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Technical Service BULLETIN

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AROCLORS IN POLYESTER AND EPOXY RESINS

MONSANTO CHEMICALS LIMITED

Monsanto Regd.

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Polyester glass-fibre laminates are becoming more and more widely used for the manufacture of industrial and consumer goods, their chief recommendation being their high strength-to-weight ratio and the ease with which large and complex forms can be fabricated.

Certain applications of polyester laminates call for the modification of some of their inherent characteristics. Those which most commonly require modification are fire-resistance and mechanical properties, and for both purposes the Aroclors are highly suitable.

The Aroclors are a range of chlorinated diphenyls and polyphenyls, three of which have proved to be economical and efficient as dual-purpose fire-retardants and plasticisers. The high proportion of available chlorine they contain imparts adequate self-extinguishing properties, while their plasticising powers increase the strength of the resin to a degree equal to that gained by a more expensive plasticising polyester.

The recommended Aroclors are readily miscible with uncured polyesters at the concentrations necessary to impart fire resistance, though the solid ones dissolve more easily at 60°C. Once mixed they have no tendency to separate on standing nor to migrate to the surface of the cured resin. In this respect they are superior to certain other chlorinated compounds whose poor compatibility with polyesters could lead to separation after mixing and thus to unsightly blooming and greasiness on the surface of the cured resin. The Aroclors also have the advantage of being practically odourless.

The Aroclors may be used to similar effect in epoxy resins as well as polyesters, being compatible with both types.

Full details of all the Aroclors, which range in physical form from mobile, oily liquids to hard, opaque resins, are given in Technical Service Bulletin G.1.

POLYESTER RESINS

(1) *Fire Resistance.*

Of the possible methods of improving the fire resistance of polyester resins, the use of the Aroclors has the advantage of being both effective and economical.

The Aroclors recommended as fire retardants are the soft, sticky resin, Aroclor 1260, and the hard, brittle resins, Aroclors 4465 and 5460. These compounds are more highly chlorinated and less volatile than the mobile liquids, and both these properties improve their efficiency as fire retardants.

Like other fire retardants for polyesters, the Aroclors are generally used in combination with antimony trioxide, itself a fire retardant. This combination is particularly effective, as the two substances are synergistic and together give a degree of fire resistance which is adequate for most possible uses. The Aroclor imparts self-extinguishing properties to the resin and the antimony trioxide reduces afterglow. The latter also plays the part of an inert filler, replacing a proportion of whichever of the many possible fillers is being used, and is usually included even in inherently fire resistant resins which contain chemically combined chlorine in the polyester molecule.

The properties of the Aroclors as fire retardants were evaluated in a series of laboratory tests using a general purpose polyester with a

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styrene content of 35%. The catalyst used was 2% of a 60% solution of methyl ethyl ketone peroxide in dibutyl phthalate, added after the Aroclor. 2% of a 1% solution of cobalt naphthenate was used as an accelerator. Specimens measuring 9" × ½" × ¼" were cast in waxed moulds without reinforcement.

The test method used was based on that laid down in the Ministry of Supply Aircraft Specification for unsaturated polyester resins, DTD 5537 Appendix 10. It consisted of clamping the test specimen in a support with its longitudinal axis horizontal and its transverse axis inclined at 45°, and placing a bunsen burner with the tip of the flame ½" to ¾" in height just in contact with the end of the specimen. At the end of 30 seconds, the flame was removed and the specimen allowed to burn. If burning did not continue, the flame was replaced for a further 30 seconds immediately it ceased, and if the specimen again failed to continue burning the material was classed as self-extinguishing.

The results obtained are shown in Table I.

(2) *Effect on Physical Properties.*

Among the special qualities of the Aroclors is the desirable plasticising effect they have on the cured resin. For general purpose polyesters a special plasticising polyester is normally included to increase the flexural strength of the naturally brittle resin. When an Aroclor is included it effects a similar improvement and thus makes the addition of a more expensive plasticising polyester unnecessary.

TABLE I

FIRE RETARDANCY

Per cent of antimony trioxide and Aroclor	5 per cent	7½ per cent	10 per cent	15 per cent
Aroclor 1260	Semi-inflammable	Semi-inflammable	Self-extinguishing *30 secs.*	Self-extinguishing *Immediate*
Aroclor 4465	Inflammable	Self-extinguishing *5 secs.*	Self-extinguishing *5 secs.*	Self-extinguishing *Immediate*
Aroclor 5460*	Self-extinguishing *60 secs.*	No test	Self-extinguishing *5 secs.*	Self-extinguishing *Immediate*

*2½% addition of Aroclor 5460 is insufficient to make the polyester self-estinguishing.

Specimens for mechanical testing were prepared from laminates with four plies of 1½ oz. woven glasscloth, giving a final thickness of approximately ⅛" and a resin content of approximately 50%. Woven glasscloth was used in preference to chopped strand mat to ensure that results should be as consistent as possible, the strength of this form of

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reinforcement varying by only 5%, compared with the 20% variation to be expected from chopped strand mat.

The following standard methods of test were used to determine the mechanical properties of 4" × 1" bars cut from the laminates: flexural strength, ASTM D.790-49T; impact strength, falling weight, B.S.2782:1957, Part 3, Method 3068, modified by the use of beam specimens on a 1" bridge support.

The effect of the Aroclors on the mechanical properties of polyester resins is shown in Table II. It will be seen that at a concentration of 10% (enough for purposes of fire-retardance) none of the Aroclors reduced the flexural strength of the cured resin significantly, and that their effect was comparable with that of a plasticising polyester. At 20% addition, the impact strength of the laminate is improved. Of the three, Aroclor 1260 reduces the flexural strength less than the solid Aroclors, and is recommended for purposes of lamination. For fire-resistant surface coatings, the solid Aroclors are preferred.

TABLE II

MECHANICAL PROPERTIES

Resin Formulation		Flexural Strength (p.s.i.)	Elastic Modulus in bending (p.s.i. × 10^{-6})	Impact Strength (ft. lb.)
Unmodified Polyester		47,210	21·9	1·73
Polyester + plasticising polyester	10% 20%	43,310 39,930	20·0 15·6	1·64 1·24
Polyester + Aroclor 1260	10% 20%	45,600 33,880	20·9 16·9	1·33 2·04
Polyester + Aroclor 4465	10% 20%	40,740 33,390	21·9 12·9	1·41 2·48
Polyester + Aroclor 5460	10% 20%	37,400 35,890	17·0 15·5	1·85 3·06

EPOXY RESINS

Epoxy resins, like polyesters, are inflammable unless a fire-retardant additive is included, and those Aroclors which are used in polyesters are equally effective at similar concentrations in epoxies. They are completely miscible with epoxy resins, though Aroclors 4465 and 5460 dissolve more readily at 60°C. Some diminution of the characteristic mechanical properties of epoxies must be expected, though careful formulation will enable the manufacturer to strike a balance between fire resistance and strength for applications where the former property is essential. Antimony trioxide is included at the same concentration as the Aroclor since the two together are more effective than Aroclor alone.

The same laboratory test methods were employed as for polyesters, using a liquid epoxy

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resin (Shell Epikote 834) cured with 8% diethylenetriamine, added after the epoxy resin, antimony trioxide and Aroclor were mixed. Specimens were prepared in waxed moulds 9" × ½" × ¼" and the results obtained are shown in Table III.

TABLE III

Per cent addition of Aroclor and antimony trioxide	5 per cent	7½ per cent	10 per cent	15 per cent
Aroclor 1242	Inflammable	No test	Inflammable	Self-extinguishing *30 secs.*
Aroclor 1260	Inflammable	Semi-inflammable	Self-extinguishing *30 secs.*	Self-extinguishing *Immediate*
Aroclor 4465	Inflammable	Semi-inflammable	Self-extinguishing *20 secs.*	Self-extinguishing *Immediate*
Aroclor 5460	Inflammable	Self-extinguishing *40 secs.*	Self-extinguishing *20 secs.*	Self-extinguishing *Immediate*

HANDLING AND TOXICITY

The Aroclors are non-oxidising and non-corrosive and they are not hydrolysed by water, alkalis or acids. At ordinary temperatures they have not presented industrial toxicological problems, but they should nevertheless be handled with care and should not be allowed to come into contact with the skin, through which they are absorbed.

If Aroclors are spilled on the skin, it should be washed with soap and water. If accidental burns occur from contact with hot Aroclors, the burn should be treated in the same way as an ordinary burn. Aroclor adhering to the burned area should be removed carefully by repeated washing with soap and water, or a vegetable oil may be used. Experimental work on animals indicates that the maximum safe concentration of vapours in workrooms is in the range of 0·5 to 1·0 milligrams per cubic metre of air, and where vapours may be encountered, local exhaust ventilation together with general workroom exhaust is necessary.

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