

# POLYESTER MOLDING COMPOUNDS

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**ROBERT BURNS**

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**POLYESTER  
MOLDING COMPOUNDS**

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Robert Burns (right) receiving a silver medal for his paper "The rheology of glass fibre reinforced polyester moulding compounds," at the Reinforced Plastics Congress, Brighton, England, 1976.

Robert Burns  
(1934-1979)

Robert Burns was born and raised in the north of England. He was trained as a chemist at Rutherford College of Technology, Newcastle-upon-Tyne, and his working life of almost thirty years was spent in the paint, plastics, and composites industries in the United Kingdom, including, most recently, twelve years at the Lathom Laboratories of Pilkington Brothers.

Through work carried out on the processing and performance behavior of reinforced plastic molding compounds and the related subjects of compound formulation, and the improvement of glass fiber reinforcements, Mr. Burns gained wide recognition in the United Kingdom, and increasingly, internationally. Fittingly, his extensive knowledge of, and enthusiasm for, this important field of plastics technology led him to write this treatise, completed only a few days before his sudden and untimely death.

It is the wish of his family and colleagues that this book should stand as a tribute to his memory and to his achievements as a technologist.

E. J. Smith  
Pilkington Brothers P.L.C.

## Preface

After very slow initial growth polyester molding compounds have become important as a result of an intensive development of materials. In the past the specter of variability has inhibited the formulation of polyester molding compounds; therefore, some emphasis has been placed on the quality of raw materials and on control procedures throughout the book. Polyester molding compounds have a unique combination of properties and, above all, are cost-effective. Until relatively recently they were the only prospect of replacing metals economically. The purpose of this book is to present the technical developments and their potential in a concise, easily accessible form. Hitherto the information has been widely scattered. It is hoped that designer, compounder, and potential user will be able to obtain the information required in their relevant areas of interest.

I would like to express my thanks to the many people who have helped me with material without which I would not have been able to compile this book. Particularly, I would like to thank Pilkington Brothers Limited from where most of the information has been obtained; in this context the assistance of Mr. Frank E. Devine, Mr. Bryan M. Lynskey, and Dr. David Pennington has been much appreciated.

Help from the following organizations has also been extremely valuable and thanks are expressed: Amoco Chemicals Corporation, Baker Perkins Chemical Machinery Limited, Bifort Engineering Limited, Erie Press Systems, Berk Chemicals Limited, Charles Ross & Son Company, Finn & Fram Inc., The Budd Company, USS Chemicals Division of United States Steel Corporation, Farrel Bridge Limited, Scott Bader Company Limited, Rohm and Haas Company, Premix Inc.

Robert Burns



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# 1

## Introduction

### 1.1 HISTORY

Synthetic-resin-reinforced molding compositions date back to Baekeland, Redman, and Swinbourne and the invention of phenol formaldehyde resins. Subsequently compounds based on melamine formaldehyde and urea formaldehyde resins appeared which enables white and pastel shades to be achieved. However, these materials suffer from severe limitations in processing. The hardening or curing reaction of these resins is a condensation reaction involving the generation of volatiles. To reduce the effects of this reaction and control viscosity, the compounds were B staged or partially reacted in a separate manufacturing operation after mixing. The resulting compositions can be made to yield satisfactory moldings by employing high pressure and "breathing" techniques to minimize porosity and obtain good surface finish.

During World War II unsaturated polyester resins thinned with styrene were developed for cold cure applications using chopped strand mat as reinforcement. With the development of relatively low-pressure curing systems in which no volatile was evolved, the potential of these resins systems was realized. Original attempts at the development of polyester molding compositions were initiated with the introduction of glass rovings from Owens Corning Fiberglas in 1949. These early developments ran into problems of segregation of resin from glass during molding. In the early 1950s it was realized that fillers played an important part in the rheology of the compounds during molding, and the first true polyester molding compounds were developed. Sisal and cellulosic reinforcements were popular at this time, and rapid development of sisal-reinforced compositions occurred in the United States mainly for cheap ducts and housings in automobiles and applications where price was a controlling factor. With the development of bulk molding compound (BMC) compositions and their improved mechanical properties and moldability, glass has become the preferred reinforcement, and unless otherwise specified, references to polyester molding compounds in this book are glass reinforced.

Much work has been carried out on the optimization of BMC compositions; such factors as resin, filler, catalyst, and pigmentation have been investigated in great detail. The compounds produced today are highly specialized, and complex materials are usually specifically formulated for particular applications.

Rapid growth has occurred in the usage of polyester resin molding compositions. From virtually nothing in 1950 they have reached an annual consumption of 58,000 tonnes in the European Economic Community (EEC) [1] and 168,000 tonnes in the United States in 1978 [2]. This rapid growth has been a result of the exceptional range of properties exhibited by these materials and has occurred despite their limitations. Variability in mechanical properties, sink, cracking, and warping all pose problems in their utilization. It has been possible, however, to produce moldings to acceptable standards by taking these limitations into consideration.

In 1961 [3] in the United Kingdom, it was realized that additions of granulated thermoplastics to the formulation gave large improvements in surface finish; somewhat later the truly low-shrink resin systems were introduced. These developments have been extremely important in the market growth of polyester molding compounds, particularly in applications of SMC to automobile parts in the United States.

Sheet molding compounds were introduced by Bayer in the late 1960s [4]. This technique has become important because of the ease of handling of material, particularly where moldings of large surface area and high strength are required. Somewhat higher glass contents could also be achieved. Significant usage of sheet molding compounds (SMC) has been found in all major areas of application of polyester molding compounds, although usage in the electrical and appliance area is by far the biggest market in the EEC. Transport applications are a significant growth area, both in the heavy truck and light car sections. More recent developments such as injection molding of polyester molding compounds promise to extend the applications of these materials even further. As these techniques become established applications, they will inevitably extend into areas at present dominated by reinforced thermoplastics.

Substantial penetration into a variety of major areas has taken place particularly since the introduction of shrinkage control, enabling good surface finish and close dimensional tolerances to be achieved. The major application areas are

Transportation

Electrical: heavy-duty switchgear, etc.

Appliances: domestic and business

Building and construction

Penetration into these markets has been the result of the unique properties of SMC and BMC. Design flexibility enabling complex parts

to be produced in a single operation with the inclusion of ribs, bosses, and fastenings has been a large factor influencing the phenomenal growth of these materials. The outstanding dimensional stability of these materials is another major factor in their selection for many applications. This feature is particularly responsible for the conversion of many applications from glass-reinforced thermoplastics. Corrosion resistance and heat resistance are also outstanding and enable them to be specified for many critical applications where contact with water, detergents, or mildly corrosive chemicals is required. Electrical insulation and fire resistance are excellent, enabling them to meet critical specifications laid down for electrical usage.

Projected levels of usage of SMC/BMC in the United States for the various major market applications have been produced (Table 1). It can be seen from these figures that by far the largest application is in the automobile and associated industries. It is estimated that this area will take approximately 70% of the total usage in 1982. The overall growth of SMC usage in the United States is broken down by market in Fig. 1.1. It can be clearly seen that overall average annual growth of between 15 and 19.5% in 1982 largely results from growth in land transportation applications, which is predicted to grow by 22% in 1982. In the same year the area of electrical applications is predicted to grow only by 8% and other applications gathered under the heading commercial by only 6.1%.

It is interesting to compare the usage of glass-reinforced polyesters in the field of transportation with the usage of other polymeric materials (Fig. 1.2). It can be seen that the growth of reinforced polyester has approximately doubled over the period 1973-1978, while the usage of other

TABLE 1.1 Market Breakdown for SMC/BMC Usage

	Tonnes $\times 10^{-3}$		% Average annual growth
	1978	1982	
Land transportation	117	224	18
Electrical/electronics	15	26.2	15
Appliance/business	12.3	20.8	14
Construction	7	11.0	12
Other	<u>17</u>	<u>24.9</u>	<u>10</u>
Totals	168.3	306.9	16

Source: From Ref. 9. Reprinted by permission.

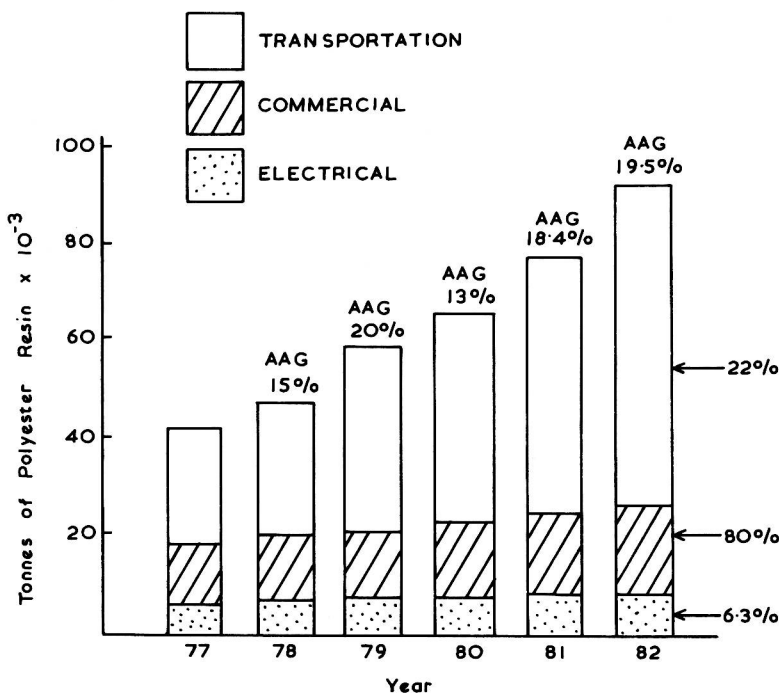


FIGURE 1.1 SMC resin usage by market. (From Ref. 9.)

reinforced polymer in materials has only increased by some 11% over the same period. This extremely small growth of other reinforced plastic materials in the field of transportation is predicted to increase markedly over the period 1978-1985. Growth is in fact predicted to double over this period. This will probably be a result of the increased application of reinforced reaction injection molded (RRIM) polyurethanes.

Reinforced RIM polyurethane is competitive with polyester molding compounds, competing in a similar field on much the same basis. In due course it will undoubtedly take some of the available applications. However, as yet the materials are relatively unproven, and manufacturing techniques have yet to be developed for large-scale application. It will inevitably take some time for the development to reach the level that is currently enjoyed by polyester compounds.

Significant advances have been made with these materials over the past few years. These have enabled designers and manufacturers to obtain improved consistency and also in many instances to obtain greater design flexibility and improved mechanical properties. The development of high-glass-content materials and anisotropic SMCs with the possibility of designing

strength in particular directions or areas is particularly interesting [5]. The great emphasis on weight saving in the U.S. automobile industry is giving impetus to the use of such materials in some instances where weight savings and performance alone are the sole criteria for selection.

The potential for weight saving with these materials [6] will enable an even greater growth rate than currently enjoyed to be obtained. The oil crisis of 1974 has put great pressure on the transport industries of the world.

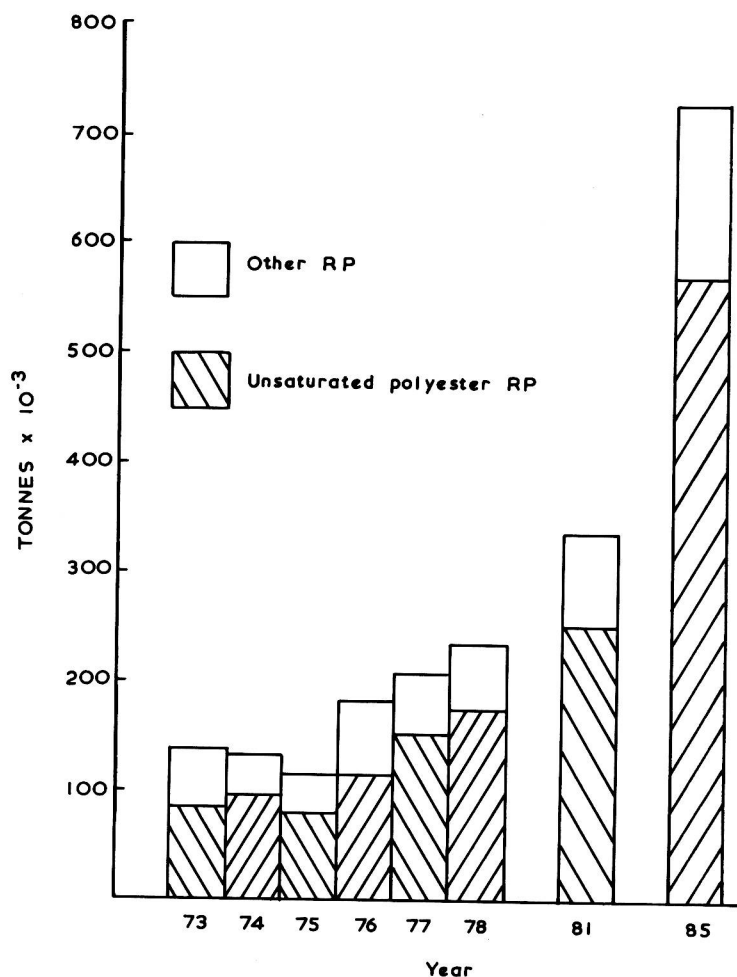


FIGURE 1.2 Comparison of total reinforced plastics usage in transportation to total reinforced polyesters. (From Ref. 9.)

This is particularly true of the United States where the use of large automobiles is prevalent. As the consumption of gasoline is related to vehicle weight [7], the usage of polyester molding compounds must accelerate in the quest for weight saving. At the present time these materials are proven replacements for steel in such applications as front and rear fascias. Doors, hoods [8], etc., are in the development stage, and huge growth in use of polyester compounds must result from these developments.

Developments in polyester molding compounds which will lead to further growth involve orientated and high-glass-content materials. This enables truly structural applications to be developed, and very often great weight savings can be achieved. Some idea of the growth of these materials up to 1982 can be seen from Fig. 1.3, which shows usage in the field of transportation. The rapid progressive growth of high-strength SMCs can clearly be seen.

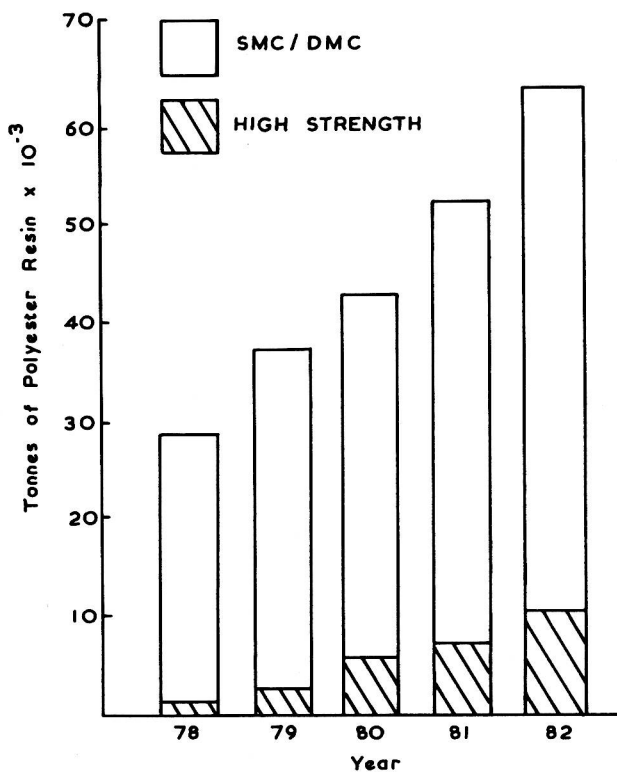


FIGURE 1.3 Comparison of high-strength compound to total usage of SMC/BMC in transportation. (From Ref. 9.)



1.2 GENERAL COMPOSITION AND CONSTITUTION

All polyester molding compounds consist essentially of polyester resin, styrene, glass fiber, and filler. The glass fiber confers most of the mechanical strength to the composite, the effect of filler being secondary in this respect, contributing only slightly to strength. However, besides acting merely as an extender to lower the cost, the filler does have a very important role in the formulation of these materials. The filler modifies the matrix (resin/filler) viscosity so that fiber separation or filtration does not occur during molding.

Sheet molding compounds usually contain higher glass contents than bulk molding compounds because of the effect of the chemical thickening agents. Figure 1.4 shows the general interaction of fillers, resin, and

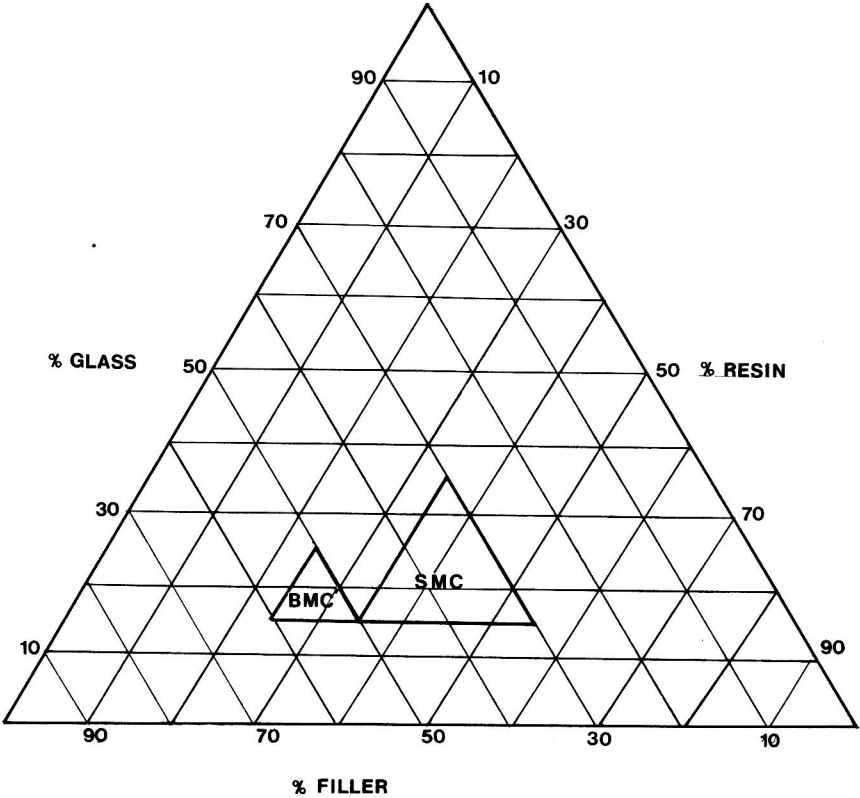


FIGURE 1.4 Composition diagram for SMC/BMC. (From Ref. 10.)