MONSANTO INDUSTRIAL CHEMICALS COMPANY

Visit At

SPRAGUE ELECTRIC COMPANY
NORTH ADAMS, MASS.
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To

Review Status of Capacitor
Aroclor (PCB) Dielectric Fluid

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SECTION I

The Need For PCB-Type Fire-Resistant Dielectric Fluids (Excerpts from the Jan. 5, 1972 report by the National Industrial Pollution Control Council - U.S. Dept. Commerce, Washington, D.C.)

I. The Need For PCB-Type Fire-Resistant Dielectric Fluids (Excerpts from the Jan. 5, 1972 report by the National Industrial Pollution Control Council - U.S. Dept. Commerce, Washington, D.C.)

A. The Need For PCB Type Dielectric Fluids In Capacitors

1. Widespread use of PCB capacitors

PCBs are used in more than 90% of the electric utility (large power) type and smaller industrial type capacitors made today. They are needed for safety, reliability and long life, and to achieve sizes compatible with equipment and installation requirements.

The principal types of PCB-impregnated capacitors and their applications are high voltage power capacitors used primarily for power factor correction in the distribution of electric power; low voltage power capacitors installed in industrial plants at the load (typically large motors); ballast capacitors to improve the efficiency of lighting systems; and small industrial capacitors for power factor improvement in such equipment as air conditioning units, pumps, fans, etc. Almost 80 million such capacitors are manufactured annually, most of them for first-time use.

Capacitors used in lighting and air conditioning applications contain 0.005 to 0.09 gallons of PCB per unit. The largest power capacitors contain about 6.7 gallons of askarel. The most popular size contains about 3.1 gallons. The National Electrical Code requires that any installation of capacitors in which any single unit contains more than 3 gallons of combustible liquid shall be in a vault like that required for transformers. During 1968, the last complete "normal" year for the electrical industry, the total amount of fire resistant PCBs used in capacitors was approximately 14.4 thousand tons.

2. Reliability, life and safety of PCB capacitors

PCBs are thermally and oxidatively more stable than mineral oils and most other dielectric fluids. Discharges, which can occur in capacitors, are less likely to generate gases from askarels than from mineral oils. The chemical stability of PCBs in the presence of capacitor

tissue and plastic films and the favorable stress distributions between solid and liquid have made it possible to design low-cost capacitors with a life expectancy of more than 10 years life in lighting applications and more than 20 years in electric utility applications. In each application the first-year failure rates are less than 0.2%. This level of life and reliability had not been achieved prior to the introduction of PCBs.

The relative non-flammability of PCBs significantly reduces the fire hazard that might otherwise accompany those failures that result in rupture of the case.

3. Consideration of other dielectric fluids for PCB-type capacitors

a) Mineral oil

The single most important property of a liquid to be used in a capacitor is its dielectric constant (the ratio of its ability to store electrostatic energy relative to air). The dielectric constant of the capacitor-grade PCB (Aroclor 1242) is 5.85 while that of mineral oil is 2.25. Reverting to an oil-paper dielectric system would increase the average capacitor volume (size) by approximately 500%, the weight by 500%, and the cost by approximately 400%. At the present levels of demand for capacitor KVAR, there would be a shortage of electrical grade paper and a shortage of capacitor factory facilities further tending to increase the cost to the utility, and ultimately to the consumer.

b) Castor oil

The dielectric constant of castor oil is 4.5 and this material is useful as an impregnant in D.C. energy storage capacitors. However, A.C. capacitors filled with this liquid have relatively short lives and are not very stable under A.C. discharges and in the presence of water derivable from the cellulosic paper.

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c) Dibutyl Sebacate

This ester is especially useful in high frequency parallel plate capacitors because of its low, flat loss characteristics over a broad frequency range. In this type of construction the liquid is the sole dielectric material. When used in conjunction with paper this ester is also unstable.

d) Silicone Fluids

These materials have a dielectric constant of 2.7 and would generally be subject to the same disadvantages as mineral oil.

4. Monsanto developed Capacitor Aroclor 1016 to achieve a higher degree of environmental compatibility.

As the environmental studies indicated that the higher boiling (the higher chlorinated) PCB isomers persist in the general environment, Monsanto substantially removed these persistent components from commonly used capacitor Aroclor 1242.

This Aroclor 1016 capacitor dielectric has the same fire-resistant rating assigned to Aroclor 1242 by the Underwriter's Laboratory.

Replacement of Aroclor 1242 with Aroclor 1016 in capacitors involved no handling, process nor capacitor design changes. This work done by Monsanto in collaboration with the capacitor industry was culminated by universal adoption of Aroclor 1016 for capacitors in mid-1971.

B. The Need For PCB-Type Dielectric Fluid In Transformers

Because of the nonflammability of transformer askarel fluids, their vapors, and their arc-formed gaseous products, transformers filled with PCBs are free of fire and explosion hazards and may be used in locations where failures of oil-insulated transformers would present a potential danger to life and property.

Most of these transformers are located inside public, commercial, or industrial buildings; on the roof tops of such buildings or in close proximity to such buildings, and require no special enclosures other than what are necessary to prevent accidental hazardous mechanical or electrical contact of persons with the equipment.

The amount of Aroclor used in various types of transformers ranges from 40 to 500 gallons (516 to 6,450 lbs.) with an average of about 235 gallons (3,032 lbs.). During 1968, the last complete "normal" year for the electrical industry, the total amount of PCBs used in transformers was approximately 1.3 million gallons (8.4 thousand tons).

The only present alternatives to Aroclor-insulated transformers are mineral oil-insulated transformers or dry-type transformers (either those open to the atmosphere or those that are gas-filled and sealed).

Alternatives

1. Mineral oil-insulated transformers

   a) If one disregards safety considerations, there are no technical reasons why mineral oil-insulated transformers could not be directly substituted for PCB-insulated transformers. The size of the unit would be unchanged; the weight and cost would be less.

   b) But one cannot disregard safety considerations, which are often embodied in legal codes.

      Obviating the safety hazards involves serious economic and space constraints, that would occur either by the use of protective vaults, or use of insulated buses (with the transformer located outdoors). Either solution, if the space is available, could cost $5,000 - $50,000 per transformer.

2. Dry-type transformers

   In most locations, dry-type transformers (either those open to the atmosphere or those that are gas-filled and sealed) could not be directly substituted for PCB-insulated transformers. There are several restrictions to such a direct substitution:

   a) The reliability of dry-type transformers is less than that of comparably rated liquid-insulated transformers. An EEI survey of failures in network transformer banks showed a 7% per year failure rate for dry-type units compared to 0.2% for liquid-insulated units.

b) Furthermore, liquid-insulated transformers have a much greater overload capability. Many liquid-insulated units can sustain a 100% overload for 8 hours and a 200% overload for 2 hours. These transformers are able to maintain continuity of electrical service during periods of temporary malfunction of related equipment.

c) Some dry-type transformers are larger by 10 to 30% than comparably rated liquid insulated units, and most are more expensive.

d) Dry-type transformers are noiser by 5-10 dB than are liquid-insulated transformers.

e) Open dry-type transformers, which are cheaper than sealed dry-type transformers, cannot be used in certain corrosive or hazardous atmospheres, e.g. on furnaces or on electrostatic precipitators near hot stacks.

3. Other fluids

The fire underwriters will not accept the use of oils, silicones and other flammable liquids for indoor transformers. No currently available liquid which will replace askarels in existing transformers is known.

SECTION II

U.S. Government Interdepartmental Task Force Report
May 14, 1972 Entitled "Polychlorinated Biphenyls and
the Environment"

II. U.S. Government Interdepartmental Task Force Report May 14, 1972 Entitled "Polychlorinated Biphenyls and the Environment

This report is available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22151. The task force included operating units of five Executive Branch Departments:

Department of Agriculture
Department of Commerce
Department of Health, Education & Welfare
Department of Interior
Environmental Protection Agency

These government agencies are fully appraised of Monsanto's voluntary actions to discontinue sale and supply of PCBs for all non-electrical uses.

The Task Force Report states:

A. "The use of PCBs should not be banned entirely. Their continued use for transformers and capacitors in the near future is considered necessary because of the significantly increased risk of fire and explosion and the disruption of electrical service which would result from a ban on PCB use. Also, continued use of PCBs in transformers and capacitors presents a minimal risk of environmental contamination. The Monsanto Company, the sole domestic producer, has reported voluntarily eliminating its distribution of PCBs to all except manufacturers of electrical transformers and capacitors."

B. Disposal of Scrap Capacitors

"Most capacitors presumably have been disposed of in landfills. PCB-containing material buried in soil is not expected to migrate but should remain in place. In the past, many fluids containing PCBs have been disposed of in sewers. More appropriate means of disposal such as high temperature (at least 970°C) incineration must be used instead."

C. Disposal of Scrap PCB Fluid

Monsanto is one of several to provide proper high temperature incineration and HCl neutralizating facilities to completely destroy PCB liquids. Monsanto charges 3 cents a pound and shipping charges are to the sender's account.

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SECTION III

Handling and Policing PCB Dielectrics

III. Handling and Policing PCB Dielectrics

A. The American National Standards Institute

ANSI Committee C107 composed of a capacitor section and a transformer section, on behalf of all parties interested in PCB dielectrics, is scheduled to publish guidelines for handling and disposal of capacitor-grade askarels and transformer-grade askarels.

B. PCB analysis

Methodology developed by Monsanto and others is in process of documentation at ASTM D-22 for sampling and analyzing of PCB from water and air.

C. Need to Avoid Environmental Contamination

While the continuing need for PCBs in closed electrical applications is conclusive, the electrical industry must well understand that continued use of these materials requires unusual protective measures and exceptionally clean "house keeping".

EPA plans to regulate the controllable sources of PCBs to the water environment. Fish and shellfish will be examined to reveal locations with high PCB content. The FDA guideline allows no more than 5 ppm PCB in the edible portion of fish.

It is not believed necessary to regulate PCBs in air, at this time.

The industry goal is "zero" concentration of PCB in plant water effluent streams. However, it is recognized that existing drain systems in (for example) capacitor manufacturing plants are probably contaminated as a result of past practices and PCB traces may continue to show up in effluent streams for some time.

Section IV

Purchase of Capacitor Aroclor

IV. Purchase of Capacitor Aroclor

A. Pounds Aroclor Purchased by Sprague Electric Co.

As Sprague is one of the early manufacturers of Aroclor capacitors, their initial use of Aroclor 1254 must date back to the 1940s.

Over the past twenty years Sprague's use has ranged from 2.0% to 7.7% of the total annual amount of capacitor Aroclor used in the USA. The annual pounds used by Sprague has ranged from 250,000 to 767,000 pounds per year during the 1950s, to the 2,002,800 peak used in 1969, when the dollar volume was also a maximum at $300,999.

The pounds of capacitor Aroclor purchased by Sprague over the past five years are shown in Table I.

B. Prices

The historical sales prices per pound for capacitor Aroclor sold to Sprague are given in Table II.

C. Monsanto Dielectric Fluids Pricing Characteristics

1. Unusual price stability through the years until 1970.

2. Increases 1970-1972 fully accounted by factors related to the PCB environmental problem; see Table III.

Table I

Sprague Electric's Purchase of Capacitor Aroclor

Pounds

968	1969	1970	1971	6 Mo. 1972
417,000	2,002,800	1,041,460	1,145,800	628,420

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Table II

Historical Price of Capacitor Aroclor Sold to Sprague

Year	Price Per Pound (Bulk)	Product
1953	14.0¢ Not Delivered	Aroclor 1242
1957	13.88¢ Delivered	Aroclor 1242
1960	14.98¢ Delivered	Aroclor 1242
1964	14.50¢ Delivered	Aroclor 1242
1966	14.95¢ Delivered	Aroclor 1242
1970	16.00¢ Delivered	Aroclor 1242
1971	18.00¢ Delivered	Aroclor 1016
1972	20.50¢ Not Delivered	Aroclor 1016

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Table III

Monsanto Dielectric Fluids
Pricing Characteristics

1. Unusual price stability until 1970 even though --

   Cost Increases

Labor Costs:	197% Increase	(1953-1972)
Raw Materials:	20% Increase	(1953-1972)
Indirect Fixed Costs:	41% Increase	(1953-1972)

   (e.g. Capacitor Fluids increased by only 7%, 1953-1969)

2. Increase 1970-1972 due to:

   A. Successful development of Aroclor 1016

   B. Loss of 45% PCB sales to other markets -- divisor loss

   C. Costs of environmental control programs --

      Incinerator Program
      Plant Clean-up

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SECTION V.

Summary of Monsanto's Actions to Meet the Electrical Industry Requirements and to Minimize PCB Environmental Pollution

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MONSANTO PRESENTATION TO FEDERAL GOVERNMENT PCB TASK FORCE

MAY 15, 1972

OBJECTIVES

- PROGRESS REPORT ON LABORATORY BIODEGRADATION OF PCB'S
- RESIDUE ACCUMULATION STUDIES IN FISH, BIRDS AND MAMMALS
- TO SHOW REDUCTION IN LESS BIODEGRADABLE PCB'S AS A RESULT OF MONSANTO ACTIONS ON SALES AND PRODUCTS

MDNS 063286

MONSANTO PCB ACTIONS

- PHASE-OUT OF PCB SALES WORLDWIDE IN ALL APPLICATIONS EXCEPT DIELECTRICS
- CONVERSION OF DIELECTRIC FLUIDS TO MORE BIODEGRADABLE PCB'S

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MONSANTO PCB SALES IN U.S.A.

(MILLION POUNDS)

	DIELECTRICS	ALL OTHERS	TOTAL
1969	37.0	30.0	67.0
1970	40.5	33.5	74.0
1972 (EST.)	32.0	--	32.0

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EFFECT OF PHASE-OUT POLICY

PCB SALES REDUCED IN U.S.A. BY

30 TO 33 MILLION POUNDS,

OR 45%

MDNS 063289

PCB PRODUCT
CHANGES IN DIELECTRICS

CAPACITORS

97% CONVERSION TO AROCLOR 1016

TRANSFORMERS

ELIMINATION OF AROCLOR 1260

MONS 063290

DEGREE OF BIODEGRADATION OF PCB'S

BASED ON DATA PRESENTED

- TRANSITION IN BIODEGRADATION OCCURS AROUND PENTA-/HEXA-CHLOROBIPHENYL
- DISAPPEARANCE OF ALL HOMOLOGS BELOW HEXA-CHLOROBIPHENYL OBSERVED
- PENTA- AND HIGHER PCB DETERMINED BY SPECIFIC GLC/MS TEST METHOD

MCNS 063291

PCB'S USED IN CAPACITORS

PCB	MAJOR USE PERIOD	% PCB (PENTA-CHLORO- AND HIGHER	% PCB (HEXA-CHLORO- AND HIGHER
AROCLOR 1254	1930-1952	77.0	29.0
AROCLOR 1242	1952-SEPT. 1971	9.0	1.0
AROCLOR 1016	OCT. 1971	1.1	0.1

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CAPACITOR FLUIDS
WHY CONVERT TO AROCLOR 1016 ?

- 9-FOLD REDUCTION IN PCB'S OF PENTACHLORO- AND HIGHER
- 10-FOLD REDUCTION IN PCB'S OF HEXACHLORO- AND HIGHER
- MINIMUM INDUSTRY TESTING REQUIRED

MDNS 063293

CAPACITOR FLUIDS
WHAT IS THE EFFECT OF AROCLOR 1016?

U.S. CAPACITOR FLUID SALES (1972):~20 $\overline{M}$ LBS.

IF AROCLOR WAS	% PENTACHLORO- AND HIGHER PCBs WOULD BE*	% HEXA CHLORO- AND HIGHER PCBs WOULD BE*
1254	15,400,000 POUNDS	5,800,000 POUNDS
1242	1,800,000	200,000
1016	220,000	20,000

*THIS DOES NOT MEAN AMOUNTS OF PCB ENTERING THE ENVIRONMENT

MONS 063294

WHAT IS CAPACITOR FAILURE RATE ?

INDUSTRY SOURCES CITE : 0.02-0.2% PER YEAR

MGNS 063295

IF CAPACITOR FAILURE RATE IS 0.2% PER YEAR (WORST CASE)

PCB ESCAPE TO THE ENVIRONMENT* IS --

	AROCLOR 1242	AROCLOR 1016
ALL PCB HOMOLOGS	40,000 POUNDS	40,000 POUNDS
PENTA CHLORO- AND HIGHER	3,600	440
HEXA CHLORO- AND HIGHER	400	40

*ASSUMES U.S. FLUID SALES OF 20 M LB./YEAR

MONS 063296

PCB CHANGES IN

TRANSFORMER FLUID APPLICATIONS

- AROCLOR 1260 BEING PHASED-OUT NOW
- INCINERATION OF SCRAP PCB'S - 1971

NOTE: ASKAREL (PCB) TRANSFORMERS ARE TIGHTLY SEALED UNITS

MONS 063297

WHAT IS FAILURE RATE IN LIQUID TRANSFORMERS?

INDUSTRY SOURCES CITE: UNDER 0.2% PER YEAR*

*ALL LIQUID TYPES - MINERAL OIL AND PCB.

MONS 063298

IF ASKAREL (PCB) TRANSFORMERS FAIL AT 0.2%/YEAR HOW MUCH PCB IS AFFECTED*?

ALL PCB HOMOLOGS 24,000 LBS.

(ESTIMATED PCB TRANSFORMER FLUID SALES IN U.S. 12 M LBS./YEAR)

*WITH INCINERATION FACILITIES AVAILABLE, NOT ALL THESE AMOUNTS WILL ENTER ENVIRONMENT.

MCNS 063299

MONSANTO'S PRESENT PROGRAM TO PREVENT ENVIRONMENTAL POLLUTION BY PCB'S

- NO MORE SALES WORLD-WIDE EXCEPT APPROVED DIELECTRIC USERS
- RESTRICT OVER 97% CAPACITOR FLUID SALES TO AROCLOR 1016 ONLY
- ELIMINATE AROCLOR 1260 FROM TRANSFORMER FLUIDS
- CONTINUE INCINERATION FACILITIES FOR SCRAP PCB'S
- ENCOURAGE DIELECTRIC INDUSTRY THROUGH ANSI C-107 TO ENFORCE STRICT ENVIRONMENTAL CONTROL OVER PCB'S

MDNS 063300

Monsanto has attempted to act responsibly as concern about the effects of PCBs on our environment developed. Based on current knowledge about PCBs, the approach presently being taken by the U.S. Government and the continued need by our customers in the electrical industry for PCB-containing dielectric fluids, Monsanto intends to maintain its policy of remaining a supplier of these materials for dielectric uses. However, should changes in present conditions occur, Monsanto may find it appropriate to revise its policy.