PLASTICS PNEUMATIC CONVEYING AND BULK STORAGE

Edited by

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Preface

Nearly all plastics raw materials are in particulate form such as powder or extrusion compounded granulate of regular shape and size. These materials are pneumatically conveyed and stored in bulk by the polymer manufacturer and often also by the processor who converts them into an artifact by an extrusion or moulding process. Thus most plastics raw materials are conveyed through at least two pneumatic systems and stored in at least two bulk silos before losing their particulate identity in the final processing operation. Considering, then, the industrial importance of the pneumatic conveying and bulk storage of plastics raw materials, it is surprising that these aspects of plastics technology receive so little attention in the literature. This book is an attempt to help fill this gap.

The first chapter is a short introduction which sets the scene and discusses the importance of the particulate properties of the solid to be conveyed and stored. Chapters 2 and 3 then deal with pneumatic conveying and bulk storage in detail. Though these two chapters are not intended to be complete design guides, they do give practical and theoretical aspects of current design methods and present the options available for handling plastics materials.

Most plastics raw materials have high electrical resistivity values and will generate high electrostatic charges during handling. They will usually ignite and propagate flame and under the right conditions will create a dust explosion which can arise from an electrostatic discharge. Chapter 4 deals with the fire and explosion characteristics of plastics raw materials and with fire and explosion prevention and protection in handling operations.

It is difficult in a multi-author book to create continuity and a uniform level of presentation. The Editor does not claim to have achieved this ideal. Nevertheless, each chapter stands on its own and should be of interest to all plastics technologists and particularly to scientists, engineers and managers involved in the design, selection, operation or maintenance of pneumatic conveying and bulk storage systems in the plastics industry.

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Contents

Chapter 1

Effects of Material Properties on Conveying and Storage

G. BUTTERS

1.1 INTRODUCTION

The engineer embarking upon the design of a pneumatic conveying and bulk storage system for a particulate plastics material has many aspects to consider before beginning the detailed design. He has to consider the pattern of output from the plant, the likely number of different grades, likely fluctuations in market demand, annual shut downs in production, and other factors which dictate how much storage capacity is needed for each grade. He needs to know whether the material will flow out of a conventional cone bottomed silo under gravity, if it is capable of being conveyed by a lean or dense phase pneumatic conveying system and if it can be separated from the conveying air with adequate efficiency by a cyclone or whether it needs filtration. Knowledge of these and other basic facts enables him to determine the optimum number of silos, their type, their method of construction and the most suitable type of conveying system.

Having roughed out the basic elements of the design he can proceed to the more detailed design. He then faces wide ranging decisions which will significantly influence the success or failure of the installation.

All stages of the design require a knowledge of the material to be conveyed and stored. It is unfortunate therefore that the study of the properties and behaviour of particulate systems has been neglected, receiving much less attention than liquids and gases. Probably the reason is that unlike liquids and gases, particulate systems generally do not follow simple scientific laws and their behaviour is difficult to quantify in terms of basic material properties. Knowledge of the application of material properties to the design of pneumatic conveying and storage systems is therefore restricted. Despite these limitations, it is essential to have some knowledge of the properties of the materials to be conveyed and stored. This introductory chapter will therefore briefly consider these properties and point to their relevance.

1.2 CHEMICAL PROPERTIES

It is logical to begin by considering chemical properties since we identify materials by their chemical name. However, whilst the chemical nature of a plastics material can be a vital consideration in many aspects of plastics technology, it can be surprisingly unimportant when considering conveying and storage processes.

1.2.1 Chemical Type

Plastics are classified as being thermoplastic or thermosetting. Thermoplastics are characterised by their ability to be repeatedly softened by heat even after processing into an artifact. Thermosetting types, by contrast, are chemically cross-linked in the final operation and thereafter cannot be softened by heat. The really large tonnage plastics are all thermoplastics.

Major plastics materials which are pneumatically conveyed and stored in bulk are listed in Table 1.1 together with an estimate of the European consumption and details of their particulate forms. With the exception of phenolic resins, these materials are thermoplastics.

1.2.2 Chemical Behaviour under Conveying and Storage Conditions

The major thermoplastics are relatively chemically inert under conveying and storage conditions. They are unlikely to react with any materials used in the construction of conveying and storage systems.

Phenolic resins and other thermosetting plastics are not so chemically inert. Many of these materials can cross-link and form a hard agglomerated mass at ambient temperatures. Some phenolic resins will spontaneously generate heat and eventually ignite when stored in bulk at ambient temperatures. Standard test methods are available to quantify the storage stability of thermosetting resins and these are described in the German and American specifications DIN 55990, Parts 7 and 8, and

TABLE 1.1
EUROPEAN CONSUMPTION AND COMMON PARTICULATE FORMS OF MAJOR PLASTICS MATERIALS

	Estimated western European consumption for 1979 ('000 tonnes)	*Common particulate forms*	*Typical mean size (μm)*
PVC	3 800	Granulate (PVC compound)	
		Roughly spherical powder particles (mass and suspension polymerised)	140
		Irregular fine cohesive powder (paste PVC)	5
High density polyethylene	1 800	Granulate	
		Irregular powder particles	100–1 000
Low density polyethylene	4 130		
Polystyrene	1 300	Granulate	
		Spherical bead	250–500
		Expanded bead	1 000–10 000
Polypropylene	1 300	Granulate	
		Irregular powder particles	100–1 000
ABS	590	Granulate	
		Spherical bead (mass and suspension polymerised)	400
		Fine powder (emulsion polymerised)	2
Phenolics	400	Fine ground powder	25
		Irregular coarse powder	<3 000
		Flake	
Acrylic	266	Granulate	
		Spherical bead (suspension)	200–700
Nylon	140	Generally only granulate	
Polycarbonate	109	Generally only granulate	

ASTM D 3451. The storage stability of these materials must be known and taken into account when designing a conveying and storage system. For example, phenolic resins with a short shelf-life are best stored in mass flow silos which operate on a 'first in first out' principle.

Thermoplastics and thermosetting plastics can both, under certain circumstances and depending upon the nature of the material, give rise to a dust fire or an explosion. This most important consideration is dealt with in detail in Chapter 4.

Cross-contamination can be a problem when any installation is used for more than one material and the possible effects of any such cross-contamination must always be considered.

1.2.3 Moisture

Many particulate plastics, especially powders, will absorb moisture from the atmosphere to an extent dependent on prevailing conditions of humidity. This does not present a serious problem in the case of the major large tonnage thermoplastics such as PVC and the polyolefins. Some plastics, however, such as nylons, polycarbonates and phenolic resins, can absorb high levels of moisture and special storage conditions may be necessary to protect against this. The effect of moisture on the material to be stored must therefore be known.

1.2.4 Volatiles

Plastics raw materials can contain traces of volatile materials such as residual monomer, organic solvent or other materials present in the polymerisation process. The presence of such volatiles must be known and their possible effect on the installation considered. For example, some volatile materials may cause or aggravate an already present explosion hazard.

1.3 BASIC PARTICLE PROPERTIES

1.3.1 Size and Morphology

Whilst the chemical properties of a particulate plastics material often have little influence on conveying and storage, the influence of particle size distribution and morphology is of paramount importance because these basic particle properties control relevant aspects of the behaviour of the bulk material, such as the flow and aerodynamic properties.

The simplest and most common technique for particle size analysis is sieving. Woven wire sieves can be used down to sizes of about 40 μm. Micromesh sieves cover the range 75–2 μm. Materials of smaller particle size, such as paste PVC, can be analysed by centrifugal sedimentation techniques. These and other suitable techniques are well documented in standard text books.[1]

Particle morphology is studied by microscopic techniques. A qualitative description is usually adequate information for the engineer designing a conveying and storage system.

Polymer manufacturers are usually able to supply detailed information concerning the particle size and morphology of their products.

Many plastics are initially manufactured in the form of a powder or bead and may be processed into a final product from these forms. More often, however, these materials are converted into a granulate form such as a cube or cut strand before processing. Other plastics are manufactured in melt form and converted directly to granulate form. Thus, particulate plastics are bulk handled in a wide range of particle sizes. The morphology of these materials is also wide ranging. Granulated plastics usually have an ordered shape whilst powders are usually irregular. It will be seen that aspects of particle structure, such as surface rugosity or roughness and internal porosity, show wide variations.

Table 1.1 gives details of the common particulate forms of the major plastics, all of which are pneumatically conveyed and stored in bulk.

Typical particle size distributions for polyethylene and PVC materials are given in Figs. 1.1 and 1.2. The granulate forms are seen to be of very

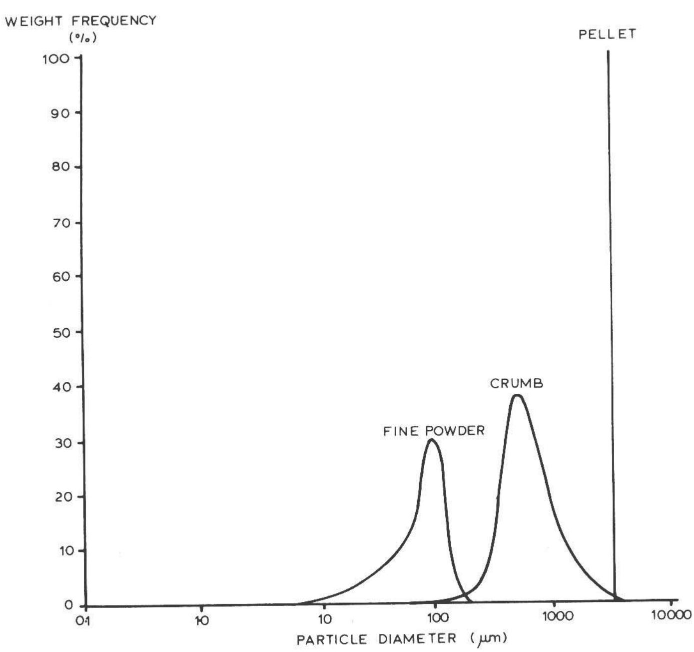

Fig. 1.1. Polyethylene particle size distributions.

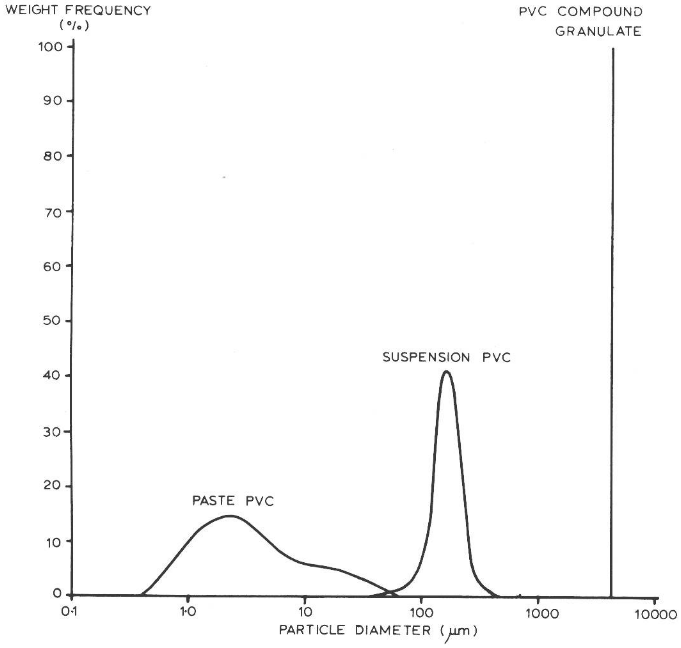

Fig. 1.2. PVC particle size distributions.

uniform size whereas the powder forms have broad distributions. As a general rule, easy flow is favoured by large particle size and narrow size distributions.

Examples of the wide variety of particle shapes and structures which can arise are shown in Figs. 1.3–1.7.

1.3.2 Density

The density of the individual particles has a significant influence on bulk density, flow behaviour and aerodynamic properties, all of which are vitally important in conveying and storage. This physical constant can be determined using a specific gravity bottle as described in BS 737:1952 or, better, using a gas pyknometer.[2]

1.3.3 Friability

It is important to check that a material is not going to be significantly broken down during conveying, since this can result in an increase in

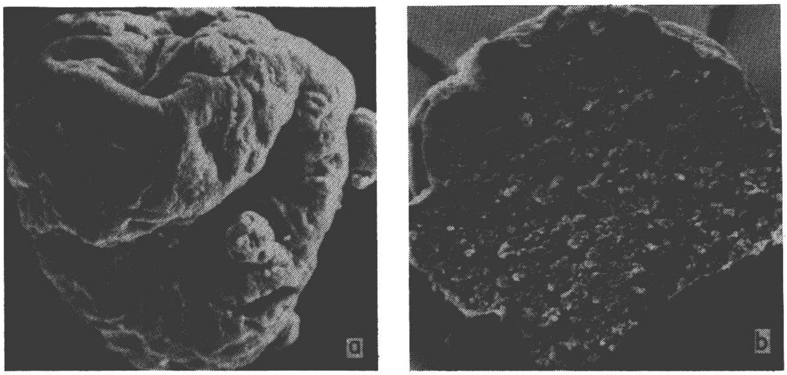

Fig. 1.3. Suspension PVC. (a) Single particle; (b) cut particle (× 400).

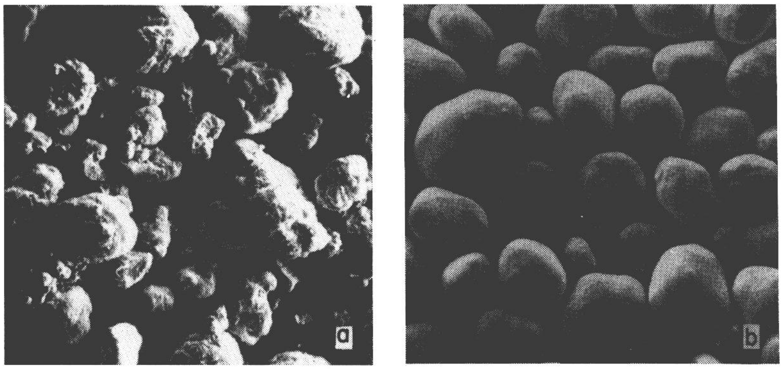

Fig. 1.4. Polyolefin powders. (a) High density polyethylene; (b) polypropylene (× 40).

fines, a more dusty product and a product having different processing properties to the original material. Unfortunately, there is no simple test for measuring the friability of a particulate material and it is necessary to rely upon experience or evaluation in a pneumatic conveying test rig. Most plastics raw materials are not very friable though particle breakdown can occur and the extent of this should be established. Where particle breakdown is a problem, it can be minimised by using dense phase conveying or by conveying at low velocity.