Spray Drying Handbook

Fifth edition

K. Masters

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Spray Drying Handbook

Many of the estimated 15 000 spray dryers in the world today are small units producing speciality powders (photograph by courtesy of Niro)

To: Bente, Caroline and Stephen

Publisher's Note

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Preface to the Fifth Edition

Since the publication of the fourth edition in 1985, there has been continuing development in spray drying technology and plant design to meet the ever-increasing demands for powder quality, lower energy consumption, designs contributing to improved environmental protection and operational practice conforming to health and safety codes. The hygienic and non-contaminating aspects of powder plant producing a wide range of products associated with human consumption and health are now very much in focus.

In the dairy and food industry, for example, these latest developments are being prompted by the need to spray dry products of higher fat and protein content (fat-filled whey, recombined milk, whey protein concentrate, cream, baking powders, high fat mixers, cheese, etc.) and also those containing higher carbohydrate levels (hydrolysed whey, ice cream mixes, beverage formulations, yogurts, etc.). Such products have been classified in the past as being difficult to dry, yet today's commercial requirements demand that these powders are free-flowing, have the required reconstitutional properties, and conform to strict quality specifications. The latest designs of nozzle tower and integrated fluid-bed spray dryers have done much to meet these requirements. They have been able to provide thermally efficient plant and also to improve powder properties by carrying out the drying at lower product temperatures, an important factor for maximum flavour and nutrient retention. Although these aspects of powder quality and reduced operational costs remain of extreme importance today, a third factor has arisen of late, namely the need to meet quality assurance standards. This has required completely new thinking regarding equipment hygiene in process design. To adapt to the new situation, designers of spray dryers have quickly had to refurbish spray dryer designs together with auxiliary equipment, e.g. fluid beds used in connection with spray dryers. Typical examples can be cited: new drying chamber constructions that remove any bacteriological hazards associated with their insulation; fully welded fluid beds that have no inaccessible hollow spaces where product could penetrate; and rotary discharge valves that have received official sanitary approval.

The utilization of spray drying technology in toxic gas removal, introduced as a new technology in the fourth edition, has been shown in the past five years to be technically successful. Electricity generating plant totalling over 13 000 MW capacity now uses spray dryer absorbers as dry (semi-dry) scrubbers, and numerous units also operate on incinerators. This technology is bound to be used extensively in the next decade as the pressure for increased air pollution control grows worldwide.

In the chemical industry, the last five years have seen the establishment of the integrated fluid-bed mixed-flow spray dryer, as the dryer design to meet the product needs of the 1990s. It has been shown ideal for producing dust-free, free-flowing powders (e.g. dyestuffs) and for reducing the building investment and operating cost of plant, while maintaining the powder quality required commercially (e.g. in detergents). The ability of this design to handle more conveniently sticky hygroscopic products has led to important applications not only within organic chemicals (e.g. chelates), but also within the food and beverage industries where, for example, conventional co-current spray dryer designs, long considered successful on products like instant coffee and sorbitol, are being replaced by integrated fluid-bed spray dryer technology.

It would appear that there is sufficient potential in this new technology to meet the needs of the next decade, and that spray drying will remain perhaps the most important dehydration technique to convert pumpable fluid feedstocks into powders of controlled particle size and properties. However, new ideas involving other evaporation aids in spray drying are being researched at this time, for example the use of acoustic energy. Here the new 'pulse combustion drying' concept can be mentioned as a novel design approach, which is now being offered to industry. There is certainly no lack of research interests in the many aspects of spray drying. The patent survey in this book clearly emphasizes this, and to those wishing to follow current research work and trends in spray drying, with its associated disciplines of atomization, particulates handling, etc., a highly recommended literature source is the monthly publication, *Particulates Technology*.[242]

As with the previous four editions, the publication of this handbook has only been possible due to Niro A/S, and thanks go especially to the Company's Group President, Mr Ole Andersen, for his encouragement to see me complete this work. I have also been most fortunate in having access to the company's photographic and diagrammatic material to illustrate the handbook, and this I graciously acknowledge. While expressing my thanks for such vital assistance, I must emphasize that the interpretation of the spray drying principles, component design and product applications is solely mine, and does not necessarily agree with the official view of the Niro Group.

Keith Masters
Copenhagen, Denmark, 1991

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Introduction

0.1 Definition

Spray drying is in the family of suspended particle processing (SPP) systems together with fluid-bed drying, flash drying, spray granulation, spray agglomeration, spray reaction, spray cooling, and spray absorption. This is because drying is accomplished while particles are suspended in the air. The main differences between spray, fluid-bed and flash drying are shown as:

	Spray dryer	*Fluid-bed dryer*	*Flash dryer*
Feed	Fluid	Solid	Solid
Residence time in dryer	5–100 s	1–300 min	1–5 s
Particle size (μm)	10–500*	10–3000	10–300

*Prime individual particles (agglomerated and granulated particles can be larger).

Spray dryers can be combined with fluid beds in cases where special drying conditions have to be achieved.

Spray drying is a unique drying process, since it involves both particle formation and drying. Powder characteristics can be controlled, and powder properties can be maintained constant throughout a continuous operation. With the designs of spray dryers available, it is possible to select a dryer layout to produce either fine- or coarse-particled powders, agglomerates or granulates.

Spray drying is by definition the transformation of feed from a fluid state into a dried particulate form by spraying the feed into a hot drying medium. It is a one-step, continuous particle-processing operation involving drying. The feed can either be a solution, suspension, emulsion or paste. The resulting dried product conforms to powders, granules or agglomerates, the form of which depends upon the physical and chemical properties of the feed and the dryer design and operation. Spray drying is a procedure which in many industries meets dried-product specifications most desirable for subsequent

processing or direct consumer usage. Intensive research and development during the last few decades has resulted in spray drying becoming a highly competitive means of drying a wide variety of products. The range of product applications (see Chapter 13) continues to expand, so that today spray drying has connections with many things we use daily. The extent of this is worth summarizing as part of the introduction.

0.2 Everyday Applications

Spray drying has moved into all major industries ranging from production in the most delicate of conditions laid down in food and pharmaceutical manufacture right through to the high-tonnage outputs within such heavy chemical fields as mineral ores and clays. There are many products and articles in use around us each day to exemplify the extensive usage of spray drying. This is apparent if we consider just one aspect of common interest to us all, namely our domestic life.

From foodstuffs to home fittings, spray drying has many associations. Each product has different powder requirements to be met during manufacture.

For example, we may be concerned only with the taste and price of the foodstuffs we buy and the quality of the household aids we use, but it is most likely one would find a wide range of foodstuffs, equipment and fittings within our homes having direct and indirect connections with the spray-drying operation. These foodstuffs may well include instant coffee, coffee whitener, dried eggs, milk, soups, baby foods, sweeteners, perhaps even powdered cheese. These are examples of products with direct connections. Spray-dried foodstuffs appeal to the eye, retain nutritive contents, and are easy to use because they are readily dry-mixed and reconstituted. This is irrespective of their dried forms, which are highly diverse. Milk powders can be in agglomerated (instant) form, whereas eggs, soup and coffee whitener have powdery, and sweeteners granular forms. Apart from dried foodstuffs that are consumed directly, there are many spray-dried products used in cooking. Examples include condiments (garlic, pimento), flavouring compounds, rennet, and ingredients in biscuits and cakes. Meat, vegetables and fresh fruit are foodstuffs with indirect connections with spray drying. Meat may be from a slaughtered animal reared on feeds based upon spray-dried skim milk, whey or fat-enriched milk (replacer) or proteins. Whereas appearance might not be so crucial here, particle size and consistency must be conducive to animal digestion. All vegetables and fruit can be connected with spray-dried agro-chemicals used in cultivation. For this application the powders must have good spreading or solubility characteristics, with emphasis on particle-size distribution and moisture content of the powder.

Passing from foodstuffs to general household commodities, many examples can be cited. Perhaps the best-known spray-drying application is household

detergents; but spray-dried surface-active agents and optical brighteners are also available. In the bathroom cabinet, spray-dried pharmaceutical products, and even cosmetics, are likely to be found. Pharmaceuticals, e.g. antibiotics, are produced under the most aseptic of conditions as finely divided powders, which are often made into tablets prior to marketing. The spray-dried powder form is ideal for rapid assimilation into the body organs. Many cosmetics rely on spray drying to provide constituents in such articles as face powders and lipsticks. Applications to home fittings and furnishings are also extensive. Wall tiling is formed by pressing coloured spray-dried clays. Paints contain spray-dried pigments. Electrical insulation material is spray-dried prior to pressing into parts for electronics and electric power supplies. Also in the electronics field spray-dried ferrites enjoy wide use, being found in pressed form in telephones, radio, television, etc. Many household aids are powered by an electric motor with a ferrite rotor. Spray-dried carbides feature in many cutting tools. All these pressing operations demand strict particle-size distributions that can be met by the spray drying operation.

No such survey of spray-dried products in the home is complete without mention of (a) plastics, as many household plastic utensils originate from a manufacturing process that includes a spray drying stage; (b) fabrics, as spray-dried dyestuffs provide the vivid colours of furnishings and clothing; (c) stationery, as spray drying provides many materials for printing while spray-dried kaolin is used in papermaking itself; (d) shoes, bags and leather wear, as spray-dried tannin is closely associated with the curing of leather; (e) starch, as the extensive processing of this, one of mankind's most basic materials, often includes a spray drying stage. Spray-dried starch and its derivatives (glucose, sorbitol) are widely used in ice-cream, confectionery, desserts, jellies, preserves, frozen fruit and soft drinks. In non-food manufacture, spray-dried starch is used in textiles, papermaking, printing and adhesives.

More examples could be cited, but the point has surely been made. The variety of spray-dried products illustrates the ability of spray drying equipment to meet a wide range of powder-product requirements.

0.3 What is Involved in Spray Drying?

Spray drying involves atomization of feed (hereafter aqueous, unless stated otherwise) into a spray, and contact between spray and drying medium (hereafter termed air, unless stated otherwise) resulting in moisture evaporation. The drying of the spray proceeds until the desired moisture content in the dried particles is obtained, and the product is then recovered from the air. These four stages are illustrated by reference to the open-cycle, co-current spray dryer layout (see Figure 0.1), the most common type of spray dryer in industry.

The word 'atomization' can be confusing initially. 'Atomization' has no