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TECHNICAL BULLETIN

AROCLOR® PLASTICIZERS

A series of inert, chemically-resistant, fire-retarding plasticizers compatible with wide variety of resins.

TECHNICAL BULLETIN O/PL-306

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TOWOLDMON0030202
WATER_PCB-00014671

AROCLOR®
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PLASTICIZERS Monsanto®

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Organic Chemicals Division / 800 N. Lindbergh Blvd. / St. Louis, Missouri 63166

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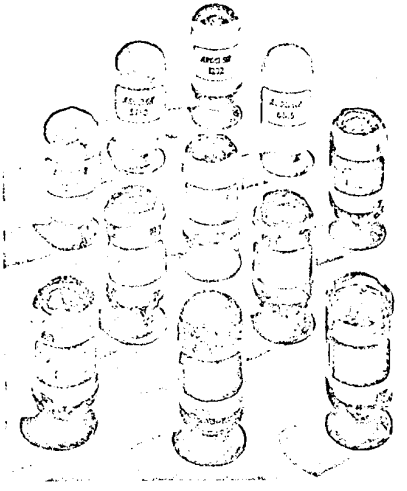

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Introduction

The unique Aroclor® plasticizers are among the most versatile chemically produced materials available. One outstanding characteristic — *inertness* — makes Aroclor useful in many ways for many different applications. The major benefits offered by Aroclor include:

- Chemical Resistance
- Fire Retardance
- Compatibility with most resins
- Nonoxidation
- Adhesivity
- Low Cost

This bulletin describes some of their many important plasticizing and related applications, including numerous suggested starting formulations. Examination of their physical properties, also given in considerable detail, may suggest scores of new uses that could not be performed by any other known material.

Additional information about the Aroclor compounds is available from your nearest Monsanto district sales office in the following technical bulletins:

PL-307.....Monsanto's Plasticizers in Synthetic-Resin Adhesives

PL-311.....Aroclor Plasticizers for Chlorinated Rubber

PL-321.....Aroclor 1221, 1232, 1242 for Polyvinyl Acetate Emulsion Adhesives

PL-327.....Monsanto's Plasticizers in Protective Coatings

PL-331.....Monsanto Modifiers for Polysulfides

CS-14.....Aroclor Fire-Retarding Plasticizers and Modifiers in Epoxy Resins

CS-18.....Aroclor Compounds (performance with waxes)

Description

Monsanto's Aroclor plasticizers comprise a series of chlorinated biphenyls and chlorinated polyphenyls. They vary from mobile, oily liquids to white crystals and hard, transparent resins.

Twelve of the Aroclor plasticizers, each of which represents a series, are discussed in this bulletin. An understanding of the system for designation of each Aroclor should prove useful in the evaluation of the property gradations among them. The last two digits indicate the approximate weight percentage of chlorine in the product, and the first two digits indicate the type of material, as follows:

12 — chlorinated biphenyls

25 — blend of chlorinated biphenyls and chlorinated triphenyls (75:25)

44 — blend of chlorinated biphenyls and chlorinated triphenyls (60:40)

54 — chlorinated triphenyls

For nearly every Aroclor mentioned, a darker, less-pure grade exists, with about the same physical and chemical characteristics, but lower in price.

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Aroclor compounds are nonoxidizing, inert, permanently thermoplastic, of low volatility, non-corrosive to metals, and low cost. Aroclor compounds are not hydrolyzed by water and resist alkalies, acids, and corrosive chemicals. The viscous, more-highly-chlorinated liquids and resins do not support combustion, and they impart fire retardance to other materials.

The crystalline Aroclor compounds are relatively insoluble, but the liquid and resinous compounds are soluble in most of the common organic solvents, thinners, and oils. All Aroclor compounds are insoluble in water and glycerine. Aroclor 5460 is insoluble in lower-molecular-weight alcohols; Aroclor 4465 is only partly soluble in the lower alcohols.

Aroclor compounds plasticize a great many resins without softening them unduly. The Aroclor compounds are unsurpassed for the plasticizing of protective coatings, particularly for use in chemical plants and other facilities that require a tough, chemically resistant surface. Aroclor plasticizers can also be used to flexibilize sealing compounds, adhesives, lacquers, inks, varnishes, free films, fabric coatings, and pigment dispersions. They are also used as components or extenders in elastomers and waxes. The properties of many end products can be improved — yet at reduced overall cost — by the use of an Aroclor as either a primary or a secondary plasticizer.

The properties imparted by Aroclor compounds (and their usefulness in particular applications) vary in regular gradient over the series. Selection of the right Aroclor for a particular use can generally be made by comparison of the properties, by "blending" two or more, and by adjusting the percentages used in the particular mixture in which the Aroclor compounds are formulated.

Monsanto's Plasticizer Council can provide specific formulation guidance that may help you improve your product or lower your processing cost. Processors are invited to ask the nearest Monsanto office for help on special problems.

Compatibility

The Aroclor plasticizers are compatible with most common plastic materials; they are compatible to the extent of practical use with the following:

- Asphalt
- Benzyl Cellulose
- Carnauba Wax
- Cellulose Acetate-Butyrate
- Chlorinated Rubber
- Coumarone-Indene Resins
- Damar Resin
- Ester Gum
- Ethyl Cellulose
- Ethylene/Vinyl Acetate
- Epoxy Resins
- Nitrocellulose
- Paraffin
- Phenolic Resins
- Polyethylene
- Polyester Resins
- Polystyrene Resins
- Polyisobutylene
- Polysulfides
- Polyurethanes
- Polyvinyl Acetate
- Polyvinyl Butyral
- Polyvinyl Chloride
- Polyvinylidene Chloride
- Rosin
- Rubber
- Styrene-Butadiene Copolymers

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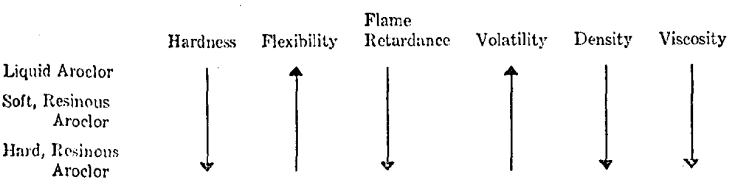
Aroclor plasticizers are not compatible with phenolic resins in the final stage of condensation or with cellulose acetate.

Aroclor plasticizers generally impart progressively increasing properties in the direction of the arrows in the following diagram:



Usually the desired balance between flexibility and hardness can be obtained either by selection of an Aroclor with the appropriate physical characteristics or by use of a blend of two or more Aroclor plasticizers.

In evaluation of formulations that contain Aroclor plasticizers, the compounder should thoroughly test an experimental product for compatibility, heat and light stability, and other properties according to normal industry practices.

Aroclor Plasticizers In Synthetic Resins

Low-cost Aroclor plasticizers are valuable for a variety of applications. They improve chemical resistance, flame retardance, and oxidation resistance. Depending upon the use, the various Aroclor plasticizer offers a number of benefits to the user. In almost all formulations, the use of an Aroclor reduces the over-all cost per pound.

In Polyvinyl Chloride

Aroclor is valuable in polyvinyl chloride and copolymers as a secondary plasticizer or as a plasticizer extender. The Aroclor plasticizers impart flame retardance and chemical resistance.

Selection of the proper Aroclor enables compounders to impart such special properties to their formulations as:

Resistance to migration to nitrocellulose lacquers (Aroclor 1260 and 1262).

Fine, uniform cell structure in vinyl foam (Aroclor 1262 and 1268).

Adhesion in vinyl coatings (Aroclor 1260 and 5460).

Viscosity stability in plastisols (Aroclor 1248 and 1254).

Compatibility

Aroclor plasticizers (except Aroclor 1268) are compatible to about 25 per cent of the total plasticizer content in polyvinyl chloride and usually somewhat greater in copolymer resins. At these levels, no exudation occurs in the loop-compatibility test, one of the most severe used by the industry.

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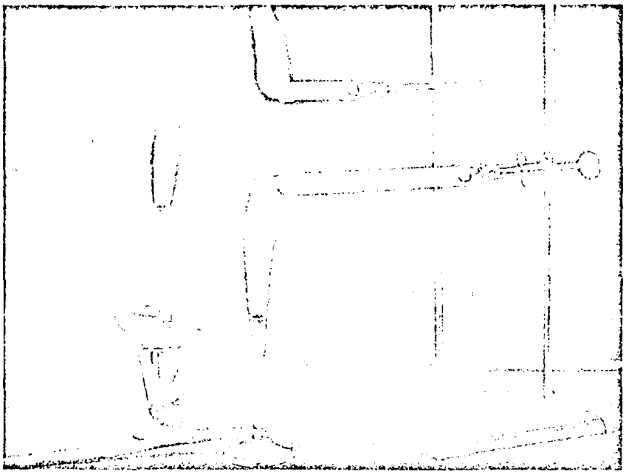

The control specimen burns rapidly; the one containing Aroclor® does not even ignite.

Performance

As an illustration of the performance of Aroclor plasticizers, Table 1 shows evaluation of the five most commonly used in polyvinyl chloride.

TABLE 1

PERFORMANCE EVALUATION OF FIVE AROCLOR® PLASTICIZERS IN POLYVINYL CHLORIDE

Aroclor	Concentration [a] (parts)	Hardness (Shore "A")	Volatility [b] (Plasticizer lost, %)	Kerosene Extraction [c] (Plasticizer lost, %)	Low-Temp Flexibility (Clash & Berg) (T_f, °C)	Tensile Strength (psi)	Modulus (psi)	Elongation (%)
1248	15	87	19	23	−26	2330	1320	342
1254	15	88	14	24	−24	2310	1360	334
1260	15	89	11	32	−22	2200	1330	315
4465	17.5	89	6	19	−19	—	—	—
5442	17.5	87	6	16	−20	—	—	—

Ingredients	*Parts by Weight*
a) Opalon® 600 PVC resin	100
Dioctyl Phthalate	45
Calcium Carbonate	40
Stabilizer	3
Aroclor	indicated

b) 24 hours at 87°C over activated carbon

c) 96 hours at 25°C

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Heat and Light Stability

Aroclor compounds impart good heat stability but somewhat reduce the light stability of vinyl formulations, but no more so than do many other secondary plasticizers commonly used in the industry. Light stability of the system may be improved by incorporation of a small amount of light-screening agent, such as 0.1 per cent *Tinuvin P.**

Chemical Resistance

For imparting resistivity to chemical attack, the Aroclor plasticizers are unsurpassed. Independent evaluations of the chemical resistance of vinyl chloride-vinyl acetate copolymer paint, modified by eight types of materials (alkyd resin, phenolic-chinawood oil varnish, ester gum-linseed oil varnish, Aroclor 1254, dioctyl phthalate, tricresyl phosphate, polymeric plasticizer, and acrylic polymer), showed that Aroclor 1254 has the "best all-around chemical resistance, failing badly only in the gasoline test."

Paints were sprayed onto solvent-cleaned, unprimed, cold-rolled-steel panels, which were then immersed in seven types of solutions until failure. The data in Table 2, excerpted from the November 1955 issue of *Official Digest* of the Federation of Paint and Varnish Production Clubs, compare the chemical resistance imparted by Aroclor 1254 and by dioctyl phthalate.

TABLE 2

COMPARATIVE CHEMICAL RESISTANCE OF PLASTICIZERS IN VINYL CHLORIDE - VINYL ACETATE COPOLYMER PAINT

Plasticizers		*Time to Failure in Corrosive Media*						
Dioctyl Phthalate (%)	*Aroclor® 1254 (%)*	*10% Sodium Hydroxide (days)*	*10% Hydrochloric Acid (hours)*	*Gasoline (days)*	*5% Sodium Hypochlorite (days)*	*10% Acetic Acid (hours)*	*Linseed Oil Fatty Acids (days)*	*1% Tide at 160°F (days)*
10	—	120[a]	92	0.4	4	84	60	21
—	10	120[a]	168[a]	5	13	168[a]	90[a]	22
25	—	60	24	0.4	4	84	27	25
—	25	120[a]	120	0.4	14.5	120	90[a]	22
40	—	60	24	0.4	4	48	22	25
—	50	120[a]	96	0.4	11	100	60	22

a) End of test

In other corrosion-resistance tests of polyvinyl chloride plastisols, containing 70 parts plasticizer per 100 parts resin a formulation that contained 1 part Aroclor 1254 to 3 parts dioctyl phthalate was much more resistant to 15 percent nitric acid at either 23° or 50°C for six months than a compound plasticized with dioctyl phthalate alone.

The plastisol modified with both Aroclor 1254 and dioctyl phthalate was also more resistant to 25 percent chromic oxide at 50°C for four weeks and was equivalent at 23°C for six months in comparison with the dioctyl phthalate-modified vinyl plastisol.

*Trademark of Googy Chemical Co.

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Migration Resistance

The use of Aroclor 1262 as a coplasticizer with dioctyl phthalate greatly enhances the resistance of plasticizer migration to nitrocellulose lacquers and films. Table 3 compares this property for four formulations.

TABLE 3

PLASTICIZER MIGRATION TO NITROCELLULOSE LACQUERS AND FILMS

Plasticizer[a]	*Aroclor® and DOP (parts)*	*Control DOP (parts)*	*Aroclor, DOP, and Polymeric (parts)*	*Polymeric and DOP (parts)*
Dioctyl Phthalate	66	71	36	38
Polymeric Plasticizer	—	—	33	35
Aroclor 1262	20	—	20	—
Hardness, Shore "A"	72	72	72	73
Time (weeks) Room Temperature				
1	No Change	No Change	No Change	Slight Marking
2	No Change	No Change	No Change	Slight Marking
3	No Change	No Change	Very Slight Marking	Slight Marking
4	No Change	No Change	Very Slight Marking	Slight Marking
5	No Change	No Change	Very Slight Marking	Slight Marking
10	No Change	No Change	Very Slight Marking	Slight Marking
50° C				
1	No Change	Slight Marking	Moderate Marking	Very Slight Softening
2	No Change	Slight Marking	Severe Marking	Very Slight Softening
3	No Change	Slight Marking	Very Slight Softening	Slight Softening
4	No Change	Moderate Marking	Slight Softening	Slight Softening
5	No Change	Moderate Marking	Slight Softening	Slight Softening
10	No Change	Moderate Marking	Slight Softening	Moderate Softening
General Motors Lacquer Test (150°F; 72 hr.; ½-psi load)	Indentation, Very Slight Softening	Extreme Softening	Lifting	Extreme Softening

a) Formulation

Ingredients	*Parts by Weight*
Opalon® 660 PVC Resin	100
Epoxy Soybean Oil	3
Barium-Cadmium Laurate	3
Calcium Carbonate	25
Plasticizer	as indicated

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Plastisols

The use of an Aroclor as a coplasticizer with dioctyl phthalate in polyvinyl chloride plastisols or organosols contributes greatly to the viscosity stability of these materials, especially at elevated temperatures. This benefit is especially important whenever shelf stability is required. Although the initial viscosity of the plastisol or organosol is increased by the use of an Aroclor in the formulation, the viscosity reduction upon temperature elevation (before the fusion temperature is reached) is much greater than when most other plasticizers are used.

A comparison of the viscosity stability of plastisol formulations with and without Aroclor is given in Table 4.

TABLE 4

VISCOSITY STABILITY OF PLASTISOLS

	Dioctyl Phthalate (80 phr) Viscosity[a] (poises)	*Aroclor® 1254 (20 phr) Dioctyl Phthalate (60 phr) Viscosity[a] (poises)*	*Aroclor 5460 (20 phr) Dioctyl Phthalate (60 phr) Viscosity[a] (poises)*
25°C			
Initial	36	49	92
1 Day	65	63	154
1 Week	97	78	161
2 Weeks	116	75	178
4 Weeks	132	148	252
40°C			
Initial	37	48	68
1 Day	84	98	136
1 Week	215	108	139
2 Weeks	305	110	164
4 Weeks	426	209	274
50°C			
Initial	66	94	100
1 Day	gel	660	470
1 Week		980	980
2 Weeks		gel	gel
4 Weeks			

a) Brookfield LVF viscometer, No. 4 spindle, 12 rpm

Dipping Plastisols. The chemical resistance of Aroclor compounds is used to good advantage in chrome-plating-bath coatings and in glove coatings, as illustrated by the following formulation for a clear glove-dipping plastisol:

Ingredients	*Parts by Weight*
Opalon® 440 PVC resin	100
Aroclor® 1254	20
Diisodecyl Phthalate	50
Santicizer® 160	25
HB-40 Secondary Plasticizer	20
Liquid Barium-Cadmium Stabilizer	2
Liquid Chelator-Stabilizer	0.5
Santocel® 54 Silica Aerogel	3

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Sealers. The adhesion-imparting characteristics of Aroclor compounds, their oxidation stability, and their chemical resistance are utilized in the manufacture of automotive sealers, such as the following suggested starting formulations:

Ingredients	*Parts by Weight*
Opalon® 440 PVC resin	96
*Vinylite** VMCH resin	4
Aroclor® 1260	50
Diisodecyl Phthalate	100
Santicizer® 160	28
Calcium Carbonate	125
Epoxy Soybean Oil	5
Dibasic Lead Phosphite	3

Fabric-Coating Vinyl Dispersions. The use of Aroclor plasticizers in organosol or plastisol formulations enables the manufacture of fire-retardant free films and coated fabrics with a high degree of hardness, yet flexibility. The following typical starting formulation for a vinyl organosol to be used for free film or coated fabric illustrates this effect:

Ingredients	*Parts by Weight*
Opalon® 440 PVC resin	100
Dioctyl Phthalate	33
Aroclor® 1254	10
Liquid Barium-Cadmium Stabilizer	2.5
Epoxy Soybean Oil	3
Thinner	20-35
Xylene	15-25

Rigid Plastisols. The viscosity characteristics of the Aroclor plasticizers are utilized in the following formulation for rigid, rotationally-cast objects. The formulation is very viscous when first made up, but when heat is applied, the viscosity decreases so that a smoothly-flowing plastisol is obtained. The finished object has a Shore "D" hardness of 63.

Ingredients	*Parts by Weight*
Opalon® 440 PVC resin	55
*Geon*** 202 PVC resin	45
Aroclor® 1254	35
Santicizer® 141	10
Epoxy Octyl Tallate	5
Liquid Barium-Cadmium Stabilizer	2
Liquid Zinc Stabilizer	0.5
Polyethylene Glycol 400 Monolaurate	1

*Trademark of Union Carbide Corp.
**Trademark of B. F. Goodrich Chemical Co.

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Sealers. The adhesion-imparting characteristics of Aroclor compounds, their oxidation stability, and their chemical resistance are utilized in the manufacture of automotive sealers, such as the following suggested starting formulations:

Ingredients	*Parts by Weight*
Opalon® 440 PVC resin	96
*Vinylite** VMCH resin	4
Aroclor® 1260	50
Diisodecyl Phthalate	100
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Calcium Carbonate	125
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Santicizer® 141	10
Epoxy Octyl Tallate	5
Liquid Barium-Cadmium Stabilizer	2
Liquid Zinc Stabilizer	0.5
Polyethylene Glycol 400 Monolaurate	1

*Trademark of Union Carbide Corp.
**Trademark of B. F. Goodrich Chemical Co.

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Vinyl Foam

Aroclor 1262 and 1268 impart fine, uniform cell structure and flame resistance to chemically-blown vinyl foam, as shown by the following formulations:

Ingredients	*Parts by Weight*		
Opalon® 440 PVC resin	100	100	100
Aroclor® 1262	—	20	—
Aroclor 1268	20	—	10
Dioctyl Pathalate	40	—	—
Diisodecyl Phthalate	—	50	30
Di-(*n*-Octyl, *n*-Decyl) Adipate	—	10	30
Santicizer® 214	—	15	—
Santicizer 409	50	—	—
Butyl Oleate	5	—	—
Liquid Barium-Cadmium Stabilizer	2	3	3
Epoxy Resin	—	2	2
Neutral Calcium Petronate	3.6	3.6	3.6
Calcium Oxide	—	1	1
Sodium Lauryl Sulfate	—	1.6	1.6
*Nitrosan** Chemical blowing agent	10	10	5

Flame-Retardant Floor Tile

The nonflammability of the Aroclor compounds suggests their use in the manufacture of flame-retardant vinyl-asbestos floor tile for military applications. In Table 5 is presented an evaluation of three Aroclor plasticizers in typical vinyl-asbestos-tile formulations. Substitution of antimony oxide for part of the limestone is suggested for still greater fire retardance.

TABLE 5

EVALUATION OF AROCLOR® IN FLAME-RETARDANT, VINYL-ASBESTOS FLOOR TILE

	Control[a] *(parts)*	*Aroclor 1254 (parts)*	*Aroclor 1260 (parts)*	*Aroclor 5460 (parts)*
Santicizer® 160	37	30	36	40
Aroclor® 1254	—	15	—	—
Aroclor 1260	—	—	17	—
Aroclor 5460	—	—	—	20
McBurney Indentation Hardness	7.8	9.6	10.4	11.2
Banbury Time (to reach 260°F, sec.)	90	96	102	115
Time to band on roll mill (sec.)	15	10	10	5
Plasticity	Excellent	Excellent	Excellent	Excellent
Tack	Excellent	Excellent	Excellent	Excellent
Surface	Excellent	Fair	Excellent	Excellent

a/ Formulation

*Trademark of E. I. du Pont de Nemours & Co., Inc.

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Ingredients	*Parts by Weight*
Opalon® 505 PVC Resin	100
Santicizer® 160	As Indicated
Aroclor®	As Indicated
Asbestos	160
Limestone	290
Titanium Dioxide	15
Stabilizer	5

In Polyvinyl Acetate

Aroclor compounds are excellent plasticizers for polyvinyl acetate-emulsion adhesives and hot-melt adhesives. The excellent tack and strong bonding power they impart and their low cost contribute greatly to the performance and profitability of these adhesives.

Emulsion Adhesives

The liquid Aroclors — such as Aroclor 1221, 1232, and 1242 — blend readily by simple stirring with polyvinyl acetate emulsion at up to 11 parts per 100 parts of emulsion. They greatly improve the quick-tack and fiber-tear properties of the adhesive. The performance of Aroclor plasticizers in polyvinyl acetate-emulsion adhesives is compared with that imparted by dibutyl phthalate in Table 6. The following is suggested as a typical starting formulation for a low-cost, quick-tack adhesive:

Ingredients	*Parts by Weight*
Gelva® S-55 PVAc Emulsion	100
Aroclor® 1232	11

TABLE 6

PERFORMANCE OF PLASTICIZERS IN POLYVINYL ACETATE-EMULSION ADHESIVES

	Dibutyl Phthalate (11 phr)	*Aroclor® 1221 (11 phr)*	*Aroclor 1232 (11 phr)*	*Aroclor 1242 (11 phr)*
Hardness (Shore "A")	69	66	86	97
Low-Temperature Flexibility (Clash & Berg, T_f, °C)	−10.2	−5.9	4.0	5.3
Volatility (24 hr., 86°C over activated charcoal) (Plasticizer lost, %)	4.0	4.8	4.3	4.0
Kerosene Extraction (24 hr., 25°C) (Plasticizer lost, %)	4.1	4.5	3.8	4.2
Formulation Viscosity (cp.)				
Initial[a]	2420	2240	2160	—
1 Day	2460	—	—	—
3 Days	—	2200	2060	—
4 Days	2520	—	—	—
5 Days	—	2200	2040	—
7 Days	—	2180	2020	—
10 Days	—	2200	2060	—

a) Initial viscosity of unplasticized emulsion: 1500 centipoises

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When the slight odor of Aroclor is objectionable in an adhesive for certain applications, it can be easily masked, at negligible cost, by the addition of a small amount of Santomask® II.

Hot-Melt Adhesives

Aroclor compounds are widely used as plasticizers in polyvinyl acetate hot-melt adhesives for bookbinding and other applications. Four suggested started formulations for evaluation are as follows:

Ingredient	*Parts by Weight*			
	Application Temperature 165° - 175°C		*Low-Melting*	*Alkali-Dispersable*
Polyvinyl Acetate	95[a]	100[b]	50[b]	38[c]
Opalon® 505 PVC resin	5	—	—	—
Modified Rosin	—	—	25	—
Coumarone-Indene Resin (soft)	—	—	—	28.3
Aroclor® 1254	—	55	12	27
Aroclor 1260	50-75	—	—	—
Dibutyl Phthalate	—	—	13	7
Santicizer® 160 (or dibutyl phthalate)	50-75	30	—	—
Clay	—	25	—	—
Fluxing Resin (Filtros® Resin WW)	—	75	—	—
Acrawax C*	—	—	—	1
Sodium Benzoate	—	—	—	0.76
Viscosity (centipoises)			2000 (120°C) Non-blocking	3500 (175°C) Non-blocking

a) Gelva® V-7
b) Gelva C-3 V-10
c) Gelva C-5 V-16

In Ethylene Vinyl Acetate

The Aroclor products are among the most compatible, effective, and versatile plasticizer/modifiers available for ethylene vinyl acetate. Both the liquid and solid Aroclor plasticizers are highly compatible with ethylene vinyl acetate and other ingredients commonly used in ethylene vinyl acetate, such as paraffin and microcrystalline waxes and other resin modifiers. Aroclor offers special functional properties and reduces formulation costs when used with ethylene vinyl acetate.

Hot-Melt Adhesives

Aroclor in ethylene vinyl acetate hot melts imparts excellent initial tack and high final bond strength. Aroclor is particularly useful in providing versatility of adhesive bond to various substrates such as aluminum foil, cellophane, polyethylene, Mylar** polyester film and paper. Liquid Aroclor, such as Aroclor 1254, provide greater flexibility and lower application viscosities. Solid Aroclor 5460 provides adhesive strength, permanence, and lowers the melt viscosity. Both liquid and solid Aroclor products are exceptionally heat stable, resistant to oxidation, moisture, and chemical attack and are, in general, very inert. Flexibility, specific adhesion, and melt viscosity may be adjusted by varying Aroclor concentration and by selection of solid and/or liquid Aroclor plasticizers.

*Trademark of Chris-Craft Industries.
**Trademark of DuPont Co.

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Pressure-Sensitive Adhesives

Aroclor in ethylene vinyl acetate pressure-sensitive adhesives imparts excellent specific adhesion and tack. Liquid Aroclor, such as Aroclor 1248 or 1254, improve flexibility and adhesion while solid Aroclor 5460 or 5442 impart a high degree of tack and bond strength.

Suggested starting point formulations for evaluation using Aroclor in ethylene vinyl acetate hot-melt and pressure-sensitive adhesives are shown below:

Hot-Melt Adhesive	*Parts by Weight*	*Pressure-Sensitive Adhesive*	*Parts by Weight*
"Elvax"®	40	*"Elvax"* 150	30
Aroclor® 5460	40	Aroclor 5460	40
Microcrystalline Wax	20	Aroclor 1254	50

In Epoxy Resins

The Aroclor plasticizers probably have greater compatibility with epoxy resins than any other available nonreactive plasticizer-modifiers. The excellent chemical resistance, oxidation resistance, and adhesive qualities imparted by the Aroclor compounds reinforce these important beneficial properties of epoxies and thereby help the compounder reduce his formulation costs materially without significant adverse affect on performance.

The lower-molecular-weight, liquid Aroclor plasticizers (such as 1221 and 1232) have maximum plasticizing efficiency and impart the most flexibility to epoxy compounds. The more viscous, resinous Aroclor products have progressively less effect on epoxy flexibility: the high-molecular-weight, solid Aroclor plasticizers (1268, 2565, 4465, 5460, etc.), in fact, tend to reinforce the compound.

The effects of Aroclor 1221 and 1248 on the properties and performance of an epoxy resin are indicated by the data in Table 7.

TABLE 7

EFFECT OF AROCLOR® 1221 AND 1248 ON PROPERTIES OF EPOXY RESINS

Formulation[a]		*Viscosity*[b]		*Physical Properties*			*Physical Property*[c] *After Heat Aging*	
Aroclor 1221	*Aroclor 1248*	*Before Curing Agent*	*After Curing Agent*	*Izod Impact Resistance*	*Clarity (Light Reflected) (%)*	*Hardness Shore "D" (10 sec.)*	*Hardness Shore "D" (10 sec.)*	*Weight Loss (%)*
—	—	12,800 (30 rpm)	7900	0.2	3.0	76	66	0.012
25	—	1650	1200	—	3.0	8	61	2.118
—	25	7700	4300	0.6	3.0	40	88	0.682

[a] Trademark of Du Pont Co.

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Ingredients	*Parts by Weight*
a/ Liquid Epoxy Resin	100
Tetraethylenepentamine	8
Aroclor 1221 or 1248	As indicated
Cure: 30 minutes at 100°C	

b/ Brookfield LVF No. 4 spindle; 60 rpm unless otherwise specified

c/ 24 hours at 80°C in activated charcoal

Development of flame-retardant epoxy resins is of wide-spread interest. Aliphatic amine-cured epoxy-resin formulations are made *self extinguishing* by the use of 20 parts of liquid Aroclor per hundred parts of resin. The incorporation of antimony oxide at 5 phr, with 15 parts of Aroclor per hundred parts of resin, yields *nonburning* formulations (Table 8).

The use of liquid Aroclor in aliphatic amine-cured epoxies also improves flexural strength and compressive-yield strength, has little effect on tensile strength, and slightly lowers heat-distortion temperature and compressive ultimate strength.

The use of solid Aroclor in phthalic anhydride-cured epoxy systems also reduces flammability and, in combination with antimony oxide, produces nonburning formulations. The solid Aroclor products also greatly improve such important properties as compressive strength, flexural strength, compressive-yield strength, and tensile strength, although they slightly lower the heat-distortion temperature (Table 9.)

Extension of epoxy-resin adhesives with Aroclor greatly reduces the formulation cost, with minimum effect on the bonding characteristic of the adhesive or surface coating.

In epoxy-resin protective surface coatings, the use of Aroclor 1254, 1260, or 1262 economically imparts excellent chemical resistance, particularly to acids and alkalies. When resistance to solvents is desired, however, Aroclors should not be used, since they are true plasticizers and do not combine chemically with the epoxy resin. Frequently, about 10 to 15 per cent Aroclor 1260 or 1262 is added to increase the flexibility of the epoxy composition, with minimum effect on the corrosion resistance and adhesion of the film.

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TABLE 8

EFFECT OF AROCLOR® 1242 AND 1260 ON FLAMMABILITY AND PHYSICAL PROPERTIES OF EPOXY RESINS

Formulation[a] Aroclor 1242 (phr)	Aroclor 1260 (phr)	Antimony Oxide (phr)	Hardness (Rockwell "M")	Flammability (ASTM 635-56T) inches burned	Rate (in./min.)	Heat-Distortion Temp. (°C)	Flexural Strength (psi)	Tensile Strength (psi)	Compressive Yield Strength (psi)	Compressive Strength (psi)
—	—	—	104	4	0.82	117.5	20,100	11,400	15,700	43,000
20	—	—	108	2.125	b	79.5	21,800	10,700	17,900	32,500
—	20	—	103	1.125	b	87	23,800	13,000	17,250	32,900
15	—	5	107	0	c	81	22,200	12,800	16,700	32,400
—	15	5	106	0	c	92	22,100	9,800	16,950	38,150

Ingredients	Parts by Weight
a) Liquid Epoxy Resin	100
Diethylenetriamine	13
Aroclor 1242 or 1260	as indicated
Antimony oxide	as indicated
Cure: 10 hours at room temperature, plus 2 hours at 100°C	
b) Self extinguishing	
c) Nonburning	

TABLE 9

EFFECT OF SOLID AROCLOR® ON FLAMMABILITY AND PHYSICAL PROPERTIES OF EPOXY RESINS

Formulation[a] Aroclor 1268 (phr)	Aroclor 5460 (phr)	Antimony Oxide (phr)	Hardness (Rockwell "M")	Flammability (in./min.)	Heat-Distortion Temp. (°C)	Flexural Strength (psi)	Tensile Strength (psi)	Compressive Yield Strength (psi)	Compressive Strength (psi)
—	—	—	113	0.6	143	16,900	11,000	20,900	23,400
20	—	—	112	0.38	128	25,900	13,500	22,300	36,500
—	20	—	113	0.38	135.5	26,300	11,500	21,000	41,700
15	—	5	112	b	134	20,000	11,100	20,500	36,700
—	15	5	111	b	135	19,000	10,200	21,200	40,700

Ingredients	Parts by Weight
a) Liquid Epoxy Resin	100
Phthalic Anhydride	75
DMP-30* catalyst	0.1
Aroclor 1268 or 5460	as indicated
Antimony Oxide	as indicated
Cure: 20 hours at 100°C	
b) Nonburning	

*Trademark of Rohm & Haas Co.

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The highly chlorinated, less-volatile Aroclor compounds such as Aroclor 1260, 4465, and 5460, are very effective and economical fire retardants for polyester resins, and they do not significantly affect the physical properties of the resin.

The Aroclor plasticizers are effectively used in combination with equal amounts of antimony oxide, since the two materials are synergistic: Aroclor imparts self-extinguishing properties to the resin, and antimony oxide reduces afterglow.

Table 10 indicates the degree of flame resistance imparted to a general-purpose polyester resin (with a 35 percent styrene content) by various equal concentrations of antimony oxide and one of these three Aroclor plasticizers.

TABLE 10

FIRE RETARDANCE IMPARTED TO POLYESTER RESINS BY AROCLOR AND ANTIMONY OXIDE

Antimony Oxide and Aroclor®	*2.5%*	*5%*	*7.5%*	*10%*	*15%*
1260	—	semiflammable	semiflammable	self-extinguishing *30 seconds*	self-extinguishing *immediate*
4465	—	flammable	self-extinguishing *5 seconds*	self-extinguishing *5 seconds*	self-extinguishing *immediate*
5460	flammable	self-extinguishing *60 seconds*	—	self-extinguishing *5 seconds*	self-extinguishing *immediate*

a) Formulation

Ingredients	*Weight Percent*
Polyester Resin (general purpose)	62
Styrene	35
Methyl Ethyl Ketone Peroxide (60% in dibutyl phthalate)	2
Cobalt Naphthenate (1% solution)	1
Aroclor and Antimony Oxide	as indicated

Inclusion of an Aroclor increases the flexural strength of the naturally brittle polyester and makes addition of a more expensive plasticizing polyester unnecessary. At a concentration of 10 percent (enough for fire retardancy), none of the Aroclor plasticizers reduced the flexural strength of the cure resin significantly (Table 11), and their effect was comparable to that of a plasticizing polyester. At 20 percent addition, they improved the impact strength, whereas the plasticizing polyester reduced it. The solid Aroclor plasticizers are preferred for fire-resistant surface coatings.

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TABLE 11

EFFECT OF AROCLOR® ON STRENGTH OF FIBER-GLASS-REINFORCED POLYESTER RESINS

Plasticizer	*(%)*	*Flexural Strength (psi)*	*Flexural Modulus (psi)*	*Impact Strength (ft.-lb./in.)*
None	0	47,210	2,190,000	1.73
Plasticizing Polyester	10	43,310	2,000,000	1.64
	20	39,930	1,560,000	1.24
Aroclor® 1260	10	45,600	2,090,000	1.33
	20	33,860	1,690,000	2.04
Aroclor 4465	10	40,740	2,190,000	1.41
	20	33,390	1,290,000	2.48
Aroclor 5460	10	37,400	1,700,000	1.85
	20	35,890	1,550,000	3.06

In Polyethylene

The need to make polyethylene and other polyolefins flame retardant is well recognized. The well-known flame retardancy of the Aroclor products suggests their evaluation for polyolefin applications such as molded products, coatings, and hot-melt adhesives.

Preliminary evaluation of Aroclor 5460 (20 percent) and antimony oxide (10 percent) showed good results in imparting flame retardancy to low-density, noncrystalline polyethylene. Compared to the use of chlorinated aliphatic hydrocarbons, the use of Aroclor greatly improved the heat stability and had considerably less effect on tensile strength, yield, and elongation of the formulation.

In Polystyrene

The Aroclor products are good plasticizers for polystyrene. The lower-molecular-weight Aroclor plasticizers have greater solvating power than the higher-molecular-weight Aroclor products. The gelling rate of various plasticizers in polystyrene resin is shown in Table 12, each plasticizer was added to the polystyrene resin at a concentration of 2 parts plasticizer per part of resin, and the time required for the material to gel was noted.

TABLE 12

GELLING RATE OF PLASTICIZERS IN POLYSTYRENE

Plasticizer (200 phr)	*Time to Gel (min.)*
Aroclor® 1221	*immediate*
Diethyl Phthalate	0.6
Dimethyl Phthalate	0.75
Aroclor 1242	2
Santicizer® 141	3
Santicizer 160	6
Santicizer S-16	18
HB-40®	30

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Aroclor products are useful as plasticizers and flame retardants in polyurethane rubbers, foams, adhesives and coatings. Having extremely low moisture content (50 ppm or less), the Aroclor plasticizers are useful in applications where low moisture is required. Other advantages exhibited by Aroclor in polyurethanes include resistance to oxidation, resistance to alkali and acids, improved adhesion, and low cost. The following formulation illustrates the use of Aroclor 1254 in a polyurethane flocking adhesive:

	Ingredients	*Parts by Weight*
Part A	*Multranil** FLD Urethane Resin	100
	*Mondur** C Isocyanate	5
	Aroclor 1254	20
Part B	*Multranil* FLD	100
	Mondur C	5-10

Part A is applied to the fabric by knife coating and allowed to dry thoroughly. The fabric is then coated with Part B, and the material is flocked immediately.

Protective urethane coatings are unusually well suited for application to concrete and metal. Aroclor 1254 is incorporated to improve adhesion and sealing. The first of the following formulations is the preferred prime coat for concrete storage tanks for gasoline and fuel oils. The second formulation is the base coat for a concrete wood-kiln coating, which remained in perfect condition after two-and-one-half-years' continuous exposure to heat, moisture, and wood distillates. The other two formulations, for primer and intermediate light-metal coating, contain Aroclor 1254 for better adhesion to metal.

Ingredients	*Unsealed-Concrete Prime Coat (parts)*	*High-Temperature Concrete Primer (parts)*	*Light-Metal Coating* *Primer (parts)*	*Intermediate (parts)*
Mondur C	19.0	12.0	21.0	25.1
Multron R-4 Polyester Resin	—	—	2.6	7.2
Multron R-10	10.0	12.0	10.5	7.2
Aroclor® 1254	5.0	2.9	2.7	1.8
Polyvinyl Acetate	0.2	—	0.3	0.3
Polyvinyl Butyral	—	0.4	—	—
Methyl Glycol Acetate	8.7	9.0	—	—
Butyl Acetate	8.7	5.4	8.0	7.5
Ethyl Acetate	8.7	4.0	8.0	7.5
Toluene	8.7	6.9	15.1	14.2
Pigment (colored)	12.5	—	6.7	21.0
Zinc Chromate	—	—	7.9	—
Titanium Dioxide (rutile)	—	15.0	—	—
Talc (micronized)	12.5	13.9	13.2	5.5

*Multranil and Mondur: Mobay Chemical Company Trademarks.

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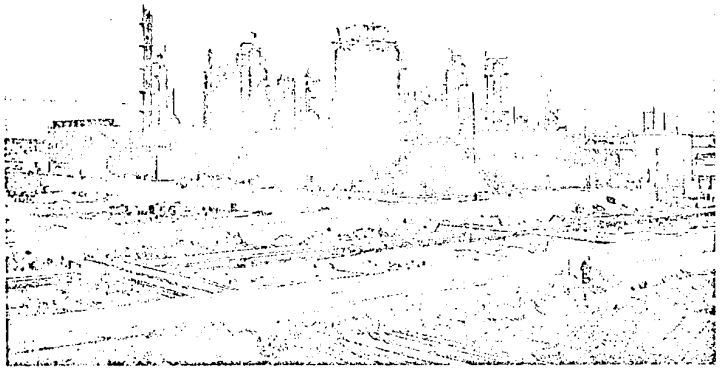
In Phenolic Resins

Considerable interest has been shown in the use of Aroclor plasticizers to make phenolic laminating resins flame retardant. The higher-molecular-weight Aroclor products (1262 and 5460) are usually evaluated for this purpose.

Aroclor 1268 and 2565 are useful in the manufacture of brake linings.



Chlorinated rubber primer and topcoat, plasticized with Aroclor® offer excellent resistance to outdoor weathering, high humidity, steam and condensed acid vapors.

Aroclor In Rubbers

In Chlorinated Rubber And Chlorinated Polypropylene

Protective coatings based on chlorinated rubber generally contain Aroclor plasticizers to enhance their chemical resistance (to water, alkali, and acid), corrosion resistance, and electrical insulating properties and to impart flame retardance. When properly pigmented, they are unusually weather resistant. Aroclor compounds strengthen the adhesive grip of chlorinated-rubber lacquers, varnishes, and paints to structural materials and improve the flexibility and life of the coating.

Typical applications include protective and decorative coatings for swimming pools, stucco homes, steel structures, tank cars, and both wood and metal maritime equipment. Their outstanding chemical resistance qualifies these coatings for use in manufacturing plants where chemical attack is prevalent. Aroclor 1254 and 1260 are used in chlorinated-rubber coatings as flexibilizing plasticizers, commonly in combination with Aroclor 5460, which serves as a resin fortifier. A variety of suggested starting formulations based on chlorinated rubber is given in the following table.

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Paints for Alkaline Surfaces

Ingredients	*Fed. Spec. TT-P-31 (parts)*	*Concrete Swimming Pool (parts)*	*Maximum Acid and Alkali Resistance (parts)*	*White Marine Paint (parts)*
*Parlon** (20 cp.) Chlorinated Rubber	18	10.2	18	20
Aroclor® 1254	10	5.1	8	6
Aroclor 1260	--	—	6	--
Aroclor 5460	6	—	—	—
Long-oil, oxidizing, alkyd resin	—	—	—	6
Medium-oil, drying, alkyd resin	—	5.1	—	—
Carbon Black	0.5	—	—	—
Iron Oxide	—	—	18	—
Titanium Dioxide	16	11.4	—	25
Zinc Oxide	2	—	—	—
*Asbestine*** 3X (magnesium silicate)	—	11.7	—	—
*Bentone**** 34 gelling agent	—	1.3	—	—
Epichlorohydrin	—	0.1	0.09	—
Stabilizer	—	—	0.9	—
*Solvesso***** 150	42.75	—	—	—
Solvesso 100	—	9.1	45	—
Turpentine	4.75	—	5	—
Xylene	—	45.7	—	23
Hi-Flash Naphtha	—	—	—	20

Aroclor compounds are also incorporated in chlorinated-rubber formulations used for heat-sealing adhesives, electrical coatings, paper and textile coatings, and printing inks. The following starting formulation is for an acid- and flame-resistant adhesive:

Ingredients	*Parts by Weight*
Chlorinated Rubber (125-cp. type)	20
Aroclor® 1254	6
Aroclor 5460	6
Toluene	68

Chlorinated polypropylene, a new film-forming resin, produces clear, colorless films, appears equal to chlorinated natural rubber in chemical resistance, and is noticeably more heat and light stable. Aroclor is very compatible with the resin and is recommended in the following starting formulations:

Ingredients	*Composition (wt. %)*	
Chlorinated Polypropylene	50.0[a]	55.0[b]
Aroclor® 5460	15.0	15.0
Aroclor 1254	24.0	24.0
Dioctyl Sebacate	4.3	4.3
Epoxy stabilizer	1.7	1.7
Solids, wt. percent in toluene	50.0	50.0

*Trademark of Hercules Inc.
**Trademark of International Talc, Co.
***Trademark of National Lead Company
****Trademark of Standard Oil Company (N. J.)

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	Film Properties	
300°F heat stability		
1 hour	v. sl. yellow	v. sl. yellow
2 hours	v. sl. yellow	sl. yellow
3 hours	sl. yellow	mod. yellow
5 hours	mod. yellow	—
18 hours	black	—
Fade-Ometer stability*		
24 hours	sl. yellow	v. sl. yellow
48 hours	sl. yellow	sl. yellow
96 hours	mod. yellow	sl. yellow
144 hours	mod. yellow	brown
Two-week chemical resistance		
water	excellent	excellent
10% hydrochloric acid	excellent	excellent
1% sodium hydroxide	excellent	excellent

a) Parlon P (10-cp, 20% in toluene) — Hercules Inc.

b) Parlon P (20-cp, 20% in toluene) — Hercules Inc.

c) Lacquers were sprayed on "bonderized" steel panels. Films were 2.5- to 3.0-mils thick after 72-hours' air drying.

In Styrene-Butadiene Copolymers

Aroclor plasticizers are very often incorporated in coatings based on styrene-butadiene copolymers to impart resistance to acids, alkalies, moisture, and corrosive chemicals. These coatings are suited for use on masonry, wood, and metal for such applications as concrete floors; architectural finishes; metal primers and finishes on maritime equipment, structures, and tank cars; baking primers; corrosion-resistant industrial films; and oil- and grease-resistant coatings.

The following suggested formulations for typical applications of styrene-butadiene-copolymer coatings offer excellent performance:

Ingredient	*Clear Vehicle (wt. %)*	*Wall Sealer (lb./100 gal.)*	*Aluminum Enamel (wt. %)*	*Paint (lb.)*	*Traffic Paint (parts)*
Styrene-Butadiene	16.60[a]	123.2[a]	7.40[c]	147[c]	250[c]
Aroclor® 1254	8.39	41.4	6.00	—	120[f]
Aroclor 1260	—	—	—	31	—
Aroclor 5460	9.11	41.4	13.40	—	130
Raw Tung Oil	1.655	—	—	—	—
Hydrogenated Methyl Abietate	—	—	—	8	—
*Troykyd*** ABC	—	—	—	3	—
Lecithin	0.545	—	—	—	—
Soya Lecithin	—	5.9	—	—	—
Petroleum Naphtha	62.70	246.4	—	—	—
Hi-Flash Naphtha	—	—	—	395	—
Mineral Spirits No. 10	—	185.3	33.60	—	340
Toluene	—	—	—	—	340
Xylene	—	—	22.40	—	—

*Trademark of Atlas Electric Devices Co.

**Trademark of Troy Chemical Co.

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Litheponc	—	339.3	—	—	—
Titanium Dioxide	—	59.2	—	179	—
Aluminum Stearate	—	5.9	—	—	—
Aluminum Paste	—	—	8.55	—	—
Zinc Oxide	—	—	—	60	—
Barium Sulfate	—	—	—	90	—
Asbestine 3X (magnesium silicate)	—	75.0	—	—	—
Calcium Carbonate, ground	—	—	—	236	—
Diatomaceous Earth	—	—	—	76	—
Mica	—	—	8.00	30	—

a) Marbon "9200" MV (Trademark of Marbon Chemical Div., Borg-Warner Corp.)

b) Pliolite S-5A (Trademark of Goodyear Tire and Rubber Company)

c) Marbon "9200" LV (Marbon Chemical Div., Borg-Warner Corp.)

d) Flaked *Piccoflex* 120 (Trademark of Pennsylvania Industrial Chemical Corp.)

e) Pliolite S-5B (Goodyear Tire and Rubber Company)

f) or Aroclor 1248

In Synthetic And Natural Rubbers

The liquid Aroclor plasticizers — 1221, 1232, 1242, and 1248 — have a strong plasticizing action on both natural and synthetic rubbers. Solid Aroclor — 1254 and 1260 — imparts permanent tackiness and adhesion to the rubber composition.

Neoprene

Compositions containing up to 40 parts of Aroclor 5460, 2565, 4465, or 1268 in 100 parts of neoprene rubber are extremely fire retardant. About 1.5 parts of Aroclor 1268 per hundred parts of neoprene imparts excellent working qualities at 225° to 325° F for injection moldings. Neoprene modified with Aroclor compounds has proved extremely useful as a wire and cable coating.

Aroclor 5460 imparts plasticization and adhesion to decorative and protective coatings that have been commercially used on rubber products for many years. Suggested starting formulations for a clear, dull coating and for three pigmented coatings are as follows:

	Parts by Weight	
Ingredients	*clear, dull coating*	*base for pigmented coatings*
Aroclor® 5460	3.70	16.00
Neoprene GRN-10	3.50	8.00
Chlorinated rubber (21 cps.)	1.30	—
High-styrene resin	1.00	4.38
Isobutyl methacrylate	0.40	1.75
Toluene	90.10	69.87

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Ingredients	*green coating*	*white (high gloss)*	*white (luster modifier)**
Paste:			
Base	20.0	43.0	29.0
Chromium Oxide	6.4	—	—
Zinc Oxide No. 3	3.6	10.5	—
Titanium Dioxide	—	15.0	—
Aluminum Hydrate	—	—	25.0
Toluene	10.0	31.5	52.0
Ready-to-Use Coating:			
Base	60.0	70.0	*
Paste	40.0	30.0	*

*To modify the luster of the white, high-gloss coating, the selected amount of the modifier composition is incorporated into the high-gloss paste to achieve the desired degree of flatness.

Polybutene

Aroclor plasticizers and *Indopol** polybutenes are blended in various proportions to make permanently tacky coatings for fabric or paper. Insecticides, for example, can be blended into such coatings to make insect traps or barriers on tree trunks for foliage or fruit protection. Such coatings can also be used for tape and sign backing.

Excellent sealing and caulking compounds are made with blends of Aroclor and polybutenes with inorganic fillers, such as:

Ingredient	*Percent*
Whiting	50
Talc	30
Lithopone	10
Asbestos	10

By various combinations of selected Aroclor compounds and polybutenes, a wide range of hardness, viscosity, flow, and bonding characteristics can be produced in durable sealing and caulking compounds.

Specialty mastics, too, are obtained by selective blends of Aroclor plasticizers with polybutenes. They have excellent adhesivity for such uses as automobile-body sealants.

*Trademark of Amoco Chemicals Corp.

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Paper-transparentizing liquids (for making tracing paper, window envelopes, and special packaging) can be formulated with Aroclor 5460 and polybutenes. A typical economical formulation is as follows:

Ingredient	*Percent*
Aroclor® 5460	30
Polybutene (*Indopol* H-300)	25
Toluene	45

Butadiene-Acrylonitrile Rubber

The Aroclor plasticizers — particularly Aroclor 5460 — are useful as softeners for Buna N rubber.

Silicone Rubber

Aroclor is a very effective flame retardant for silicone rubbers.

Crepe Rubber (Natural)

Aroclor 1262 is used as a low-cost plasticizer for crepe rubber in paint compositions. In concentrations of from 5 to 50 per cent of the weight of the rubber, the Aroclor increases the films alkali resistance, and adhesivity to steel.

Polysulfide Rubber

Aroclor plasticizers are widely used to flexibilize, improve the bonding strength, increase the chemical resistance, and reduce the cost of *Thiokol** polysulfide liquid rubbers. Among the many uses of polysulfide formulations are joint-sealant compounds used in construction, solvent-resistant gaskets, adhesives for concrete, potting and encapsulation, protective coatings, and binders.

Although the Aroclor plasticizers are highly compatible with polysulfide rubbers — up to 100 phr — the concentration to be used depends on the handling and performance properties required in the finished compounds. Suggested concentrations of Aroclor range from about 15 phr for sealant compounds to about 40 phr for casting formulations.

Liquid Aroclor (such as Aroclor 1248) is used to reduce the viscosity and permit the use of higher filler concentration, whereas the solid Aroclor (such as Aroclor 5460) is useful where low volatility is desired.

The following suggested starting formulations illustrate the use of Aroclor 1232 in a joint sealant compound and of Aroclor 1248 in a polysulfide casting formulation:

*Trademark of Thiokol Chemical Corp.

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Ingredient	*Sealant (parts)*	*Casting Compound (parts)*
Thiokol LP-32 polysulfide	100	—
Thiokol LP-2 polysulfide	—	100
Aroclor® 1232	5-15	—
Aroclor 1248	—	20-40
Calcium Carbonate	20	—
Calcined Clay	20	—
Titanium Dioxide	10	—
Phenolic Resin	5	—
Stearic Acid	1	—
Zinc Sulfide	—	40
Sulfur	0.1	0.1
C-5 Paste[a]	15	15
Property		
Cast sheets, after cure of 7 days at room temperature:		
Tensile strength, psi	150-200	150-200
Elongation, percent	500-700	300-400
Hardness, Shore "A"	30-40	25-35

a) lead peroxide, 50%; dibutyl phthalate, 45%; stearic acid, 5%; passed three times through a tight paint mill.

Aroclor In Cellulosic Resins

In Ethyl Cellulose

Ethyl cellulose formulations plasticized with Aroclor are used as protective lacquers, adhesives, and strippable coatings. The solids, such as Aroclor 5460, are widely used with ethyl cellulose or cellulose acetate-butyrate resins in hot-melt applications for the protection of tools and metal parts.

The Aroclor plasticizers are highly compatible with ethyl cellulose: the liquid Aroclor imparts flexibility; the solids impart hardness. For example, 75 parts of Aroclor 1242 with 100 parts of ethyl cellulose produces a very flexible, slightly tacky material. Aroclor 5460 at the same concentration yields a very hard, somewhat brittle composition. Hard films that contain Aroclor 4465 are not brittle at ordinary temperatures.

For high-gloss coatings with exceptional weathering qualities to be applied to rigid surfaces, compositions containing equal parts by weight of Aroclor 5460 and ethyl cellulose are suggested. When a more flexible coating is required, a softer Aroclor should replace either all or part of the Aroclor 5460.

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The following five typical formulations indicate the versatility of various Aroclor plasticizers in compounding for widely different types of applications. They are intended as guides to the use of Aroclor compounds with ethyl cellulose.

Ingredients	*Lacquer (parts)*	*White Alkali-Resistant Lacquer (parts)*	*Liquid Adhesive (parts)*	*Strippable Coating (parts)*	*Hot-Melt Adhesive (parts)*
Ethyl Cellulose	50	25	50	49	24
Aroclor® 1254	—	16	—	49	—
Aroclor 1260	50	—	—	—	—
Aroclor 5460	—	76	40	—	7
Dow 276, V-9	—	—	8	—	—
Octylphenol	—	1	2	1	—
Stearic Acid	—	—	—	1	—
Rutile Titanium Oxide	—	50	—	—	—
Epoxy Resin	—	1	—	—	—
Santonox® Anticxidant	—	—	—	—	1
Mineral Oil	—	—	—	—	57
Castor Oil	—	—	—	—	5
Epoxidized Soya Oil	—	—	—	—	3
Paraffin Wax (m.p. 135°F)	—	—	—	—	3

The first four of these formulations may be dissolved in suitable solvents, such as mixtures of about four parts of toluene to one part of butanol, to obtain the desired viscosity.

In Nitrocellulose

In nitrocellulose lacquers, the Aroclor compounds can function either as plasticizers to modify the properties of the film or as resin extenders to add film-forming body. They are highly compatible with nitrocellulose and with other resins and plasticizers commonly used in lacquer formulations. They impart weather resistance, luster, adhesion, and flame retardance. Their excellent electrical characteristics and their ability to retard the passage of moisture and gases through nitrocellulose films make the Aroclor compounds especially valuable in coatings for electric-insulating materials.

The following trilinear diagrams (Figure 1), show the limits of practical compatibility of Aroclor 1254, 1260, and 1262 when used in nitrocellulose lacquers in combination with some other resins or plasticizers. The less viscous Aroclor plasticizers (1242 and 1248) are more compatible than those shown; the more resinous Aroclor (1268, 2565, 4465, 5442, and 5460) is less compatible.

In these trilinear diagrams, compositions represented by any point in an unshaded area produce homogenous nitrocellulose-lacquer films. On the other hand, compositions represented by points in the shaded areas produce impractical (segregated, brittle, or soft) films.

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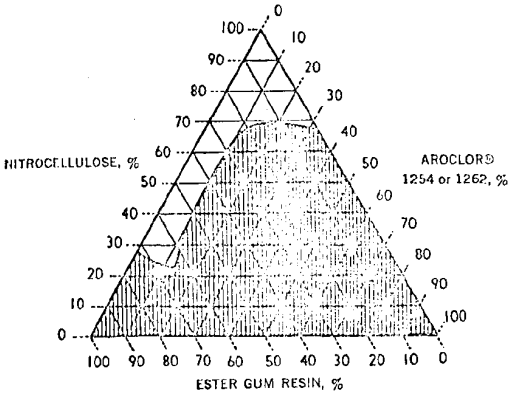
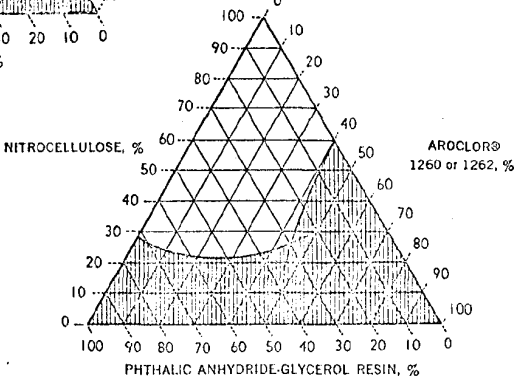
Fig. 1 — Limits of Practical Compatibility of Aroclor® in Nitrocellulose Lacquers





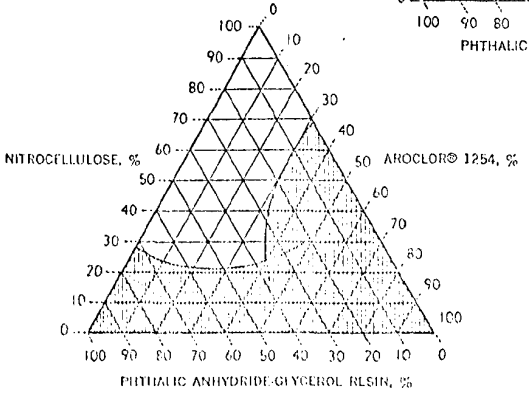


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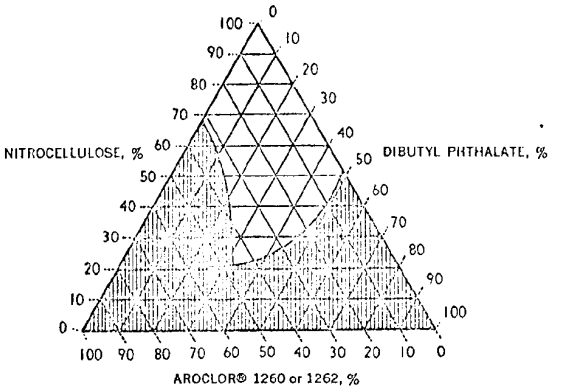
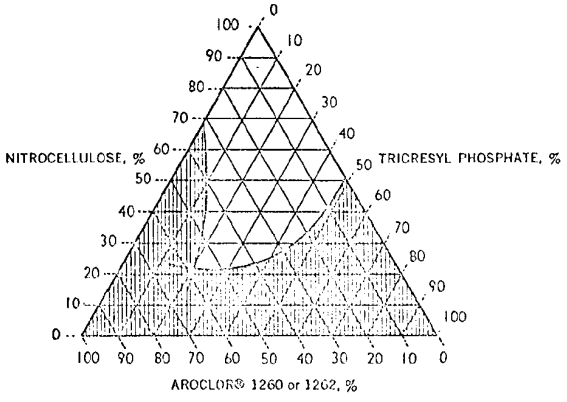
Fig. 1 (Continued)





The following formulations are given to illustrate modifications that can be obtained by variations in composition. They all have excellent durability, but the first two are much harder and less flexible than the third. The first two also have excellent sanding and polishing qualities, but No. 3 is too soft for sanding. The cable lacquer (No. 4) has extremely high flexibility, as required for high-tension automobile cables.

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Ingredient	No. 1 (parts)	No. 2 (parts)	No. 3 (parts)	No. 4 Cable Lacquer (parts)	No. 5 Chrome Lacquer (parts)
Nitrocellulose (¼ sec.) (wet)	—	—	—	—	100
Nitrocellulose (½ sec.) (dry)	100	100	100	—	—
Nitrocellulose (15-20 sec.)	—	—	—	100	—
Aroclor® 1242	—	—	—	80	—
Aroclor 1260	20-39	20	80-70	—	—
Aroclor 5460	—	—	—	—	47
Dibutyl Phthalate	20-0	20	—	—	32.5
Tricresyl Phosphate	—	—	39-70	120	—
Damar Resin	80	—	—	—	—
Ester Gum	—	80	—	—	—

In Cellulose Acetate-Butyrate

The high-chlorine-content Aroclor plasticizers are highly compatible with cellulose acetate-butyrate and are widely used in the manufacture of low-cost, flame-resistant lacquers. Typical uses for these products include paper coatings, lacquers for plastics, strippable coatings for paint booths, and hot-melt adhesives. Typical starting formulations, illustrative of these uses, are suggested as follows:

Ingredients	Paper Lacquers: Low-Cost Flame Resistant (wt. %)	Paper Lacquers: Curl Resistant (wt. %)	Clear Wood Filler (wt. %)	Plastics[a] Lacquer (wt. %)	Paint-Booth Strippable Coating (wt. %)	Hot-Melt Adhesive (wt. %)
Half-Second Cellulose Acetate-Butyrate	20	20	7	6	20	35
Aroclor® 1260	—	20	—	1.5	—	—
Aroclor 1262	15	—	—	—	—	—
Aroclor 5460	—	—	15	—	9	30
Dioctyl Phthalate	—	—	—	—	9	15
Epoxy Soybean oil	—	—	—	—	9.5	—
Acrylic Resin	—	—	—	2.5	—	—
Dow 276, V9	—	—	—	1.5	—	—
Socony Vacuum 200	—	—	—	—	2.5	—
"*Newport* V40"* pine resin	—	—	—	—	—	19.89
Acetone	—	10	—	—	10	—
Methyl Ethyl Ketone	—	—	—	10	—	—
Methyl Isobutyl Ketone	—	—	—	5	—	—
Isobutyl Acetate	5	10	22	—	5	—
Ethanol	12	10	—	33.5	10	—
Butanol	—	—	5	—	—	—
Isobutanol	—	—	—	25	—	—
Toluene	48	30	6	15	25	—
Santonox® Antioxidant	—	—	—	—	—	0.1
Syn Fleur No. 6 odorant	—	—	—	—	—	0.01
Asbestine X (magnesium silicate)	—	—	45	—	—	—

a/ Coatings for cellophane, cellulose acetate, and cellulose acetate-butyrate.

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In Paint And Varnish

Aroclor is soluble in paint and varnish oils and solvents and compatible with most film-forming coating resins. The Aroclor plasticizers improve adhesion to the substrate and impart to the film properties that correspond to the particular character of the Aroclor used: the hard, resinous Aroclor tends to give increased hardness; the viscous Aroclor imparts flexibility.

Aroclor 4465 and 5460 produce paints that are very quick drying and yet have excellent durability. The amount of Aroclor used may be from 30 to 50 percent of the weight of the oils.

Aroclor 1260 is best for short-oil varnishes that are required to be flexible. The Aroclor plasticizers impart water and alkali resistance and also enhance the value of the other resins used in the varnish. A suggested starting formulation is two parts of oil, one part of Aroclor 1260, and one part of other resin. These proportions can be varied as required. The Aroclor may be considered to play the same role in the varnish formulation as oil, except that it does not oxidize and lose its flexibility on exposure.

The Aroclor plasticizers do not react chemically with oils, hence there is no advantage in heating together in making a varnish. They are best added as a "chill back" or as a cold cut in the thinning operation. The only reason to heat the Aroclor is to fluidize it so that it can be more readily mixed with the oils. Alkyd, phenolic, or ester gum resins, with a harder Aroclor such as 5460, may be used in making varnish formulations. To illustrate the use of Aroclor plasticizers in alkyd resins the following suggested starting formulation is shown.

Ingredients	*Parts by Weight*
Alkyd (60% Nonvolatile)	81
Kettle Bodied Linseed Oil (Gardner-Holdt Visc. Z-2)	20
Raw Linseed Oil	35
Aroclor 5460	34
Titanium Dioxide (Rutile)	34
Titanium Dioxide (Anatase)	67
Magnesium Silicate	100
Mineral Spirits	38
Drier-Absorption Agent	1.3
Penyl Mercury Naphthenate (10% Mercury)	2.7
Cobalt Naphthenate (6% cobalt)	1.5
Lead Naphthenate (24% lead)	3.2
Antiskinning Agent (Volatile type)	0.67

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The following suggested starting formulation for a fire-retardant enamel illustrates use of the flame retardancy of an Aroclor in alkyds:

Ingredients	*Parts by Weight*
38% Phthalic Anhydride-Soya Alkyd	63
Aroclor® 5460 Solution (Aroclor 5460, 53; Hi-Flash Naphtha, 22)	75
Whiting	84
Colloidal Grinding and Dispersing Agent	2.7
Antimony Oxide	42
Titanium Dioxide (Rutile)	33
Grind above ingredients, and thin with:	
38% Phthalic Anhydride-Soya Alkyd	96
Xylene	38
Cobalt Naphthenate (6% cobalt)	1
Manganese Naphthenate (6% manganese)	1
Lead Naphthenate (24% lead)	2.3

Aroclor plasticizers are excellent grinding and dispersion media for pigments used in paints and varnishes. Aroclor 1254 is used to disperse aluminum powder in a paste form that can be incorporated easily into paints and varnishes. The Aroclor imparts excellent leafing qualities, brightness, or luster and does not tarnish the aluminum pigment on aging. Moreover, the composition does not support combustion.

Aroclor is an important ingredient of heat-resistant aluminum paints and enamels that contain silicone resins. For example, the following suggested formulation for a heat-resistant coating can withstand a maximum temperature of 800° F and continuous-service temperature of 400° F. The heat-resistant enamel can withstand temperatures of 900° to 1000° F in such applications as jet-engine components, exhaust manifolds, and incinerators. The heat-resistant paint has excellent resistance to a programmed heat test, including 8 hours at 1200° F, and to salt-water spray after programmed heating to 500°, 600°, and 900° F.

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	Heat-Resistant Coating (lb./100 gal.)	*Heat-Resistant Enamel (lb./100 gal.)*	*Heat-Resistant Paint[a] (lb./100 gal.)*
"Dow Corning 805"® Resin (50% Nonvolatile)	220	—	—
G E Silicone Resin SR-82 (60% in xylene)	—	174.2	93.6
G E Silicone Resin SR-112 (50% in xylene)	—	313.3	—
Styrene-Butadiene (50% in xylene) (*Pliolite* S-5B)	—	—	207.9
Aroclor® 4465 (60% nonvolatile)	332	—	—
60% Aroclor Solution (Aroclor 4465, 36 wt. %) (Aroclor 1262, 24 wt. %) (*Solvesso* 100, 24 wt. %) (Xylene, 16 wt. %)	—	435.6	—
Aroclor 5460 (60% in xylene)	—	—	93.6
Aroclor 1254	—	—	47.8
Aluminum Paste (74% nonvolatile)	384	250.0	240.0
Cobalt Octoate (6% cobalt)	—	4.4	—
Xylene	114	—	140.8
Mineral Spirits	—	—	113.1

a) Meets Spec. TT-P-0028

In Waxes

The Aroclor plasticizers, especially 5460, are compatible with various natural waxes, and are blended with waxes for many uses, including "lost-wax" casting, impregnating compounds, and inexpensive sealers. Waxes formulated with Aroclor are nontacky and stable.

Much of the highest quality precision-casting wax used in the "lost-wax" process is formulated with Aroclor, most frequently 5460, 4465, and 1254. Waxes containing Aroclor are widely used in making dental castings, costume jewelry, and precision-cast aircraft parts.

Usually from one-fourth to one-half the composition consists of Aroclor 5460, which contributes these desirable properties to the formulation: hardness without brittleness, shrinkage resistance, sharp definition, sharp melting point, fire resistance, low volatility, and volatilization without carbonization during final curing.

Excellent impregnating compounds to prevent sticking of furniture drawers, double-hung windows, etc. are made from selected Aroclor plasticizers, such as 5460, and various waxes. Combinations of resinous Aroclor with waxes make excellent and inexpensive sealers for masonry, wood, fiberboard, and paper.

Aroclor imparts moisture and gas resistance, adhesion, alkali and chemical resistance, flame resistance, lubricity, and insulation to impregnants for cloth, paper, wood, and asbestos. They are combined with such materials as waxes, asphalt, tars, sulfur, aluminum stearate, and inorganic pigments so as to provide exactly the physical characteristics required for the specific purpose. Aroclor 1254, 4465, and 5460 are suggested as most applicable.

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Wood is decidedly toughened, hardened, and made more moisture-resistant when impregnated by the vacuum-pressure method with the following mixture:

Ingredients	*Per Cent*
Aroclor® 4465	70
Microcrystalline Wax	20
Sulfur	10

The coating is very resistant to acids and alkalies but can be attacked by aliphatic, aromatic, or chlorinated hydrocarbons. The paintable surface is not appreciably discolored. Various degrees of hardness and adhesion are obtained by variations in the proportions of the ingredients.

Blends of Aroclor 1268 and 1242 have the unusual capability to extend carnauba wax satisfactorily and at an attractive saving in cost:

Ingredients	*Parts by Weight*				
Aroclor® 1268	10	19.6	30	35	35
Aroclor 1242	5	4.9	5	5	5
Carnauba Wax	5	6.8	10	30	50
Ceresin Wax	20	19.6	20	20	10
Paraffin Wax	60	49.0	35	10	—
Characteristics					
Color	Pale Yellow, White	Pale Yellow	Pale Yellow	Pale Cream	Cream
Texture	Smooth, hard, non-tacky	Smooth, hard, non-tacky	Smooth, hard, slightly brittle	Slight surface crystallinity	Smooth; carnauba-ringed surface
Softening point, °C	60	77	73	79	80.5
Melting point, °C	78	79	78	86	88

In Asphalt

Self-extinguishing asphalt formulations for caulking, roof coatings, and sound-deadening coatings are obtained by incorporation of at least 30 percent Aroclor 5460 or other solid, resinous Aroclor.

In Allyl Starch

Substitution of the hydroxy hydrogen atoms of the starch molecule by allyl groups produces allyl starch, which upon polymerization forms stable, cross-linked molecules. A minimum of 20 weight-percent plasticizer is required to make the film flexible. The aroclor plasticizers are highly compatible and very efficient plasticizers for allyl starch.

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Miscellaneous Applications Of Aroclor

With their wide range of physical properties, their inertness, lubricity, and low vapor pressures — Aroclor plasticizers are valuable ingredients in an incredible variety of formulated products. They are compatible with many solvents and oils and most resins. They are virtually non-volatile and permanently thermoplastic; they do not react with other chemicals in the formulation. Finally, their low cost makes their use for special purposes eminently practical and economical.

Dust Prevention And Dust Catching

Aroclor 1254 is a low-cost dedusting agent that "holds down" the dusting of a variety of chemical materials. Since Aroclor 1254 resists both oxidation and combustion, it can even be used to control the dusting of highly reactive compounds. As a typical example, a few tenths of a percent controls the dusting of calcium hypochlorite.

Since Aroclor is non drying and tacky, it makes excellent coatings to capture dust, lint, and other fine, airborne particles. Glass fiber, metal mesh, and other materials used to filter air and gas streams are coated with Aroclor 1260 and 5460.

Vapor Suppression (For Longer Insecticide Kill-Life)

The effective kill-life of expensive chlorinated insecticides is extended as much as ten-fold by the incorporation of equal parts of Aroclor 5460, which acts both as a vapor suppressant and as a sticking agent. Hard surfaces (painted or metallic) sprayed with lindane or benzene hexachloride fortified with Aroclor 5460 remain toxic to flies, ants, roaches, and silverfish for as long as three months, compared with one week for unfortified sprays.

The Aroclor retards the rapid evaporation of the volatile insecticides without adding odor or objectionable residue. Formulation into an insecticide is simple: a solution of the Aroclor in a suitable solvent is merely added and mixed into the other ingredients.

Aroclor 5460 is also recommended for nonerop insect formulations containing chlordane, aldrin, and dieldrin. The other resinous Aroclor products (1254, 1260, 1262, 4465, and 5442), also nonvolatile and sticky or tacky, likewise merit evaluation as insecticide extenders.

Moisture Proofing

In moisture-proof coatings for wood, paper, concrete, or brick, Aroclor is best combined with waxes, especially paraffin or carnauba; oils such as mineral oil or drying oils; or synthetic resins, including modified alkyds, phenolics, chlorinated rubber, polystyrene, styrene-butadiene copolymers, ethyl cellulose, cellulose acetobutyrate, benzyl cellulose, or vinyl resins. The material to be used with the Aroclor should be selected according to the end-use requirements of the specific application.

Some very simple compositions contain only Aroclor and paraffin. One very efficient moisture-proofing compound, consisting of 96 weight percent Aroclor 5460 and 4 percent paraffin (melting point 54°C), has

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an ASTM softening point of about 82°C. A similar compound, based on Aroclor 4465, has a softening point of about 58°C.

Softening point and viscosity when melted are further decreased by the use of mixtures of Aroclor. For example, a composition containing 40 percent Aroclor 1260, 56 percent Aroclor 5460, and 4 percent paraffin, is very soft at room temperature. A higher concentration of paraffin also produces softer compounds.

An excellent melt coating for paper and cloth, made according to the following suggested formulation, may be applied by knife or roller at 350°F, requires no solvent, and provides an extremely flexible coating.

Ingredients	*Percent*
Half-second Cellulose Acetate-Butyrate	50
Dioctyl Phthalate	9.9
Aroclor® 1260	40
Santonox® antioxidant	0.1

Pigment Dispersion

Aroclor 4465 is a useful resin in rotogravure and other printing inks. It is an important ingredient in the following mimeograph ink suitable for use on bond paper:

Ingredients	*Percent*
Aroclor® 4465	40
Lubricating Oil (SUV 1200 @ 100°F)	35
Paraffin Oil (SUV 76 @ 100°F)	20
Carbon Black	4
Oil-Soluble Dye	1

Aroclor 4465 is also used in the preparation of imitation gold leaf. Bronze powder is spread upon a hot coating of Aroclor on one side of a sheet of paper. When the paper treated with Aroclor and bronze powder is placed on the object to be imprinted and a hot die is pressed against it, the Aroclor softens, sticks the bronze to the object, and coats the powder to prevent tarnishing.

Aroclor 1254 and 4465 serve as pigment vehicles for decoration of glass and ceramics. When the decorated object is fired, the Aroclor volatilizes without carbonization and thus avoids discoloration. Aroclor plasticizers are also valuable as grinding and dispersing mediums for pigments used in plastics.

Sealing And Impregnation

The liquid Aroclor plasticizers, 1221 and 1254, because of their low vapor pressures and fire resistance, are excellent sealants. These non-evaporating fluids have good flow at slightly elevated temperatures and are chemically stable at elevated temperatures. These liquid Aroclor products therefore are excellent fluid seals wherever the use of oil would create a fire hazard. In the trough of annealing furnaces, for example, *Aroclor plasticizers are dependable, fire-safe roof sealants.*

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Because of their nonflammability, high resistivity and dielectric strength, and low power factor, the liquid and resinous Aroclor plasticizers are extremely valuable impregnants for many electrical applications. One important use of Aroclor 1200, 4465, and 5460 is in wire and cable coatings and as impregnants for braided cotton-asbestos insulation. Their high purity and excellent electrical resistance make Aroclor 1254, 5460, and 1268 excellent dielectric sealants: to close the pores of carbon resistors, and to seal electrical bushings and terminals.

Aroclor plasticizers are essential components of coatings for flameproofing cotton drill for outer garments and for rendering olive-drab canvas fire-retardant, water-repellent, and rot-proof for tents, tarpaulins, etc., according to the following formulations:

Flameproofing Formula for Cotton Drill

Ingredients	*Parts by Weight*
(A) Urea-formaldehyde resin monomer	9.62
Catalyst for resin	0.40
Water	22.26
(B) Oil-modified alkyd resin	3.89
Aroclor 1254	12.00
Aroclor 5460	14.40
Stoddard solvent	25.15
(C) Antimony oxide, 300 mesh or finer	12.28

Dissolve the solids in the indicated solvents, add the aqueous solution (A) to the hydrocarbon solution (B) with stirring, and then disperse the antimony oxide in the emulsion.

Fire-Retardant, Water-Repellent, Rot-Proof Canvas Coating

Ingredients	*Per Cent*
Modified phenol-formaldehyde resin	4
Aroclor® 1254	16
Aroclor 5460	4
Antimony Oxide	8
Tricresyl Phosphate	1.5
Aluminum Stearate	0.5
Copper Naphthenate (8% copper)	8
Mica, ground	3
Limestone, ground	6
Iron Oxide, yellow	7
Chrome Orange	2
V M & P Naphtha	40

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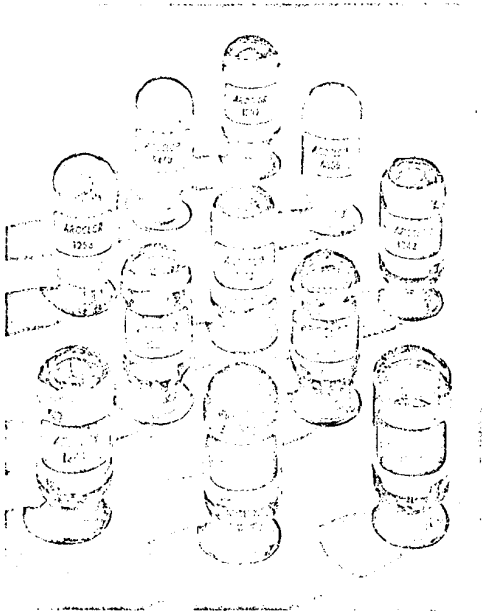
Mobile Liquids Viscous Liquids Soft Resins Brittle Resins



Numerous applications for the Aroclor plasticizers have been suggested and described in the preceding sections of this bulletin. Their success depends on the general inertness of the compounds and on the range and gradation of their physical properties, including physical state, density, viscosity, melting and boiling points, volatility, and solubility. These and other properties, as well as handling and shipping information, are presented in detail in the remainder of the bulletin.

Solubility

The Aroclor liquids and resins are readily soluble in most common organic solvents and drying oils. Although all Aroclor plasticizers are insoluble in water, the hard, crystalline materials are generally less soluble than the liquids and softer resins. Solubilities of some Aroclor plasticizers are shown in Table 13.

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TABLE 13

SOLUBILITIES OF AROCLOR® PLASTICIZERS IN VARIOUS SOLVENTS

Solvent	Aroclor 1242 25°C	Aroclor 1242 Hot	Aroclor 1248 25°C	Aroclor 1248 Hot	Aroclor 1254 25°C	Aroclor 1254 Hot	Aroclor 1268 Cold	Aroclor 1268 Hot	Aroclor 4465 Cold	Aroclor 4465 Hot	Aroclor 5460 25°C
Acid											
Acetic Acid	S	S	—	—	S	S	—	—	SS	S	—
Oleic Acid	S	S	—	—	S	S	—	—	S	VS	—
Benzoic Acid	10.0[37°C]	—	10.0[32°C]	—	—	—	—	—	—	—	—
Aldehyde											
40% Formaldehyde	I	I	I	I	I	I	I	I	I	I	—
Furfural	VS	VS	VS	VS	VS	VS	SS	SS	VS	VS	—
Amine											
Aniline	S	S	—	—	S	S	—	—	VS	VS	—
Pyridine	132.5[20°C]	440[95°C]	—	—	114[31°C]	425[100°C]	—	—	VS	VS	—
Chloro derivatives											
Amyl chlorides — mixed	S	S	S	S	S	S	—	—	VS	VS	—
Carbon Tetrachloride	S	S	S	S	S	S	—	—	VS	VS	156
Chloroform	S	S	S	S	S	S	S	S	VS	VS	—
Dichloroethylene	—	—	—	—	—	—	—	—	VS	VS	—
Ethylene Dichloride	S	S	S	S	S	S	S	S	VS	VS	—
Monochlorobenzene	S	S	S	S	S	S	—	—	VS	VS	—
Orthodichlorobenzene	—	—	—	—	—	—	—	—	VS	VS	—
Tetrachlorethane	S	S	S	S	S	S	—	—	VS	VS	—
Trichlorethene	S	S	S	S	S	S	—	—	VS	VS	—
Trichlorethylene	S	S	S	S	S	S	—	—	VS	VS	—
Drying Oil											
Tung Oil	S	S	S	S	S	S	—	—	VS	VS	—
Linseed Oil	S	S	S	S	S	S	I	S	VS	VS	—
Ester											
Amyl Acetate	S	S	S	S	S	S	S	S	VS	VS	—
Butyl Acetate	S	S	S	S	S	S	S	S	VS	VS	—
"Cellosolve"® Acetate	S	S	S	S	S	S	—	—	VS	VS	—
Cottonseed Oil	S	S	S	S	S	S	—	—	S	VS	—
Dibutyl Phthalate	S	S	S	S	S	S	S	S	S	VS	—

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Diethyl Phthalate	S	S	S	S	S	S	—	—	S	VS	—
Ethyl Acetate	S	S	S	S	S	S	SS	SS	S	VS	—
Ethyl Lactate	S	S	S	S	S	S	I	S	VS	VS	—
Ethylene Glycol Diacetate	S	S	S	S	S	S	—	—	VS	VS	—
Methyl Acetate	S	S	S	S	S	S	SS	SS	S	S	—
Tricresyl Phosphate	S	S	S	S	S	S	—	—	SS	S	—
Ether: Ethyl Ether	S	S	S	S	S	S	S	S	S	—	—
Ether Alcohol											
Carbitol†	224[21°C]	307[95°C]	VS	VS	173[26°C]	259[98°C]	I	S	SS	—	—
Cellosolve	S	S	S	S	S	S	I	S	S	—	—
Diethylene Glycol	—	—	—	—	—	—	—	—	S	—	—
p,p'-Dihydroxy Ethyl Ether	16.9[23°C]	19[23°C]	SS	SS	8[30°C]	10[100°C]	—	—	SS	—	—
Hydrocarbon											
Benzene	VS	VS	VS	VS	VS	VS	S	S	VS	VS	143
Gasoline	VS	VS	VS	VS	VS	VS	—	—	VS	VS	—
Kerosene	VS	VS	VS	VS	VS	VS	SS	S	VS	VS	—
Mineral Spirits	VS	VS	VS	VS	VS	VS	S	S	VS	VS	—
Paraffin	2.0[25°C]	S	2.0[28°C]	S	—	S	—	—	5.0	S	—
Pine Oil	S	S	VS	VS	S	S	S	S	S	S	—
Toluene	VS	VS	VS	VS	VS	VS	S	S	VS	VS	142
Turpentine	VS	VS	VS	VS	VS	VS	S	S	VS	VS	—
Xylene	VS	VS	VS	VS	VS	VS	S	S	VS	VS	176
Hydroxy derivatives											
Amyl Alcohol	S	S	—	—	S	S	SS	S	S	S	—
n-Butyl Alcohol	S	S	—	—	S	S	I	SS	SS	S	—
Ethyl Alcohol (3-A)	23.3[25°C]	80.0[70°C]	—	—	10[27°C]	28[75°C]	I	I	SS	—	—
Glycerine	I	I	I	I	I	I	I	I	I	I	—
Methyl Alcohol	42.5[23°C]	68.5[60°C]	—	—	15[26°C]	22.2[65°C]	—	—	SS	—	—
Phenol — 90%	194[23°C]	S	—	—	SS	S	SS	S	S	S	—
Ketone: Acetone	S	S	—	—	S	S	I	I	S	S	260
Miscellaneous											
Carbon Disulfide	S	S	—	—	S	S	S	S	VS	VS	—
Nitrobenzene	S	S	—	—	S	S	—	—	VS	—	—
Water	I	I	I	I	I	I	I	I	I	I	—

I — Insoluble SS — Slightly Soluble S — Soluble VS — Very Soluble.
Figures show grams of Aroclor per 100 milliliters of solvent at 25°C unless otherwise indicated.

†Trademark of Union Carbide Corp.

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TABLE 14

CHEMICAL AND PHYSICAL PROPERTIES OF REPRESENTATIVE AROCLOR® PLASTICIZERS AND RESINS

Property	*Aroclor 1221*	*Aroclor 1232*	*Aroclor 1242*	*Aroclor 1248*	*Aroclor 1254*
Appearance	Clear, mobile oil	Clear, mobile oil	Clear, mobile oil	Clear, mobile oil	Light-yellow viscous liquid
Color, maximum	*100 APHA	*100 APHA	*100 APHA	*100 APHA	*100 APHA
Chlorine, percent	20.5-21.5	31.5-32.5	42	48	54
Acidity, mg KOH/g, maximum	*0.014	*0.014	*0.015	*0.010	*0.010
Moisture, ppm, maximum	—	—	*50	*50	*50
Ave. Coefficient of Expansion, cc/cc/°C	0.00071 (15°-40°C)	0.00073 (25°-100°C)	0.00068 (25°-65°C)	0.00070 (25°-65°C)	0.00066 (25°-65C°)
Specific Gravity	*1.182-1.192 (25°/15.5°C)	*1.270-1.280 (25°/15.5°C)	*1.381-1.392 (25°/15.5°C)	*1.405-1.415 (65°/15.5°C)	*1.495-1.505 (65°/15.5°C)
Density, pounds per gallon, 25°C	9.85	10.55	11.50	12.04	12.82
Distillation Range, °C, corrected (ASTM D-20, modified)	275-320	290-325	325-356	340-375	365-390
Evaporation Loss, %, 100°C, 6 hours (ASTM D-6, mod.) 163°C, 5 hours	1.0-1.5	1.0-1.5	0-0.4 3.0-3.6	0-0.3 3.0-4.0	0-0.2 1.1-1.3
Flash Point (Cleveland Open Cup), °C °F	141-150 286-302	152-154 305-310	176-180 348-356	193-196 379-384	None to boiling point
Fire Point (Cleveland Open Cup), °C °F	176 349	238 460	None to boiling point	None to boiling point	None to boiling point
Pour Point (ASTM E-97), °C °F	1 (crystals) 34 (crystals)	—35.5 —32	—19 2	—7 19.4	10 50
Softening Point (ASTM E-28), °C °F	—	—	—	—	—
Refractive Index, n D-20 20°C	1.617-1.618	1.620-1.622	1.627-1.629	1.630-1.631	1.639-1.641
Viscosity, Seconds Saybolt Universal (ASTM D-88) 100°F (37.8°C) 130°F (54.4°C) 210°F (98.9°C)	*38-41 35-37 30-31	*44-51 39-41 31-32	*82-92 49-56 34-35	185-240 *73-80 36-37	1800-2500 260-340 *44-48

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Aroclor 1260	*Aroclor 1262*	*Aroclor 5442*	*Aroclor 4465*	*Aroclor 2565*	*Aroclor 5460*	*Aroclor 1268*
Light-yellow, soft, sticky resin	Light-yellow sticky, viscous resin	Clear yellow sticky resin	Clear, light-yellow, resin	Black, opaque, brittle resin	Clear, yellow-to-amber, brittle resin or flakes	White to off-white powder
*150 APHA	*150 APHA	*2 NPA (molten)	*2 NPA (molten)	—	*2 NPA (molten)	*1.5 NPA (molten)
60	61.5-62.5	42	65	65	58.5-60.6	68
*0.014	*0.014	0.05	0.05	1.4	0.05	0.05
*50	—	—	—	—	—	—
0.00067 (20°-100°C)	0.00064 (25°-65°C)	0.00123 (25°-99°C)	0.00061 (25°-65°C)	0.00066 (25°-65°C)	0.00179 (25°-124°C)	0.00067 (20°-100°C)
*1.565-1.566 (90°/15.5°C)	*1.572-1.583 (90°/15.5°C)	1.470 (25°/25°C)	1.670 (25°/25°C)	1.734 (25°/25°C)	1.670 (25°/25°C)	1.804-1.811 (25°/25°C)
13.50	13.72	12.24	13.91	14.44	13.91	15.09
385-420	390-425	215-300 (4 mm. Hg)	230-320 (4 mm. Hg)	—	280-335 (5 mm. Hg)	435-450
0-0.1 0.5-0.8	0-0.1 0.5-0.6	0.01 0.2	0-0.02 0.2-0.3	0.2-0.3	0.03	0-0.06 0.1-0.2
None to boiling point	None to boiling point	247 477	None to boiling point	—	None to boiling point	None to boiling point
None to boiling point	None to boiling point	>350 >662	None to boiling point	—	None to boiling point	None to boiling point
31 88	35-38 99	46 115	—	—	—	—
—	—	*46-52 115-126	*60-66 140-151	*66-72 149-162	*98-105 208-222	*150-170 (hold 302-338 point)
1.647-1.649	1.6501-1.6517	—	1.664-1.667	—	1.660-1.665	—
3209-4500 *72-78	600-850 (160°F; 71°C) *86-100	300-400	90-150 (266°F; 130°C)	—	—	—

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Density

All the Aroclor plasticizers are heavier than water, a valuable property for many applications. Densities are shown in Figure 2.

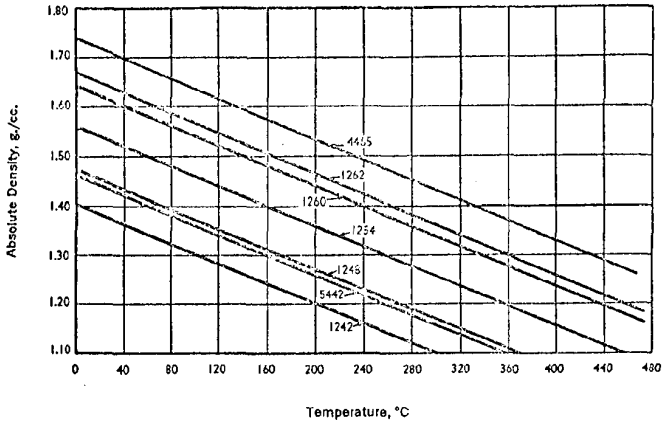

Fig. 2 — Densities of Aroclor® Plasticizers at Various Temperatures

Specific Volume

The specific volume of Aroclor 1248 at different temperatures is as follows:

Temperature (°F)	*Aroclor 1248 Specific Volume (ml/g)*
0	0.674
100	0.699
200	0.726
300	0.755
400	0.790
500	0.828
600	0.870

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The low vaporization loss of Aroclor plasticizers is indicated in Table 15.

TABLE 15

VAPORIZATION RATES OF AROCLOR® PLASTICIZERS

Plasticizer (Surface area: 12.20 sq. cm.)	*Wt. Loss (g)*	*Exposure at 100°C (hr.)*	*Vaporization Rate (g/sq. cm./hr.)*
Aroclor 1221	0.5125	24	0.00174
Aroclor 1232	0.2572	24	0.000874
Aroclor 1242	0.0995	24	0.000338
Aroclor 1248	0.0448	24	0.000152
*Cloratin**-42-S	0.0745	48	0.000126
Dioctyl phthalate	0.0686	48	0.000117
*Dutrex*** 25	0.0256	24	0.000087
Aroclor 1254	0.0156	24	0.000053
Shell Dutrex 20	0.0047	24	0.000016
Aroclor 1262	0.0039	24	0.000013
Aroclor 1260	0.0026	24	0.000009
Aroclor 4465	0.0064	72	0.000007
Aroclor 5442	0.0039	72	0.000004
Aroclor 5460	0.0032	72	0.000004
Tricresyl phosphate	0.0010	24	0.000003

It is concluded that the vaporization rates of Aroclor plasticizers — especially the most widely used 1254 and 1260 — compare most favorably with the similar constants of other plasticizers selected specifically for these tests because of their low vaporization rates.

*Trademark of Hercules, Inc.

**Trademark of Shell Oil Co.

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The vapor pressures of several Aroclor plasticizers are indicated in Figure 3 over the temperature range 150° to 300°C.

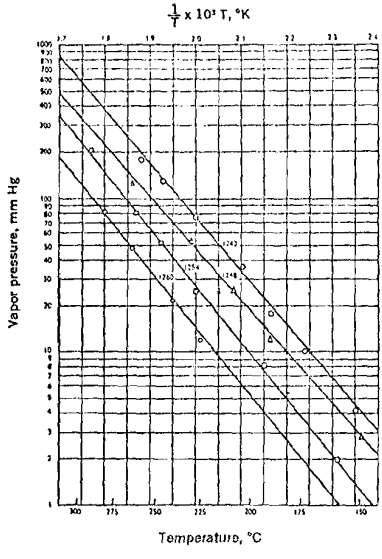

Fig. 3 — Vapor Pressures of Aroclor® Plasticizers

The estimated vapor pressures of several Aroclor plasticizers at 100°F shown in the following table were determined by extrapolation from the values shown in Figure 3.

Approximate Vapor Pressure of Aroclor® Plasticizers
Estimated at 100° F (37.8° C)

Aroclor 1232	0.005 mm. Hg
Aroclor 1242	0.001 mm. Hg
Aroclor 1248	0.00037 mm. Hg
Aroclor 1254	0.00006 mm. Hg

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Viscosity

The viscosities of the Aroclor plasticizers vary according to whether the base material is a biphenyl or a polyphenyl and on the degree of chlorination. In general the low-chlorinated biphenyls have the lowest viscosities (Figure 4).

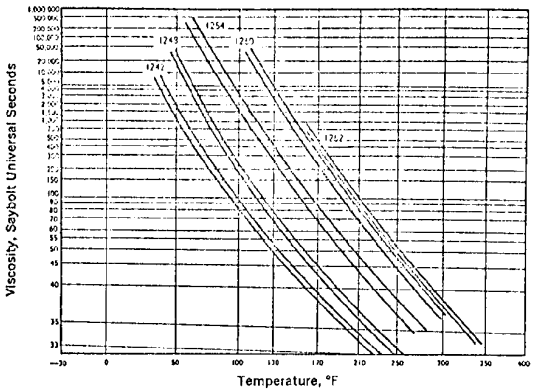

Fig. 4 — Viscosity Ranges of Some Aroclor® Plasticizers

Stability

Toward Alkalies

The Aroclor plasticizers are remarkably resistant to the action of either hydrolyzing agents or high temperature. They are not affected by boiling with sodium hydroxide solution.

Toward Acids

No hydrogen chloride was evolved when Aroclor 1254 was stirred with an equal volume of 10 percent sulfuric acid for 150 hours. Even after prolonged treatment (255 hours) with concentrated sulfuric acid only a slight trace (too small for quantitative measurement) of hydrogen chloride was evolved.

Toward Heat

Because of their stability to heat, the Aroclor plasticizers are useful heat-transfer media. Aroclor 1254 and particularly the less viscous Aroclor 1248 are recommended for this purpose, because they may be heated up to 315°C (600°F) in a closed system for long periods without appreciable decomposition, and because they are nonflammable.

Toward Light

The Aroclor plasticizers have good light stability in heavily pigmented compounds and fair light stability in clear formulations. The materials become discolored, but their physical properties are not degraded. For critical applications, incorporation of a small amount of a light-

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screening agent greatly improves light stability at reasonable cost. The following data show that as little as 0.01 percent *Tinuvin* P in Aroclor 1254 nearly doubles the service life in the 50-to-100-hour range and that 0.1 percent *Tinuvin* P results in a 10-fold improvement.

Tinuvin P Concentration (%)	*Fade-Ometer Exposure (hours)*				
	0	*50*	*100*	*150*	*500*
	Color (Gardner Units)				
0	0	5	10	11	14
0.01	0	1	6	7	14
0.05	0	0	3	4	11
0.1	0	0	1	2	6

Toward Oxidation

When Aroclor plasticizers are heated to 140°C with oxygen in a bomb at 250 psi, no evidence of oxidation occurs, as judged by absence of sludge formation or increased acidity. Also, no increase in acidity occurred after 4 hours heating with air at 260°C and 210 psi.

Nonflammability

The viscous Aroclor liquids and the resins do not support combustion when heated alone, even at their boiling points — above 350°C. Most of the Aroclor plasticizers flux readily with resinous and pitch-like materials to give products with decreased fire hazard. Aroclor products incorporated in plastic products and rubber foams retard the rate of burning.

Nondrying Properties And Thermoplasticity

The Aroclor plasticizers are nondrying. When exposed to the air, even in thin films, no noticable oxidation or hardening takes place. Despite this property, Aroclor plasticizers do not retard the drying rate of lacquer films. Quick-drying varnishes and paints may be made with Aroclor resins without affect on drying characteristics.

The Aroclor plasticizers are permanently thermoplastic. They apparently undergo no condensation or hardening upon repeated melting and cooling. Clear Aroclor resins are available with softening points up to 105°C. The opaque crystalline solids are available with melting points up to about 160°C.

Electrical Properties

The electrical properties of Aroclor plasticizers are extremely interesting: high resistivity and dielectric strength and low power factor, as listed in Table 16. The dielectric constants of the various Aroclor plasticizers range from 3.3 to 4.9 at 100°C and 1000 cycles.

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TABLE 16

ELECTRICAL PROPERTIES OF AROCLOR®

Aroclor	Dielectric Constant (ASTM D-150-47T) 1000 cycles 25°C	100°C	Volume Resistivity (ASTM D-257-46) 500 Volts D.C., 100°C (ohm-cm.)	Dielectric Strength (ASTM D-149-44) (KV)	Power Factor (ASTM D-150-47T) 1000 cycles, 100°C (%)
1232	5.7	4.6			
1242	5.8	4.9	Above 500 x 10^9	Above 35	Below 0.1
1248	5.6	4.6	Above 500 x 10^9	Above 35	Below 0.1
1254	5.0	4.3	Above 500 x 10^9	Above 35	Below 0.1
1260	4.3	3.7	Above 500 x 10^9	Above 35	Below 0.1
1268	2.5				
5442	3.0	4.9	Above 500 x 10^9		
5454	2.7	4.2			
5460	2.5	3.7			
4465	2.7	3.3			

How To Emulsify Aroclor

Emulsions of Aroclor plasticizers can be made simply in several ways; the method can be selected to suit the particular Aroclor and the type of formulation in which it will be used.

Emulsifiable Concentrated Stock Solutions of Aroclor

Stock solutions made according to the following formulation are readily emulsified with water. The amount of toluene may be increased as needed to dissolve the more resinous Aroclor plasticizers.

Ingredient	Parts by Weight
Aroclor	79
Toluene	16.70
Isopropanol	3.55
Sterox® CD (nonionic emulsifier)	1.00
Santomerse® No. 3 (anionic wetting agent)	0.75

Emulsifying Liquid Aroclor

Ingredient	Parts by Weight
Portion 1 Aroclor 1254	100
Oleic Acid	4
Portion 2 Water	100
Ammonium Hydroxide (28%)	2

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Mix the polystyrene and ammonium hydroxide in warmed water with vigorous agitation. Mix the Aroclor 1254 and oleic acid, heat to 45°C, and agitate vigorously. Maintain the 45°C temperature and agitation, and *slowly* add in the aqueous portion (Portion 2). Continue agitation for one-half hour until phase inversion is complete.

Emulsifying Viscous Aroclor

Ingredient	*Parts by Weight*
Portion 1	
Aroclor 1254	64
Stearic Acid	4
Portion 2	
Water	32
Triethanolamine	1

Heat the Aroclor to a workable viscosity (180°F or higher) and stir in the stearic acid thoroughly. Heat the water almost to boiling (207°F) and stir in the triethanolamine thoroughly. Pour the Aroclor-stearic acid portion into the water-triethanolamine portion with vigorous agitation. Process the combined portions either with a high-speed emulsifying stirrer or through a colloid mill.

Toxicity And Safe Handling

Inhalation

At ordinary temperatures the Aroclor chlorinated polyphenyls have not presented industrial toxicological problems. The hazard of potential toxic exposure varies with their volatility: the lower-chlorinated, more-volatile ones present more of a potential problem from the standpoint of both inhalation and skin contact. When Aroclor plasticizers are used at elevated temperatures, engineering controls must be applied, either by the use of closed systems or by effective local-exhaust ventilation together with general workroom exhaust.

Vapor of the liquid Aroclor plasticizers at room temperature should not be breathed in a confined space, and no vapor of any Aroclor evolved at elevated temperatures should be allowed to be dispersed into the general workroom.

Inhalation tests on animals indicate that the maximum safe concentration of vapor is in the range of from 0.5 to 1.0 milligram of the lower-chlorinated Aroclor plasticizers per cubic meter of air. The threshold limits (maximum allowable concentration for an 8-hour working day) set by the American Conference of Government Hygienists are 1.0 milligram of the lower-chlorinated Aroclor compounds per cubic meter of air and 0.5 milligram of the more-highly-chlorinated compounds, such as Aroclor 1254, per cubic meter of air.

Skin Contact

Schwartz patch tests on 200 volunteers showed that Aroclor 1254 was neither a primary skin irritant or a sensitizer.

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Continuous or repeated skin contact with the Aroclor plasticizers must be avoided by the use of gloves and protective garments, because of the possible occurrence of a condition called chloracne. Although reports of this condition caused by Aroclor are rare, it can be produced by excessive skin contact. If any Aroclor is spilled on the skin, the skin should be washed in the usual manner with a soap solution.

A burn caused by contact with a hot Aroclor should be treated like any ordinary burn. Aroclor plasticizer adhering to the burned area need not be removed immediately, unless treatment of the burn demands it, in which case either soap and water or repeated washings with a vegetable oil are recommended.

Shipping

Freight Classification

Aroclor 1221, 1243, 1242, 1248, 1254, 1260, 1262	Synthetic Resin, Liquid, NOIBN

Rail Classification

Aroclor 1268, 2565, 4465, 5442, 5460	Synthetic Resin, Other Than Liquid, NOIBN

Truck Classification

Aroclor 1268, 2565	Synthetic Resin, Powder, NOI
Aroclor 4465, 5442, 5460	Synthetic Resin, Lumps or Solid Mass, NOI

Shipping Regulations	None

Standard Containers

Aroclor 1221	Tank car, 520-lb. steel drum, 50-lb. can
Aroclor 1232	Tank car, 550-lb. steel drum, 50-lb. can
Aroclor 1242, 1248, 1254, 1260, 1262	Tank car, 600-lb. steel drum, 50-lb. can
Aroclor 1268	200-lb. fiber drum, 25-lb. fiber drum
Aroclor 2565, 4465	500-lb. steel drum, 50-lb. can
Aroclor 5442	450-lb. steel drum, 50-lb. can
Aroclor 5460 (flaked)	100-lb. bag

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