MONSANTO CHEMICAL COMPANY

SALESMEN'S MANUAL

AROCLOR

DESCRIPTION AND PROPERTIES

The Aroclors are a series of chlorinated hydrocarbons based on biphenyl and terphenyl. They are not pure compounds but are mixtures of closely related chlorine substitution products manufactured essentially to a set of specifications based on physical properties rather than chemical composition.

The approximate chlorine content is indicated by the last two figures of the Aroclor number. The chemical composition closely approaches the average for the indicated chloro-derivatives as follows, but should not be represented as simple chemical compositions according to the formula shown:

Approximate Equivalent	Chemical Compound
1241	Monochlorobiphenyl
1232	Dichlorobiphenyl
1242	Trichlorobiphenyl
1248	Tetrachlorobiphenyl
1254	Pentachlorobiphenyl
1260	Hexachlorobiphenyl
1262	Heptachlorobiphenyl
1268	Nonachlorobiphenyl
1271	Decachlorobiphenyl
5460	Nonachloroterphenyl

Reference should be made to technical bulletin P-115 for tables and graphs of physical properties. This manual contains only that information which is not designed for general public distribution or has been made more recently available than permitted incorporation in the printed bulletin.

The following Aroclors not in commercial production (but available) have been proposed:

Aroclor No.	5448	5454
Fixed Chlorine	47.9%	54.83%
Color (Lovibond)	6.0	20.0
Pour Point	60°C	84°C
Softening Point	63°C	85°C

MONS 092643

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10-1-44

Aroclor No.	5448	5454
Viscosity 98.9°C (210°F)	395.0*	-
Flash Point	250°C	-
Burn Point	400°C	-
Chlorides	None	None
Acidity - mg. KOH/g.	0.008	0.004
Evaporation	0.006	0.007
Resistivity	--	--
Ageing	--	--
Dielectric Constant	4.65	4.17

*SUS

ELECTRICAL PROPERTIES

	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 5442
*Dielectric Constant @ 100°C	4.9	4.63	4.15-4.35	3.6-3.8	4.92
**Resistivity @ 100°C, OHMS/Cm³	500x10⁹	Above 500x10⁹	Above 500x10⁹	1469x10⁹
***Dielectric Strength		35 KV Min.		
Power Factor (100°C, 1000 kc)		Less than 0.1%		Less than 0.1%

* IRS Method H-3955871
** Resistivity @ 100° under 500 Volts DC
*** ASTM D-177-11

Refractive Index	Range	Midpoint
Aroclor 1270	1.691-1.74	1.712
Aroclor 1271	1.691-1.74	1.712
Tetradecachlorometaterphenyl	1.712-1.718	--
Tetradecachloroparaterphenyl	1.691-1.74	1.712

Heat of Vaporization	B.I.U./lb.
Aroclor 1260 (3 mm. pressure)	104
Aroclor 1262 (760 mm. pressure)	72.4
Aroclor 1169 (0.151 atm. @ 350°C)	69.2
(0.079 atm. @ 325°C)	70.6

MONS 092644

10-1-44

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SOLUBILITY

Solvent	Aroclor 1268 Cold	Aroclor 1268 Hot
Acetone	I	I
Alcohol, Formula 3-A	I	I
Amyl Acetate	S	S
Amyl Alcohol	PS	S
Benzene	S	S
Butyl Acetate	S	S
N. Butyl Alcohol	I	PS
Carbitol	I	S
Carbon Disulfide Carbon Tetra chloride	S ~45	S ~70 @ 50°C
Cellosolve	I	S
Chloroform	S	S
Di Butyl Phthalate	S	S
Ether	S	S
Ethyl Acetate	PS	PS
Ethyl Lactate	I	S
Ethylene Dichloride	S	S
40% Formaldehyde	I	I
Furfural	PS	PS
High Test Gasoline		
Glycerin	I	I
Kerosene	PS	S
Linseed Oil	I	S
Methyl Acetate	PS	PS
Mineral Spirits	8	11 @ 50°C
Paraffin		
Phenol 90%	PS	S
Pine Oil	S	S
Pyridine	S	S
Toluene	S	S
Tri Cresyl Phosphate	S	S
Tung Oil	I	S
Turpentine	15	22 @ 50°C
Xylene	25	43 @ 50°C

I = Insoluble
PS = Partially Soluble
S = Soluble

Solvent	Gms. Aroclor 1270 per 100 cc. Solvent	Approx. Temp. at which soln. complete
Furfural	2.0	105-110°C
Furfural	4.0	120-125°C
Secondary Amyl Acetate	4.0	110-115°C
Secondary Amyl Alcohole	4.0	Not completely soluble at boil
Carbitol	4.0	Above 125°C
Heavy White Mineral Oil	4.0	110-115°C

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STABILITY

Toward Heat

Aroclor 1248 was heated to 650°F in stainless steel autoclave with the resulting changes indicated in the following tabulation:

	Time of Heating (Hours)	Temperature	Acidity mg.NaOH/gm. Aroclor 1248
Original Sample	0	--	.0021
Autoclave #1	331	343°C. 650°F.	.0392
Autoclave #2	500	343°C. 650°F.	.0809
Autoclave #3	669	343°C. 650°F.	.0800

These results are interpreted as indicating very excellent stability for Aroclors under the conditions of test.

Toward Oxidation

When Aroclor 1254 is heated for 50 or 60 days at 150°C in the presence of oxygen and copper, there is likely to be some attack on the copper. Examination of Aroclor 1254 after that period of time will usually show the presence of soluble copper. This also occurs with mineral oil and other insulating liquids.

In general, even after severe oxidation conditions no evidence of chlorine splitting from the parent hydrocarbon has been found.

Toward Acids

Aroclors 1242 and 1254 were stirred with an equal volume of concentrated Sulfuric Acid (98%), dilute Sulfuric Acid (10%), Nitric Acid (70%), and dilute Nitric Acid (5%), at room temperature (25°C) for 150-250 hours. The Aroclor was then washed until neutral, dehydrated with Sodium Sulfate. then analyzed in comparison with a control sample for the various properties which are regularly considered, without causing these properties to depart from specification limits.

Aroclor 1262 was treated for 160 hours suspended in the same acids as above at 50 to 55°C. The concentrated Nitric Acid caused an increase in color, otherwise no significant change in characteristics.

The acid layer from the treatment of Aroclor 1254 was concentrated Sulfuric Acid at room temperature for 150 hours and was tested for chloride content. The quantity of HCl found was so small that it was not possible by ordinary methods to obtain a quantitative figure. Thus it appears that practically no hydrogen chloride is evolved under these conditions.

MONS 092646

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CORROSION

Additional corrosion data not included in bulletin P-115 (Pl 4-43-R) is as follows:

Metal	Temperature	Time of Exposure	Penetration in/yr.
Monel	342°C	360 hrs.	.008
Dow Metal	150°C	40 days	.001
Yellow Brass	325°C	2,960 hrs. in steel bomb	.003
Al alloy 17ST	120°C	21	.00035*
Al alloy 52SH	120°C	21	.00035*
Al alloy 53ST	120°C	21	.00038*

*The weight loss occurred in the first seven days of the test. Negligible loss was encountered in the last 14 days.

The vapor condenser and the product receiver of the plant distillation unit for producing Aroclor 1254 is constructed of Monel and no failure in the system nor any noticeable reaction between the Aroclor and the Monel has been discovered after three years of operation.

SOLUBILITY OF WATER IN AROCLOR 1242

The water content of a sample of Aroclor 1242 saturated with water at approximately 30°C was determined, using the Karl Fischer reagent, to be about 0.08%.

Aroclor 1242, as regularly produced, contains by the same test less than 0.001% water.

SURFACE TENSION

The surface tension of Aroclor 1254 is as follows:

Temperature	Dynes per Centimeter
25°C	50.3
80°C	44.0
100°C	42.0

TOXICITY

All chlorinated hydrocarbons have measurable degrees of toxicity to the animal organism. Aroclors are no exception. The symptoms of Aroclor poisoning are:

1. Pore acne (chlor-acne) nodular eruptions of the hair follicles or sebaceous glands as a result of insufficient cleansing of the skin.

MONS 092647

2. Acute yellow atrophy of the liver in which the liver cells show swelling, hypergranulation, hyaline inclusions and vacuolation as a result of extensive exposure over long periods of time.

These symptoms may also result from exposure to other chlorinated hydrocarbons of commerce, such as: carbon tetrachloride, dichlorethylene, trichlor ethylene, chlorinated naphthalene (Halowax). The best known (at present) measure of the degree of toxicity of the Aroclors is presented below:

Permissible Limits (in mg./cu.m.) of Concentration in Air of Work Rooms: (Journal of Industrial Hygiene & Toxicology 21: 155, 1939)

Tested on Rats by Inhalation

	Chlorine Content %	Permissible Limit mg./cu.m.
Aroclor 1268	68	10.0
Aroclor 4465	65	0.5 *
Aroclor 5460	60	0.5
Aroclor 1254	54	0.5
Trichlornaphthalene plus trace Tetrachlornaphthalene	49.9	10.0 *
Tetra and Pentachlornaphthalenes	56.4	1.0 *
Penta and Hexachlornaphthalenes	62.6	0.5 *
Tetra and Pentachlornaphthalenes plus Refined Chlorinated Diphenyl	43.5	0.5 *
90% Penta and Hexachlornaphthalenes / 10% Aroclor 4465	63.0	0.5 *
Chlorinated Diphenyl Oxide	54.0	0.5
Chlorinated Diphenyl Oxide	57.0	0.5
Hexachlor Diphenyl Oxide / 5% Trichlornaphthalene	50-55	0.5
Hexachlornaphthalene and Crude Chlorinated Diphenyl	--	0.5
Special Chlorinated Naphthalene	50-56	0.5

*Tested also by feeding.

Summary of Gross Feeding Experiments

Of the various materials fed rats in large doses, Trichlornaphthalene plus traces of Tetrachlornaphthalene was quite innocuous. Tetra and Pentachlornaphthalene showed definite liver damage. Penta and Hexachlornaphthalenes caused a similar grade of injury. The addition of chlorinated diphenyl to Penta and Hexachlornaphthalenes increased the toxicity. Chlorinated Diphenyl alone produced liver lesions but in the dosage used was less effective than when mixed with highly chlorinated naphthalenes. In no case did the compounds

used produce acute yellow atrophy but the lesions observed indicate this might be possible if one found a dosage which could act for the proper period of time.

Feeding Precise Doses by Stomach Tube: The compounds employed were suspended in gum acacia. In figuring the dosage the total amount a man of 50 kg. would inhale in an 8-hour day, assuming an air concentration of 20 mgm. per cu.m., was first calculated and reduced to milligrams per kilogram. The rats and rabbits received this dose each day. The compounds used were those employed in the gross feeding experiments and the results were essentially similar though the lesions were less severe.

Subcutaneous Injections: The same gum acacia suspensions were injected subcutaneously into rats and rabbits, the dosage being calculated on the basis of 4 mgm. per cu.m. of air. Again similar results were obtained. In all such experiments there must of necessity be differences in the degree of effect but invariably the liver was the sole organ affected and the lesions were those already described many times.

Recommendations for Industrial Practice: Unless there is a very good reason for using the hot method of impregnation, all new installations should use the cold or solvent method of impregnation with chlorinated naphthalenes and diphenyls. Where the hot method is now being used it should be changed over to cold, if possible, or surrounded with every known protective measure.

General hygienic measures should be followed, but in no case should these be allowed to supersede engineering control of the primary source of the exposure, the operations in the plant.

The following hygienic measures may be considered good practice where these compounds are handled:

(a) Two lockers for each worker exposed to chlorinated waxes (one for working and one for street clothes).

(b) All work clothes above the underwear should be provided and laundered at least twice a week by the management.

(c) The workers should change to clean underwear at the end of each shift before getting into his street clothes.

(d) Supervised cleaning: (1) At noon the workers should remove outer clothing and scrub hands and face under supervision; (2) at the end of the shift they should be required to take a supervised shower before changing back to street clothes.

(e) Protective skin creams or protective clothing should be provided by the management at the discretion of the foreman, nurse, medical, or plant superintendent.

(f) All departments handling chlorinated synthetic waxes should be thoroughly cleaned according to a prearranged schedule. This should include the removal of all deposits of waxy material from the machines, floors and surrounding objects. Workers doing the cleaning should be provided with protective clothing and supplied air or organic vapor masks where exhaust ventilation is inadequate or not possible.

The foremen of all departments where this material is handled should be apprised of the toxic nature of the material and instructed in safe handling procedures. These men should make it their duty to check up on the workers in their departments and instruct them in safe practice.

Pre-employment and periodic physical examinations should be made of all exposed workers. These should include the taking of a full clinical history, with special emphasis on gastro-intestinal disturbances and dermatitis. In addition, the skin should be carefully examined periodically and the more reliable liver function tests performed. Gastro-intestinal complaints developing in a worker at any time should be a signal for an immediate medical check-up. A history of liver disease, jaundice, or antisyphilitic treatment should automatically exclude a worker from jobs involving a possible toxic exposure. Pregnant women should not be employed where there is a possible exposure to the synthetic chlorinated waxes.

Engineering control of plant operations cannot be over-emphasized but specific recommendations are not applicable to all cases. It would be wise for a plant using this class of materials to check their control measures with the state industrial hygiene agency, the insurance carrier and some competent consultant before occupational disease occurs.

APPLICATIONS OF AROCLORS

ADHESIVES

Adhesives of good electrical characteristics can be prepared containing Aroclors. The following are typical examples:

		Typical Values
#103	Aroclor 4465 (Code 3140-0144)	47.0%
(XW)	Paraffin 50.8oC	1.0
	Mineral Oil (Extra Heavy White)	2.0
	Barytes - Mepham's #2	50.0

		Typical Values
#103B (XB)	Aroclor 2565 (S.P. 77.5°C) (Code 3140-0114)	46.50%
	Paraffin 50.8°C	1.17
	Mineral Oil (Extra Heavy White - Sonneborn's)	2.33
	Barytes - Mepham's #2	50.00
#131	Aroclor 4465 (Code 3140-0144)	16.10%
E-11	Ester Gum - BKEG #1202XXXX Pale	14.35
65B	Paraffin 50.8°C	4.55
	Barytes - Mepham's #2	65.00
#135	Aroclor 4465 (Code 3140-0144)	20.70%
	Ester Gum - BKEG #1202XXXX Pale	18.45
	Mineral Oil (Extra Heavy White - Sonneborn's)	5.85
	Barytes - Mepham's #2	55.00
#H	Aroclor 4465 (Code 3140-0144)	46.0%
50B	Mineral Oil (Extra Heavy White - Sonneborn's)	4.0
	Barytes - Mepham's #2	50.0
#"M"	Aroclor 4465	89.5%
	Mineral Oil (Extra Heavy White - Sonneborn's)	10.5
#"M"	Aroclor 4465	58.2%
	Mineral Oil (Extra Heavy White - Sonneborn's)	6.8
	Silica (Schultz, Champlain & Bibbo)	35.0

For the preparation of thermo-plastic adhesives Purdue University found that the harder Aroclors are better than anything else discovered to date. primarily because of their high compatibility with other resins and their thermo-stability.

ELECTRICAL

Dielectrics and Electrical Insulators

The Aroclors have excellent dielectric properties, that is, low dielectric constant and resistivity and low power factor. Aroclor 1242 has the highest dielectric constant of the whole series which we are manufacturing commercially, while higher chlorine Aroclors have higher resistivity.

The Aroclors have found usefulness as a dielectric in condensers and as a dielectric and cooling medium in transformers, and a number of miscellaneous similar uses where the characteristics above named are of importance.

AROCLORS AS SATURANTS

Saturation may be defined as that operation by which liquids or gases are caused to penetrate relatively porous materials. The penetrating medium is known as the saturant and is generally in

the liquid state. Saturation may be assisted or accelerated by means of increased temperature and pressure or by the use of a vacuum.

Various classes of products are saturated for the purpose of giving them a wide variety of properties. Some of the properties attained by saturation are: water and flame resistance; resistance to chemicals; abrasion; moisture; light and weather changes; increased strength; and increased weight.

Among the articles that are treated to obtain some one or all of the above mentioned properties are included the various fibres and fabrics: animal; vegetable and mineral; woods, both hard and soft; ceramics ware and cement; and certain kinds of electrical apparatus, such as carbon resistors.

The saturants, or, as they are sometimes called, the impregnants, are usually made up of waxes, oils, resins, or water solutions of certain inorganic salts.

Applications

At present the saturating applications that are of chief interest are insulated wire, low voltage cable commonly called network cable, and carbon resistor fields. These proposed uses are described more fully under the separate headings which follow.

Network Cable

Attempts are being made to develop a use for Aroclor as a saturant for secondary network or low voltage cable. Cable of this kind is used in electrical network distribution systems. Generally, it consists of the copper conductor or conductors, the paper insulation, and the lead sheath. The paper is saturated with an oil, usually a good grade of oil such as the General Electric Company's Transil Oil. This form of construction is objectionable because under the conditions imposed by a short circuit, combustible gases are generated which flow through the conduits to the manholes, at which point they may form explosive mixtures with the air and, in turn, cause explosions in the manholes. Both the paper and the oil are sources of combustible gases. It is therefore desirable to replace them -- the paper with an inert form of insulation, if possible, and the oil with a non-inflammable saturant such as Aroclor. Thus far, Aroclor 1254 appears to meet the requirements of this use.

The more important cable manufacturers in the country are already at work on the development of a flame resistant cable and also one in which the explosion hazard will be lessened or eliminated.

Carbon Resistors

Carbon resistors are small molded rods of a mixture of carbon black and sand with a resinous binder. They are porous and their electrical resistance is seriously affected by the entrance of moisture.

To prevent moisture getting into the units they are usually impregnated with some material to fill up the voids and to coat the surface of the resistor. A wax is generally used for this purpose and serves very well as far as moisture-proofing is concerned. However, after completion, the resistor must be lacquered for identification. Lacquer does not adhere well to the waxed surfaces.

Aroclor 4465 Moisture-proofing Compounds give moisture proofness (Humidity test) equal to that of wax and, in addition, give a surface to which lacquer will adhere.

The Aroclor Compound is non-crystalline and therefore does not have a definite melting point and does not become extremely fluid at the melting point of most waxes that are used in this application, but it gradually softens under increased temperature.

In extensive tests to find the most effective medium for impregnating radio resistors to stabilize the electrical resistivity under exaggerated and extreme humidity tests, Aroclor 5460 gave by far the best results when compared with Santowax and various petroleum waxes and compounds.

This excellent Aroclor success was accomplished by grinding off or sanding the surface of the carbon resistor prior to impregnating, thus exposing the inner pores of the resistor, permitting excellent penetration. Penetration has always been a problem in the impregnation of resistors with resinous materials such as Aroclor.

Cable Insulation

Electrical conductors and cables insulated with asbestos are frequently lacking in waterproofness. Impregnation with wax compositions gives an insulating medium resistant to atmospheric moisture and sometimes even to immersion in water for a short time, but hitherto no composition having the required characteristics of heat resistance and flameproofness has given sufficient water resistance to withstand immersion for prolonged periods.

An improved method of impregnating asbestos is described in U. S. Patent 2,162,953, assigned to Rockbestos Products Corporation, which depends on the use of a phenolic resin in conjunction with a chlorinated diphenyl. It has already been proposed to use each of these substances separately for a similar purpose, but alone the first lacks flameproofness and the second resistance to water.

The phenolic resin used for this purpose should be thermoplastic, solid and rather brittle at ordinary temperatures, with a flow point of 105°C. Bakelite XR 8430 is suggested as a suitable type. The best chlorinated diphenyl for this process is stated to be one having a viscosity of 96 sec. Saybolt at 100°C, and, of course, it must mix readily with the phenolic resin. One containing about 62 per cent chlorine is said to be satisfactory, for example, Aroclor 1262.

The two ingredients are mixed in equal parts by weight at 160°C, preferably with the addition of 5 per cent by weight of a plasticizer such as Tricresyl Phosphate. The resulting mixture is stable and can be stored.

In manufacturing the cable the individual conductors are insulated, twisted and covered with the layers of impregnated asbestos and varnished cambric (or the like) in the manner well understood in the art. A layer of loosely felted dry asbestos of suitable thickness is then applied around the thus assembled cable, and a dry asbestos braid is applied over the felted layer of asbestos. The so-covered cable is then passed through the impregnating compound (mixture of resinous phenolic condensation product and chlorinated diphenyl) while maintaining the compound at a temperature of about 155°C. The time required to impregnate the layer of felted asbestos and asbestos braid will depend on the thickness of the layer. As the cable emerges from the heated bath of impregnating compound, it is passed through suitable snubbing devices to remove the excess compound from its outer surface.

In order to prevent migration of the outer surface compound when the finished wire or cable is subjected to high temperatures in service, it has been found advantageous in some instances to apply to the impregnated layer of asbestos a second coat of the impregnating compound to which has been added about 15 to 20% of ground mica or other finely divided inert solid material. The impregnating compound on the outer surface of the impregnated asbestos then contains dispersed finely divided particles of the inert solid material which act to thicken the compound and render it less susceptible to flow. The admixture of mica or the like is not required or desirable in the compound used to impregnate the asbestos layer, since the asbestos fibres themselves satisfactorily perform the function of retaining the compound within the mass by capillary attraction.

The insulated conductor or cable of the invention possesses all the necessary characteristics of heat resistance, flameproofness, pliability, dielectric strength and resistance to water. The outer insulating layer of asbestos impregnated with a mixture of resinous phenolic condensation product and chlorinated diphenyl is substantially waterproof, even when submerged in water for extended periods of time or subjected to hydrostatic pressure as high as 25 pounds per square inch. In general, the use of asbestos

as an electrical insulating material has heretofore been limited to locations where high temperatures or the hazard of inflammable material made the use of ordinary forms of insulation (such as rubber, varnished cambric, paper, etc.) undesirable or prohibitive. It will, therefore, be evident that the invention widely extends the usefulness of asbestos insulated wires and cables.

Condensers

A rapidly growing use of Aroclor is in the manufacture of the small condensers employed in fluorescent lighting fixtures for offices, business houses and factories.

AROCLOR EMULSION FORMULA

16 pounds of Aroclor - liquid
8 pounds of Water
16 ounces of Stearic Acid
4 ounces of Triethanolamine

The Aroclor is heated to a workable viscosity above 82°C (180°F) and the Stearic Acid is added and completely stirred in. The water is heated to 97°C (207°F) and the Triethanolamine added and thoroughly stirred in. After both of these operations have been carried out, the Aroclor-Stearic Acid combination is poured into the water mixture while the latter is well agitated and then the whole mixture is processed through a colloid mill. Good results may even be obtained without the use of a colloid mill, provided the mixture is agitated with a high-speed emulsifying stirrer.

FLAMEPROOFERS

The Aroclors are not inflammable and when mixed in sufficiently large proportion with many other materials have rendered the complete compound non-inflammable. For instance, a mixture of about equal parts of Aroclor 2565 and asphalt gives a resulting compound that will not permit the spread of flame. Wood may be impregnated sufficiently with one of the higher chlorine Aroclors, such as 4465, that it will pass the most rigid tests now applied to wood which has been treated for flameproofness, such as the tests used by the Forest Products Laboratory and by the Building Department of the City of New York.

We have not yet found a market for Aroclor in the field of flameproofing wood because in most cases where the wood is treated for flameproofness it is used indoors where it is not exposed to leaching by rain, so that one of the phosphate salts is generally used. However, there may be special uses where these materials are not acceptable and where the price of Aroclor is justified.

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There is throughout the country a tremendous market for compounded waxes for all manner of uses. It is very likely that in some of the applications of these materials it would be desirable to have them non-inflammable. It is also likely that the incorporation of Aroclor with some other resinous or waxy materials would give other desirable properties. These applications could probably be worked out in conjunction with companies who are now in the business of compounding and selling such materials. There are some of these companies in each of our sales territories.

Aroclors 4465 and 5460 are the most likely ones in this application.

Tests are under way to determine the suitability of the substitution of Aroclor 1260 for chlorinated paraffin in the treatment of paulins and tentage for use by the Army. This is for the purpose of producing non-inflammability, improving moisture resistance, and mildew proofing.

The Aroclors are remarkably stable and their superiority in this respect to chlorinated paraffin customarily employed for this purpose is demonstrated in the following results reported by our laboratory.

Light Stability Tests

In order to be certain that the tests were comparable in every respect, they were conducted by personnel of the A. French Textile School, Georgia School of Technology, Atlanta, Georgia.

The samples used in these tests had been prepared at Anniston prior to this visit. They consisted of sections of kierboiled cotton sheeting impregnated with compositions as shown in the tabulation below. Approximately 10% of chlorinated hydrocarbon was applied to each of the impregnated samples. The chlorinated paraffin used had the following characteristics:

% Cl_2	43.15
Sp.Gr. @ 25/25°C	1.183
Viscosity @ 210°F	175 SUS
Pour Point	-8°F

As will be noted, several pigments, namely, Fe_2O_3, Sb_2O_3, and $CaCO_3$, were also applied to the fabric. These pigments were used in the following proportions:

Fe_2O_3 - 10 parts Fe_2O_3 to 8 parts chlorine in the chlorinated hydrocarbon.

Sb_2O_3 - 10 parts Sb_2O_3 to 8 parts chlorine.

$CaCO_3$ - 7½ parts $CaCO_3$ to 10 parts chlorine.

In the tests with the pigmented mixtures, the pigment adhered to the surface of the cloth and was not very evenly distributed.

The actual tests made at Georgia Tech. involved exposure for two hours in a Cooper-Hewett lamp cabinet, then conditioning at 70°F and 65% R.H. for four hours or longer, and finally testing for warpwise tensile strength by the grab method with a Scott tester. The Cooper-Hewett cabinet had a Uviarc (fused quartz mercury arc) lamp as the source of ultra-violet light. On the basis of dye fading tests conducted at Georgia Tech. over an extensive period several years ago, two hours' exposure in the Cooper-Hewett cabinet is roughly equivalent to 20 days' average outdoor weathering. This relation does not necessarily apply to tensile strength deterioration tests. Judging by the deterioration of the tensile strength of unimpregnated samples, it would appear that 2 hours' exposure in the Cooper-Hewett was equivalent to much more than 20 days' outside exposure.

Summarized data for the tensile strength tests were as shown in the following tabulation:

Impregnation Mixture	Tensile Strength (X) Unexposed	Exposed
None (Plain cloth only)	53.75	27.9
Chlorinated Paraffin	57.75	15.1
" " & Fe_2O_3	60.9	17.75
" " & Sb_2O_3	57.0	17.9
" " & $CaCO_3$	57.9	18.25
Aroclor 1254	54.5	24.0
" " & Fe_2O_3	60.1	27.1
" " & Sb_2O_3	56.2	24.5
" " & $CaCO_3$	58.75	25.9
Aroclor 1260	59.4	25.75
" " & Fe_2O_3	58.0	30.1
" " & Sb_2O_3	62.4	34.9
" " & $CaCO_3$	59.25	30.9
Aroclor 5442	60.1	33.5
" " & Fe_2O_3	65.5	34.1
" " & Sb_2O_3	63.9	40.6
" " & $CaCO_3$	62.4	40.9

(X) Units are in pounds and, except for three instances, the values shown are averages of 4 tests.

The conclusion from these tests was that the Aroclors contributed little, if any, to the deterioration of tensile strength of the cloth upon exposure to ultra-violet light, whereas chlorinated paraffin did appreciably accelerate deterioration under the same

conditions. Also, under the conditions of these tests, all of the pigments tried decreased to some extent the tendering effect of the ultra-violet light. This is probably not abnormal, since the pigments should have reflected a portion of the light rays.

It has been reported that certain pigments decrease the heat stability of chlorinated paraffin, thus accelerating tendering of treated cotton goods upon exposure in hot climates. Heat stability tests on all of the impregnation mixtures tried as outlined above are now being run in the laboratory at Anniston.

Compared with plain cloth unexposed (100%) the hydrocarbon treatments alone effected the following improvement in tensile strengths:

Chlorinated Paraffin	7.5%
Aroclor 1254	1.3%
Aroclor 1260	10.5%
Aroclor 5442	11.8%

This increase in tensile strength through impregnation is compensated for in the following calculation.

When the "Exposed Tensile Strength" is expressed as per cent of "Unexposed Tensile Strength" the following relationship is evident:

	Per cent Resistance to Deterioration on Exposure to Ultra-violet Light
Untreated Cloth	51.9
Chlorinated Paraffin	28.10
" " & Fe_2O_3	29.15
" " & Sb_2O_3	31.40
" " & $CaCO_3$	31.52
Aroclor 1254	44.05
" " & Fe_2O_3	45.10
" " & Sb_2O_3	43.62
" " & $CaCO_3$	44.19
Aroclor 1260	43.36
" " & Fe_2O_3	51.86
" " & Sb_2O_3	56.00
" " & $CaCO_3$	52.10
Aroclor 5442	55.70
" " & Fe_2O_3	52.05
" " & Sb_2O_3	63.53
" " & $CaCO_3$	65.53

The advantage of the Aroclors in comparison with Chlorinated Paraffin as a non-inflammable, waterproof impregnant for cotton fabric as measured by resistance to loss of tensile strength on

exposure to ultra-violet light is expressed in the following relationship, basis equivalent Chlorinated Paraffin treatment as 100%:

		Per cent Improvement in Resistance to Deterioration over Comparable Treatment with Chlorinated Paraffin	
Aroclor 1254		56.7	
" "	& Fe2O3	54.7	
" "	& Sb2O3	42.1	
" "	& CaCO3	40.1	
	Average		48.4
Aroclor 1260		54.3	
" "	& Fe2O3	77.9	
" "	& Sb2O3	78.3	
" "	& CaCO3	65.3	
	Average		68.9
Aroclor 5442		98.2	
" "	& Fe2O3	78.6	
" "	& Sb2O3	102.2	
" "	& CaCO3	107.9	
	Average		96.7

Heat Stability Tests

These tests were made by absorbing and titrating the HCl evolved from 20 grams of chlorinated hydrocarbon when held at 175°C and blown with air at the rate of 0.01 cubic foot per minute for four hours. This is the method outlined on pages 375-378 of the August 30, 1943, issue of the American Dyestuff Reporter, Vol. 32, No. 18. James R. Redmond, Textile Technologist, Jeffersonville, Q.M. Depot, was the author of the article.

Data for the tests that have been completed were as follows:

Chlorinated Hydrocarbon Composition		% HCl Evolved in 4 hrs. at 175°C
20 gms. Chlorinated Paraffin		0.41
20 gms. " "	+ 2.0 gms. Fe2O3	20.00
20 gms. " "	+ 10.5 gms. Sb2O3	0.29
20 gms. " "	+ 6.3 gms. CaCO3	0.29
20 gms. Aroclor 1254		0.00
20 gms. " "	+ 2 gms. Fe2O3	0.01
20 gms. " "	+ 2 gms. Sb2O3	0.01
20 gms. " "	+ 2 gms. CaCO3	0.02

MONS 092659

MONSANTO CHEMICAL COMPANY

Chlorinated Hydrocarbon Composition		% HCl Evolved in 4 hrs. at 175°C
20 gms. Aroclor 1260		0.002
20 gms. " "	+ 2 gms. Fe_2O_3	0.02
20 gms. " "	+ 2 gms. Sb_2O_3	0.005
20 gms. " "	+ 2 gms. $CaCO_3$	0.01
20 gms. Aroclor 5442		0.00
20 gms. " "	+ 2 gms. Fe_2O_3	0.00
20 gms. " "	+ 2 gms. Sb_2O_3	0.02
20 gms. " "	+ 2 gms. $CaCO_3$	0.02

These data clearly demonstrate the markedly superior heat stability of the Aroclors as compared to chlorinated paraffin. Particularly significant is the accelerating action of Fe_2O_3 on the decomposition rate of chlorinated paraffin. No such accelerating action was noted with the Aroclors.

While in most of the tests with the Aroclors our titrations indicated the evolution of HCl ranging up to 0.02%, the titrations were so small as to possibly be within the range of experimental error. At any rate, we are quite sure that 0.02% HCl evolution represents the maximum HCl loss under the conditions of the tests.

Chlorinated Hydrocarbon Mixture	% HCl Evolved in 4 hrs. at 175°C
20 gms. Chlorinated Paraffin and 2 gms. Zinc Borate #3167	15.6
20 gms. Aroclor 1254 and 2 gms. Zinc Borate #3167	0.01
12 gms. Aroclor 5442 and 8 gms. Tricresyl Phosphate	0.02
12 gms. Aroclor 5442 and 8 gms. Tricresyl Phosphate and 2 gms. Fe_2O_3	0.00
12 gms. Aroclor 5442 and 8 gms. Tricresyl Phosphate and 2 gms. Sb_2O_3	0.01
12 gms. Aroclor 5442 and 8 gms. Tricresyl Phosphate and 2 gms. $CaCO_3$	0.00
12 gms. Aroclor 5442 and 8 gms. Tricresyl Phosphate and 2 gms. Zinc Borate #3167	0.01

Again it will be noted that the Aroclors are far more stable than Chlorinated Paraffin in the presence of Zinc Borate.

MONSANTO CHEMICAL COMPANY

HEAT TRANSFER MEDIUM

Aroclor has been used for a number of years at Anniston as a heat transfer medium. It is now employed as such in the HB-40 plant.

Company (075050) used Aroclor as a heat transfer medium in maintaining a molten lead bath in which they soaked 14 inch armour piercing projectiles. They operated one unit using Aroclor and another using Dowtherm. Both of these units were used for several years. They then discontinued the use of Aroclor after discovering corrosion in the Aroclor system, which did not occur in the Dowtherm system.

A company developed some equipment for heating pyrites in which they intended using Aroclor as the heat transfer medium. Since the equipment was never sold commercially, none of these units involving Aroclor are now in operation

Many people considering Aroclor as a heat transfer medium gave it up either because it would not stand the temperature they required, or on account of fumes coming from the Aroclor, or because it cost more than oil normally used for this purpose.

Favorable features to the use of Aroclor for this purpose are:

1. Liquid at room temperature.
2. Does not oxidize.
3. Has nearly twice the specific heat of petroleum oils generally used for this purpose.
4. Non-inflammable.

HYDRAULIC FLUID

Company (576,450) operating a high pressure steam-electric generating plant use Aroclor 1248 as an hydraulic medium in their governor system. They do not use it as a lubricant. The Aroclor is used instead of oil, merely because of its non-inflammability. When oil is used in the governor system, it is customary to use the same oil reservoir, both for the lubricating and governor systems. When Aroclor is used in the governor system and petroleum oil in the lubricating system, it is necessary to segregate the two systems and use separate pumps for the lubricating and governor systems.

Westinghouse have been the principal promoters of the use of Aroclor in the governor system as a result of having the oil in a governor system catch fire in one of the Jersey Central Light and Power Company's stations while Westinghouse engineers were working with the unit.

MONS 092661

MONSANTO CHEMICAL COMPANY

ENAMELS

Company (104460) has obtained some interesting results with baked-on enamels containing Aroclor 1254, Acryloid Resin and Tricresyl Phosphate, pigmented with Titanium Dioxide and Zinc Oxide. The enamel is baked on at 135°C (275°F). They have found that Tricresyl Phosphate aids the Aroclor on baking, giving a hard surface.

This same company has found that mixes of Aroclor and Vistanex (No. 6 B-80 and B-100) or Aroclor and Vixtac (No. 1 and No. 2) give interesting properties somewhat like shellac. They state that these products have good adhesion.

LACQUERS

We have a very good general line-up on the use of Aroclor in lacquers in the booklet P-115 which we have published for distribution. This booklet gives the limits of compatibility of Aroclors 1254 and 1262 in Nitrocellulose lacquers. Since this booklet has been published, a number of companies have started using Aroclor 1242 in special flexible lacquers, such as are used on high tension cables, etc. The compatibility limits of Aroclor 1242 are higher than those of the higher chlorine Aroclors so that it is possible to incorporate enough of the Aroclor to give it extreme flexibility. You have the formula for Aroclor Lacquer No. 34 which gives the details of the use of this Aroclor in cable lacquer.

The work done in our laboratory using Aroclor in lacquers indicates that we get somewhat less chalking with the Aroclor lacquers than with those made up by other formulae. We get practical freedom from checking and cracking and, we believe, better color retention in the white and light colored lacquers. These are important considerations in lacquer manufacture, and Aroclor should be given much more consideration from now on for general use such as an automobile lacquer, etc., than it has received in the past because of the rising prices of other resins which are generally used.

We have a number of customers who use Aroclors 1242, 1254 and 1262 in the manufacture of lacquer.

Lacquer Formulation Chart

Non-Volatile Constituents

1. A resin
2. Nitrocellulose (cellulose nitrate)
3. A plasticizer or softener

MONS 092662

Volatile Constituents

1. The alcohol constituent
2. The ester constituent
3. The hydrocarbon constituent

Finished Lacquer

X per cent of the non-volatile
(100 - X) per cent of the volatile

The percentage X, of the non-volatile or film-forming constituents, may vary between 20% and 30% of the weight of the finished lacquer

Non-Volatile Constituents

As has been shown by the table, the non-volatile components of a lacquer consist of a resin, cellulose nitrate and a plasticizer or softener. For the resin, some one of those of synthetic origin may be employed, or a natural resin such as Gum Dammar may be used. Gum Dammar is a generally used resin in lacquer formulation, and it can be taken as the number one component. The number two component is the cellulose nitrate itself. It is also known as Nitrocellulose, Pyroxylin and "PX." To the industry in general it is "cotton." It can be purchased in two kinds, the AS and RS grades. The latter grade is the one that is chiefly used by lacquer manufacturers.

The initials indicate a difference in the method of manufacture, AS meaning that the cotton is alcohol-soluble, and RS meaning that it is regularly soluble.

Both grades are usually bought wet with denatured alcohol. The viscosity of the cotton is another determining factor with regard to its use. The cotton that is commonly employed by the industry has a viscosity of one-half second and is known as "half-second cotton." For the third component dibutyl phthalate, tricresyl phosphate or castor oil may be used.

At this point an explanation of the terms "plasticizer" and "softener" becomes necessary. The average lacquer technologist uses these terms synonymously, and for this reason they have come to mean almost one and the same thing in this industry. Strictly speaking, a true plasticizer should be a solvent for the "cotton" and the resin. In addition, it should have a low vaporization loss and should confer such properties as flexibility, pliability, and durability on the lacquer film. Both dibutyl phthalate and tricresyl phosphate meet these requirements. Castor oil, on the other hand, does not, in that it is only a partial solvent for "cotton." It does, however, give to the film the qualities already mentioned, in short, it exerts a softening effect - hence the name "softener." The difference, then, between a plasticizer and a "softener" is that the former is a true solvent for the

non-volatile constituents of a lacquer, while the latter is a non-solvent, or, at best, only a partial solvent. Castor oil is typical of this latter class and is widely used as a lacquer "softener."

Volatile Constituents

The volatile constituents form what is known as a balanced solvent mixture, the purpose of which is to be used as a solvent or thinner for the non-volatile constituents. The components of this mixture must be in such a proportion to each other so as to insure a uniform evaporation rate when the lacquer film dries, and also to make sure that no precipitation of the "cotton" will occur at the time of thinning.

The number one, or the alcohol, component is generally composed of ethyl alcohol - 95% and butyl alcohol. The ester component is made up in general of ethyl acetate and butyl acetate, while the hydrocarbon component usually consists of some compound such as toluol or, for special lacquers such as cable dopes, benzol.

Finished Lacquer

The finished lacquer is prepared by taking a given weight of the non-volatile constituents and dissolving them in a given weight of the volatile constituents.

Competition

The question of competition will have to be viewed from two angles; first with regard to the Aroclors as resins, and second with regard to them as softeners. Since the Aroclors have more the properties of softeners than of resins, the softeners are nearly competitive with the Aroclors than are the resins.

Competing Resins - Synthetic

Name	Number	Manufacturer
Amberol	801	The Resinous Products & Chemicals Co. Philadelphia, Pennsylvania
Bakelite	XR-302	Bakelite Corporation New York, New York
Beckacite	(1110) (1114)	Beck, Koller & Company, Inc. Detroit, Michigan
Glyptal	1202	General Electric Company Schenectady, New York
Lewisol	(2) (3)	John D. Lewis, Inc. Providence, Rhode Island

MONS 092664

MONSANTO CHEMICAL COMPANY

Competing Resins - Synthetic

Name	Number	Manufacturer
Paraplex*	(5-B) (RG-2)	The Resinous Products & Chemicals Co. Philadelphia, Pennsylvania
Rezyl	(12) (19)	American Cyanamid & Chemical Corp. New York, New York
Rezyl Balsams	-	American Cyanamid & Chemical Corp. New York, New York
Teglacs	-	American Cyanamid & Chemical Corp. New York, New York

*Paraplex can probably be considered a softener as well as a resin.

Competing Resins - Semi-Synthetic

Name	Number	Manufacturer
Ester Gum	None (One of the most generally used resins.)	There are many manufacturers

Natural Resins

Gum Dammar	(Batavia) (Singapore)	Imported - obtained through brokers

Competing Plasticizers or Softeners

Name	Grade	Trade Name	Manufacturer
Dibutyl Phthalate*	-	-	Monsanto Chemical Co. St. Louis, Missouri
Tricresyl Phosphate*	-	-	Monsanto Chemical Co. St. Louis, Missouri
		Kronitex	Kavalco Products, Inc. Nitro, West Virginia
		Lindol	Celluloid Corporation Newark, New Jersey
Abalyn	(A rosin product recommended for lacquer formulation)		Hercules Powder Company Wilmington, Delaware

MONS 092665

MONSANTO CHEMICAL COMPANY

Competing Plasticizers or Softeners

Name	Grade	Trade Name	Manufacturer
ADM-100	(A modified linseed oil for lacquer formulation)		Archer-Daniels Midland Co. Milwaukee, Wisconsin
Castor Oil (Baker's)*	Number 4	Blown	The Baker Castor Oil Co. Jersey City New Jersey
	Number 15	Blown	
	Number 16	Blown	
	AA	Unblown	
Spencer-Kellogg Oil	(A modified castor oil for lacquer formulation)		Spencer-Kellogg & Sons Buffalo, New York

*There are other manufacturers of these products - this list is by no means complete.

In listing these products, only those that are in more or less general use have been included. There are some notable exceptions, however, in the cases of such materials as Abalyn, ADM-100 Oil, and Spencer-Kellogg Oil.

The materials listed in these tables must not be thought of entirely as competing products because they may be more important as aids or auxiliaries in co-development work with the Aroclors. In fact, it is believed preferable to regard them more in this light than as competitors.

Advantages

In thinking of any advantages the Aroclors may have, the statements made in the final paragraph under "Competition" must be borne in mind. It is preferable to confine oneself to a discussion of the outstanding properties of the Aroclors, for it is believed that it is only through the development of some specific property that progress is going to be made.

The properties of the Aroclors that should be emphasized are:

1. Low vaporization loss
2. Pale color
3. Adhesion
4. Chemical Stability
   a. to light
   b. to water, acids and alkalies
   c. to heat
   d. to oxidation
   e. to chemical action in general

5. Non-inflammability
6. Non-corrosiveness
7. Solubility in commonly used lacquer solvents

A resume of the properties that Aroclors impart to lacquers and the types of lacquers for which they are recommended may be given briefly as follows:

In a Dammar-type lacquer the plasticizer-softener combination, such as the usual dibutyl phthalate-castor oil combination, may be advantageously replaced by an Aroclor alone. The resulting lacquer is less subject to checking and cracking on outside exposure and retains its gloss.

Aroclor 1262 may also be substituted entirely for the resin in certain types of lacquer. The clear lacquer, so produced, is practically colorless and provides an excellent base for white enamels. Such enamels, however, do not withstand weathering as well as those containing Dammar in addition to the Aroclor.

The advantageous properties of the Aroclors in imparting added weather resistance to properly formulated lacquers may be traced to their resistance to the action of sunlight, to their permanency in the film, and to their extreme chemical stability. The Aroclors do not oxidize, "dry," or harden. The Aroclors are unaffected by dilute acids and even by hot caustic solutions. They are not subject to polymerization, rancidity or other change, as far as is known.

When added to a nitrocellulose solution, the Aroclors reduce the viscosity slightly. This change in viscosity takes place at once and no further change due to the presence of the Aroclor occurs on several months' aging in closed containers.

By virtue of their high refractive index, they impart apparent depth to the lacquer film. Aroclor 1262 has adhesive properties and the lacquers containing it have good adhesion. Lacquers containing the Aroclors dry normally and give a hard, non-tacky, durable film of excellent gloss.

Certain lacquer technologists have found that a lacquer containing Aroclor can be polished with a minimum of rubbing and, furthermore, that the Aroclor seems to impart a harder finish to a lacquer film than oils, tricresyl phosphate, or dibutyl phthalate. It has also been reported that properly formulated lacquers containing Aroclor show no tendency to "spew" or "sweat out" when buffed.

In addition to the properties of general interest, other properties of the Aroclors are of value in formulating lacquers to fit special requirements. Aroclors 1254, 4465, 5460 and 1262 do not support combustion, and when present in nitrocellulose films they

MONS 092667

retard the rate of burning. The Aroclors retard the rate of transfer of moisture and of gases through a nitrocellulose film, and by virtue of this fact have already found extensive use in protective lacquers for application over those types of electrical insulating materials, such as rubber, that deteriorate rapidly in contact with oxygen, ozone, moisture or other vapors.

Procedure

Upon visiting a lacquer company, every effort should be made to see the chemist in charge of formulation or production. In large companies the director of research should always be seen. As a general rule, a great deal will not be accomplished until these respective individuals are seen.

A complete discussion of the properties of the Aroclors should be given, emphasis being placed upon the possible formulation of a new lacquer with some one of these properties as the background.

When discussing the use of Aroclors in lacquers, the salesman should remember that the Aroclors are not solvents for nitrocellulose and that for this reason an excessive amount of Aroclor must never be used in the formulation of a lacquer. The limiting percentages that can be used for successful results have been carefully worked out by a large number of experiments. The few simple rules that must be followed in formulating lacquers with the Aroclors are embodied in a booklet entitled "The Properties of Two Aroclors of Special Interest to Manufacturers of Lacquers." Copies of this booklet may be had on application to our sales offices. It is recommended that the salesman offer copies of this booklet and the bulletin "Plasticizers & Resins - Organic Division" to interested lacquer manufacturers.

Attempts should be made to determine what particular lacquers a manufacturer specializes in and what problems he is studying at the time of the call.

Aroclors have fair or good compatibility with nitrocellulose, Formvar, Butvar, vinyl copolymers, polyvinyl acetate, poly-styrene, chlorinated rubber and ethyl cellulose. In general, the liquid or semi-solid Aroclors act like true resins. One principal value is their chemical inertness. Where great flexibility is to be obtained, it may be necessary to employ auxiliary plasticizers. Some of the exceptions are in chlorinated rubber and in ethyl cellulose where flexibility or hardness may be varied simply by selecting an Aroclor of the proper physical characteristics.

The liquid Aroclors such as 1242, 1248 or 1254 will greatly increase flexibility but will cause softness. The semi-solids such as 1260 or 5442 will impart some flexibility without the marked softening effect. The brittle, resinous Aroclors such as 4465 or 5460 produce very hard compositions with excellent adhesion and

weathering qualities. If a single Aroclor does not impart the desired combination of properties, usually some mixture of Aroclors will do so. It would seem that in polystyrene molding compositions, the resinous Aroclors could be used as a flux or flow promoter at molding temperatures without causing softness and flow at normal temperatures. Some mixture of Aroclors or a combination of an Aroclor with another plasticizer either solid or liquid might be required for this purpose.

Of course, it is well known that for alkali resistant coatings, combinations of Aroclors (1254-1260 and 5460) with chlorinated rubber have been used for a long time. At the present time, the use of equal parts of Aroclor 5460 and ethyl cellulose is being pushed by Company (331850) as a weather resistant coating. Similar coatings of low viscosity polystyrene and Aroclors would probably be of value.

ARMY-NAVY AERONAUTICAL SPECIFICATION

LACQUER - CAMOUFLAGE

AN-L-21
8 October 1943 - Page 14

TABLE IV
Control Formula - Clear Vehicle

Ingredients		Weight Percent	Weight lbs. per 100 gal.	Volume gal. per 100 gal.
Paraplex RG-2	(100%)	11.1	90	-
Amberlac B-94	(80% in xylene)	5.6	45	-
Aroclor 5460	(100%)	4.3	35	-
Ethyl Cellulose	(3 to 4 sec)(100%)	4.3	35	-
Cellulose Nitrate	(1/4 sec. R.S.) (65% in ethyl alcohol)	9.4	75	-
Ethyl Alcohol		3.5	--	4
Ethyl Acetate		4.5	--	5
Butyl Alcohol		12.4	--	15
Butyl Acetate		22.4	--	25
Aromatic Petroleum Naphtha Type 1, Grade B		22.5	--	25

It is also of value in other resins where a highly alkali resistant plasticizer is required. Papers by Bowran, Paint Technology (reference for December 1936, dated January 1937) indicate many possible applications for the Aroclors. Sales to lacquer trade at present are confined to specialty manufacturers.

The compatibility of Aroclor 4465 in 1/4 second nitrocellulose is indicated as:

1. Between 24.2% and 26.5% by inspections for blush in thin aged films.

2. Between 13.7% and 16.6% by inspection for loss of gloss in thin aged films.

The presence of a mutual solvent such as dibutyl phthalate raises the compatibility.

The formulation of a flexible lacquer designed for oven drying is given as follows:

Non-Volatile 25%	15-20 Sec. R.S. Nitrocellulose	32%
	Tricresyl Phosphate	40%
	Aroclor 1242	28%
Volatile 75%	Benzol	62%
	Alcohol	22%
	Ethyl Acetate	16%

This formula is intended for application followed by oven drying. Air drying at atmospheric temperature causes blushing. A modification of the volatile portion is suggested when air drying is used.

Volatile	Alcohol	6.4%
	Ethyl Acetate	6.4%
	Butanol	6.4%
	Butyl Acetate	30.8%
	Toluol	50.0%

Experiments on flock insulation and lacquers for aircraft indicated Tricresyl Phosphate as a choice over Aroclors in Ethyl Cellulose lacquers, especially since there is no tendency to settle out when Tricresyl Phosphate is used. Aroclor is more effective in flame retarding, however.

Stop-Off Lacquers

Rather detailed information is given in the Monsanto (Organic Products Division) Plasticizers and Resins Booklet on the preparation of Nitrocellulose lacquers containing Aroclors. A

suggested formulation is as follows:

1/2 second Nitrocellulose, Dry	100
Aroclor 1260	80-70
Tricresyl Phosphate	39-70
Santicizer B-16 may be substituted for Tricresyl Phosphate	

If the Nitrocellulose itself does not have sufficient resistance, a composition of Aroclor with a chlorinated rubber, Ethyl Cellulose or a Vinyl Resin again using Aroclor is suggested, and if the flexibility is not sufficient, it can be improved by the addition of a small amount of one of the liquid Aroclors such as 1242 or 1254, although again Tricresyl Phosphate or Santicizer B-16 could be used.

In coatings, as a general rule, the hard resinous Aroclors will produce very hard and very resistant compositions, but these will be brittle. The liquid Aroclors will tend to produce flexibility but may be lacking somewhat in adhesion. It is for that reason that we have suggested Aroclor 1260, which is about half-way between and will produce a combination of flexibility and adhesion. It will be obvious that hardness can then be increased by the addition of a harder Aroclor such as 5460 or the flexibility can be increased by the use of a liquid Aroclor. The Aroclors themselves are unaffected by acid and alkali.

Stop-Off Waxes

The characteristics of a stop-off wax should be as follows:

a. Tightly adherent to metal surfaces.
b. Should not be removed at a bath temperature of 160°F.
c. Should not be affected by the acids or alkalies of electrolytic baths.
d. Should prevent electrolytic activity on the surface covered.
e. Should be capable of removal by solvent vapor phase cleansing baths, by melting in boiling water, or ordinary cleaning solutions.

Suggested compositions are as follows:

		Softening Point
Methide (Monsanto Merrimac)	40%	
Aroclor 5442	60%	118°C.
Methide (Monsanto Merrimac)	20%	
Aroclor 4465	80%	108°C.

An attempt was made to use these compositions in solution form by dissolving them in turpentine. This was not particularly

successful since at room temperature the degree of solubility was less than 12%. It might be possible to use a 25% concentration of wax in turpentine at 50-75°C, painting the metal surface with the hot solution.

PAINTS

Paints containing Aroclor have shown remarkable durability, far better than any other paints against which they were tested.

One serious drawback, however, is that paints containing Aroclor do not brush as readily as the normal house paints. Paint manufacturers interested in quick drying paints should be encouraged to try Aroclor. Under war conditions there is great interest in the manufacture of fire-proof painting for the interior of ships. Aroclors should be a definite contribution to their formulation.

Aroclor 5460 is successfully used in camouflage paint where it imparts flameproofness.

VARNISHES

There has been only a limited amount of work done in our laboratory on the subject of Aroclor in varnishes and from that work it has been concluded that the most likely field for Aroclor in varnishes is in conjunction with some other resin such as Ester Gum or Dammar, or one of the other commonly used gums, since the use of Aroclor alone has, in our experience at least, given a tackiness to the film.

Aroclor 1262 mixed with East India Gum and cut with naphtha furnishes a varnish base.

The Aroclors may be used in alkali-proof varnishes by incorporating them as a cold cut or as a chill back -- and for the purpose we recommend Aroclor 1262. The Aroclor may be said to function either as a resin or as an oil. In other words, by the addition of the Aroclor, a short oil varnish takes on many of the physical characteristics of a long oil varnish. Our work along this line has indicated that the best procedure is to cook (in the usual manner) using as a resin base a pure phenolic resin but using only half the usual amount of china-wood oil. When the varnish attains proper body, the Aroclor may be added directly as a chill back and the varnish then thinned in the usual manner.

Since Aroclor 1262 is a semi-solid resin, it is best heated until liquid before introducing as the chill back.

An optional method is to dissolve it in the thinner and add in the usual thinning operation. This was worked out as a possible means of extending the supplies of china-wood oil. In other words, it acts as an oil substitute more than as a resin substitute.

In regard to the alkali resistance, we have found that provided the other materials have, of themselves, considerable alkali resistance, then the Aroclor will add to that resistance. It is not possible, however, to use a resin such as limed rosin or ester gum having poor alkali resistance and impart high alkali resistance by the addition of the Aroclor.

Aroclor 1262 can be used to replace up to 50% of the china-wood oil in varnishes.

1. If ester gum, rosin, or other cheap resin is used, the varnish will be suitable only for interior work.

2. If a good 100% phenolic resin is used, the varnish will be satisfactory for exterior purposes.

Varnishes containing Aroclor 1262 are not superior in quality to similar varnishes made with tung oil alone, with the possible exception of a very slight improvement in alkali resistance, flexibility and adhesion in some formulations.

Varnishes containing Aroclor 1262 soften at lower temperatures than do varnishes employing only tung oil, and so are more subject to "printing" and marring when warm.

The advantage of increased flexibility of Aroclor varnishes is lost at low temperatures due to embrittlement of the Aroclor.

Because Aroclors weigh more per gallon than china-wood oil, they increase the cost of varnishes (which are sold by the gallon) even if put at the same price per pound as the oil.

LUBRICANTS

An outstanding service is performed by Aroclor 1254 as a lubricant for high pressure air compressors operating at 4400 pounds per square inch pressure. Besides avoiding flammability, it is claimed that the lubricant is superior to oil, no corrosion deposits result, and there is no excessive wear on the equipment (Company 15850).

Company (233950) is using Aroclor in a special drawing compound. Company (541370) tested Aroclor 1248 in one of their pumps operating at 2500 pounds pressure with the following results:

Compressibility change is 0.3% compared to 0.5% for petroleum oil. The wear rate of the pump was measured by observing the slip of the pump at intervals during the endurance run. Inspection of the pump showed the wear to have occurred on the piston hole walls in the cylinder and on the hardened surface of the pintle, the surface of the pintle felt wavy - not smooth. A wear rate of 22% per 1000 hours was found to exist. The viscosity slope of Aroclor 1248 was poor.

MONS 092673

The conclusion of these tests is reported as follows: Aroclor 1248 is not a very satisfactory fluid for general use in oil gear pumps at 2500 pounds per square inch. It is expensive as the pump requires special paint on the outside and inside; the operating range is narrow and the wear rate on the pump tests was 22% per 1000 hours at 100°F and 25 pounds pressure.

Our experimental work in using Aroclor as a lubricant in steam turbines was not successful, due principally to the fact that the Aroclor is of such high density that it picks up any bit of grit that may be in the system and floats it up in the bearing.

Petroleum oil having so much lower density allows most of these particles to settle in the bottom of the reservoir.

United States Patent #2,245,649, assigned to Celluloid Corporation, describes a steam turbine lubricant consisting of 50 parts of chlorinated diphenyl and 50 parts of triaryl phosphate.

E. P. Lubricants

Much attention is being given by lubricating men to the matter of increasing the film strength or load carrying capacity of lubricants, particularly so as to be able to use smaller gears for a given load

There are a great many such lubricating compounds now on the market. As a class they are called "Extreme Pressure" or E. P. Lubricants.

It is well accepted in the lubricating industry that by the additions of certain elements as Chlorine, Sulphur 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 was a pure mineral oil, seizure or scoring would result at once through film failure.

In attempting to discuss Aroclor as an extreme pressure base, it is very difficult to evaluate its comparative load-carrying capacities with other extreme pressure bases, such as lead soap, active sulphur, saponifiable oils, sulphur chloride, etc., without actual results from exhaustive tests not only of the various E. P. testing machines, but also from actual service under normal operating conditions. It is recognized by the lubricating industry that results obtained on testing machines, such as Almen machine, Timken machine and others, mean very little unless the results are correlated and proved by service conditions. It is true that in the past Aroclor has been tested as an E. P. base on the Timken machine at Timken Roller Bearing and on the General

Motors machine at General Motors Research, and in each case the Aroclor addition has shown a marked increase in load carrying capacity.

Several companies are purchasing Aroclor today for use in E. P. Lubricants, but indications are that they sometime add other elements along with the Aroclor to achieve commercial results at a lower price. Since we have never run service tests on the Aroclor ourselves and the few companies purchasing Aroclor are naturally very reluctant to divulge their experience along with what other chemicals, if any, they are using in conjunction with the Aroclor, the best that can be done is to offer comments by several of the companies who have tested the Aroclor and possibly give a general interpretation or suggestions as to where it might find more general present day application.

Top Cylinder Lubricant

Recently the practice of putting a lubricant in motor gasoline has become quite general. This is, of course, to lubricate the top section of the cylinder.

We have two customers who purchase Aroclor regularly for use in the top cylinder lubricant, which they make and sell.

We do not know the function of the Aroclor in this use other than that these customers tell us that it prevents the deposit of carbon on the valves. We understand that they use a relatively small percentage of Aroclor in the lubricant.

One of these customers uses Aroclor 1248 and the other uses Aroclor 1154.

We have done very little work with the Aroclor as a top cylinder lubricant but would suggest that Aroclor 1248 be used in small percentages. This Aroclor will be found completely soluble in low viscosity oil and should not cause any appreciable difference in its cold test. This is often added to the gasoline to achieve top-cylinder lubrication.

Company (735900) obtained excellent results using Aroclor 1254 on a bearing test, operating in straight Aroclor at 255-260°F (124-129°C) for two weeks. Much less carbonization and decomposition than with the usual spindle oil under the same conditions.

PLASTICS

Compatibility of Arocolors with Cellulose Acetate

Experimental Work. The compatibility limits of Aroclor 1262 were determined with five grades of cellulose acetate. For these

cellulose acetates the limits were as follows:

Eastman Cellulose Acetate Number	Compatibility Limit of Aroclor 1262 (per cent)
7025	Between 10.0 and 13.6
7026	Between 16.2 and 17.9
7027	Between 13.1 and 16.6
7028	Between 17.8 and 19.7
10246	Between 16.4 and 18.1

These figures, as well as all the compatibility limits given in this report, refer to the limits as determined on thin films dried slowly in dry air and deposited from solutions containing, as is customary, 0.1 gram of "solids" per cubic centimeter of solution. The solvent was a mixture of 80% by weight of ethylene dichloride and 20% of alcohol (denatured, Formula 3A).

Another solvent mixture comprising 33.3% acetone, 33.3% ethyl lactate, 16.7% alcohol and 16.7% ethyl acetate (all percentages by weight) was less suitable than the solvent given above, and gave lower compatibility limits in the cases tried.

The compatibility limits of several Aroclors with one cellulose acetate (#10246) were determined. The observed limits were as follows:

Aroclor No.	Limit (Per cent)
1242	From 25.9 to 28.7
1254	From 25.7 to 29.1
1262	From 16.4 to 18.1
4465	From 14.2 to 16.8
5465	From 10.1 to 13.0

The ternary systems, comprising a cellulose acetate, Aroclor 1254, and a common plasticizer, were investigated.

The constants of the cellulose acetates, as given by Eastman Kodak Company, are as follows:

Cellulose Acetate No.	Acetyl (Per cent)	Viscosity (Seconds)	
7025	39.3	5	
7026	40.4	7	
7027	40.8	39	
7028	36.4	34	
10246	41.4	6	Corresponds in viscosity characteristics approx. to 0.5-second (Lacquer grade) Nitrocellulose.

MONS 092676

Conclusions

The compatibility limits of various Aroclors in a specific cellulose acetate and of one Aroclor in various cellulose acetates are comparatively low. The type of solvent employed affects the observed limits, the solvent which gives the more favorable results being the mixture of ethylene dichloride and alcohol. The compatibility limits of the Aroclors in cellulose acetate are, in general, more difficult to determine and less readily checked than the limits in nitrocellulose. The actual observed limit apparently depends upon the rate of drying, the thickness of the deposited film, the humidity of the air, and the solvent employed.

In the tests of compatibility made by Eastman Kodak Company, the limits were found to be 5% to 10% (Rittenhouse). Their low results were probably due to their method of detecting incompatibility, in which delicate optical methods were employed to detect haze in the film.

The work on the effect of Aroclors upon the rate of burning of cellulose acetate films, as given in the table, leads to the following conclusions:

1. Cellulose Acetate alone burns slowly.

2. The rate of burning, where burning takes place at all, is accelerated by each of the substances tried.

3. While the Aroclors increase the rate of burning, they at the same time give a flickering uncertain flame which tends to go out, that is, they tend to quench the flame.

4. Triphenyl Phosphate is an effective flameproofer, it being impossible to ignite the film containing 25% of it.

5. If flexibility and lack of tendency of the film to wrinkle or curl on drying is taken as a criterion of plasticizing power, the Aroclors are more effective plasticizers than either dibutyl phthalate or Tricresyl Phosphate.

6. The thick film containing 25% Aroclor 1254 (slightly below the compatibility limit for thin films) was blushed. This is in accord with the earlier observations of the effect of film thickness on the compatibility limit.

Company (756593) has found that mixtures of decachlorodiphenyl and styrene are non-inflammable and have a heat distortion point 20°F higher than polystyrene.

United States Patent No. 2,227,637, assigned to Leverkusen-I.G. Werk, describes a composition of matter comprising a resin-like chlorinated diphenyl of an average chlorine content of about 62%

and about 7.5% of polyvinyl carbazole.

RUBBER

Company (297400) have found that Aroclor 1262 is the best plasticizer for rubber hydrochloride. It is compatible up to 100% rubber hydrochloride, although the usual working range is 5 to 10% of Aroclor 1262 based on the weight of the chlorinated rubber. Below 50% Aroclor no difficulty is encountered with brittleness. Aroclor tends to increase the gloss of rubber hydrochloride films, e.g., Plioform, Pliofilm, Pliolite. Five per cent rubber hydrochloride added to Aroclor reduces the tack.

On the other hand, Company (331850) recommends the use of Aroclor 1254 with chlorinated rubber, e.g., Parlon.

Concrete Think Pliolite S-8 Aroclor 1260.

A rubber composition of reduced flammability comprises:

Rubber	100 parts
Chlorinated rubber	35 parts
Aroclors	65 parts
Sulfur	2.8 parts
Zinc Oxide	5 parts
Vulcanizing Accelerator	1 part
Ammonium Borate	40 parts

This composition shows a flame resistance and a notable absence of melting around the burning material.

Aroclor 1268 is used in the manufacture of Cellular rubber of low flammability for the aircraft industry.

Company (284144) has found that 15% of Aroclor 1242 added to Vistinex (polybutene) makes a de-icing coating for airplane propellers that looks promising. By the addition of plasticizer C-24 or plasticizer SC, low temperature characteristics can be obtained.

It is indicated that Aroclor 1242 may act as a solvent for one of the materials which is producing tack in Buna S.

The characteristics of Type E Neoprene compositions are said to be improved by the addition of Aroclor 1254 increasing water resistance. (Company 16947)

The use of Aroclor 5160 is under investigation as an extender for Hycar OR.

There are several different applications for Aroclor in rubber as follows:

As a plasticizer for hard rubber

Aroclor 1262 has been used as a plasticizer for hard rubber in dental plates, etc., for a couple of years. It should be equally useful in plasticising hard rubber for other purposes where brittleness is undesirable.

To render rubber permanently tacky

Aroclors 1262 and 1254 are milled into rubber so as to make a homogeneous compound which has permanent tackiness or adhesion.

To flameproof rubber, Neoprene, and other synthetic rubbers

Aroclor 1269 is a hard crystalline material of high melting point. It may be ground very fine. This finely ground Aroclor is milled into the rubber just as any inert filler would be. The milling temperature is not high enough to melt this Aroclor and so there is no solvent action. It has been found that the incorporation of sufficient Aroclor 1269 in rubber prevents the spread of flame. This is suggested especially for flameproofing rubber for use on insulated wire.

THERMOSTATS

Aroclor 1248 is being used by several manufacturers of thermostats as the expanding medium in the bulb. Aroclor has been used in this service by one manufacturer for the last ten years. Aroclor has proved entirely satisfactory. Every precaution must be taken to eliminate the possibility of moisture or other foreign matter getting into the Aroclor. The thermostat equipment must be thoroughly cleaned before filling.

We do not recommend the use of Aroclor at temperatures above 600°F (315°C).

TEXTILES

Company (645300) reports that Aroclors, although more expensive, exert better fire retardant effect than chlorinated paraffins and smaller amounts are required.

Company (049900) claimed that Aroclors 1262 and 5460 showed a 10% increase in tensile strength when substituted for the standard Jeffersonville Quartermaster Depot specified impregnant for rope, which is the following formula:

41% Copper Naphthenate 800-8 98%
14% Asphalt
30% Paraffin Wax
15% Mineral Seal Oil

Aroclor 1260 is proposed as a flameproofing, waterproofing, mildewproofing agent in the production of J.Q.D.'s specification 242 paulins and tentage for army use. Exact formulation and approval of the Quartermaster Corps has not yet been worked out.

WOOD

Aroclor as an Introfier for Sulfur in Wood Impregnation

It has been found desirable for some purposes to impregnate wood and other fibrous materials with sulfur. However, sulfur does not go into these materials without difficulty. The use of 10% of Aroclor 4465 mixed with the sulfur acts as an introfier, causing thorough penetration.

The impregnation is performed as follows:

A mixture of 90% sulfur and 10% Aroclor 4465 is melted and mixed and placed in an autoclave or pressure tank with the wood or other material to be impregnated and held at a temperature of 125°C to 140°C and a pressure of 100 pounds per square inch. The time necessary depends upon the kind of wood or other material being treated. The initial freezing point of this mixture is 107.5°C. The viscosity at 125°C is reported as 27 Seconds Saybolt Universal.

A typical impregnation of a yellow pine 2" x 8" plank gave an increase in weight of 127% and about 100% in tensile strength.

The valuable qualities contributed by this treatment are added strength, rigidity, resistance to moisture, to acids and to splintering. The electrical insulating properties are increased. The wood is made practically free from the effect of weather and resists attack by insects. The treated wood is practically free from shrinkage and swelling.

Possible uses of wood treated in this way are:

Transmission line crossarms.

Tanks to resist acids, etc.

Equipment in which swelling or splintering is objectionable.

Timbers likely to be attacked by termites, etc.

Perhaps many other applications where the qualities described above are desirable.

The requirement is that the wood so treated should stand being used 15 or 20 times in concrete forms, that it must remain smooth, and not show annular ring or grain structure on the concrete

MONS 092680

where the forms are used. Plywood impregnated with a mixture of Aroclor 2565 and 10-20% hard paraffin (melting point 60-68°C) would be suitable for the construction of concrete forms. Addition of sulfur up to 20% of the mixture may be beneficial in reducing the cost of impregnating material and in making the treated wood harder.

The recommended procedure consists of keeping the plywood submerged for 30 minutes in the Aroclor-Paraffin mixture (or Aroclor, Paraffin, Sulfur mixture) at 80-90°C, then letting the boards drain at about 50°C and passing them between rollers to wipe off the excess of the wax.

Plywood treated in this manner increases in weight from 37 to 66% and gains only 3.1 to 5.7% in weight when immersed in water for six hours. Untreated wood gains 29% in weight when kept in water for an equal length of time.

Standard maple wood blocks used by the shoe last industry from (Company 769520) were treated with various compounds to prevent dimensional change from water absorption. The most effective composition was found to consist of:

70% Aroclor 2565
20% Paraffin (hard or soft)
10% Sulfur

When this composition was applied under the conditions shown below the results indicated were obtained:

	Weight of Treatment mg/sq.in.Surface	Effect of Soaking in Water 24 hrs. Gain in Wt. g/sq.Meter	% Perimeter change
1. 60 min. at 100°C.; 30 min. cooling	45.36	340	0.349
2. 60 min. at 100°C.; 30 min. cooling	42.96	375	0.349
3. 60 min. at 100°C.; 30 min. cooling	49.26	351	0.349
4. 60 min. at 100°C.; 30 min. cooling	49.50	367	0.525
5. Vac. 30 min. at 90°C 5 min., released 10 min.	36.49	487	0.175
Maximum tolerable limit			0.556

MONS 092681

From another series of tests conducted on hickory fishing pole handles it is concluded that the best results will be obtained using the following conditions:

Temperature	90-100°C
Vacuum	16-100 mm. for 25 min.
Atmospheric pressure	5 min.

Remove, drain and dry

MISCELLANEOUS

Purdue University found that Aroclor 1242 was very useful as a base upon which to flow gelatin solutions for the production of films, thus making it possible to eliminate mercury for this purpose.

As a result of interest aroused in the Aroclors, several suggestions have been made regarding uses which may prove of value.

1. Aroclor 1260 as an adhesive in a joint compound for glass building blocks.

2. A water emulsion of Aroclor 1262 for use in leather, paper, textiles, rubber and casein paints.

3. As a protective coating on certain pigments to prevent "livering" of paints containing resins of a high acid number. Specifically, zinc oxide pigment in water emulsion of "Aquaplex," a water emulsifiable alkyd resin.

4. A waterproofing for concrete.

5. Aroclor 1262 or 5460 as an ingredient of molding compositions made with such materials as ethyl cellulose, benzyl cellulose, soy bean meal and corn protein.

10-1-44

MONSANTO CHEMICAL COMPANY

SUGGESTED FORMULAE FOR MOISTUREPROOFING COMPOUNDS

Compound A	96.0% Aroclor 5460 4.0% Hard Paraffin
Compound B	96.0% Aroclor 4465 4.0% Hard Paraffin
Compound C	96.0% Aroclor 5060 4.0% Hard Paraffin
Compound D	96.0% Aroclor 4065 4.0% Hard Paraffin

When a relatively low softening point material is desired, we suggest those compounds using Aroclor 4465. When a higher softening point is required, we suggest the compounds using Aroclor 5460.

Compounds C and D are black materials and are useful where color is of no importance.

We do not prepare these compounds.

MONS 092683