CHLORINATED BIPHENYL DIELECTRICS

THEIR UTILITY AND POTENTIAL SUBSTITUTES

1. Introduction

In 1971, Monsanto voluntarily withdrew chlorinated biphenyl from a number of major applicational areas. By 1973, product was sold only to manufacturers of sealed electrical equipment such as transformers and capacitors.

Major applications affected by our withdrawal were carbonless paper, fire resistant hydraulic fluids, heat transfer fluids, and plasticizers.

Sales for other miscellaneous minor applications were discontinued at the same time.

This action resulted in a reduction, in the use of chlorinated biphenyl in areas where entry to the environment was less controllable, of 32.5 million lbs. per year.

We decided at that time to continue supply to closed electrical applications because we believed that:

a) Entry of chlorinated biphenyl to the environment was limited and controllable;
? b) The capacitor industry could use more biodegradable lower chlorinated homologs; and
c) Withdrawal would have brought to a halt production of equipment essential to the safe and efficient distribution and use of electrical energy.

Today we continue to sell chlorinated biphenyl observing the following policy.

1. We supply only to manufacturers of sealed electrical equipment such as capacitors and transformers.

2. We supply lower chlorinated homologs, Aroclor 1016, to the capacitor industry.

3. We offer an incineration service for liquid PCB wastes.

4. We continue to work with ANSI Committee C107 and other bodies to establish appropriate handling and control procedures for equipment containing chlorinated biphenyl.

5. We do not reclaim used dielectric fluid and, in those cases where our advice is sought, we seek to ensure that reclaimers are knowledgeable about PCB and exercise proper control.

6. We allocated increased research resources in 1969 to seek and develop effective replacements. This program continues.

7. In seeking possible replacements, we will ensure that differences between Aroclor and candidate fluids, from our program, are widely reviewed in order that the potential impact of any compromises is fully evaluated.

The implementation of these and other programs both by ourselves and electrical equipment manufacturers was prompted by the utility of this dielectric family and the difficulties inherent in developing substitutes to effectively and fully replace it.

2. Utility of Chlorinated Biphenyl in Capacitors

Fire Resistance

The adoption of chlorinated biphenyls in 1929 as capacitor dielectrics stemmed from their superior dielectric properties compared to mineral oil. However, recognition of the fire resistant character of the fluids influenced system and equipment design and standards over the subsequent 45 years. It is probably true that today many people find it difficult to assess potential capacitor fire hazard purely because Aroclor has been used for 45 years.

Particular examples where fire resistance in a capacitor is of benefit include:

a) fluorescent lighting ballasts;
b) air-conditioner motor capacitors;
c) television capacitors;
d) large power capacitors where high fault currents can cause case rupture and ejection of fluid from pole mounted units close to people and buildings;
e) industrial furnace capacitors.

Stability

The persistence of chlorinated biphenyl in the environment is associated with the high degree of thermal, chemical, oxidative, and hydrolytic stability which permits capacitor manufacturers to supply to the exacting reliability requirements which exist today.

Dielectric Constant/Dielectric Strengths

These properties are important in determining the size of a capacitor. In a mixed dielectric system, e.g., Paper/Aroclor or Paper/Polypropylene/Aroclor, the dielectric properties of Aroclor permit optimization of stress distribution between the components making up the dielectric layer.

This has enabled capacitor manufacturers to reduce paper and film volumes for a given capacitance. I shall discuss under the heading of "potential substitutes" the impact that this could have on:

a) paper/film availability;
b) design of equipment containing capacitors.

3. Utility in Transformers

Chlorinated biphenyl transformers represent less than 15% of transformers in service. Their use is associated with the need to limit fire hazard in installations.

1. Railroad Transformers

   Multiple unit cars as used in rapid transit systems have transformers mounted beneath each car. By nature of the type of service, involving high passenger density, safety is essential.

2. Urban Power Substations (e.g., Underground Vaults)

   These designs need to take account of city center space limitations and, also, the safety of the public and maintenance crews. Fire resistant liquid transformers are helpful to all these objectives.

3. Industrial Load Centers

   Efficient system designs for large, power intensive, manufacturing plants (e.g., automotive assembly, steel production) often incorporate transformers close to the electrical load centers. The use of Aroclor transformers at these centers, in the heart of the plant, or overhead in roof structures, protects both employees and plant.

4. Transformer/Rectifiers

   Programs to reduce the emission of particulate matter from stack gases, for example in fossil fuel generating plants, include installation of electrostatic precipitators. The transformer/rectifiers energizing the precipitator field must be located close to the electrodes. In many designs, the multiple transformers are located in a penthouse above the precipitator. A fire in the penthouse could lead to close down of the precipator and thus, the generating plant, if pollution control is to be maintained. A fire resistant fluid is of obvious benefit in this application.

In each of these applications, Aroclor protects the system from:

a) An electrical fault within the transformer initiating a transformer fluid fire;
b) Electrical breakdown of the fluid causing emission of flammable gases;
c) Propagation of fire if the transformer liquid content is involved in an external fire.

4. Potential Substitutes in Capacitors

Research Objectives

In seeking potential substitutes, our research objectives, of necessity, related to those properties which gave Aroclor its value. Equally, we recognized the need that an Aroclor replacement should eliminate environmental concerns.

Desirably, a replacement should operate across the full range of current Aroclor capacitor applications while requiring minimum changes in design of capacitors and equipment utilizing capacitors.

The use of chlorinated biphenyl is worldwide. Monsanto manufactures chlorinated biphenyls both in America and Great Britain. We supply to the capacitor industry of many countries. We sought potential replacement product that could be made available with the consistent quality control applied to Aroclor on a worldwide basis.

We referred earlier to availability of co-dielectric components in capacitors. A solution which required substantial changes in availability of polypropylene film (quantity or quality) or a major increase in short-term availability of capacitor paper, we considered unsatisfactory. If in 1974, such increased quantities had been required, they would not have been available. Capacitor production would have fallen short of demand, further jeopardizing efficient power supply.

Our research objectives can be broadly summarized in the following Table 1.

POTENTIAL SUBSTITUTES

CAPACITORS

RESEARCH OBJECTIVES

1. MATCH OR EXCEED AROCLOR 1016 CAPABILITY.

   A) DIELECTRIC CONSTANT - AVAILABILITY
   DIELECTRIC STRENGTH CONVERTABILITY

   B) STABILITY - RELIABILITY
   POWER FACTOR

   C) SAFETY - FIRE RESISTANCE

2. GOOD ENVIRONMENTAL COMPATIBILITY.

3. A) SPAN EXISTING APPLICATIONS - COMPLETE SOLUTION.

   B) INTERNATIONALLY AVAILABLE - NOT SOLELY USA SITUATION.

Why discuss this?

MCS 1043

Before I refer to non-PCB fluids, I would like to raise the matter of potential use of dichlorobiphenyl as a capacitor dielectric. MCS 1043 is predominantly dichlorobiphenyl and contains no pentachlorobiphenyl homologs. Its dielectric properties and stability make it an attractive candidate to many capacitor manufacturers. While it is somewhat less fire resistant than Aroclor 1016, it is considerably more fire resistant than some of the other alternates which we will discuss. Its commercialization would require further detailed environmental study and significant plant modification.

One of the key issues for discussion in earlier sessions and in the session tomorrow, devoted to possible controls, is the difference in environmental impact of higher and lower chlorinated biphenyls. This same issue was faced squarely in France when th~~is summer when regulation of chlorinated biphenyls was pub-~~ lish~~ed in the "Journal Officiel", July 26, 1975. A tr~~anslation of ~~the major provisions is attached. (Appendix A~~). The French Ministry of Industry and Research formally recognize a difference between, in U. S. terms, Aroclor 1254 and Aroclor 1016.

If a further modification in isomer content is useful and desirable, it will be difficult to proceed further before agencies, on the basis of their studies of the past 3 years, make some more positive and overt conclusions regarding the difference between existing higher and lower chlorinated homologs.

Non-PCB Candidates

The capacitor industry is currently examining two Monsanto non-PCB (candidate) dielectrics. These contain no chemical biphenyl and are not chlorinated products.

The two fluids are designated:

MCS 1238
MCS 1588.

MONS 047932

Both are based on a single concept. We have used a base liquid with good dielectric strength, but with dielectric constants lower than Aroclor 1016. To these, we have added a limited quantity of a liquid of very high dielectric constant to yield a mixture of equivalent dielectric constant to Aroclor 1016.

Both of these products are blends of synthetic hydrocarbons with a high dielectric constant additive.

Table 2, on the following page, lists some of the properties of MCS 1238 and MCS 1588 compared to Aroclor 1016.

You will observe that we have labelled the line, Corona Inception Voltage/Extinction Voltage, "Industry". These values are more a function of capacitor design than of the liquid, itself. While preliminary industry results demonstrate acceptable results in capacitors, more full scale work is required before definite conclusions can be drawn.

Dielectric constants relate closely to those of Aroclor 1016 over the temperature range of capacitor operation.

Hydrolysis stability is mentioned because of work carried out on earlier candidates based on esters which gave concern because of hydrolysis instability.

Dissipation factors for the fluid and a model capacitor are given to indicate that while the fluid has, inherently, a higher "loss" than Aroclor 1016, this is not pronounced in the final capacitor.

PROPERTY	AROCLOR 1016	MCS 1238	MCS 1588
DK 25°C	5.9	6.0	6.1
100°C	4.85	5.1	5.1
CORONA IV/EV	INDUSTRY	INDUSTRY	INDUSTRY
HYDROLYSIS STABILITY* (NEUTRALIZATION NUMBER)	0.00	0.00	0.00
DISSIPATION FACTOR FLUID TAN δ 60 HZ. 100°C	0.0025	0.05	0.05
DISSIPATION FACTOR MODEL CAPACITOR AT 90°C	0.0032	0.0039	0.0035

*SEE TEXT

Fire Resistance

Neither MCS 1238 or 1588 is fire resistant. This deficiency versus Aroclor 1016 must be closely considered.

Environmental Considerations

The environmental/health evaluation of capacitor replacement fluids must be related to:

a) Exposure - Extent of Human Exposure? How will material enter the environment? In what quantities?

b) Degradation - If some quantity enters the environment, at what rate and through which mechanism will it degrade?

c) Accumulation

d) Toxicity - Occupational Safety
Environmental Compatability

Exposure - We expect to see similar routes and quantities as experienced with Aroclor 1016.

Degradation - Biodegradation has been studied using a semi-continuous activated sludge technique. Forty-eight hour exposure of Aroclor 1254, Aroclor 1016, and MCS 1238 dielectric fluids to activated sludge using a semi-continuous procedure resulted in the following percent biodegradation rates and 95% confidence limits:

Table 3

Material	% Biodegradation	Feed Concentration, ppm
Aroclor 1254	15 ± 38	1
Aroclor 1016	33 ± 14	1
MCS 1238	70 ± 10	3

For the polychlorinated biphenyl (PCB) materials, the level of chlorination appears to be the most significant factor in their relative biodegradability. The rate of biodegradation decreases as the number of chlorine atoms per biphenyl molecule increases. Chromatograms representing samples after exposure to activated sludge show significant alteration in the Aroclor 1016 isomer distribution, but little for Aroclor 1254. Degradation of the non-halogenated fluid, MCS 1238, proceeds much more rapidly than for the halogenated PCB fluids with no evidence of resistant components.

Methodology for this technique is described in Appendix B.

Accumulation

Table 4 (Graph) depicts the results of Rat Tissue Residue Level Studies vs. Time and compares Aroclor 1242, Aroclor 1016, and MCS 1238. (See following page.)

Results of Feeding Study

A fraction of the ingested Aroclor 1242 and Aroclor 1016 was stored in rats' lipid reservoirs. However, most of this residue was depleted after the rats had been on the basal laboratory diet for several weeks. During the course of the feeding study, residues of Aroclor 1016 accumulated more slowly and to a significantly lesser extent than those of Aroclor 1242. During the recovery period these PCB residues decreased to lower values for Aroclor 1016.

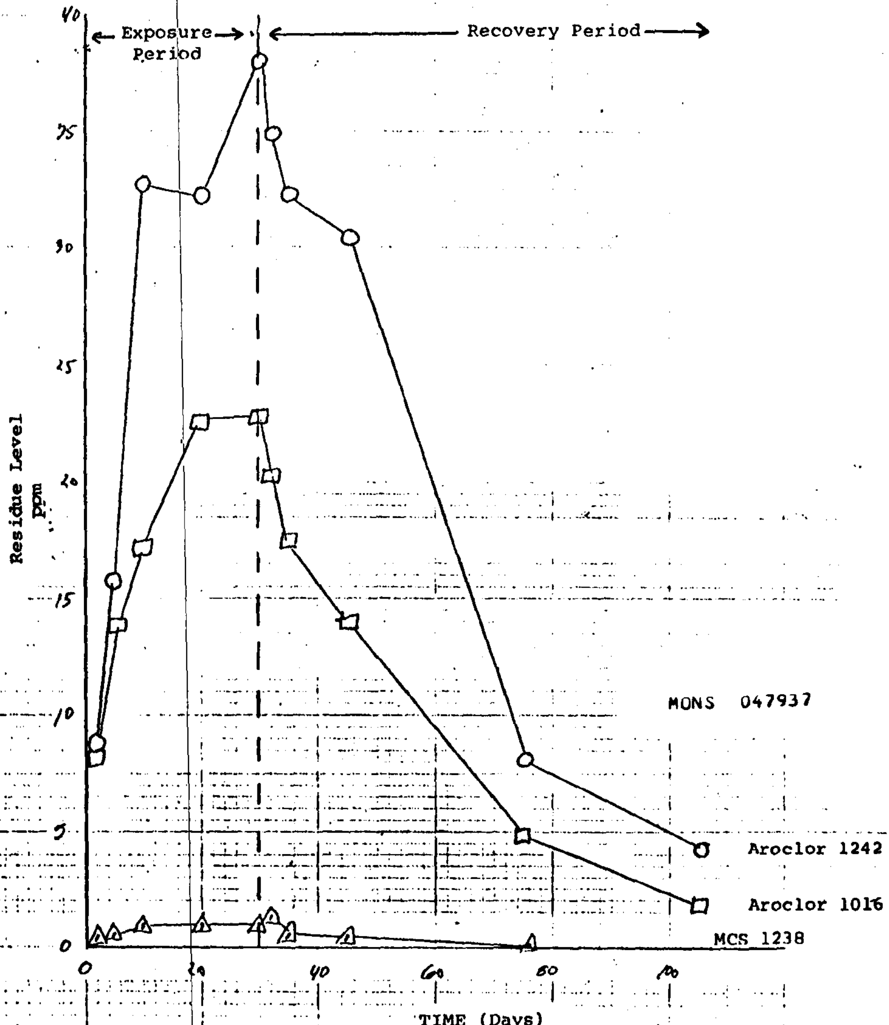
The residue concentrations of MCS 1238 quickly reached a stable level well below the concentration in the feed. The residues did not increase with continued exposure. After feeding of the treated chow was ceased, the MCS 1238 residues were rapidly metabolized and/or excreted.

The tissue residue accumulation and depuration profile of MCS 1238 shown in Table 4 is markedly different than those of the Aroclor fluids, especially that of Aroclor 1242.

Methodology is given in Appendix C

FAT TISSUE RESIDUE LEVEL VERSUS TIME Table 4

25 ppm Feed Level For Rats



MONS 047937

Toxicity

Before samples of MCS 1238 could be evaluated in the capacitor industry and within Monsanto, acute toxicity data was gathered.

1. Rat - Acute single oral dose LD 50 - 3800 mgs./kg.

2. Rabbit - Dermal LD 50 5.0-8.0 gms. per kg.

3. Rabbit - Potential eye irritation - A slight degree of irritation resulted when 0.1 ml. of undiluted MCS 1238 was placed in the conjuctival sac of the rabbit eye. The average maximum score recorded at one and again at 24 hours after treatment was 12.0 on a scale of 110.0. All eyes had regained normal appearance 72 hours after dosing.

4. Rabbit - Potential skin irritation - When undiluted, MCS 1238 was held in continuous 24-hour contact with intact rabbit skin, a moderate degree of irritation resulted. The maximum average score was 3.6 on a scale of 8.0.

   Further programs are in process, or scheduled, to study the following:

   a) Vapor Inhalation
   b) Ultimate Degradation
   c) 90-Day Pilot Feeding Study
   d) Long-Term (2-Year) Feeding Studies
   e) Fish Tissue Residues.

To summarize Monsanto research activities:

1. A large number of single compounds and mixtures have been evaluated in terms of physical property data, environmental compatability, fire resistance, and model capacitor life testing.

2. These have led us to conclude:

   a) Aroclor 1016 may be sufficiently degradable to remain in controlled use.
   b) MCS 1043, a modification of current practice is available longer-term if lower chlorinated materials are more environmentally compatible.
   c) MCS 1238 is a potentially acceptable replacement with the qualification it is not fire resistant.

3. Further programs must be completed with MCS 1238 in order to ~~deepen~~:

   a) Deepen our knowledge of its environmental compatibility.
   b) Permit complete evaluation by the capacitor industry across their range of applications.
   c) Enable utilities, capacitor users, and agencies to evaluate the significance of decreased fire resistance.

As a closing thought to this section, I would like to comment that since 1929 when Aroclor was first developed as a capacitor dielectric, normal commercial pressures have spurred efforts to find superior replacements. The awareness of environmental accumulation of chlorinated biphenyls from other applications added further impetus for more intensive research in the chemical and electrical industries. Aroclor has resisted 45 years of search for a superior replacement.

5. <u>Substitute Transformer Fluids</u>

Neither Monsanto nor any other company, to our knowledge, has developed a transformer dielectric with equivalent fire resistance to that of Aroclor. The difficulties that we face in common with other workers in this field are two-fold:

1. Aroclor has become the subjective standard for fire resistance in transformers because it works and has worked for 45 years. To establish standards to guide research effort, (There is a need for objective evaluation of the fire hazard associated with the major sectors of transformer use.)

2. The chemistry which imparts fire resistance tends also to produce stable molecules. Monsanto seek replacement products that will provide protection against:

   a) Fire from transformer faults under the liquid surface;
   b) Fire from secondary ignition of gaseous arc decomposition products;
   c) Spread of fire if the transformer is involved in an externally initiated fire.

   We have to accomplish this and produce an environmentally compatible product.

We have four candidates which we are currently introducing to the transformer industry. These materials are in a sufficiently early stage of development that it would be premature to give detailed property data at this meeting.

APPENDIX A

OFFICIAL GAZETTE OF THE REPUBLIC OF FRANCE

MINISTRY OF INDUSTRY AND RESEARCH

Entries in the Registers of Poisonous Substances (Section I)

The Minister of Agriculture, Minister of Health and Minister of Industry and Research,

Considering the code of public health, and in particular articles L.626, R.5149 and R.5150;

The Order of 15th November 1951 as amended and supplemented by subsequent orders, specifying the composition of section I of poisonous substances;

and the opinions expressed by the French Supreme Council of Health,

Order :

Art. I - the following products are entered in section I of register C of poisonous substances :

Polychlorobiphenyls (P.C.B.);
Polychloroterphenyls (P.C.T.),

with the exception of those which are contained in the closed systems specified below in conformity with the requirements for make-up, presentation and use laid down by an order made under article R.5168 of the Code of Public Health:

Transformers and industrial electrical equipment such as rectifiers, rheostats, resistances and induction coils:

Condensers;

Heat-carrying systems;

Hydraulic systems.

Art. 2 - the Director of Chemical, Textile and Miscellaneous Industries at the Ministry of Industry and Research, the Director General of Administration and Finance at the Ministry of Agriculture, the Head of the Central Department of Pharmacy and Medicaments at the Ministry of Health are instructed, each for the matters concerning him, to implement this order which will be published in the Official Gazette of the Republic of France.

Made at Paris, 8th July 1975

The Minister of Industry and Research
for and on behalf of the Minister:
Head of Department, Jacques Darmon.

The Minister of Agriculture
for and on behalf of the Minister,
Head of Department Gabriel Vught

The Minister of Health
for and on behalf of the Minister,
Head of Department Dominique le Vert

Does not this position by the Fr. govt support to passage of the Toxic Sub Act

CONDITIONS FOR THE USE OF POLYCHLOROBIPHENYLS

The Minister of Agriculture, Minister of the Quality of Life, the Minister of Health and Minister of Industry and Research, considering the Code of Public Health, and in particular articles L.626, R.519, R.5150 and R.5168;

The Order of 8th July 1975 supplementing register C (Section I) of poisonous substances;

The opinion of the French Supreme Council of Public Health;

The communication dated 23rd July 1974 to the Commission of the European Communities,

ORDER:

Art.1 - the marketing and use of polychlorobiphenyls or mixtures containing polychlorobiphenyls and polychloroterphenyls are subject to the restrictions of the present order.

In the following articles the above-mentioned substances are called "P.C.B." for abbreviation.

Art.2 - the use of PCBs is authorized under the conditions laid down in articles 6 to 8 below in closed systems permitting control of the product and described with restrictive effect below:

1. Transformers and industrial electrical appliances such as rectifiers, rheostats, resistances and induction coils; provided that these systems are planned to permit the recovery of more than 95% of the PCBs contained in them.

2. Condensers not specified in article 3.

3. Heat-carrying systems, save in installations for the treatment of foodstuffs for human or animal food or for the preparation of pharmaceutical or veterinary products, provided that all measures are taken for any escapes which may occur to be fully recovered and not to be dispersed in any way in the environment.

4. Hydraulic systems used in mining plant, excluding those used for any other purpose.

For the systems specified in 3 and 4 above, the provisions laid down will only come into force, so far as installations in operation are concerned, on the expiry of a period of 1 year after the date of publication of this order in the case of heat-carrying circuits and two years after this date of publication in the case of hydraulic systems.

Art.3 - the use of PCB in condensers containing less than 1 kg thereof is authorized, provided that:

The average number of chlorine atoms in the molecule is not more than three;

The total content of pentachlorobiphenyls and more strongly chlorinated homologs is not more than 3.5% in weight.

Waste or manufacturing rejects must be destroyed and any risk of dispersal in the environment must be avoided.

Art.4 - the use of PCBs in installations or for purposes connected with scientific and technical research is authorized provided that no risk results to the environment.

Any new uses which arise from this must be the subject of a new order.

Art.5 - all other uses of PCBs are prohibited, in particular certain applications such as paints for swimming pools, water plant and materials normally in contact with foodstuffs.

Art.6 - the emptying and recovering of PCBs used or contained in unused equipment specified in article 2 is obligatory.

When equipment is no longer used it is the duty of users of PCB or owners of systems specified in article 2 containing it to contact either a manufacturer or importer of PCB of their choice, or the builder, fitter or importer of the system in question, or a body for the treatment of chemical waste which is approved for the treatment of PCBs.

As soon as they are informed of the request and if they do not collect the material themselves, the manufacturer or importer of PCB, the builder, fitter or importer of equipment or the body for the treatment of waste must remind the user or owner of the PCB of the measures to be taken for emptying if possible, package and despatch, and the user or owner must comply with these measures. Condensers will be despatched as they stand.

Manufacturers or importers of PCB, builders, fitters or importers of systems and bodies for the treatment of chemical waste which are approved for the treatment of PCBs, must treat or procure the treatment of the PCBs which they receive with a view to their regeneration or destruction under conditions which must avoid any risk of dispersal in the environment.

The provisions laid down in the third paragraph of this article and the treatment required in the fourth paragraph are subject to approval by the authorities.

Art.7 - the approval of a waste-treatment body for the destruction or regeneration of PCBs is given by a joint order of the Minister in Charge of Industry and the Minister in Charge of the Environment, on sight of an application which is shown to be a proper one with regard to technical and economic factors.

The authorities have a period of three months commencing with the receipt of a file which is judged to be sufficiently complete, in order to decide applications for obtaining approval. In the absence of any reply after the expiry of this period approval is deemed to have been given.

Approval may be partial or subject to any conditions deemed necessary by the authorities. It may not be given for a period of more than five years.

Art.8 - for all uses in closed systems specified in article 2, the importer, builder or fitter must place on the equipment, in a visible location, an indelible inscription on a yellow background of dimensions not less than 50 x 75mm bearing the following statement which may be accompanied by the brand name of the product:

"This equipment contains PCBs which could contaminate the environment and the elimination of which is subject to regulations. If the equipment does not operate properly or is no longer used, you must conform with the provisions of the order of ..."

Art.9 - manufacturers and importers of PCB and the manufacturers, importers or sellers of equipment specified in article 2 must be in a position to supply the authorities with a list of their customers and to facilitate controls to see that articles 6 to 8 are carried out.

Manufacturers and importers of PCB must be in a position to supply on request statistics of the quantities of PCB manufactured, marketed, used or treated.

Art. 10 - the Director of Chemical, Textile and Miscellaneous Industries at the Ministry of Industry and Research, the General Director of Administration and Finance (Department for the Prevention of Fraud and Control of the Quality of Life) at the Ministry of Agriculture the Director for the Prevention of Pollution and Nuisances at the Ministry of the Quality of Life and the Head of the General Department of Pharmacy and Medicaments at the Ministry of Health are instructed, each for the matters concerning him, to carry out the present order which will be published in the Official Gazette of the Republic of France.

MONS 047946

Made at Paris, 8th July 1975.

The Minister of Industry and Research,
for and on behalf of the Minister:
Head of Department, Jacques Darmon

The Minister of Agriculture,
for and on behalf of the Minister:
Head of Department, Gabriel Vucht

The Minister of the Quality of Life,
for and on behalf of the Minister:
Head of Department, Georges Badault

The Minister of Health,
for and on behalf of the Minister:
Head of Department, Dominique Levert.

APPENDIX B

Biodegradation Method

Since activated sludge is one of the most important agents for sewage treatment, test procedures evaluating its action are of great importance.

The semi-continuous activated sludge (SCAS) method has been extensively utilized in the development of biodegradable detergents. In our SCAS procedure, patterned after the Soap and Detergents Associations standard method (1,2) mixed liquor (activated sludge and supernatant) from a local domestic sewage treatment plant is charged to magnetically-stirred glass vessels of 1.5 liter capacity. Means for aeration and sampling are provided. The SCAS unit is generally operated using a retention or aeration time cycle of 24 to 72 hours. At the beginning of each cycle, synthetic sewage (300 mg glucose, 200 mg. nutrient broth, and 130 mg K_2HPO_4) and the appropriate test material in ethanol solution are added to the mixed liquor (2500 mg/liter suspended solids concentration). Aeration is maintained until the end of the cycle, at which time the sludge is settled and one liter of supernatant drummed. The cycle is then re-initiated by the addition of tap water, synthetic sewage, and test material. Operation of the units can be continued for an indefinite period of time until consistent degradation rates are observed.

Sample Analysis

Biodegradation of the test material was determined during one cycle each week by analyzing 20 to 50 ml mixed liquor samples withdrawn after feeding and at the end of the aeration cycle. The mixed liquor analytical procedure involved extraction with three successive 25 ml portions of hexane, and drying combined extracts with anhydrous sodium sulfate. Extracts were concentrated in a Kuderna-Danish evaporative concentrator equipped with a 3-ball Snyder condenser, and measured by electron capture, or flame ionization, gas chromatography. Calibration curves for each product were prepared by plotting detector response (total peak area) versus nanograms of standard injected.

The percent biodegradation was calculated from the following equation: % Biodegradation = $(C_o - C_n)/C_o \times 100$ where C_o and C_n use the initial and final concentration of test material, respectively, on the mixed liquor.

References

1. J. Am. Oil Chem Soc. 42, 986 (1965).

2. J. Am. Oil Chem.Soc. 46, 432 (1969).

APPENDIX C

Methodology for Feeding Study

Feeding and Sampling

Rat chow containing 25 ppm Aroclor 1242, Aroclor 1016, or MCS 1238 was prepared by mixing the products into Ralston Purina rat chow. The treated chow was fed ad libitum to adult albino rats for an exposure period of 30 days. Following the 30-day exposure period, all remaining rats were placed on the basal laboratory diet. At predetermined intervals during the exposure and recovery periods, five rats from each exposed set and a control set were sacrificed. Fat tissue was excised for analysis and composited for each group. Samples were quick-frozen and stored in glass containers with aluminum foil-lined caps to minimize risk of contamination.

Isolation

The dielectric fluid residues were isolated from the fat by solvent extraction. A weighed amount of fat was placed in an Erlenmeyer flask and homogenized three times with 25 ml of pesticide grade hexanes and anhydrous sodium sulfate using an ultrasonic homogenizer. The combined supernatants and washings were filtered through anhydrous sodium sulfate and diluted to 100 ml with hexane.

Lipid Weight Determination

A 5 ml aliquot of the extract solution was pipetted into a tared 50 ml beaker. After evaporation of the solvent under a stream of nitrogen, the beaker and residue were reweighed to obtain the lipid weight of the aliquot. All residue levels are reported as ppm on a lipid weight basis.

PCB Clean-Up and Measurement

Sample clean-up for the extracts containing Aroclor 1242 and Aroclor 1016 residues was accomplished by pipetting an aliquot of the extract onto a 5% deactivated alumina column and eluting with 125 ml of hexanes. The column eluate was collected in a Kuderna-Danish evaporative concentrator, a 3-ball Snyder condenser was attached, and the solution was concentrated to 5 ml. The residue levels in the extracts were measured by gas chromatography using an electron capture detector.

Non-PCB Clean-Up and Measurement

Sample clean-up for the extracts containing MCS 1238 residues required separation of the residues from the lipid by preparative scale gel permeation chromatography. Following the GPC separation, the extracts were further cleaned up on an alumina column, collected, and concentrated as above. The residue levels in these extracts were measured by gas chromatography using a flame ionization detector.

Calculations

Calibration curves for each product were prepared by plotting detector response (total peak area) versus nanograms of standard injected. Residue levels in the samples were determined by summation of the total area of peaks corresponding to peaks in the standard and use of the appropriate calibration curve. The calculations were done as follows:

$$\text{Residue (ppm)} = \frac{(N)(V_F)}{(V_I)(W)},$$

where N = amount of product from calibration curve (ng)
V_F = volume of final concentrate (ml)
V_I = volume injected (ul)
W = lipid weight of original sample (g).

IN 1972 MONSANTO VOLUNTARILY DISCONTINUED SALE OF PCB-CONTAINING PRODUCTS TO THE FOLLOWING MAJOR APPLICATION AREAS:

- -CARBONLESS PAPER
- -FIRE RESISTANT HYDRAULIC FLUIDS
- -HEAT TRANSFER
- -PLASTICIZER

OTHER MISCELLANEOUS MINOR APPLICATIONS
DISCONTINUED AT THE SAME TIME.

SALES IN THESE AREAS FELL FROM
32.5M LBS. IN 1970 TO 0 IN 1973.

IN 1975 WE CONTINUE TO SELL TO THE ELECTRICAL INDUSTRY FOR INCLUSION IN CAPACITORS, TRANSFORMERS AND ASSOCIATED CLOSED ELECTRICAL EQUIPMENT

BECAUSE -

1. UTILITY - THE AROCLOR FLUIDS PERFORM AN ESSENTIAL ROLE IN ELECTRICAL DISTRIBUTION.

2. LACK OF EFFECTIVE PROVEN REPLACEMENT.

3. OUR BELIEF THAT USE IN CLOSED SYSTEMS IS CONTROLLABLE.

MONSANTO CURRENT MARKETING POLICY - PCB

1. SUPPLY ONLY MANUFACTURERS OF SEALED ELECTRICAL EQUIPMENT SUCH AS CAPACITORS/TRANSFORMERS.

2. SUPPLY LOWER CHLORINATED HOMOLOGS FOR CAPACITOR APPLICATIONS, E.G., AROCLOR 1016.

3. DO NOT RECLAIM ELECTRICAL FLUIDS.

4. OFFER INCINERATION SERVICE FOR LIQUID PCB WASTES.

5. CONTINUE RESEARCH PROGRAM (STARTED 1969) TO DEVELOP EFFECTIVE REPLACEMENTS.

6. ENSURE THAT SIGNIFICANT DIFFERENCES BETWEEN AROCLOR DIELECTRICS AND REPLACEMENT CANDIDATES ARE FULLY REVIEWED.

UTILITY IN CAPACITORS

PROPERTY		FUNCTION
FIRE RESISTANCE	→	CONSUMER/PLANT SAFETY
THERMAL STABILITY CHEMICAL STABILITY HYDROLYTIC STABILITY POWER FACTOR	→	RELIABILITY
DIELECTRIC CONSTANT DIELECTRIC STRENGTH	→	AVAILABILITY OF OTHER SYSTEM COMPONENTS CAPACITOR SIZE ECONOMY

UTILITY IN TRANSFORMERS

FIRE RESISTANCE - SAFETY

THERMAL/CHEMICAL STABILITY - RELIABILITY

TRANSFORMER APPLICATIONS

1. RAILROAD TRANSFORMERS - RAPID TRANSIT SYSTEMS.
2. URBAN SUBSTATIONS.
3. INDUSTRIAL LOAD CENTERS.
4. ELECTROSTATIC PRECIPITATORS - POLLUTION CONTROL IN POWER PLANTS.

FIRE RESISTANCE OF ASKAREL TRANSFORMERS

1. FIRE INITIATION.
2. ARC FORMED GASES.
3. FIRE PROPAGATION.

POTENTIAL SUBSTITUTES

CAPACITORS

RESEARCH OBJECTIVES

1. MATCH OR EXCEED AROCLOR 1016 CAPABILITY.

   A) DIELECTRIC CONSTANT - AVAILABILITY
   DIELECTRIC STRENGTH CONVERTABILITY

   B) STABILITY - RELIABILITY
   POWER FACTOR

   C) SAFETY - FIRE RESISTANCE

2. GOOD ENVIRONMENTAL COMPATIBILITY.

3. A) SPAN EXISTING APPLICATIONS - COMPLETE SOLUTION.

   B) INTERNATIONALLY AVAILABLE - NOT SOLELY USA SITUATION.

Out

MCS 1043

1. DICHLOROBIPHENYL TYPE.

2. COULD BE SUBSTITUTED FOR AROCLOR 1016.

3. SLIGHTLY LESS FIRE RESISTANT.

4. FURTHER DEVELOPMENT CONTINGENT ON INDUSTRY/GOVERNMENT/PUBLIC/MONSANTO CONCLUSIONS ON DIFFERENCE IN PCB HOMOLOGUES.

NON-PCB

THE CAPACITOR INDUSTRY IS CURRENTLY EXAMINING

MCS 1238

MCS 1588

1. THESE CONTAIN NO CHLORINATED BIPHENYL.

2. THEY REPRESENT A SINGLE CONCEPT.

3. NEITHER PRODUCT IS CHLORINATED.

THE ADDITION OF A LIMITED QUANTITY OF VERY HIGH DIELECTRIC CONSTANT FLUID TO A GOOD DIELECTRIC BASE LIQUID TO GIVE A DIELECTRIC MIXTURE "EQUIVALENT" ELECTRICALLY TO AROCLOR 1016.

1. MCS 1238 = HYDROCARBON + HIGH DK COMPONENT

2. MCS 1588 = HYDROCARBON + HIGH DK COMPONENT

PROPERTY	AROCLOR 1016	MCS 1238	MCS 1588
DK 25°C	5.9	6.0	6.1
100°C	4.85	5.1	5.1
CORONA IV/EV	INDUSTRY	INDUSTRY	INDUSTRY
HYDROLYSIS STABILITY* (NEUTRALIZATION NUMBER)	0.00	0.00	0.00
DISSIPATION FACTOR FLUID TAN δ 60 HZ. 100°C	0.0025	0.05	0.05
DISSIPATION FACTOR MODEL CAPACITOR AT 90°C	0.0032	0.0039	0.0035

*SEE TEXT

MONSANTO CANDIDATES ARE NOT FIRE RESISTANT.

ENVIRONMENTAL CONSIDERATIONS

EXPOSURE

DEGRADATION

ACCUMULATION

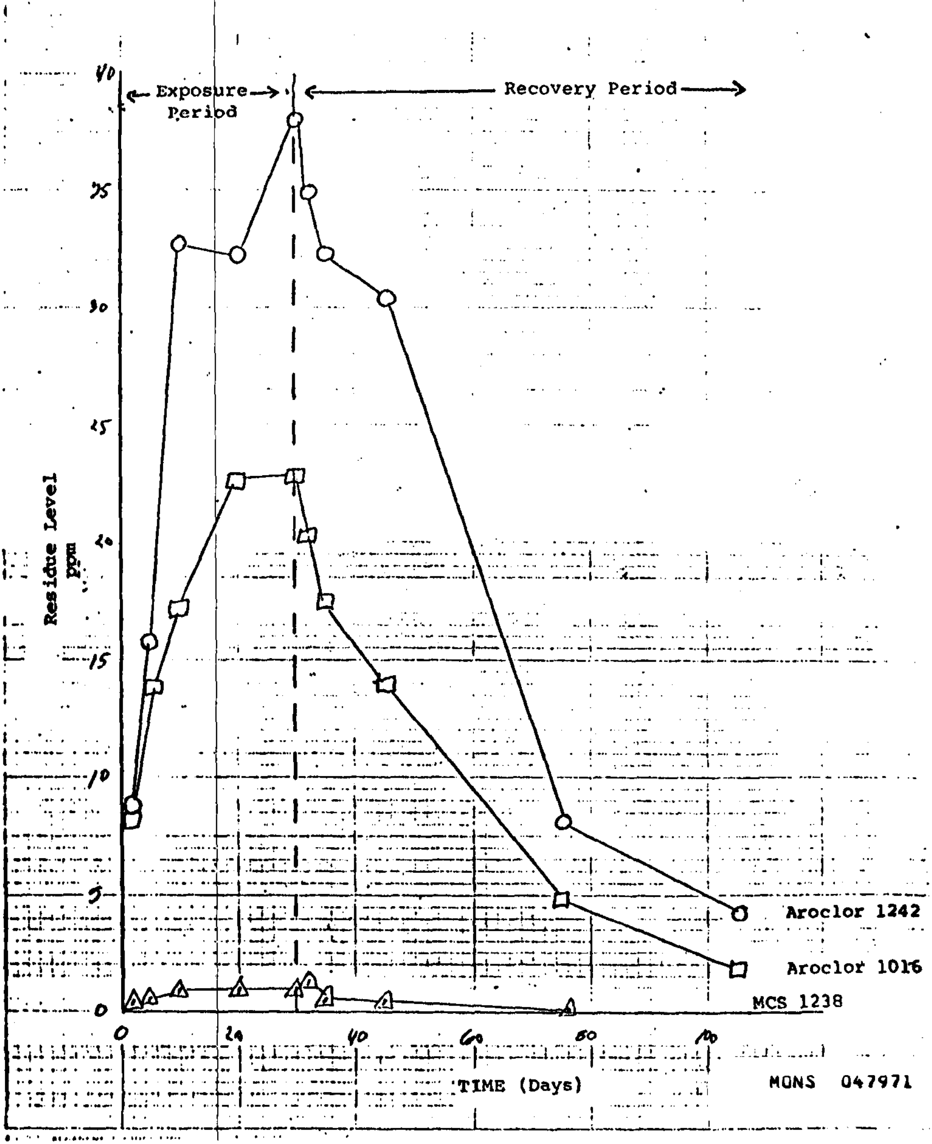
TOXICITY → OCCUPATIONAL SAFETY

TOXICITY → ENVIRONMENTAL COMPABILITY

BIODEGRADATION OF DIELECTRIC FLUIDS

Material	% Biodegradation	Exposure Time
Aroclor 1254	15	48
Aroclor 1016	33	48
MCS 1238	70	48

FAT TISSUE RESIDUE LEVEL VERSUS TIME
25 ppm Feed Level For Rats



MONS 047971

TOXICITY STUDIES - MCS 1238

IN-PLANT HANDLING

1. RATE - ACUTE SINGLE ORAL DOSE LD 50 - 3800 MGS/KG.

2. RABBIT - DERMAL LD 50 - 5.0 - 8.0 GMS PER KILOGRAM.

3. RABBIT - POTENTIAL EYE IRRITATION - 12.0/110.0
NORMAL AFTER 72 HOURS.

4. RABBIT - POTENTIAL SKIN IRRITATION (24 HR. CONTACT) - 3.6/8.0.

MCS 1238 - FURTHER PROGRAMS IN PROCESS OR SCHEDULED

1. VAPOR INHALATION.

2. ULTIMATE DEGRADATION.

3. ARC GASES.

4. PILOT FEEDING STUDY (90 DAY).

5. LONG-TERM (2 YEAR) FEEDING STUDIES.

6. FISH TISSUE RESIDUES.

CAPACITOR REPLACEMENT

STAGE	1	2	3
MONSANTO	SCREEN (ELEC) MULTIPLE FLUID →	A. SELECT B. SCREEN (TOX.) PRELIM.	→ BROADEN ENVIRONMENTAL SCREEN
INDUSTRY			→ MULTIPLE APPLICATION SCREEN
AGENCIES			→ CONSIDER SAFETY ASPECTS

2

TRANSFORMERS

NEITHER WE NOR ANY OTHER COMPANY TO OUR KNOWLEDGE HAS DEVELOPED A TRANSFORMER INSULANT WITH EQUIVALENT FIRE RESISTANCE TO AROCLOR.

A. PROTECTION UNDER TRANSFORMER FAULT CONDITIONS.

B. ARC FORM GASES.

C. POTENTIAL SPREAD OF EXTERNAL FIRE.

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WE DO HAVE CANDIDATES WITH

INTERMEDIATE FIRE RESISTANCE

OUR MAJOR OBSTACLE

ABSENCE OF OBJECTIVE STANDARDS TO

GUIDE

- POTENTIAL FLUID SUPPLIER
- TRANSFORMER PRODUCERS
- TRANSFORMER USERS
- INSURANCE GROUPS
- SAFETY ORGANIZATIONS
- GOVERNMENT AGENCIES

ON REQUIRED LEVEL OF FIRE RESISTANCE.