INDUSTRIAL DRYING EQUIPMENT

Selection and Application

C. M. van 't Land

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Preface

Drying is an important unit operation in the process industry. This book treats drying as a method for accomplishing a liquid/solid separation by other than mechanical means. Usually, heat is supplied, leading to evaporation of a liquid (usually water), and this leaves a solid behind. Drying accomplishes the transformation of a process stream and, as such, produces a salable product. As drying is an energy-intensive activity and dryers are expensive pieces of equipment, drying must be carried out as economically as possible.

Among those interested in drying are chemical engineers, energy specialists, and mechanical engineers. The objective of this book is to assist the process development engineer, the process engineer, and the plant engineer in their selection of drying equipment. The criteria to be observed are discussed, as are the means to estimate the financial consequences of a choice. Procedures for sizing equipment are also covered.

This book is primarily practical in nature, but it can also be used in conjunction with available theoretical books.

C. M. van 't Land

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Contents

1

INTRODUCTION

Drying can be defined as a unit operation in which a liquid/solid separation is accomplished by the supply of heat, with separation resulting from the evaporation of liquid. Although in the majority of cases water is the liquid being removed, solvent evaporation is also encountered. The definition may be extended to include the dehydration of food, feed, and salts and the removal of hydroxyl groups from organic molecules.

This book is based on personal experience gained in the selection of drying equipment while employed by Akzo, a multinational company that manufactures fibers, bulk and fine chemicals, pharmaceuticals, and coatings.

During the early stages involving the selection of a new dryer or the replacement of one, a person should seek the cooperation of a reputable dryer manufacturer. Such close cooperation between the manufacturer and the potential user is essential, because one partner is knowledgeable about the equipment and the other person has expertise in the product. Since small-scale testing of drying equipment can be performed, this procedure can give very valuable insight into ultimate dryer selection. However, it is important that the partners have some insight into the other's field. Thus, the user can make value judgments on the equipment being recommended by the manufacturer. The size of the equipment must be checked, using various techniques (estimating methods, rule of thumb, rough-and-ready calculations, etc.). This book covers these techniques for each class of dryer, with some computer programs for screening purposes also included.

Various reasons exist for drying materials to a specific level or range:

1. It is often necessary to obtain a free-flowing material that can be packed, transported, or dosed.
2. Contractual limits exist for some products, e.g., salt, sand, and yarn.
3. Statutory limits are in force for some materials, e.g., tobacco and flour.
4. A moisture content within a specified range may have to be obtained for quality reasons. For many dried foods, too much moisture may adversely affect shelf life and nutritional value, whereas a moisture content too low may make the product less enjoyable and the over-drying may cause the loss of valuable nutrients.
5. The efficiency of subsequent process steps sometimes requires the moisture content to be between specified limits, as in, e.g., the milling of wheat, or the pressing of pharmaceutical tablets.
6. The onset of mildew and bacterial growth in textiles, such as woolen cloth, can be prevented by drying the cloth to a specific moisture content.
7. For the manufacture of ready-to-use pottery articles.

Heat required for drying can be supplied by the fundamentally different mechanisms of convection, conduction, and radiation.

1. *Convection.* A carrier gas (usually air) supplies the heat for the evaporation of the liquid, i.e., the conversion of sensible heat into latent heat. The carrier gas subsequently removes the volatile matter.
2. *Conduction.* The heat is supplied indirectly and the carrier gas serves only to remove the evaporated liquid. Typically, the air quantity is approximately 10% of the quantity used in a convective process.
3. *Radiation.* This type of drying can be nonpenetrating, such as the drying of paint by infrared (IR) radiation, or penetrating, by microwaves. For a material to be effectively evaporated by microwaves the evaporated molecule must have a dipole. Microwave drying is the only process in which heat is developed in the material being dried rather than having heat diffused into the material. Again a carrier gas is required to remove the evaporated liquid.

Usually, a combination of two or more mechanisms is encountered in many dryers.

A distinction should be made between free and bound water. Initially, free water is evaporated until the critical moisture content is reached. The free water's latent heat during evaporation is essentially equal to that on evaporating from a pool, with the heat transfer being the rate-determining step. The evaporation occurs at a constant rate if the heat supply is constant. Drying to below the critical moisture content requires the evaporation of bound water, with the evaporation rate decreasing if the heat supply is kept constant. Bound water can be located in pores or crevices, can be physically absorbed, or can be present as water of hydration. The latent heat of evaporation of bound water is usually higher than that of free water; e.g., the ratio of the latent heats of evaporation of water on wool containing by weight 16% and 30% water (the critical moisture content) is approximately 1.1:1.

In Chapter 2, it is recommended that the drying step not be considered in isolation but rather be reviewed in the context of the entire process. Upstream process modifications can have a large impact on the drying stage, whereas the method of drying is often of paramount importance to product quality.

Unlike with, e.g., a centrifuge, usually one refers to a dryer as consisting of a number of pieces of equipment grouped together in subsystems. It is therefore more correct to refer then to drying systems. Convective drying systems are more complex than contact or radiation dryer systems. Drying is often the last processing step, which is followed by a solids-handling system, traditionally dealt with by mechanical engineers. In addition, being an energy-intensive process, drying may often be handled by energy specialists. It can therefore be considered a unit operation that falls at the interface of three disciplines, namely, chemical, mechanical, and energy engineering.

Procedures for determining the optimum dryer are covered in Chapter 3. One scheme is presented for continuous dryers with a separate scheme for batch dryers. Chapter 4 provides an introduction to convective drying and Chapters 5 through 8 cover in detail the four main categories of convective dryers. In these chapters, the performance of dryers has been analyzed, their literature data interpreted, and the design methods covered. The material that is presented permits an estimation of both fixed and variable costs for convective dryers. For this operation, computer programs are included in the appendixes.

In Chapter 9, miscellaneous convective and conductive continuous dryers are discussed and batch dryers are treated in Chapter 10. Special drying techniques, such as infrared and microwave drying, are dealt with in Chapter 11, and the very important issue of safety is covered in Chapter 12. Gas and dust explosions are also considered in that chapter. Chapter 13 covers continuous solids- and gas-moisture measurement, dryer control, and energy recovery. The separation of particulate solid material from spent drying gas by means of cyclones, fabric filters, and scrubbers are the topics in Chapter 14, and the selection of feeders for dryers is taken up in Chapter 15.