CRYSTIC MONOGRAPH No.2

Polyester Handbook

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'Reinforced Plastics' : this statue was sculpted by Peter Peri with Crystic resin and is situated above the entrance to the Polyester Technical Service Laboratories at Wollaston.

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Preface

The demand for basic background information on glass fibre reinforced plastics continues unabated and comes from all over the world. This is to be expected, since reinforced plastics are rapidly expanding both in established fields and in many new ones. This Crystic Monograph is the second in our series of new publications to replace the old style Polyester Handbook first published in 1953. It is designed to provide an introduction to reinforced plastics, especially for newcomers to the industry, and covers the basic chemistry as well as the reinforcements, resins and moulding methods in current use.

The uniqueness of reinforced plastics lies in the often-unappreciated fact that the moulder is simultaneously making his material of construction *and* his end product. Quality control thus assumes a major significance in the process and inevitably has its effect on the excellence of the product.

It is hoped therefore that the general guidance, advice and technical data contained in this volume will help the moulder in what has now become one of the most exciting and rapidly expanding industries of today – reinforced plastics.

September 1977 Crystic Research Centre

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Introduction

The nature of reinforced plastics

This book is mainly about the material that is often called 'Fibreglass', but 'glass fibre reinforced plastics' or 'glass fibre reinforced polyester' (GRP) are better names. GRP is a light, durable and astonishingly tough constructional material which can be fabricated into all manner of products. It may be translucent, opaque or coloured, flat or shaped, thin or thick. There is virtually no limit to the size of objects which can be made, and single pieces over 60 metres long have already been fabricated as boat hulls.

GRP is unique amongst materials of construction in that the fabricator actually makes the material. Whether he is making roof sheeting, chemical tanks, pipes, silos, buildings, vehicle bodies, or boats he is not merely assembling pre-existing components but making the structural material *in situ*.

What then is GRP? It is a composite of a resilient durable resin with an immensely strong fibrous glass. The resin is the main component and is normally a polyester resin. It is supplied in the form of a viscous syrup, which when suitably activated sets to a hard solid. Buttons and castings are made from such a resin, but just as concrete may be reinforced with steel rods, so polyester resins may be reinforced with glass fibres to form GRP. This is what the fabricator does. He uses a single surface mould or form on which he impregnates layers of glass mat with liquid resin until he has built up the required thickness, so forming a laminate or moulding. After removal of this product from the mould he can make many more in the same way.

In the remainder of this chapter the nature of GRP within the whole family of plastics is examined and subsequent chapters of this monograph consider in detail the techniques and problems of GRP manufacture.

Plastics

Plastics are man-made materials which can be moulded into useful articles. The first of these plastics was produced in 1862 in England by Alexander Parkes. It was known as *Parkesine* and was the forerunner of Celluloid.

Since then a large variety of plastics have been developed commercially, most of them in the last twenty-five years. They extend over a wide range of properties. Phenol formaldehyde (PF) is a hard thermoset material; polystyrene is a hard, brittle thermoplastic; polyethylene and plasticised polyvinyl chloride (PVC) are soft tough thermoplastic materials, and so on. Plastics also exist in various physical forms. They can be bulk solid materials, rigid or flexible foams, or in the form of sheet or film.

All plastics have one important common property. They are composed of macromolecules, i.e. large chain-like molecules consisting of many simple repeating units. The chemist calls these molecular chains *polymers* (Greek *poly-*, many). Not all polymers are used for making plastic mouldings. Some are used for making paint, some for man-made fibres, nylon, rayon, Terylene, etc., and some for making ice-cream.

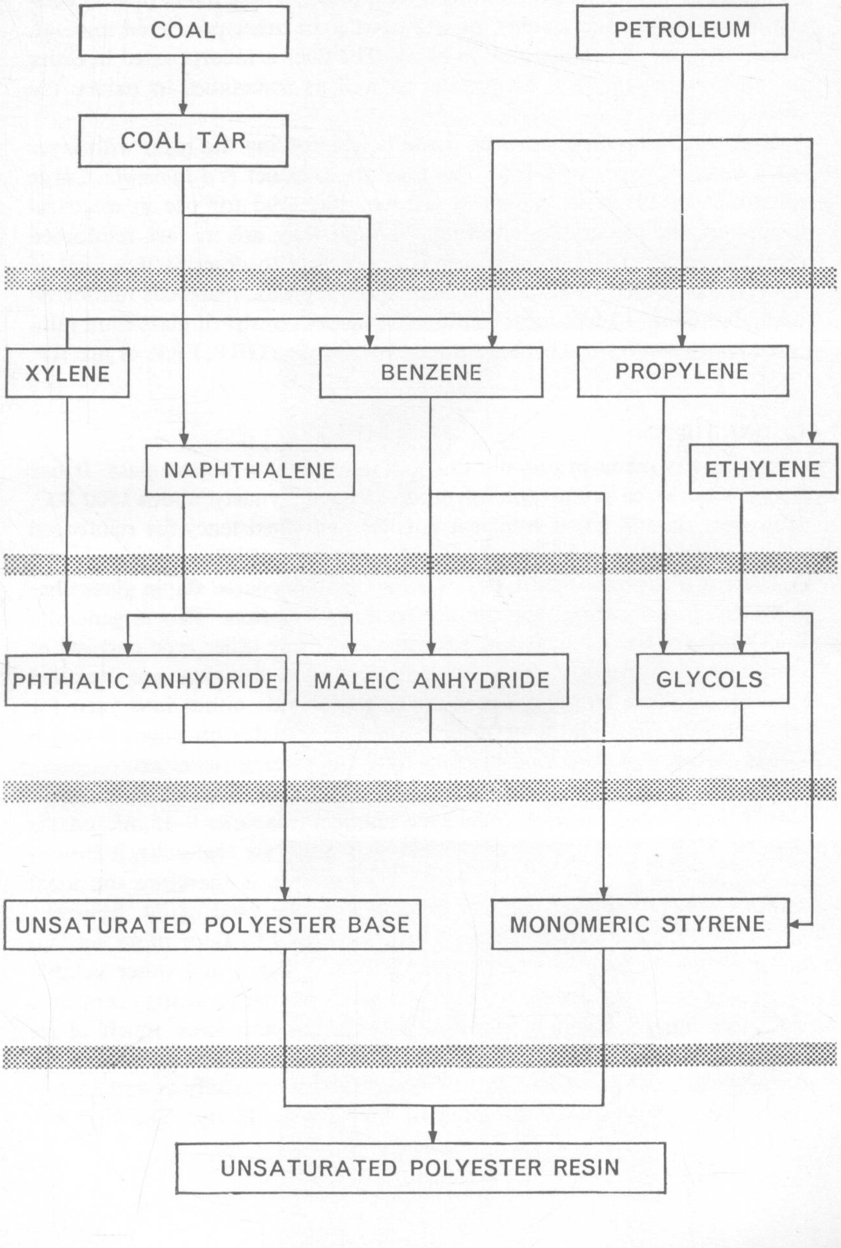
Many polymers occur naturally. Examples include cellulose (wood and cotton), protein (hair and silk) and rubber. Man-made polymers are called *synthetic resins* (or simply resins) until they have been moulded in some way, when they are called *plastics.* Most synthetic resins are made from chemicals derived from oil or coal (see Table 2).

Table 1 Comparative properties of glass reinforced plastics and other materials

Material	Glass content %volume	Glass content %weight	Specific Gravity	Tensile strength MPa	Tensile modulus GPa	Specific strength MPa
Polyester/glass rovings	54	70	1·9	800*	30*	400*
Polyester/glass cloth	38	55	1·7	300	15	200
Polyester/glass mat	18	30	1·4	100	7	70
Mild steel (structural)	—	—	7·8	310	200	40
Duralumin	—	—	2·8	450	70	150
Douglas Fir	—	—	0·5	75	13	150
Hickory	—	—	0·8	150	15	200
Portland cement	—	—	2·0	10	17	5
Cement/glass fibre 28 days air storage	3·1	4·3	2·1	17	20	8

*In fibre direction.

Table 2 Derivation of compounds used in the manufacture of a typical polyester resin



Reinforced plastics

Synthetic resins are often combined with *fillers*. These fillers usually consist of wood flour, china clay, quartz powder or other powdered mineral, and in the case of rubber, carbon black. The filler is incorporated in order to improve the physical properties, as well as sometimes to reduce the cost.

High strength plastics can be made by reinforcing the resin with layer upon layer of paper or fabric. The resulting product is a *laminate*. Large quantities of PF resin laminates are manufactured for use in electrical insulation and decorative sheeting. Though they are in fact reinforced plastics, the term *reinforced plastic* is never used to describe this kind of material. It is used to describe certain specific plastic materials reinforced with glass fibre. In fact most reinforced plastics consist of glass fibre reinforced polyester resin. This is usually abbreviated to GRP, FRP, or just RP.

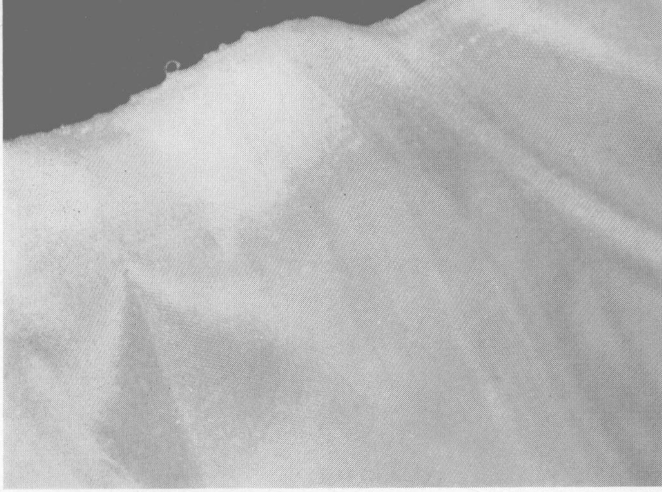
Glass fibre

Glass fibre is made by rapidly drawing and cooling molten glass. It has been known since at least the Egyptian XVIIIth Dynasty, about 1500 B.C. However, glass fibres of sufficient fineness and consistency for reinforced plastics were not available commercially until the 1930's.

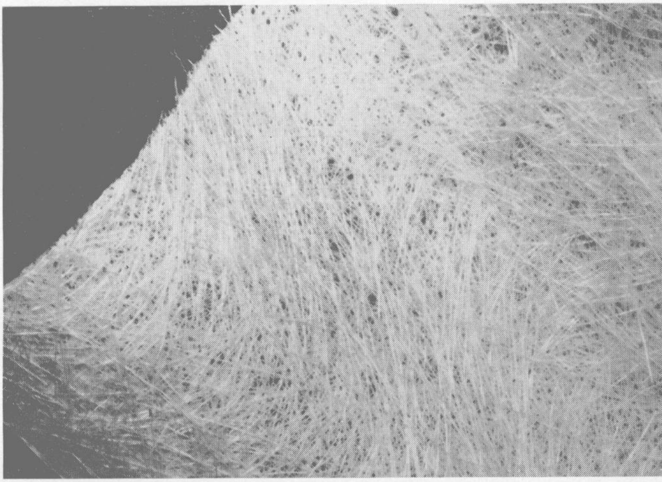
There are two principal types of glass fibre. A coarse staple glass fibre is widely manufactured for use as thermal insulation. This is generally unsuitable for use as a plastics reinforcement. The other type consists of continuous filaments, which immediately after drawing are bundled together to form strands. These in turn are made either into yarn for weaving into glass cloth, or into rovings. The plates on pages 5 and 6 illustrate the various forms of glass fibre reinforcing materials.

Glass fibre is one of the strongest of all materials. The ultimate tensile strength of a freshly drawn single glass filament (diameter 9–15 microns) is about 3·5 GPa. It is made from readily available raw materials, it is non-combustible and chemically resistant. Glass fibre is therefore the ideal reinforcing material for plastics. It could not be used easily, however, for reinforcing the earlier types of resin such as PF, since these need to be cured under high pressures because of the steam and other volatile by-products evolved during the curing process. Under these high pressures the glass fibre becomes mechanically damaged and loses much of its strength. As soon as resins were developed which could be cured without the application of pressure, glass fibre was used successfully as a reinforcement. This marked the beginning of the GRP industry. The first *low*

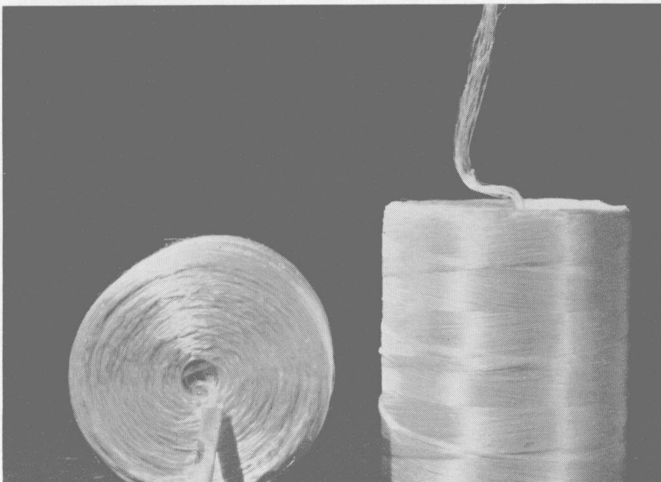
Glass fibre reinforcing materials



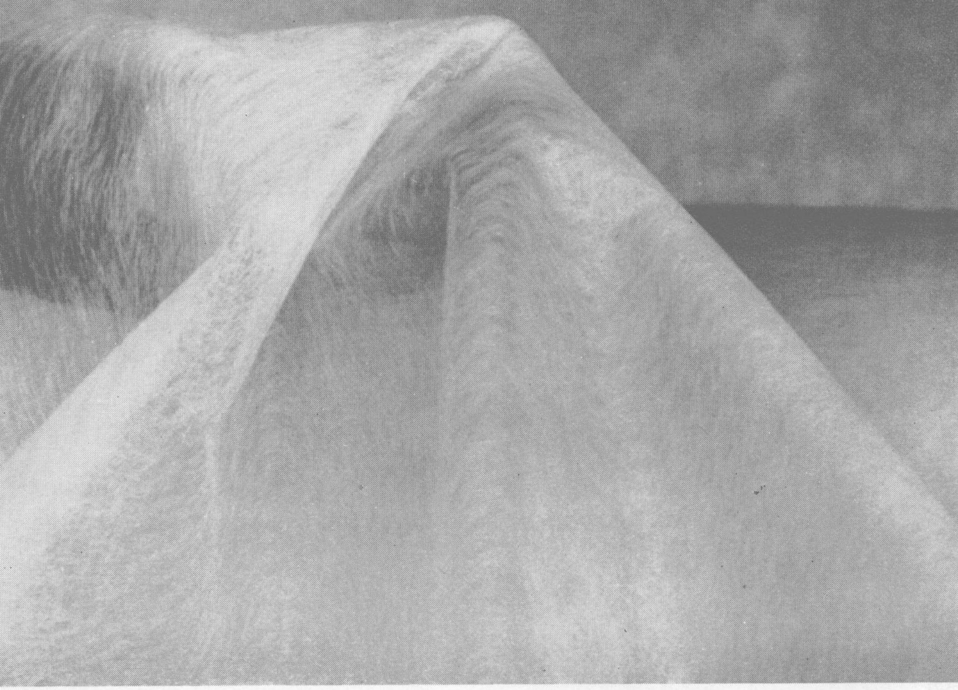
Woven cloth



Chopped strand mat



Rovings



Surfacing tissue

Glass fibre reinforcement

Woven rovings