Jack Clayton

The AROCLORS

Physical Properties and Suggested Applications

APPLICATION DATA BULLETIN No. P-115

Manufactured by

MONSANTO CHEMICAL COMPANY
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FOREWORD

The Aroclors*, chlorinated biphenyl and chlorinated poly-phenyls, possess unique properties which enable the fulfillment of requirements not met by other materials. This has won a prominent place for Aroclors, particularly, in the electrical insulating field and in such widely differing applications as non-flammable hydraulic media, high-temperature and high-pressure lubricants, heat transfer and expansion media, sealing compounds, adhesives and protective coatings, including plastics, pigments, lacquers, paints and varnishes.

This booklet describes the properties of thirteen Aroclors, each of which is representative of a series. For almost every Aroclor described there is a dark-colored grade of otherwise approximately the same physical and chemical characteristics. These darker products are less pure but lower in price.

The Aroclors are efficient and very economical, both when used alone to accomplish results not attainable by other materials and when used as extenders to enhance the properties of other products.

They are produced exclusively by Monsanto Chemical Company.

*Registered in U. S. Patent Office.

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General Properties

The Aroclors range in form and appearance from mobile oily liquids to fine white crystals and hard transparent resins. They are non-oxidizing, permanently thermoplastic, of low volatility and non-corrosive to metals. They are not hydrolyzed by water, alkalies or acids. The viscous liquids and the resins will not support combustion when heated alone.

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

The excellent electrical properties, fire resistance and inertness of the Aroclors make them useful in many applications.

The properties imparted by the Aroclors and their usefulness for particular applications vary in regular gradients over the series so that the selection of the right Aroclor for a specific use can generally be made simply by a comparison of the physical properties of the several Aroclors.

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TABLE

GENERAL PHYSICAL PROPERTIES

	Aroclor 1221	Aroclor 1232	Aroclor 1242	Arcolor 1248	Aroclor 1254
Form	Colorless mobile oil	Practically colorless mobile oil	Practically colorless mobile oil	Yellow tinted mobile oil	Light yellow viscous oil
Color—APHA	50 Max.	60 Max.	100 Max.	100 Max.	150 Max.
Acidity—Maximum (Mgm. KOH per Gm.)	0.015	0.015	0.015	0.015	0.015
Coefficient of Expansion.....cc/cc/°C	0.000707 (15°–40°C)	0.000725 (25°–100°C)	0.000678 (25°–65°C)	0.000702 (25°–65°C)	0.000661 (25°–65°C)
Density—					
Specific Gravity 25°/25°C (77°/77°F)	1.177 to 1.187	1.262 to 1.272	1.378 to 1.388	1.447 to 1.457	1.538 to 1.548
Pounds per Gallon—25°C (77°F)	9.82	10.51	11.50	12.08	12.83
Distillation Range—ASTM D-20 Mod Corr. °C	275°–320°	290°–325°	325°–360°	340°–375°	365°–390°
Evaporation Loss—%—ASTM D-6 Mod.					
163°C.....5 hrs.	—	—	3.0 to 3.6	3.0 to 4.0	1.1 to 1.3
100°C.....6 hrs.	1.0 to 1.5	1.0 to 1.5	0.0 to 0.4	0.0 to 0.3	0.0 to 0.2
Flash Point—Cleveland Open Cup.....°C	141°–150°	152°–154°	176°–180°	193°–196°	None
°F	286°–302°	305°–310°	348°–356°	379°–384°	
Fire Point—Cleveland Open Cup.....°C	176°	238°	334°	None	None
°F	349°	460°	633°		
Pour Point—ASTM D-97.....°C	Crystals at 1°C	−35.5°	−19°	7°	10°
°F	Crystals at 34°F	−32°	2°	19.4°	50°
Softening Point—ASTM E-28.....°C	—	—	—	—	—
°F	—	—	—	—	—
Refractive Index—D-line—20°C	1.617–1.618	1.620–1.622	1.627–1.629	1.630–1.631	1.637–1.641
Viscosity—Saybolt Universal 210°F (98.9°C) Sec. (ASTM—D-88)	30–31	31–32	34–35	36–37	44–48
130°F (54.4°C)	35–37	39–41	49–56	69–78	260–340
100°F (37.8°C)	40–42	47–50	80–93	185–240	1800–2500

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I

OF SOME OF THE AROCLORS

Aroclor 1260 Light yellow soft sticky resin	Aroclor 1262 Light yellow sticky clear resin	Aroclor 1268 Pale yellow opaque brittle resin	Aroclor 1270 White crystalline powder	Aroclor 4465 Yellow transparent brittle resin	Aroclor 5442 Yellow transparent sticky resin	Aroclor 5460 Yellow transparent resin	Aroclor 2565 Brown-black opaque resin
150 Max.	150 Max.	1.5 Max.	1.5 Max.	2.0 Max.	1.5 Max.	2.0 Max.	—
0.015	0.02	0.05	0.175	0.05	0.05	0.07	1.4
—	0.000640 (25°–65°C)	—	—	0.000611 (25°–65°C)	0.00123 (25°–99°C)	0.00179 (25°–124°C)	0.000656 (25°–65°C)
1.618 to 1.629	1.646 to 1.653	1.804 to 1.811	1.944 to 1.960	1.712 to 1.723	1.432 to 1.447	1.740 to 1.745	1.724 to 1.740
13.50	13.72	15.13	16.24	14.28	11.96	14.50	14.41
385°–420°	400°–430°	435°–450°	450°–460°	230°–320° at 4 mm. Hg.	215°–300° at 4 mm. Hg.	280°–335° at 5 mm. Hg.	—
0.5 to 0.8	0.5 to 0.6	0.1 to 0.2	0.0 to 0.1	0.2 to 0.3	2.0	0.03	0.2 to 0.3
0.0 to 0.1	0.0 to 0.1	0.0 to 0.06	0.0 to 0.02	0.0 to 0.02	0.05	1.5 to 1.7 (at 260°—5 hrs.	—
None	None	None	None	None	247° 477°	None	None
None	None	None	None	None	>350° >662°	None	None
31°	37°	—	—	—	46°	—	—
88°	99°	—	—	—	115°	—	—
—	—	135° to 160° (hold pt.)	249° to 300° (hold pt.)	60° to 66°	45° to 50°	100° to 105.5°	66° to 72°
—	—	275° to 320° (hold pt.)	561° to 572° (hold pt.)	140° to 151°	113° to 122°.	212° to 222°	149° to 162°
1.647–1.649	1.6501–1.6517	—	—	1.664–1.667	—	1.660–1.665	—
75–80	90–103	—	—	90–150 (266°F or 130°C)	300–400	—	—
3200–4500	600–850 (160°F or 71°C)	—	—	—	—	—	—
—	—	—	—	—	—	—	—

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TABLE II — Resistance of Structural Materials to Aroclors

Metals	Aroclor Number 1248 25°C	1248 125°C	1254 25°C	1254 125°C	4465 125°C	5460 125°C
Aluminum	R	R	R	R	*RR	RR
Copper	R	D	D	R	D	D
Magnesium	RR	R	R	R	RR	*RR
Nickel	RR	R	R	RR	RR	R
Silver	R	R	R	R	R	R
Tin	R	R	R	R	R	R
Zinc	R	R	R	R	R	RR
Mild Steel	RR	R	RR	RR	R	RR
Phosphor Bronze	R	D	R	R	R	R
Red Brass	D	D	R	D	R	De
Stainless Steel	RR	RR	RR	RR	RR	RR
Yellow Brass	R	Re	R	De	Re	Re
Plastics						
Alkyd Resin No. 46594-12	*P	P	*P	P	P	P
Alkyd Resin No. 46594-13A	*D	P	*D	P	P	P
Butvar Low Plasticized	*D	T	D	T	T	T
Butvar Themoset	*P	P	*P	P	P	P
Cellulose Acetate (Fibestos)	D	P	D	P	P	P
Cellulose Nitrate (Nitron 205D)	D	T	D	T	T	T
Durite Phenol Furfural Resin	*D	P	*R	P	D	P
Ethyl Cellulose (Ethofoil)	*R	P	*D	P	P	P
Formvar Highly Plasticized	De	T	Pe	T	T	T
Formvar Low Plasticized	PS	T	PS	T	T	T
Glyptal 1276	R	P	D	P	P	P
Glyptal 7136	*D	T	*R	T	T	T
Maleic Resin No. 46594-13B	P	P	*P	P	P	P
Maleic Resin No. 46594-13C	P	P	*R	P	P	P
Plexiglas (Methyl Methacrylate)	*D	P	*D	P	P	P
Polystyrene (Lustron B)	P	T	P	T	T	T
Resinox Mineral Filled Melamine Resin	*D	*P	*R	R	*P	*D
Resinox Wood Flour Filled Melamine Resin	*D	P	*R	D	R	P
Resinox Mineral Filled Phenol Formaldehyde	*D	D	*D	D	R	P
Resinox Wood Flour Filled Phenol Formaldehyde	*D	P	*D	*R	D	P
Resinox Rag Filled Phenol Formaldehyde	*D	D	*D	*D	*D	P
Urea Formaldehyde Resin (Plaskon Co.)	*D	P	*D	*P	P	P
Vinyl Acetate (Gelva 60)	D	T	P	T	T	T
Vinyl Chloride (Vinylite)	RR	T	RR	T	T	T

Meaning of Abbreviations:

*—Based on weight *gain* calculated as penetration value shown.

RR—Excellent resistance—less than 1.0×10^{-6} cm/day penetration or .00014 in/yr.

R Good resistance—has penetration between 1.0×10^{-5} and 10×10^{-6} cm/day or between 0.00014 and 0.0014 in/yr.

D—Doubtful resistance, penetration between 10×10^{-6} cm/day and 100×10^{-6} cm/day or between 0.0014 and 0.014 in/yr.

P—Poor resistance—penetration greater than 100×10^{-6} cm/day or 0.14 in/yr.

PS—Poor resistance due to visible local action although weight change indicates greater resistance.

e—Following the letter indicating resistance signifies material may be better than indicated if totally immersed since weight loss is believed to come from oxidation of the part of test strip exposed to air.

T—Material alone will not stand temperature.

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Adhesiveness

The Aroclor resins ahdere strongly to smooth surfaces, such as glass, metal and varnished or lacquered coatings.

The softer Aroclors are indicated where a flexible, non-drying, water-resistant strongly adhesive material is required.

The Aroclor adhesives are thermoplastic; are readily applied hot without solvent; do not require high temperatures for easy application, and are set immediately upon cooling.

Coefficient of Expansion

Specific Volume

Temp. °F	Aroclor 1248 Specific Volume ml/gm
0	0.674
100	0.699
200	0.726
300	0.755
400	0.790
500	0.828
600	0.870

Using the simple formula $Vt = Vt_1 [1+a\ (t-t_1)]$, the coefficient, *a*, has been calculated at 100°F increments, as follows:

Temp. Range °F	Coefficient of Expansion
0 to 100	0.000371
100 to 200	0.000386
200 to 300	0.000399
300 to 400	0.000463
400 to 500	0.000481
500 to 600	0.000507

Corrosion

The Aroclors show practically no corrosive effect on metals within normal ranges of temperature. They do attack many plastics materials of construction as shown in Table II.

Density

All the Aroclors are heavier than water, a valuable property for many applications. Densities are shown in Figure 1.

FIG. 1

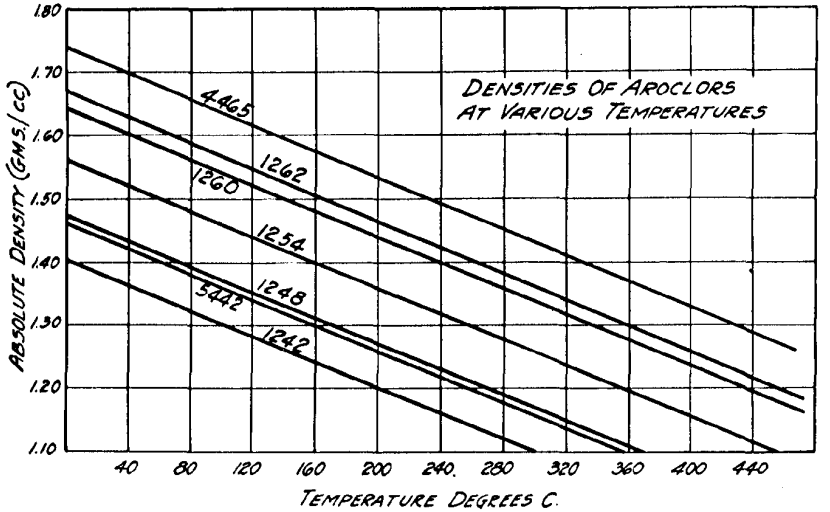

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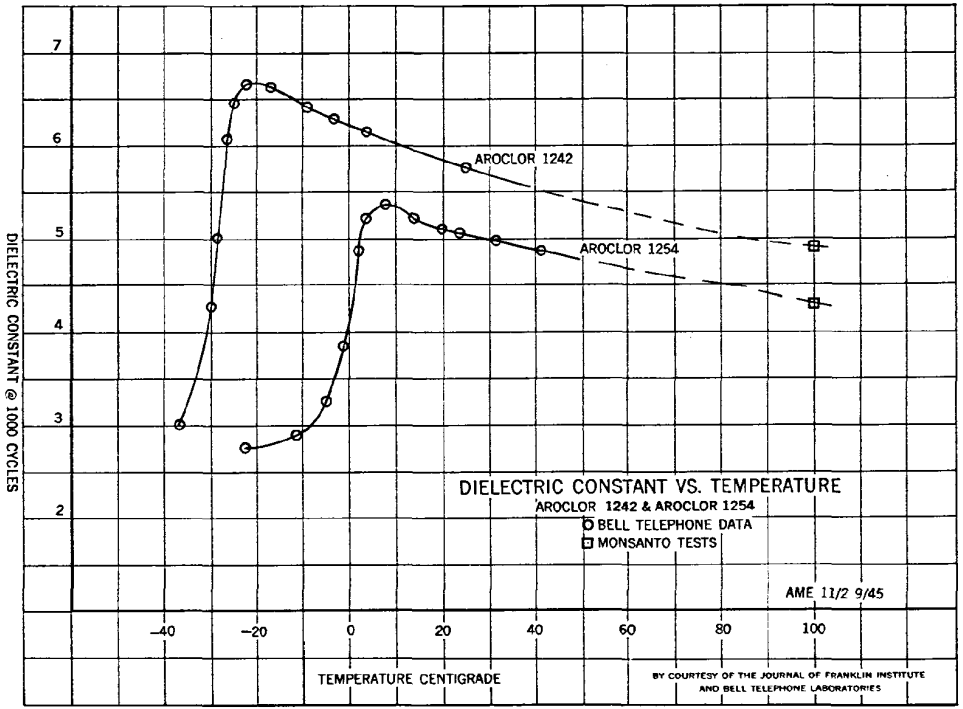
FIG. 2



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Electrical Properties

The Aroclors have extremely interesting electrical characteristics: high resistivity and dielectric strength and low power factor. The dielectric constant ranges from 3.4 to 5.0 at 100°C and 1000 cycles, depending upon the particular Aroclor.

The dielectric constants of Aroclors 1242 and 1254 at various temperatures are shown graphically in Figure 2.

Non-Drying Properties

The Aroclors are non-drying, and when they are exposed to the air, even in thin films, no noticeable oxidation or hardening takes place. However, when used as ingredients of lacquers, they do not retard the rate of drying of the lacquer films. Quick drying varnishes and paints may be made with Aroclor resins.

Nonflammability

The viscous Aroclor oils and the resins do not support combustion when heated alone, even at their boiling points — temperatures above 350°C. Most of the Aroclors flux readily with resinous and pitch-like materials to give a product having a decreased fire hazard. When incorporated in nitrocellulose films and rubber foams the Aroclors retard the rate of burning.

Solubility

All Aroclors are insoluble in water. Solubilities of some of the Aroclors in the more common substances are shown in Table VI.

The Aroclor oils and resins are readily soluble in most of the common organic solvents and drying oils. The hard crystalline materials are in general less soluble than the Aroclor oils or softer resins. Compatibility data on Aroclors in nitrocellulose lacquers are shown on page 18.

Specific Heat and Thermal Conductivity

The specific heat at different temperatures of several of the Aroclors is shown in Figure 3. This, together with the thermal conductivity data given in Table IV, enable calculations involved in the use of Aroclors as high-temperature, low pressure, fluid heat-transfer media.

TABLE IV

Thermal Conductivity of Aroclor 1248

Temperature °C	Temperature °F	Density g/cc.	Thermal Conductivity BTU./Hr./Sq. Ft./°F/Ft.	Viscosity Saybolt Univ. Sec.
30	90	1.441	0.0613	360
60	140	1.411	0.0698	60
100	212	1.370	0.0800	36

TABLE III — Electrical Properties

	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 5442
*Dielectric Constant @ 100°C and 1000 Cycles	4.6	4.9	4.6	4.1—4.3	3.6—3.8	4.9
Resistivity @ 100°C Ohms/Cm³ 500 Volts D.C.	...	...	500×10^9	Above 500×10^9	Above 500×10^9	1469×10^9
**Dielectric Strength	...	...	...	35 KV Min.	30 KV Min.	
Power Factor (100°C, 1000 kc)	...	...	less than 0.1%	....	...	less than 0.1%

* IRS Method H-3955871.
** ASTM D-177-11.

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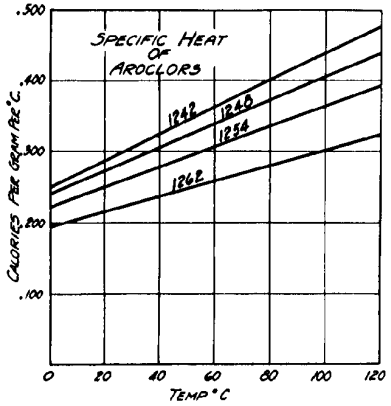
FIG. 3



Stability

Toward Alkalies

The Aroclors 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

Experiments were made to determine whether hydrogen chloride is evolved during the treatment of Aroclors with sulfuric acid. Aroclor 1254 (selected as typical) was stirred with an equal volume of ten per cent sulfuric acid for a period of 150 hours. Any gases escaping from the reaction flask had to pass through a trap filled with silver nitrate solution, which solution would give a precipitate of silver chloride if any HCl came in contact with it. After 150 hours of treatment, neither the trap solution nor the acid layer in the treating flask showed any hydrogen chloride present. Even prolonged treatment (255 hours) with concentrated sulfuric acid indicated only a slight trace (too small for quantitative measurement) of hydrogen chloride in the acid layer.

Toward Heat

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

Toward Oxidation

When Aroclors are subjected to a bomb test at 140°C with 250 pounds oxygen per square inch oxygen, there is no evidence of oxidation as judged by development of acidity or formation of sludge.

Surface Tension

The surface tension of Aroclor 1254 in dynes per centimeter is as follows:

Temperature	Surface Tension—dynes/cc
25°C	50.3
80°C	44.0
100°C	42.0

Thermoplasticity

The Aroclors are permanently thermoplastic. They apparently undergo no condensation or hardening upon repeated melting and cooling. The clear Aroclor resins are now being produced with softening points up to 105°C. The opaque crystalline solids are produced with initial melting points up to approximately 290°C.

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TABLE VI — Solubility of Aroclors in 100 Milliliters of Various Solvents

Type of Solvent	Aroclor 1242 25°C	1242 Hot	1248 25°C	1248 Hot	1254 25°C	1254 Hot	1270 Cold	1270 Hot	4465 Cold	4465 Hot	5460 25°C
Acid											
Acetic Acid	S	S	—	—	S	S	—	—	SS	S	—
Oleic Acid	S	S	—	—	S	S	—	—	S	VS	—
Benzoic Acid	10.0 31°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 30°C	440 99°C	—	—	114 31°C	425 100°C	—	—	VS	VS	—
Chloro — derivative											
Amyl chlorides — mixed	S	S	S	S	S	S	—	—	VS	VS	—
Carbon Tetrachloride	S	S	S	S	S	S	3.7	—	VS	VS	50
Chloroform	S	S	S	S	S	S	—	—	VS	VS	—
Dichlorethylene	—	—	—	—	—	—	3.0	—	VS	VS	—
Ethylene Dichloride	S	S	S	S	S	S	—	—	VS	VS	—
Monochlorobenzene	S	S	S	S	S	S	2.9	—	VS	VS	—
Orthodichlorobenzene	—	—	—	—	—	—	—	—	VS	VS	—
Tetrachlorethane	S	S	S	S	S	S	—	—	VS	VS	—
Trichlorethane	S	S	S	S	S	S	3.3	—	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	—	—	VS	VS	—
Ester											
Amyl Acetate	S	S	S	S	S	S	—	—	VS	VS	—
Butyl Acetate	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	—	—	VS	VS	—
Dibutyl Phthalate	S	S	S	S	S	S	—	—	S	VS	—
Diethyl Phthalate	S	S	S	S	S	S	—	—	S	VS	—
Ethyl Acetate	S	S	S	S	S	S	—	—	S	VS	—
Ethyl Lactate	S	S	S	S	S	S	—	—	VS	VS	—
Ethylene Glycol Diacetate	S	S	S	S	S	S	—	—	VS	VS	—
Methyl Acetate	S	S	S	S	S	S	—	—	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 31°C	307 99°C	VS	VS	173 26°C	259 93°C	—	—	SS	—	—
Cellosolve	S	S	S	S	S	S	—	—	S	—	—
Diethylene Glycol	—	—	—	—	—	—	—	—	S	—	—
p-p' Dihydroxy Ethyl Ether	16.9 23°C	19 99°C	SS	SS	8 30°C	10 100°C	—	—	SS	—	—
Hydrocarbon											
Benzene	VS	VS	VS	VS	VS	VS	3.5	—	VS	VS	62
Gasoline	VS	VS	VS	VS	VS	VS	—	—	VS	VS	—
Kerosene	VS	VS	VS	VS	VS	VS	—	—	VS	VS	—
Mineral Spirits	VS	VS	VS	VS	VS	VS	—	—	VS	VS	—
Paraffin	2.0 27.5°C	S	2.0 28°C	S	—	S	—	—	< 5.0	S	—
Pine Oil	S	S	VS	VS	S	S	—	—	S	S	—
Toluene	VS	VS	VS	VS	VS	VS	—	—	VS	VS	—
Turpentine	VS	VS	VS	VS	VS	VS	—	—	VS	VS	62
Xylene	VS	VS	VS	VS	VS	VS	—	—	VS	VS	67
Hydroxy — derivative											
Amyl Alcohol	S	S	—	—	S	S	—	—	S	S	—
n-Butyl Alcohol	S	S	—	—	S	S	—	—	SS	S	—
Ethyl Alcohol (3-A)	23.3 29°C	80.0 70°C	—	—	10 27°C	28 75°C	—	—	SS	—	—
Glycerine	I	I	I	I	I	I	I	I	I	I	—
Methyl Alcohol	42.5 20°C	88.5 60°C	—	—	15 25°C	22.2 65°C	—	—	SS	—	—
Phenol — 90%	194 30°C	S	—	—	SS	S	—	—	S	S	—
Ketone											
Acetone	S	S	—	—	S	S	—	—	S	S	—
Miscellaneous											
Carbon Disulfide	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 S — Soluble SS — Slightly Soluble VS — Very Soluble

Figures show grams of Aroclor per 100 milliliters of solvent at 25°C unless otherwise indicated.

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FIG. 4

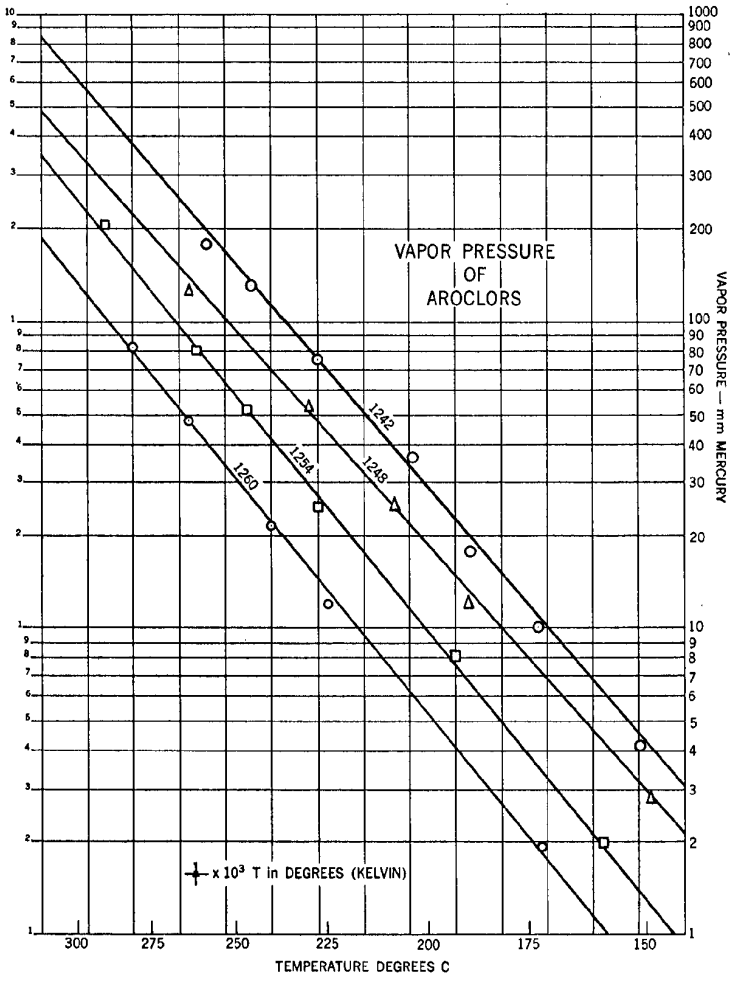

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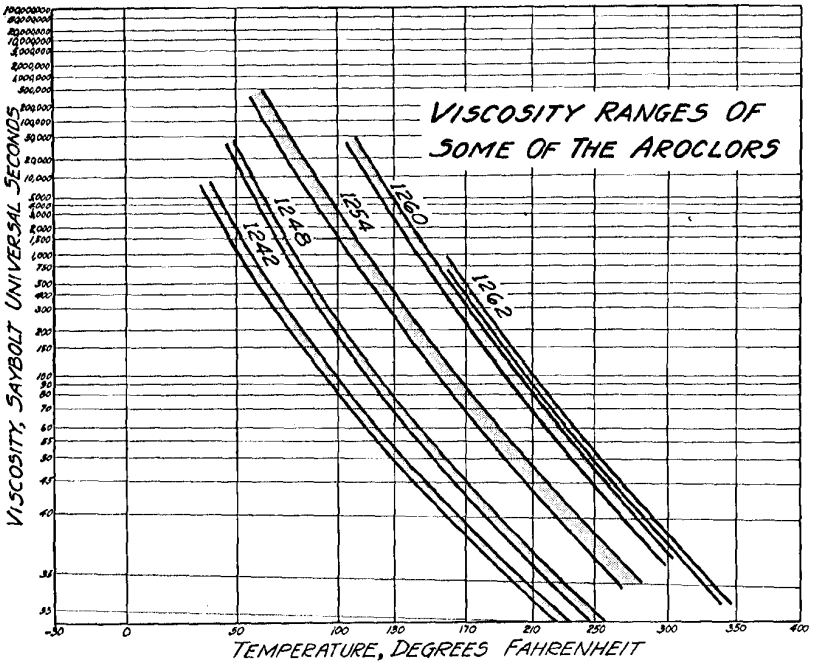
FIG. 5



Toxicity

Experimental work on animals shows that prolonged exposure to Aroclor vapors evolved at high temperatures or by repeated oral ingestion will lead to systemic toxic effects.

Repeated bodily contact with liquid Aroclors may lead to an acne-form skin eruption.

Suitable draft ventilation to control the vapors evolved at elevated temperatures, as well as protection by suitable garments from extensive bodily contact with liquid Aroclors, should prevent any untoward effect.

Vaporization Loss

The Aroclors have low vaporization losses as shown in the data in Table 1.

Estimated vapor pressures of several Aroclors extrapolated from Figure 4 are shown in Table VII.

TABLE VII

Approximate Vapor Pressures Calculated 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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APPLICATIONS

Adhesives

The heavier resinous Aroclors, because of their excellent adherence to smooth surfaces, are very adaptable to compounding in water-insoluble adhesives. Aroclors 1260, 1262, 4465 and 5460 are suggested as constituents of compositions for this use.

Electrical Equipment

Because of their nonflammability, high resistivity and dielectric strength and low power factor, the liquid and resinous Aroclors are extremely useful materials for the electrical industry.

Aroclor 5460 is useful as an impregnant for carbon radio resistors to reduce the influence of moisture. Since the liquid Aroclors will absorb sufficient moisture from the atmosphere to impair the electrical characteristics, it is customery to treat Aroclor intended for this application before use with a dehydrating clay. An effective product for this purpose is Attapulgus clay 80/300 mesh dried for 4 hours at 400°C. and used at the rate of 0.125% based on the weight of Aroclor, followed by filtration. Treatment is improved if the Aroclor is heated to 80-85°C.

Expansion Medium

Because of their stability under variations in temperature and freedom from gum formation from oxidation, the Aroclors are useful as expanding media in bellows controls and in thermostats.

Hydraulic Medium

Power Transmission

The Aroclors are superior hydraulic media for power transmission. Because of their greater density and E. P. characteristics they approach more closely the theoretical transmission values for mechanical power as illustrated in Figure 6. This greater efficiency makes possible a reduction in the size of the hydraulic coupling design.

In order to meet extremely low-temperature weather conditions, it is necessary to adjust the freezing point of the Aroclor selected by the addition of a pour point depressant. Suitable adjustments can be made in the composition to reach a pour point of minus 65°F.

The steepness of the viscosity-temperature curve of the Aroclors is a handicap to the application of Aroclors to many types of fluid transmission. This curve can be flattened to a marked degree by introduction of a viscosity-index corrector. By proper choice of viscosity modifiers and pour point depressants, the viscosity-temperature curve can be made to coincide with any standard hydrocarbon oil viscosity curve.

Information will be gladly furnished.

Hydraulic Pressure Medium

It is customary to employ a D. T. Light Oil (mineral base) as a hydraulic medium in many types of pressure operations. A widespread use is in the operation of zinc-alloy die casting machines where pressures of 800 to 1500 pounds per square inch are encountered. Condensate from the atmosphere above the liquid level in the breather tank frequently introduces water, which, having a greater density, sinks to the bottom and is drawn into the system. Under the influence of heat and pressure the water causes oxidation of the hydrocarbon oil, forming fatty acids which corrode the pump vanes and the regulating valves of the system, causing loss of pressure, lowered production rate and final shut down for repairs. A break in the hydraulic system around the open flames necessary to maintain the molten condition of the die-casting alloy almost invariably results in a fire with its attendant hazards.

Aroclor 1248 is recommended to overcome these difficulties. It is heavier than water, thus excluding it from the system. It is stable—not hydrolyzed

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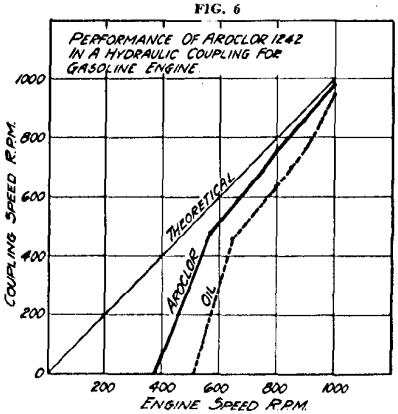
FIG. 6



under heat and pressure—and thus avoids corrosion and expensive delays for repairs. It is nonflammable, thus adding to the safety of the operators and to continuity of production.

Gaskets

Gaskets made from the usual types of material and synthetic rubber are unsuited for retaining Aroclors which have a swelling effect on such gaskets. Much more suitable are gaskets made from non-swelling elastomers such as Thiokol 1605-A (Thiokol Corporation) or Resistoflex B-1001 (Resistoflex Corporation).

Liquid Heating Medium

Aroclors 1242, 1248 and 1254 are used as a circulating heating medium with great success. Good circulation and a well designed heating system are necessary to prevent local overheating of the Aroclor heating medium. Aroclor 1248 is recommended for universal use up to 315°C (600°F) because of its fluidity at low temperatures and its nonflammability.

In processes where a cooling cycle must also be introduced, provision can be easily made for shunting circulating Aroclor through a water cooled heat exchanger, thus employing one medium for both heating and cooling.

In special cases, Aroclors 1242 and 1254 can be substituted for the Aroclor 1248. If extremely low outside temperatures are encountered, the less viscous Aroclor 1242 can be used, but it has the disadvantage of being flammable above 330°C (626°F).

Higher temperatures up to 325°C (617°F) can be attained in the heating medium if Aroclor 1254 is used. Provision can easily be made for warming the Aroclor after a shut-down so that it can be pumped.

Design for a simple, effective liquid Aroclor heating system for small unit operations is available.

Lubrication

Air Compressors

The presence of oil, oil vapors or mixtures of oxygen and oil fractions in the discharge lines and receivers of air compressors presents a constant hazard which needs only a particle of hot carbon to create a serious explosion.

This problem has been solved by engineers of one large user of this type equipment by employing Aroclor 1254 as the internal lubricant for high compression air compressors. Their experience with more than 15 high-pressure compressors of various types is reported in the American Machinists' Magazine, September 28, 1944.

High Temperature

The heat-resisting, nonflammable characteristics of the Aroclors make them attractive as lubricants under conditions of high temperature, as, for example, in governor systems of central power stations. Aroclor 1248 is well suited to this application. Straight Aroclor 1254 gave excellent results on a roller bearing test operating at 255°-260°F with much less carbonization or decomposition than the usual spindle oil under the same conditions.

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Extreme Pressure

It is a well accepted hypothesis in the lubrication industry that by the addition of certain elements such as chlorine, sulfur and others in the proper form to a lubricating oil, a certain chemical combination takes place with the iron or steel metal bearing surfaces. These surface compositions tend to prevent seizure of the rubbing surfaces under extreme loads and under which loads, if the sole lubricant were a pure mineral oil, seizure or scoring would result at once through film failure.

As an extreme pressure (E. P.) lubricant base added to a petroleum hydrocarbon oil in amounts up to approximately 15% by weight, Aroclors 1248 and 1254 materially increase the load-carrying properties without reducing the viscosity of the resulting composition. These Aroclors represent one of the more adequate carriers for the element chlorine as an extreme pressure base, possessing the following advantages:

1. *Stability.* They are stable, even at higher temperatures, which permits neither separation of components nor appreciable change in physical or chemical properties during long periods of operation and should not cause continued chemical action on metal parts except the particular chemical metal surface combination which is necessary to effect high load-carrying capacities.

2. *Non-volatile.* Many other types of chlorine bearing compounds are so volatile as to render them unfit for long periods of service because of the escape of the elements from the lubricant. The Aroclors are non-volatile at normal temperatures.

3. *Non-oxidizing.* Aroclors do not oxidize or thicken up to an objectionable degree.

4. *Non-corrosive.* Aroclors are non-corrosive toward metal surfaces.

5. *Non-abrasive.* Aroclors exert no abrasion on the machined surfaces.

6. *Non-hydrolysis.* Aroclors do not hydrolyze in the presence of water, thus avoiding the generation of hydrochloric acid.

7. *Compatibility.* Aroclors are completely miscible with mineral oils.

8. *Color.* Aroclors do not darken or change the color of the lubricating oil.

Submerged Lubrication

Under conditions of lubrication subjected to exposure to water displacement such, for example, as lubrication of bridge rollers, a heavier-than-water lubricant can be prepared from mixtures of Aroclor and oil, of which the following are typical examples:

Mix No.	—% by Wt.— Oil*	Aroclor 1248	Pour Point	Gravity at 15.5°C	Approx. lbs./gal.
1	50	50	0°F	1.1263	9.4
2	25	75	+5°F	1.2703	10.6

*Bright Stock: Gravity API 22-23
Viscosity 210° F—160 Saybolt Secs.
Color ASTM—7-8
Flash Point—545°F
Pour Point—15°F

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SUGGESTED USES FOR AROCLORS

in

PLASTICS, PIGMENTS, LACQUERS, PAINTS and VARNISHES

The Aroclors are compatible with most of the common plastics materials (see compatibility table on this page). The degree of flexibility imparted by the Aroclors diminishes progressively in the order of liquid Aroclor — soft resin — hard resin. The hardness of the resulting compositions increases in the same order. Usually a satisfactory balance between flexibility and hardness can be obtained either by selecting the Aroclor of proper physical characteristics or by using a mixture of two or more Aroclors.

Compatibility With Various Materials

Asphalt	C
Benzyl Cellulose	C
Cellulose Acetate	I
Chlorinated Rubber	C
Coumarone and Indene Resins	C
Dammar Resin	C
Ester Gum	C
Ethyl Cellulose	C
Manila Gum	I
Nitrocellulose	C
Paraffin	C
Phenolic Resins	Varies.*
Polystyrene Resins	C
Rosin	C
Rubber	C
Sulfur	C
Vinyl Resins	C

C — Indicates compatibility to a degree sufficient to be of value.

I — Indicates incompatibility.

* Not compatible in final stage.

Ethyl Cellulose

The Aroclors are very compatible with ethyl cellulose, the liquids imparting great flexibility and the resinous products great hardness. 75 parts by weight of Aroclor 1242 with 100 parts of ethyl cellulose produces great flexibility and just a slight tackiness. Aroclor 5460 in the same proportion produces a very hard and somewhat brittle composition. Aroclor 4465 produces hard films which are not brittle at ordinary temperature.

For coatings of high gloss and exceptional weathering qualities to be applied to rigid surfaces, compositions containing equal parts by weight of Aroclor 5460 and ethyl cellulose are suggested. If greater flexibility is required, one of the softer Aroclors should be used, either alone or as a replacement for part of the Aroclor 5460 and the proportion of Aroclor should be decreased.

A typical formula is as follows:

Ethyl Cellulose	15%
Aroclor 1260	15%
Toluene	56%
Butanol	14%
	100%

Graphic Arts

The Aroclors are used as vehicles for carrying pigments employed in glass decoration. When the decorations have been applied and the glass is fired, the Aroclors volatilize without carbonization and thus avoid discoloration of the glass. Aroclors 1254 and 4465 are used.

Aroclor 4465 is a useful resin for compounding rotogravure inks.

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A mimeograph ink suitable for use on bond paper contains the following ingredients:

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 may also be used in the preparation of imitation gold leaf. A thin coating of the Aroclor is applied hot to one side of paper. While it is still hot, bronze powder is spread upon the coating. The bronze powder adheres to the Aroclor completely covering the paper. This product is used in making the "gold leaf" letters on books, etc. The paper treated with Aroclor and bronze powder is placed upon the book binding. A hot die is pressed upon it. The Aroclor softens and sticks the bronze to the binding and forms a coating over it to protect it from tarnishing.

Impregnation

The Aroclors may be used to impregnate cloth, paper, wood or asbestos in order to impart moisture and gas resistance, adhesion, insulating properties, alkali or other chemical resistance, flame resistance, or lubricating qualities. For this type of work they are used in combinations with other materials such as waxes, inorganic pigments, asphalt, tars, aluminum stearate, sulphur, etc., in order to obtain exactly the physical characteristics desired for the specific purpose. Aroclors 1254, 4465 and 5460, or the corresponding dark-colored products, are suggested as most applicable.

Wood impregnated by vacuum-pressure method with the following mixture:

Aroclor 4465	70%
Microcrystalline Wax	20%
Sulfur	10%

is definitely tougher, harder and more moisture resistant than untreated wood. This coating is very resistant to acids and alkalies but will be attacked by aromatic, aliphatic or chlorinated hydrocarbons. The surface is not appreciably discolored and can be painted. Various degrees of hardness and adhesion can be obtained by varying the Aroclor: wax: sulfur ratio.

Moisture Proofing

For use as moisture proof coatings the Aroclors are best combined with waxes, such as paraffin or carnauba, oils such as mineral oil, and resins such as ester gum or other synthetic resins. The simplest compositions contain only Aroclor and paraffin. A moisture proofing compound composed of 96% (by weight) of Aroclor 5460 and 4% of paraffin (melting point 54°C) has an ASTM softening point of about 82° C and is very efficient. Substituting Aroclor 4465 for Aroclor 5460 produces a compound with a softening point of about 58°C.

Softening point and viscosity when melted may be further decreased by using mixtures of Aroclors. For example, a composition containing 40% of Aroclor 1260, 56% of Aroclor 5460 and 4% of paraffin will be very soft at ordinary temperatures. Increased proportions of paraffin will also produce softer compounds.

Pigment

Aroclor 1270 is a hard, white crystalline product of high melting point, insoluble in most solvents, resistant to chemicals and to oxidation. When ground to a fine powder it makes an excellent organic pigment for use with the various plastics. It may be used alone or with conventional pigments.

Paints and Varnishes

The Aroclors are soluble in paint and varnish oils and impart properties corresponding to the physical character of the particular Aroclor. The hard resinous Aroclors tend to give increased hardness to the films while the viscous resins impart flexibility.

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The Aroclors 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. As far as incorporation of the Aroclors is concerned, the only reason for heating is to make the Aroclors liquid so that they can be readily mixed with the oils.

Aroclors 4465 and 5460 will produce paints that are very quick drying and yet have excellent durability. The weight of Aroclor used should be from 30% to 50% of the weight of the oils.

Aroclor 1260 is best for short oil varnishes that are required at the same time to be flexible. The Aroclor may be considered to play the same role as oil, with the difference that it does not oxidize and lose its flexibility on exposure. Resins of the alkyd, phenolic or ester gum type, or a harder Aroclor such as 5460, may be used in making varnish formulations. It is suggested that for two parts by weight of oil, one part of Aroclor 1260 and one part of other resin be used. These proportions can be varied as required. The Aroclors impart water and alkali resistance and in these qualities enhance the value of the other resins used in the varnish.

Rubber and Rubber Substitutes

The Aroclors when in a liquid condition have a solvent action on rubber, both natural and synthetic. Aroclors 1254 and 1260 are milled into rubber in order to impart permanent tackiness and adhesion. A small amount of Aroclor 1260 added to hard rubber acts as a plasticizer and reduces the brittleness.

Aroclor 1270, being a hard crystalline material of high melting point, can be ground to a powder and then milled into rubber. The milling temperature being below the melting point of the Aroclor, the latter is dispersed through the mass of rubber and acts as an efficient flame reducer. This same procedure can be used with synthetic rubbers to impart fireproofness. From 5% to 25% of Aroclor 1270 based on the weight of the resin is required.

Aroclor 1262 is recommended as a plasticizer for crepe rubber resin in paint compositions. Used in concentrations of 5% to 50%, based on the weight of the rubber resin, it increases the gloss and alkali resistance of the film and increases its adhesiveness toward steel.

Aroclor imparts water resistance to Thiokol.

Modified Rubber Finishes

Aroclors 1242, 1254, 1260, and 1262 are recommended as plasticizers for modified rubber finishes (chlorinated rubber, rubber hydrochloride and cyclicized rubber). Used in ratios of 5 to 50 parts to each 100 parts by weight of modified rubber, they yield tough, flexible compositions, when used alone or in combinations with resins and oils. Resinous Aroclors 4465 and 5460 used in the proportion 50 to 100 parts to 100 parts of modified rubber yield harder films. The Aroclors are especially valuable in compositions of modified rubber used as finishes for alkaline surfaces such as concrete, brick, stucco, etc. And as acid and alkiline coatings.

Vinyl Resins

The Aroclors are compatible with all the vinyl resins and are of value because of their chemical resistance. The properties imparted depend upon the particular Aroclor and the vinyl resin used. The selection of the correct Aroclor for a particular use can usually be made by consideration of the physical properties of the Aroclor series.

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Nitrocellulose Coatings

The Aroclors function both as plasticizers and resins and may be used alone with the nitrocellulose or in combinations with other plasticizers or resins. They impart weather resistance, luster, adhesion and decreased burning rate. Their excellent electrical characteristics (high dielectric strength and resistivity and low power factor) and their property of retarding the passage of moisture and gases through nitrocellulose, chlorinated rubber, and other similar plastics films make the Aroclors of special value in coatings for electrical insulating materials.

The accompanying trilinear diagrams show the practical compatibility limits of Aroclors 1254 and 1262 when used in conjunction with some other resins and plasticizers. Aroclor 1260 gives values almost the same as those shown for 1262. The less viscous Aroclors have greater and the more resinous Aroclors less compatibility than for those shown. (See trilinear diagrams that follow.)

To illustrate the differences possible to obtain by changes in formulation, three formulas are given below. All have excellent durability but the third is much softer and more flexible than the other two. Only the solids contents are given.

The amounts tabulated are parts by weight.

Aroclor Lacquers

	No. 1	No. 2	No. 3
½ second Nitrocellulose (dry)	100	100	100
Dammar resin	80	—	—
Ester Gum	—	80	—
Aroclor 1260	20-39	20	80-70
Dibutyl Phthalate	20- 0	20	—
Tricresyl Phosphate	—	—	39-70

No. 1 and No. 2 have excellent sanding and polishing qualities. No. 3 is very flexible but too soft for sanding.

Where extremely high flexibility is desired, as for example in lacquers for high tension automotive cables, the following composition is suggested: 15 — 20 sec. R. S.

Nitrocellulose	100 parts by weight
Tricresyl Phosphate	120 parts by weight
Aroclor 1242	80 parts by weight

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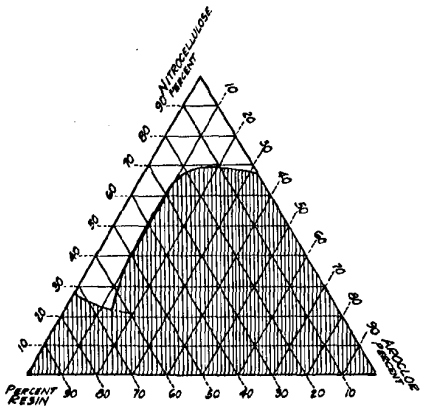
DIAGRAMS SHOWING PRACTICAL COMPOSITION OF LACQUERS USING AROCLORS 1254 AND 1262

In the trilinear diagrams the compositions, represented by any point in the unshaded areas, are those which produce homogeneous lacquer films. On the other hand compositions represented by points in the shaded areas produce impractical, segregated, brittle or soft films. For detailed information as to the derivation and use of these diagrams reference is made to the following articles:

Jenkins & Foster, "Compatibility Relationships of the Aroclors in Nitrocellulose Lacquers," Ind. Eng. Chem. 23, 1362 (1931).

Hofmann & Reid, "Graphical Methods in Lacquer Technology," Ind. Eng. Chem. 20, 431 (1928); "Formulation of Nitrocellulose Lacquers," Ind. Eng. Chem. 20, 687 (1928).



For combinations where the resin is Ester Gum or Amberol and where the Aroclor is Aroclor 1254 or Aroclor 1262.

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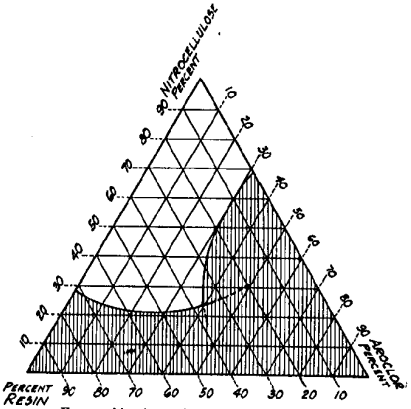
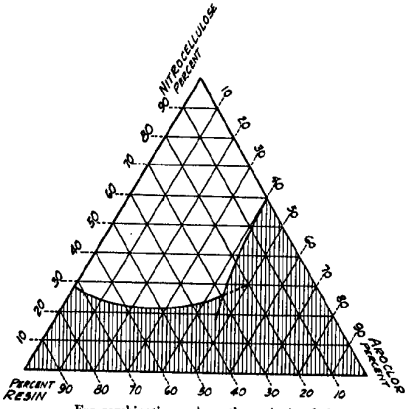
Practical Composition of Lacquers using Aroclors 1254 and 1262 — (continued)



For combinations where the resin is of the phthalic anhydride-glycerol type and where the Aroclor is Aroclor 1262.*

*Aroclor 1260 may be substituted without material change.



For combinations where the resin is of the phthalic anhydride-glycerol type and where the Aroclor is Aroclor 1254.

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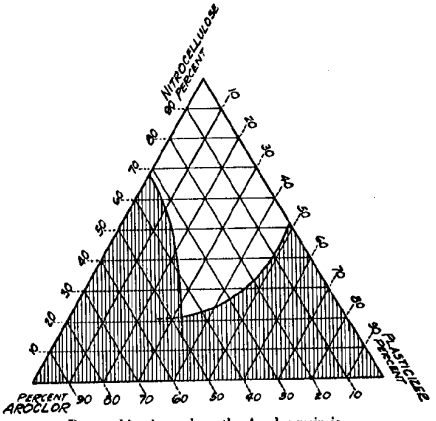
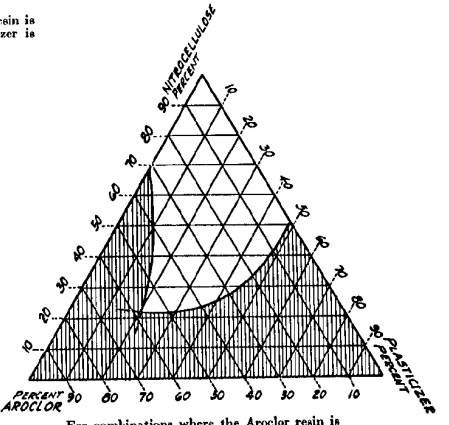
Practical Composition of Lacquers using Aroclors 1254 and 1262
— (concluded)



For combinations where the Aroclor resin is Aroclor 1262* and where the plasticizer is Dibutyl Phthalate.



For combinations where the Aroclor resin is Aroclor 1262* and where the plasticizer is Tricresyl Phosphate.

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