POST-1966 EVOLUTION OF MONSANTO DIELECTRIC TECHNOLOGY

I. We found that lower chlorinated biphenyls degraded more rapidly than higher chlorinated. Therefore, we:

- A) Substituted Aroclors 1254 (penta) and 1242 (tri) for Aroclors 1260 (hexa) and 1254 in transformers.
- B) Substituted Aroclor 1016 (tri with higher homologs removed) for 1242 in capacitors (10-71).
- C) Produced MCS 1043 (di) and submitted it to G.E. and Westinghouse (6-72).

II. We tried to minimize the amount of PCB needed.

- A) Produced MCS 1489 (Aroclor 1016, sulfone)
  - 1) Requires 10% less paper and foil
  - 2) Diminishes PCB usage by ~20%
  - 3) Permits smaller size for equal rating

III. Developed non-PCB fluids.

- A) Based on sulfone technology
  - 1) MCS 1238 (MIPB, sulfone)
    - a) Sent to G.E. and E.U.C. (6-72)
  - 2) MCS 1475 (S-711, sulfone)
    - a) Sent to G.E. and E.U.C. (6-73)
  - 3) MCS 1588 (Santosol 100, sulfone)
    - a) Sent to G.E. and E.U.C. (3-74)
- B) Alkyl chlorophenyl ethers
- C) Ketones

WHAT DIELECTRIC OILS DO

1) The dielectric strength of a liquid is greater than that of a gas permitting higher voltage rating for a given interelectrode spacing.

2) Corona discharge inception and extinction voltages for liquid impregnated systems are much higher than for unimpregnated ones.

3) The capacitance for a given electrode area and spacing can be greatly increased because liquids have much higher dielectric constants than gases.

4) Better distribution of electrical stress within the composite dielectric system can be achieved by proper choice of dielectric constant of the liquid.

5) Heat transfer is improved.

6) As a result of the preceding factors, capacitors, transformers and cables which give better performance at lower cost can be produced. They use less material, occupy less space, weigh less, and last longer.

AC LIFE TESTS

	Temp °C	Stress V/mil	Time (hrs)	Failures
Aroclor 1016	90	760	3494	None
MCS 1043	90	760	3494	None
MCS 1717	90	760	3494	None
MCS 1719	90	760	3494	None
MCS 1238	90	760	3024	None
MCS 1588	90	760	3024	None
Aroclor 1016	90	850	504	2
MCS 1238	90	850	504	None

MONS 042897

DC LIFE TESTS

	Temp °C	Stress V/mil	Time (hrs.)	Failures
Aroclor 1016	85	1000	336	4
Aroclor 1016 + 0.5% anthraquinone	85	1000	336	2
MCS 1489 + 0.5% anthraquinone	85	1000	336	2
MCS 1588 + 0.5% anthraquinone	85	1000	336	0
MCS 1588 + 0.5% anthraquinone	85	1530	1176	0
MCS 1238 + 0.5% anthraquinone	85	1530	1176	2
MCS 1475	85	1530	1176	1

MONS 042898

FIELD TESTS

MCS 1475	E.U.C. Mallory
MCS 1588	E.U.C.
MCS 1238	G.E. E.U.C.
MCS 1475	Schweitzer Paper (metallized paper capacitors)

TABLE II

PROPERTIES OF AROCLOR TYPE DIELECTRIC FLUIDS

Properties	Aroclor 1016	MCS 1043	MCS 1489
	Data on Fluids		
Sp. G. 25/25°C	1.368	1.246	1.348
DK 25°C	5.9	6.0	8.1
100°C	4.85	5.0	6.5
Tan δ 60 Hz 100°C	0.0025	0.0006	0.05
R_S 100°C x 10^9 Ω cm	150,000	10,000	2,000
Viscosity, cs.			
@ 100°F.	14.3	5.6	21.5
@ 210°F	2.12	1.47	2.54
Flash Point °F.	358°	318°	358°
Fire Point °F	None to BP (620)	None to BP (515)	610°
AIT °F.	1185°	1155°	1125°
Hydrolysis **	0.00	0.00	0.00
	Data on 2 μF Capacitors* Impregnated with Above Fluids		
Capacitance @ 25°C.	1.95	1.99	2.20
Dissipation Factor @ 25°C.	0.0034	0.0037	0.0040
Capacitance @ 90°C.	1.83	1.89	2.07
Dissipation Factor @ 90°C.	0.0032	0.0037	0.0033
Terminal to Case Resist.	240 x 10^9		89 x 10^9

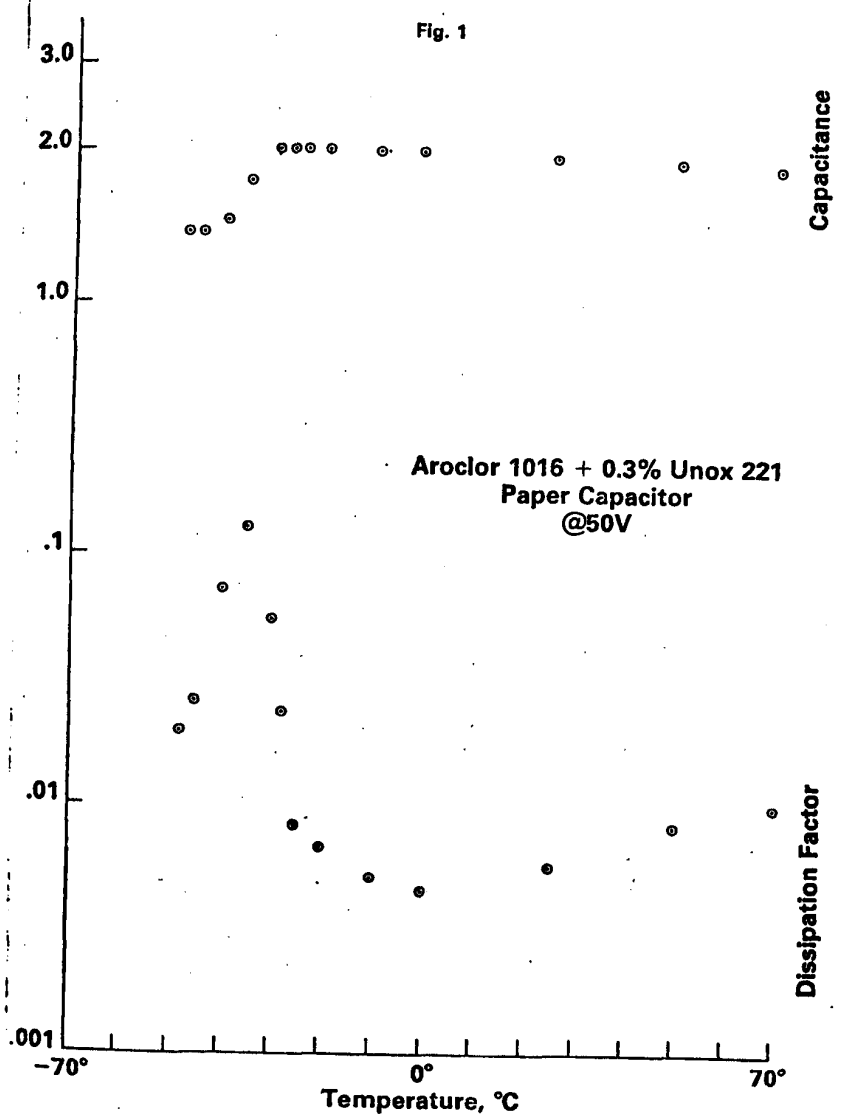
MONS 042900

* Standard 2 μF, 585 VAC Capacitors, 2 layers 0.00066, 0.90 density paper, 0.3% Unox† 4221.

** Neutralization number of sample with 0.5% water added heated for 168 hrs. at 210° in a stainless steel bomb along with an aluminum and a mild steel coupon.

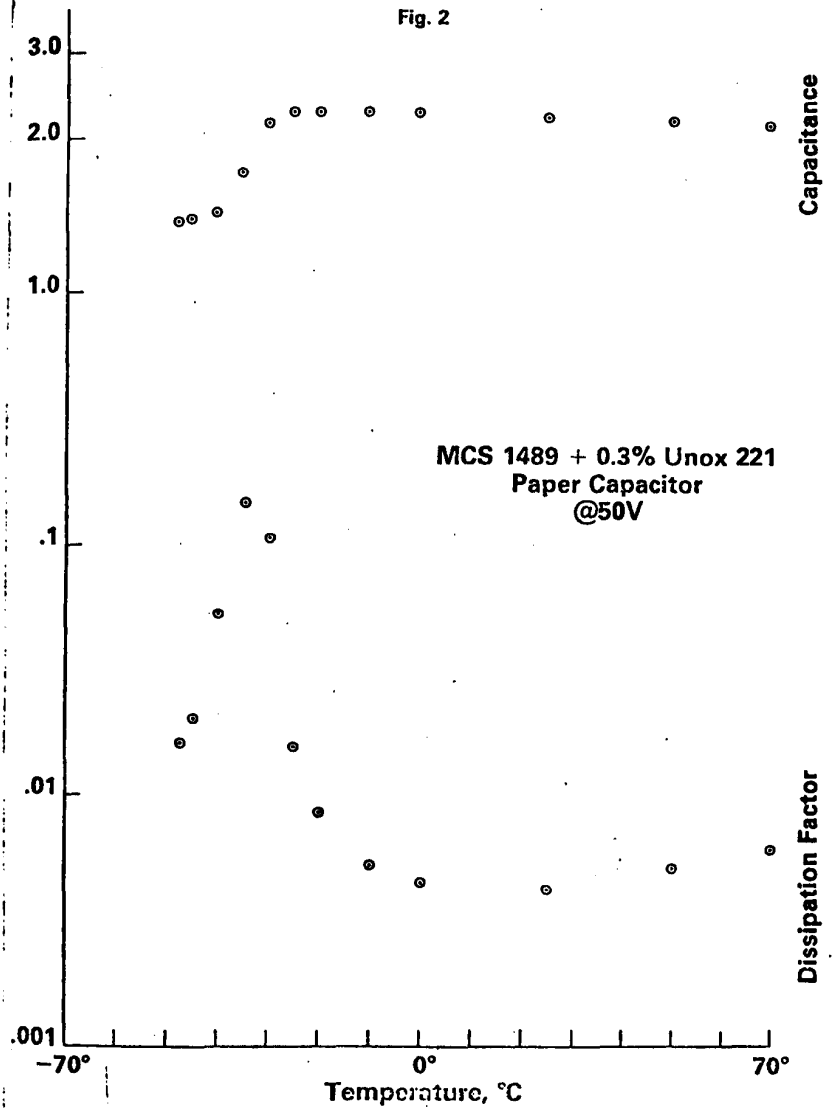
† Registered trademark of Union Carbide Corp.

Fig. 1



MONS 042901

Fig. 2



MONS 042902

TABLE III

PROPERTIES OF ESTER TYPE DIELECTRIC FLUIDS

Properties	DOP	DINP EXXON	MCS 1475
	Data on Fluids		
Sp. G. 25/25°C	0.983		0.988
DK 25°C	5.3	4.6	6.2
100°C	4.3	3.9	5.0
Tan δ 60 Hz 100°C	0.075	0.01	0.022
R_S 100°C x 10^9 Ω cm	211	1900	500
Viscosity, cs.			
@ 100°F.	29.0		26.4
@ 210°F	4.3		4.33
Flash Point °F.	440°	430°	432°
Fire Point °F	-	495°	495°
AIT °F.	-	-	730°
Hydrolysis**	0.11	0.15	0.17
	Data on 2 μF Capacitors* Impregnated with Above Fluids		
Capacitance @ 25°C.	1.85		1.95
Dissipation Factor @ 25°C.	0.0033		0.0034
Capacitance @ 90°C.	-		1.84
Dissipation Factor @ 90°C.	-		0.0032
Terminal to Case Resist.	1 x 10^9		2.6 x 10^9

MONS 042903

*Standard 2 μF, 585 VAC Capacitors, 2 layers 0.00066, 0.90 density paper, 0.3% Unox 4221 added.

**Neutralization number of sample with 0.5% water added heated for 168 hrs. at 210°F in a stainless steel bomb along with an aluminum and a mild steel coupon.

Fig. 3

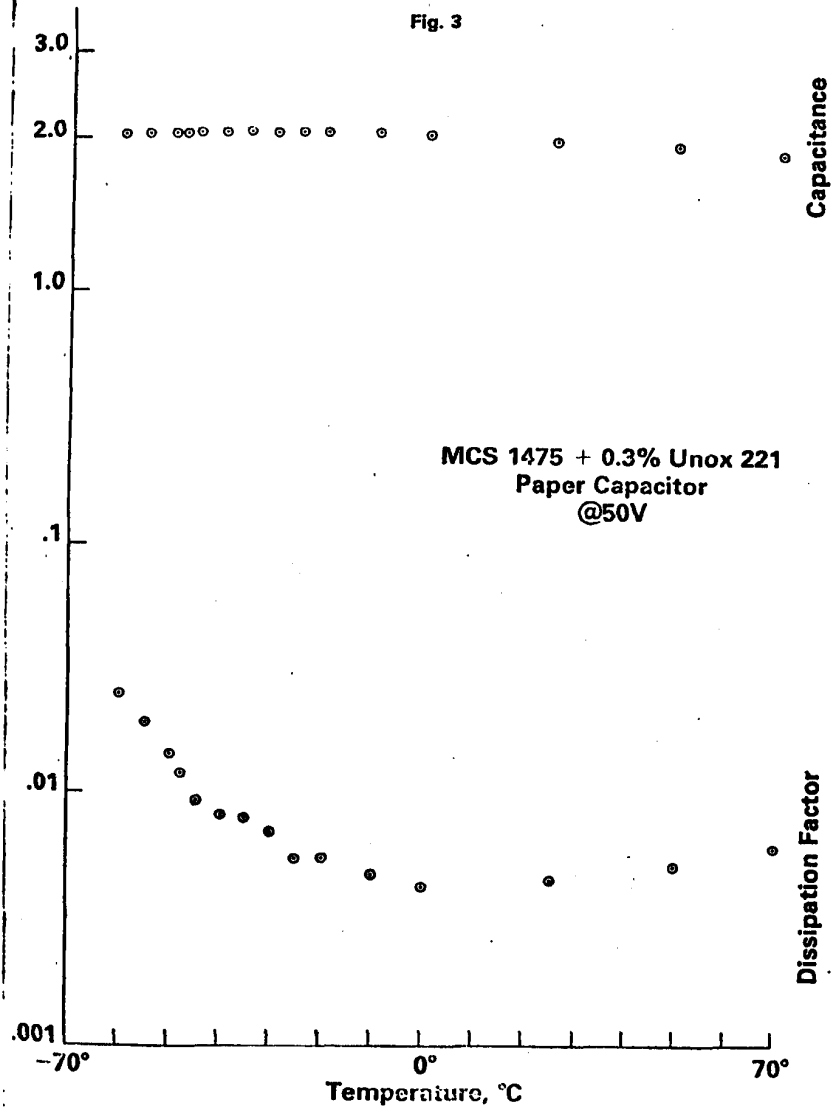

3.0
2.0
1.0
.1
.01
.001
Capacitance
Dissipation Factor
MCS 1475 + 0.3% Unox 221
Paper Capacitor
@50V
-70°
0°
70°
Temperature, °C
MONS 042904

TABLE IV

PROPERTIES OF HYDROCARBON BASE DIELECTRIC FLUIDS

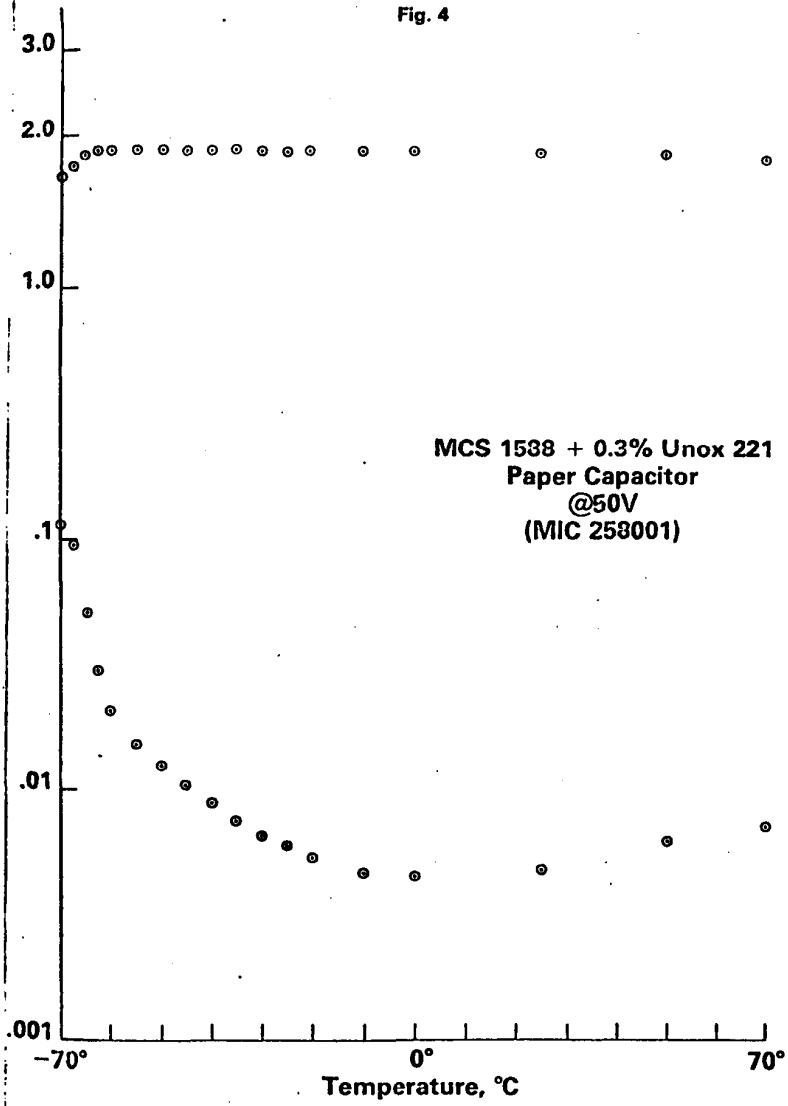
Properties	MCS 1238	MCS 1588
	Data on Fluids	
Sp. G. 25/25°C	1.018	1.030
DK 25°C	6.0	6.1
100°C	5.1	5.1
Tan δ 60 Hz 100°C	0.046	0.1
R_S 100°C x 10^9 Ω cm	1,000	620
Viscosity, cs.		
@ 100°F.	9.1	7.14
@ 210°F	1.98	1.96
Flash Point °F.	303°	325°
Fire Point °F	328°	350°
AIT °F.	835°	870°
Hydrolysis**	0.00	0.00
	Data on 2 μF Capacitors* Impregnated with Above Fluids	
Capacitance @ 25°C.	1.97	1.98
Dissipation Factor @ 25°C.	0.0037	0.00361
Capacitance @ 90°C.	1.87	1.87
Dissipation Factor @ 90°C.	0.0039	0.0035
Terminal to Case Resist.	-	51 x 10^9

MONS 042905

*Standard 2 μF, 585 VAC Capacitors, 2 layers 0.00066, 0.90 density paper, 0.3% Unox added.

**Neutralization number of sample with 0.5% water added heated for 168 hrs. at 210°F in a stainless steel bomb along with an aluminum and a mild steel coupon.

Fig. 4



MONS 042906

PROPERTIES OF DIELECTRIC FLUIDS AND SYSTEMS

	Aroclor 1016	MCS 1043	MCS 1238	MCS 1448	MCS 1475	MCS 1489	DOP	MCS 1588
	Data on Fluids							
Spg. 25°C/25°D	1.368	1.246	1.018	0.969	0.988	1.348	0.983	1.030
DK 25°C	5.9	6.0	6.0	4.7	6.2	8.1	5.3	6.1
100°C	4.85	5.0	5.1	4.0	5.0	6.5	4.3	5.1
Tan δ 60 Hz 100°C	.0025	.0006	.046	.018	.1	.05	.075	.07
R_s 100°C x 10^9 Ω cm	150,000	10,000	1,000	3,075	500	2,000	211	620
Viscosity, cs @ 100°F	14.3	5.6	9.1	23.0	26.4	21.5	29.0	7.14
@ 210°F	2.12	1.47	1.98	4.2	4.33	2.54	4.3	1.96
Flash Point °F	358°	318°	303°	425°	432°	358°	440°	325°
Fire Point °F	None to BP (620)	None to BP (515)	328°	480°	495°	610°	-	350°
AIT °F	1185°	1155°	835°	-	730°	1125°	-	870°
Hydrolysis***	0.00				0.17		0.11	0.00
	Data on 2 μF Capacitors* Impregnated with Above Fluids							
Capacitance @ 25°C	1.95	1.99**	1.97	1.78	1.95	2.20	1.85	1.98
Dissipation Factor @ 25°C	.0034	.0037	.0037	.0032	.0034	.0040	.0033	.00361
Capacitance @ 90°C	1.83	1.89**	1.87	1.67	1.84	2.07	-	1.87
Dissipation Factor @ 90°C	.0032	.0037	.0039	.0028	.0032	.0033	-	.0035
Terminal to Case Resist.	$240x10^9$			$11x10^9$	$2.6x10^9$	$89x10^9$	$1x10^9$	$51x10^9$

* Standard 2 μF, 585 VAC Capacitors, 2 layers 0.00066, 0.90 density paper, 0.3% Unox 221 added.

** Standard 2 μF, 585 VAC Capacitors, 2 layers 0.00066, 0.90 density paper, without 0.3% Unox 221 added.

*** Neutralization number of sample with 0.5% water added heated for 168 hrs. at 210°F in a stainless steel bomb along with an aluminum and a mild steel coupon.

MONS 042907

G.E. CAPACITOR TECHNOLOGY

1) BASIC STRATEGY:

   a) TO BE THE INDUSTRY LEADER.

   b) USE NEW TECHNOLOGY TO ACCOMPLISH THIS.

   c) TO USE MATERIALS MANUFACTURED ON A LARGE SCALE FOR OTHER USES TO GET LOW COST.

   d) TO HAVE MORE THAN ONE SOURCE OF SUPPLY.

   e) TO HAVE PATENT PROTECTION FOR THEIR TECHNOLOGY AND LICENSE IT TO COMPETITORS TO AVOID MONOPOLY CHARGES.

   f) TO USE VERTICAL INTEGRATION WHERE POSSIBLE.

   g) TO AVOID ENVIRONMENTAL AND CUSTOMER LIABILITIES.

   h) TO MAINTAIN A "GOOD" PROFIT MARGIN BY THIS STRATEGY.

OUR STRATEGY AT G.E.

SUPPLY FLUIDS DESIGNED TO FILL THE NEEDS THEY EXPRESS.

ANTICIPATE THEIR NEEDS.

AROCLOR	1016	
MCS	1489	
MCS	1043	
MCS	1717	11% TXS, 89% MCS 1043
MCS	1238	23% TXS, 77% MIPB
MCS	1588	23% TXS, 77% SANTOSOL 100
MCS	1633	22% TXS, 78% H27D4 BOTTOMS
MCS	1719	16% TXS, 84% SANTOSOL 100
MCS	1475	10% TXS, 90% SANTICIZER 711
MCS	1731	3% TXS, 97% SANTICIZER 711

ELECTRICAL PROPERTIES

Property	MCS 1839	72% MCS 1839 28% TCB	MCS 1558	MCS 1767
Dielectric Strength, KV	>50	>50		25
Impulse Strength, KV		>120, <160		
Power Factor, %	0.02	0.11		0.07
Dielectric Constant	2.20	2.56	3.32	2.33
Gassing Tendency, ml/min ASTM D2298	33.3	9.5		90.3

- would like to have no flammable are four gases
- can't do a/c chlorine
- can try to develop hi flash pt homo

MDNS 042910

FIRE RELATED PROPERTIES

Property	MCS 1839	72% MCS 1839 28% TCB	MCS 1558	MCS 1767
Flash Point, COC, °F	520	315	415	480
Fire Point, COC, °F	585	None to b.p.	660	580
Auto Ignition Temp., °F	755	750	1105	750
Oxygen Index	17.2	18.3	28.2	17.4

— competition to Dow - Corning Silicone
- it hydrolyzes
- good compet cost

MONS 042911

PHYSICAL PROPERTIES I

Property	MCS 1839	72% MCS 1839 28% TCB	MCS 1558	MCS 1767
Specific Gravity				
@ -30°C	0.915	1.027		0.914
-15°C	0.904	1.016		0.904
0°C	0.895	1.005		0.894
25°C	0.897	0.987	1.32	0.878
50°C	0.864	0.970		0.862
100°C	0.832	0.933		0.830
150°C	0.800	0.895		0.798
Coefficient of Exp., ml/ml, °C	0.000748	0.000750		0.000750
Viscosity, c.s.				
@ -40°C		19,620		22,820
-30°C		5,119		6,085
-15°C	15,568	1,040		1,191
0°C	3,075	306	130	334
25°C	432	69.5	24.0	72.5
50°C	109	24.4	8.0	25.4
100°C	17.7	6.44	2.2	6.93
150	6.33	2.88	1.1	3.18
Pour Point, °F	-15	-50	-29	-60
Temperature °C at which Vapor Pressure is:				
1 Torr	180	58		259 ext.
10 Torr	250	104		278
100 Torr	302	169		316
760 Torr	358	248		360

MONS 042912

PHYSICAL PROPERTIES II

Property	MCS 1839	72% MCS 1839 28% TCB	MCS 1558	MCS 1767
Specific Heat, BTU/lb.				
@ 25°F	0.472	0.412		0.465
50°F	0.493	0.430		0.486
100°F	0.536	0.466		0.527
150°F	0.579	0.501		0.567
Thermal Conductivity BTU/ft., hr.				
@ 25°F	0.0862	0.0785		0.0764
50°F	0.0848	0.0771		0.0749
100°F	0.0821	0.0744		0.0718
150°F	0.0793	0.0716		0.0687

MDNS 042913

COMPETITIVE TECHNOLOGY

CAPACITOR FLUIDS

- DOP - G.E.
- DINP - Exxon
- Butylated chlorodiphenyl ether - Dow
- Butylated chlorodiphenyl - Prodelec
- DDB Oil]- Japan

Alternative Technology

- Metallized film, impregnated
- Metallized film, tight wound dry
- Metallized paper
- Single sheet paper

TRANSFORMER FLUIDS

- Oil
- Silicone

Alternative Technology

- Dry type - air insulated
- Vaporizing gas filled

Paul Wright

Biological Chemistry

Environmental Compatibility Assessment

Types of Tests

1. Biodegradation
2. Residue Accumulation
3. Acute Toxicity
4. Subacute Toxicity

Target Organ Response
Teratogenicity
Mutagenicity
Carcinogenicity

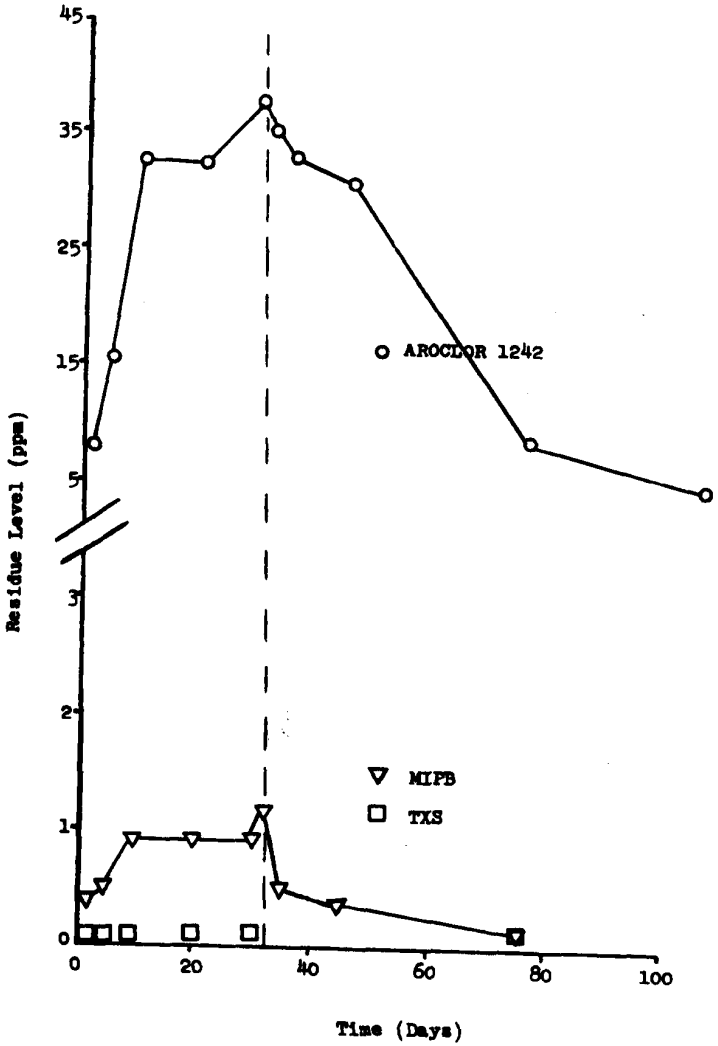
Biodegradation Studies with

MCS 1238 Components and AROCLOR 1254

		SCAS (% lost/24 hrs)	CO_2 Evolution
	AROCLOR 1254	<1	Minimal
MCS 1238	MIPB (MCS 1045)	~75	Complete
MCS 1238	TXS (MCS 1302)	~25	Partial

Tissue Residue Accumulation and Depletion

in Rats Fed 25 ppm



MONS 042917

Acute Toxicity Studies with

MCS 1238 and AROCLOR 1242

Mammalian	MCS 1238	AROCLOR 1242
Oral (g/kg)	4	8
Dermal (g/kg)	5	1
Skin Irritation	moderate	moderate
Eye Irritation	slight	moderate
Aquatic LC_{50} (ppm)		
Bluegill	3	<1*
Trout	2	<1*

Difference not significant

*represents lowest values obtained

Required Program with MCS 1238 Components

1. Biodegradation

   River Die-Away
   $^{14}CO_2$ Evolution

2. Residue Accumulation

   Aquatic Organisms
   ^{14}C Metabolism

3. Subacute Toxicity

   Target Organ MIPB (1000 ppm N.E.)
   TXS
   Teratogenicity
   Mutagenicity
   Carcinogenicity MIPB (10/75-10/77)
   TXS (10/75-10/77)

completion anticipated 7/76 unless indicated.