paper Dielektrol II Liquid Impregnated

1524 volts/section, avg. stress 1037 volts/mil, film stress 1246 volts/mil

Test Vehicles — Capacitors which had been subjected to a DC dielectric withstand test and P.F. stabilized by AC energization.

Step 1 — Open one capacitor and DC breakdown rolls (elements)

Establish — Average roll breakdown in volts DC

Step 2 — Test remaining three capacitors

a. Read rating voltage PF — @ 25°C

b. Apply 3 times rated AC for 5 seconds @ room temperature — all three units passed.

c. Energize the three units @ 130% rated AC for 240 hours in room temperature ambient — all three units survived.

d. Subject units to 6.25 x rated DC for 10 seconds — all three units passed.

Step 3 — Characterize the three units tested.

Rated Voltage Power Factor Recheck:
All values within 0.005 of the original.

Roll Breakdown:
Average in volts DC greater than Step 1

All values above 6.25 x rated

Conclusion — Cat. No. 58L107KC2 passed. Assurance of reliable long-lived service by capacitors of this design and construction which are manufactured by the same processes is provided because: (1) the capacitor's ability to withstand voltage acceleration without degradation of the dielectric system is demonstrated by the power factor stability and (2) the capacitor's ability to survive transients and extended overvoltage is proven by the maintenance of dielectric strength.

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