BETE®

PERFORMANCE SPRAY ENGINEERING

SPRAY DRY MANUAL

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CONTENTS

SPRAY DRY MANUAL

1.0 Introduction

1.1 Why dry?

Drying is the process of removing liquid from solids by evaporation. The drying process has been used for thousands of years to reduce transport weight and increase the storage life of numerous products and materials. For centuries, drying meant spreading a product out in the open air and letting the sun provide the energy for water evaporation. With the dawn of the industrial age, many different drying processes have been developed to increase drying speed and improve product quality and uniformity.

1.2 Why Spray Dry?

In the world of industrial dryers, there are few types that accept pumpable fluids as the feed material at the inlet end of the process and produce dry particulate at the outlet. Spray drying is unique in its ability to produce powders with a specific particle size and moisture content without regard for the capacity of the dryer and the heat sensitivity of the product. This flexibility makes spray drying the process of choice for many industrial drying operations.

Advantages of spray drying:

- Able to operate in applications that range from aseptic pharmaceutical processing to ceramic powder production.
- Can be designed to virtually any capacity required. Feed rates range from a few pounds per hour to over 100 tons per hour.
- Powder quality remains constant during the entire run of the dryer.
- Operation is continuous and adaptable to full automatic control.
- A great variety of spray dryer designs are available to meet various product specifications.
- Can be used with both heat-resistant and heat-sensitive products.
- As long as they are can be pumped, the feedstock can be abrasive, corrosive, flammable, explosive or toxic.
- Feedstock can be in solution, slurry, paste, gel, suspension or melt form.
- Product density can be controlled
- Nearly spherical particles can be produced.
- Material does not contact metal surfaces until dried, reducing corrosion problems.

1.3 Brief history of spray drying

The development of spray drying equipment and techniques evolved over a period of several decades from the 1870s through the early 1900s. The first known spray dryers used nozzle atomizers, with rotary atomizers introduced several decades later. Because of the relatively unsophisticated designs of the early spray dryers and practical difficulties in operating them continuously, very little commercial use of the process was made until the 1920s.

By the second decade of the twentieth century, the evolution of spray dryer design made commercial operations practical. Milk drying was the first major commercial application of the technology. During the next 20 years, manufacturers developed designs to accommodate heat-sensitive products, emulsions and mixtures. Spray drying came of age during World War II, with the sudden need to reduce the transport weight of foods and other materials. This surge in interest led to developments in the technology that greatly expanded the range of products that could be successfully spray dried.

1.4 Spray drying basics

1.4.1 Concentration

Feedstock is normally concentrated prior to introduction into the spray dryer. The concentration stage increases the solids content thereby reducing the amount of liquid that must be evaporated in the spray dryer.

1.4.2 Atomization

Spray dryers are characterized by the atomization of the feedstock and the contacting of the spray with heated air. The atomization stage is designed to create the optimum conditions for evaporation and to lead to a dried product having the desired characteristics. Nozzles and rotary atomizers are used to form sprays. Dryers can range from just one nozzle to having over 100.

1.4.3 Droplet-air contact

The central element of a spray dryer is the spray dry chamber. In the chamber, atomized liquid is brought into contact with hot gas (usually air, at a vacuum), resulting in the evaporation of 95%+ of the water contained in the droplets in a matter of a few seconds. The way in which the spray makes contact with the air in the dryer influences the behavior of the droplet during the drying phase and has a direct bearing on the properties of the dried product. The type of contact between the spray and the air is determined by the position of the atomizer relative to the air inlet. Nozzle headers are usually located at the top of the dryer and spray down.

1.4.4 Droplet drying

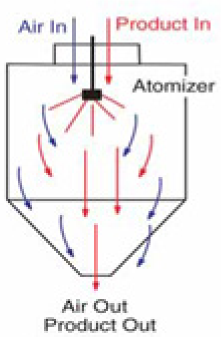
Moisture evaporation takes place in two stages. During the first stage, the temperature in the saturated air at the surface of the droplet is approximately equal to the wet-bulb temperature of the drying air. There is sufficient moisture in the drop to replace the liquid evaporated at the surface and evaporation takes place at a relatively constant rate. The second stage begins when there is no longer enough moisture to maintain saturated conditions at the droplet surface, causing a dried shell to form at the surface. Evaporation then depends on the diffusion of moisture through the shell, which is increasing in thickness. The rate of evaporation falls rapidly during the second phase. Different products have differing evaporation and particle-forming characteristics. Some expand, others contract, fracture or disintegrate. The resulting particles may be relatively uniform hollow spheres, or porous and irregularly shaped.

1.4.5 Separation

Following completion of drying, the particles of product must be separated from the drying air. Primary separation is accomplished by the particles simply falling to the bottom of the chamber. A small fraction of the particles remain entrained with the air and must be recovered in separation equipment. Cyclones, bag filters, and electrostatic precipitators may be used for the final separation stage. Wet scrubbers are then often used to purify and cool the air so that it can be released to atmosphere.

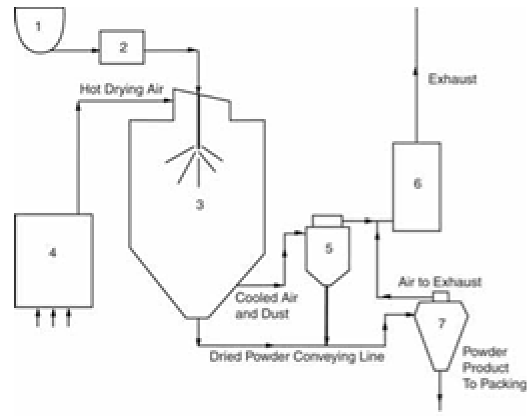
2.0 Spray Dryer Type

2.1 Co-current flow dryer



Co-current Flow Dryer
Fig 2.1.1

In a co-current dryer (Fig. 2.1.1, Fig. 2.1.2), the spray is directed into the hot air entering the dryer and both pass through the chamber in the same direction. Co-current dryers are the preferred design for heat- sensitive products because the hottest drying air contacts the droplets at their maximum moisture content. Spray evaporation is rapid, and the temperature of the drying air is quickly reduced by the vaporization of water. The product does not suffer from heat degradation because the droplet temperature is low during most of the evaporation time. Once the moisture content reaches the target level, the temperature of the particle does not increase greatly because the surrounding air is now much cooler. Dairy and other heat-sensitive food products are usually dried in co-current dryers.

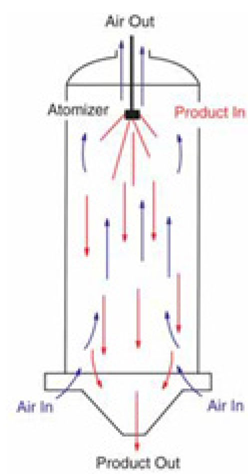


Open Cycle Co-current Flow Layout
Fig. 2.1.2

1. Feed storage
2. Pump
3. Drying chamber
4. Air heater
5. Cyclone
6. Gas scrubber
7. Separator

2.2 Counter-current flow dryer

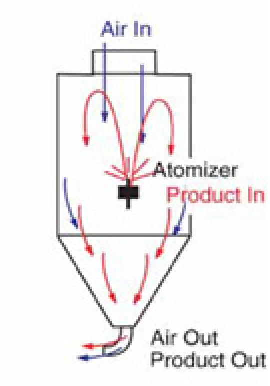
In this dryer design (Fig. 2.2.1), the spray and the air are introduced at opposite ends of the dryer, with the atomizer positioned at the top and the air entering at the bottom. A counter-current dryer offers more rapid evaporation and higher energy efficiency than a co-current design. Because the driest particles are in contact with hottest air, this design is not suitable for heat-sensitive products. Counter-current dryers normally use nozzles for atomization because the energy of the spray can be directed against the air movement. Soaps and detergents are commonly dried in counter-current dryers.



Counter-current Flow Dryer
Fig 2.2.1

2.3 Mixed flow dryer

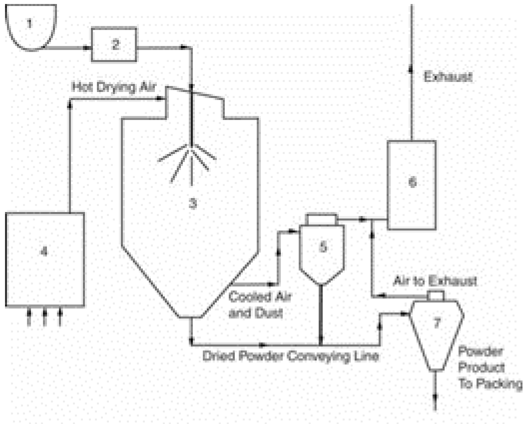
Dryers of this type (Fig. 2.3.1) combine both co- current and counter current flow. In a mixed flow dryer, the air enters at the top and the atomizer is located at the bottom. Like the counter-current design, a mixed flow dryer exposes the driest particles to the hottest air, so this design is not used with heat-sensitive products.



Mixed Flow Dryer
Fig 2.3.1

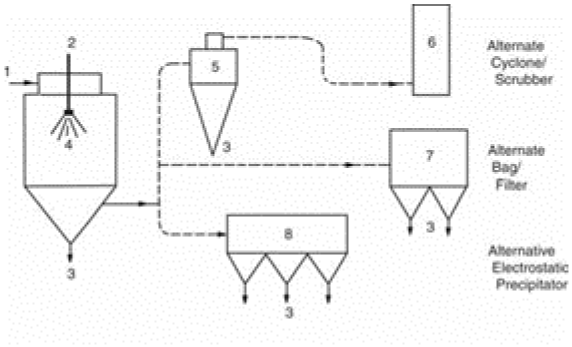
2.4 Open Cycle Layout

In an open cycle dryer (Fig. 2.4.1, Fig. 2.4.2), drying air is drawn from the atmosphere, heated, conveyed through the chamber and then exhausted to the atmosphere. This is by far the most commonly used design.



Open Cycle Co-current Flow Layout
Fig 2.4.1

1. Drying air
2. Feedstock
3. Dried product
4. Drying chamber
5. Cyclone
6. Wet scrubber
7. Bag filter
8. Electrostatic precipitator



Open Cycle Layout
Fig. 2.4.2

1. Drying air
2. Feedstock
3. Dried product
4. Drying chamber
5. Cyclone
6. Alt. A: wet scrubber
7. Alt. B: bag filter
8. Alt. C: electrostatic precipitator

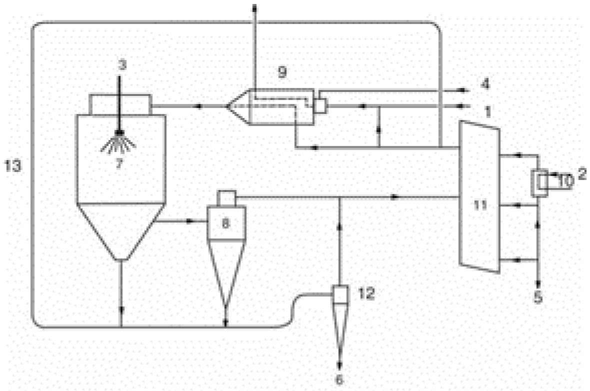
2.5 Closed cycle dryer

A closed cycle dryer recycles the drying gas, which may be air or more commonly, an inert gas such as nitrogen. Closed cycle units are the dryers of choice when:

- Feedstock consists of solids mixed with flammable organic solvents.
- Complete recovery of solvent is required.
- The products are toxic
- Pollution due to vapor, particulate emissions or odor is not permitted.
- Explosion risks must be eliminated.
- The powder will degrade by oxidation during drying.

2.6 Semi-closed cycle dryer

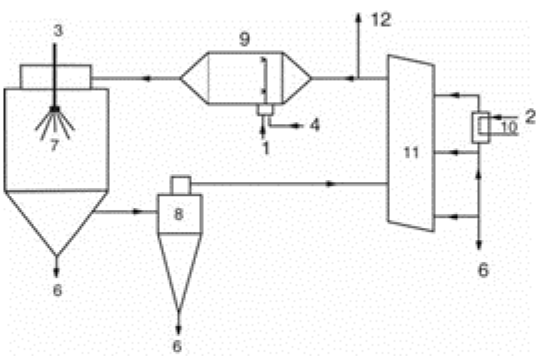
This design is a cross between open and closed cycle dryers and it is not gas tight. There are many variations on this design, with the most important being the “direct heated” or “self-inertizing” system (Fig. 2.6.1). In the self-inertizing design, a direct-fired heater is used and the air entering the system is limited to that required for combustion. An amount of air equal to the combustion air is bled from the system at the other end of the process. The gas (mainly products of combustion) is recycled through the dryer. The recycled gas has a very low oxygen content, making it suitable for materials that cannot be exposed to oxygen, due to explosive hazard or product degradation.



Semi-closed Cycle Layout
Figure 2.6.1

1. Combustion air
2. Coolant
3. Feedstock
4. Fuel
5. Condensed waste discharge
6. Dried product
7. Dryer chamber
8. Cyclone
9. Indirect heater
10. Heat exchanger
11. Scrubber/condenser
12. Transport cyclone
13. Pneumatic transport system

Another variation of the Semi-Closed cycle design has an indirect air heater (Fig. 2.6.2).



Semi-closed Cycle Layout
(Self-inertizing)
Fig. 2.6.2

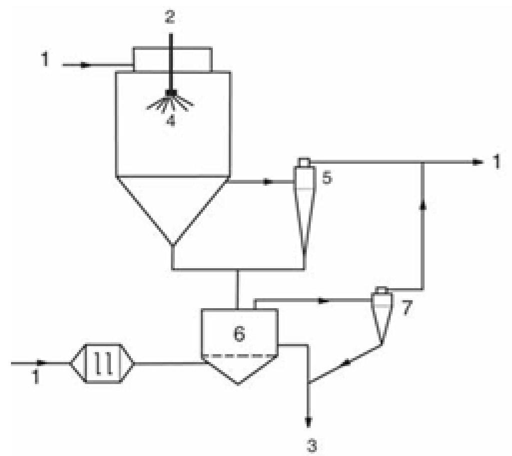
1. Combustion air
2. Coolant
3. Feedstock
4. Heater fuel
5. Condensed water discharge
6. Dried product
7. Drying chamber
8. Cyclone
9. Direct heater (gas)
10. Heat exchanger
11. Scrubber/condenser
12. Air bleed to atmosphere

2.7 Single stage dryer

In a single stage dryer, the moisture is reduced to the target (typically 2% - 5% by weight) in one pass through the dryer. The single stage dryer is used in the majority of designs.

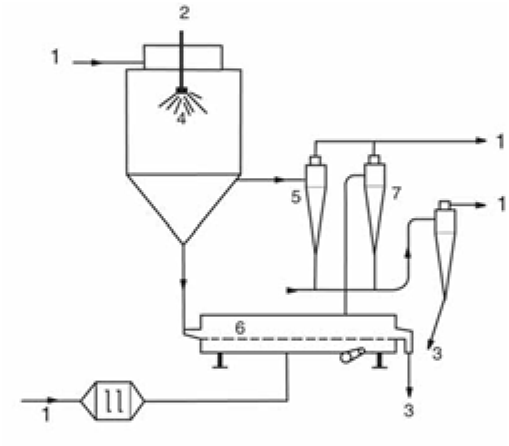
2.8 Two stage dryer

In a two stage dryer, the moisture content of product leaving the chamber is higher (typically 5% - 10%) than for the final product. After leaving the chamber, the moisture content is further reduced during a second stage. Second stage drying may be done in a fluidized bed dryer (Fig. 2.8.1) or a vibrating bed dryer (Fig. 2.8.2). Two stage dryers allow the use of lower temperatures in the dryer, making the design a good choice for products that are particularly heat- sensitive.



Two Stage Dryer with Fluid Bed Dryer
Fig. 2.8.1

1. Air
2. Feedstock
3. Dried product
4. Drying chamber
5. Cyclone
6. Stationary fluid bed
7. Fluid bed cyclone
8. Transport cyclone

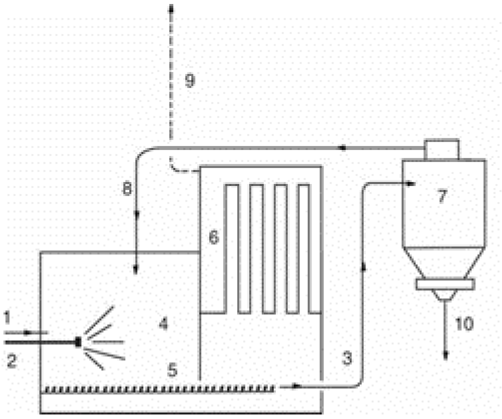


Two Stage Dryer with Vibrating Bed Dryer
Fig. 2.8.2

1. Air
2. Feedstock
3. Dried product
4. Drying chamber
5. Cyclone
6. Vibrating fluid bed
7. Fluid bed cyclone
8. Transport cyclone

2.9 Vertical dryer
The chamber of a vertical (tower) dryer has the form of a tall cylinder with a cone-shaped bottom. Spray nozzles may be located at the top (co-current flow) or bottom (counter-current flow or mixed flow) of the chamber. BETE Twist & Dry™ nozzles are commonly used in vertical dryers. Inlets for the drying air may be located at the top, bottom or side of the chamber. Vertical spray dryers are usually large and the residence time of sprayed particles is relatively long, allowing the use of higher flow nozzles such as the TD, which produce relatively large particles. Manufacturers of vertical spray dryers include Stork, Niro and APV Anhydro.

2.10 Horizontal dryer
The chamber of a horizontal dryer (Fig. 2.10.1) has the form of a rectangular box with either a flat or a "V" shaped bottom. Nozzles in a box dryer normally spray horizontally, with the dried particles falling to the floor, where they are removed to a bagging area by a sweep conveyor or screw conveyor. Box dryers are usually small and the particle residence time relatively short, requiring the use of low flow nozzles such as the low flow version of the BETE Twist & Dry, which produce relatively small particles. Manufacturers of flat-bottom box dryers include: CE Rogers, Marriott Walker, Henningsen Foods, Food Engineering Co. and Henszey Co. Manufacturers of "V" bottom dryers include: Blaw-Knox, Bufflovak and Mora Industries.



Horizontal Dryer
Fig. 2.10.1

1. Drying air
2. Feedstock
3. Pneumatic conveyor
4. Drying chamber
5. Powder conveyor
6. Filter bags
7. Cyclone
8. Dust return
9. Exhaust to atmosphere
10. Dried powder

3.0 Atomization and Sprays

3.1 Atomization
The purpose of the atomizer is to meter flow into the chamber, produce populations of liquid particles of the desired size and distribute those liquid particles uniformly in the drying chamber. The selection of a specific atomizer is made based on the feedstock, the required powder properties, the dryer type and capacity and the atomizer capacity.

3.2 Rotary atomizers
Rotary atomizers use the energy of a high speedrotating wheel to divide bulk liquid in to droplets. Feedstock is introduced at the center of the wheel, flows over the surface to the periphery and disintegrates into droplets when it leaves the wheel.

Advantages of rotary atomizers:
- Because the break-up energy is supplied by the motor-driven wheel, the liquid feed system can operate at relatively low pressure.
- Able to handle applications where clogging would be a problem for nozzles.
- Particle size can be changed by changing the wheel speed.

Disadvantages of rotary atomizers:
• Produce large quantities of fine particles, which can result in pollution control problems.

- High capital cost.
- Very expensive to maintain.
- Cannot be used in horizontal dryers.
- Difficult to use with highly viscous materials.

Because of the problems and costs associated with rotary atomizers, there is interest within segments of the spray dry industry in replacing rotary atomizers with spray nozzles. Making such a change is not a simple process and generally must involve the dryer OEM.

3.3 Pressure nozzles
Pressure nozzles such as the BETE Twist & Dry, are the most commonly used atomizers for spray drying. Nozzles generally produce coarser, freer flowing powders than rotary atomizers. Pressure nozzles used in spray drying are called "vortex" nozzles because they contain features that cause the liquid passing through them to rotate. In the BETE Twist & Dry, the vortex is generated by the tangential inlet to the swirl. Because the swirl chamber of the Twist & Dry has no restricted passages, clogging is minimized and wear life is increased. Some nozzle designs use slotted vanes or cores to generate the vortex. The disadvantages of slotted designs are that they are prone to clogging and premature wear.

The rotating fluid allows the nozzle to convert the potential energy of liquid under pressure into kinetic energy at the orifice by forming a thin, high-speed film at the exit of the nozzle. As the unstable film leaves the nozzle, it disintegrates, forming first ligaments and then droplets.

Pressure nozzles can be used over a large range of flow rates, and can be combined in multiple-nozzle installations to give them a great amount of flow rate and particle size flexibility.

The range of operating pressure range for pressure nozzles used in spray drying is from about 250 PSI (17.4 bar) to about 10,000 PSI (690 bar). The BETE Twist & Dry is capable of handling this entire pressure range. The TD-K should be used for pressures above 3500 PSI and up to 10,000 PSI. See the TD Material Selection Guide for the appropriate TD nozzle setup for your operating conditions.

3.4 Two-fluid nozzles
Liquid feedstock and compressed air (or steam) are combined in a two-fluid nozzle. The design utilizes the energy of compressed gas to atomize the liquid. Two-fluid nozzles are able to atomize highly viscous feeds, but they are expensive to operate because of the high cost of compressed air. Two advantages of the two-fluid nozzle are its ability to produce very fine particles and to atomize high viscosity fluids. Two fluid nozzles are often used in laboratory and pilot plant spray dry applications because of their ability to produce a wide range of flow rates and droplet sizes. The BETE SpiralAirTM and the BETE XA series are two-fluid nozzles that can be used as spray dry atomizers.

Please contact Applications Engineering for help in choosing the appropriate nozzle:

Email: appeng@bete.com
Phone: 413-772-0846 ext. 341

4.0 Spray and Powder Terminology

4.1 Droplet
A subdivision of the feed being sprayed from the atomizer. As long as there is surface moisture in the spray, it is said to be composed of droplets.

4.2 Particle
A subdivision of the dried product. The shape of a particle depends on how the droplet was formed and how it behaved during drying

4.3 Agglomerate
An agglomerate is composed of two or more particles adhering to each other.

4.4 Particle Size
The size of a spherical particle is expressed as its diameter. For non-spherical particles, the size can be represented as an apparent diameter.

4.5 Particle shape
The process of atomizing and drying produces many particles that are non-spherical in shape. A "shape factor" is used to express the divergence of a particle shape from spherical.

4.6 Size distribution
Droplets and particles produced in a spray dryer are never of one particular size. Any nozzle will produce both large and small droplets. The dryer must operate so that it is able to dry the largest droplet without scorching the smallest one. Size distributions can be represented by a cumulative distribution curve.

4.7 Mean or median size
A mean or median particle or droplet size represents a single value most suited to represent the entire distribution. There are many types of mean values. Mean values can represent diameter, surface area, length, volume and other parameters.

4.8 Sauter mean diameter (D32)
The diameter of the particle whose ratio of volume to surface area is equal to that of the entire sample.

4.9 Volume (mass) median diameter (DV50)
The diameter of the particle that divides the volume or mass of the sample into two equal halves. One half of the sample will be composed of droplets or particles with diameters less than the DV05, and the other half of the sample will be composed of particles with diameters greater than the DV05.

4.10 Micron
The unit of measurement used for particles. One micron equals one millionth of a meter, or 0.0000394 inches.

4.11 BETE Twist & Dry Droplet Size
BETE has done extensive droplet size testing on the Twist & Dry in the BETE laboratory, spraying water. The Twist & Dry nozzle is capable of producing sprays with sauter mean diameters ranging from about 30 microns to 120 microns, depending on the pressure and flow rate.

The BETE Nozzle Wizard software will calculate an estimated sauter mean diameter for any set of operating conditions.

5.0 Feedstock
One important advantage of spray drying is that the feedstock can be in virtually any form that can be pumped. Solutions, slurries, pastes, gels and suspensions can be successfully spray dried. The first step in the spray drying process is to prepare the feedstock for spraying by optimizing the temperature, concentration, viscosity or other characteristic.

5.1 Feed temperature
The temperature of the feedstock affects the viscosity and the transfer of heat from the drying air in the chamber to the droplets. Both the temperature of the feedstock and the temperature of the chamber air need to be considered when selecting nozzle seal materials.

5.2 Melting temperature
Some feedstock is solid at room temperature and must be melted in order to atomize them. Prilling or spray cooling involves forming pellets or crystals by spraying melted feedstock into a chamber through which cooling air is flowing.

5.3 Abrasion
The abrasiveness of the feedstock must be considered when selecting the material for the internal nozzle components. For most applications, tungsten carbide is the material of choice for Twist & Dry swirls and orifice disks. Tungsten carbide has excellent resistance to abrasion and good corrosion resistance for most feedstock.

5.4 Corrosion
For some feedstock, corrosive attack on the nozzle components is a greater problem than abrasion. For these cases, 316 stainless steel or nickel alloy C22 may be good choices.

5.5 Specific gravity
The specific gravity is the density of the feedstock relative to water. A specific gravity greater than 1.0 means that the feedstock is denser than water. Increasing the specific gravity reduces the flow through a nozzle. Converting your density units to g/mL will yield the specific gravity value, since water has a density of 1 g/mL.

5.6 Solids content
The solids content is the percent of the feedstock that is composed of solids. Most feedstock has about 50% solids, although the range is from about 20% to 70%. Increasing the solids content reduces the amount of moisture removed in the spray drying process. As the solids content increases, the feedstock becomes more difficult to pump and atomize.

5.7 Surface tension
Surface tension is the force acting on the surface of a liquid that tends to minimize its surface area. Reducing surface tension makes a feedstock easier to atomize.

5.8 Viscosity
Viscosity is the resistance to flow of fluids. The most commonly used unit is the centipoise. Increasing viscosity tends to increase droplet size. For some nozzle designs, including the BETE Twist & Dry, increasing the viscosity tends to increase the flow rate.

6.0 Powder
Spray dryers transform liquid feedstock into particles of powder. Like liquid feedstock, powders have important properties that are monitored during the drying operation.

6.1 Powder Shape
Many spray drying operations produce spherical particles while others result in non-spherical particles. Particles may be hollow or solid. Non-spherical particles are characterized by their aspect ration, which is the ratio of their longest dimension to their shortest dimension.

6.2 Powder Size
It is important to differentiate between droplet size and particle size because the two are generally not the same. The relationship between the mean size of liquid droplets and dried particles is not consistent and no general statements can be made on this subject. The methods used to measure the sizes of dried particles include sieving, microscopy, sedimentation and laser techniques.

Pressure spray nozzles can produce particles ranging in size from 20 to 600 microns, depending on the nozzle type, feedstock properties and operating conditions. Two-fluid nozzles generally produce particles with sizes in the range from 10 to 200 microns and larger.

6.3 Size distribution
The size distribution of dried particles is generally narrower than the size distribution of atomized liquid particles. Rotary atomizers produce more uniform particle sizes compared to pressure atomizers.

6.4 Bulk density
Bulk density is the weight of dried powder per unit volume. This is a critical factor for most spray drying operations since it determines the size (or fullness) of containers and influences the handling and shipping costs. Bulk density is constantly monitored during the spray drying process.

6.5 Factors affecting bulk density

- Increasing feed rate increases bulk density if the residual moisture increases
- If increasing feed temperature leads to the production of spherical droplets instead of 'threads', bulk density increases.
- For easily atomized feeds, increased temperature can lower bulk density.
- Bulk densities often increase on powder cooling.
- A coarse homogenous powder has a lower bulk density than a fine homogenous powder.
- A powder with a wide distribution of particle sizes will have a higher bulk density than a powder with a narrower distribution of particle sizes.
- Increasing feed solids generally increases bulk density.
- Feed aeration decreases bulk density.
- Feed suspensions give higher bulk densities than feed solutions.
- Increasing residual moisture content increases bulk density.
- Increasing inlet air temperature decreases bulk density.
- Reducing the outlet air temperature increases residual moisture and therefore increases bulk density.
- Co-current dryers produce powders with lower bulk densities than counter-current dryers.
- Mechanical handling of powders that reduces particle size by attrition and increases bulk density.

6.6 Agglomeration

It is sometimes desirable to have product particles that are larger than those produced by a single stage spray drying process. Agglomeration is the process of enlarging particles by getting them to stick to each other. Agglomerated particles may have improved solubility, higher bulk density, improved flow properties and less dust.

Occasionally, the second stage of a two stage dryer is used to agglomerate product particles. Since the particles leaving the first stage are still sticky, they will bond with other particles during the second stage drying.

Some installations spray wet particles from the first stage with additional feed in the second stage. The fresh feed softens the surface of the particles and allows them to grow. This process is called "instantizing" or "re-wetting agglomeration".

Most dryer operations include the recycling of fine particles fines captured by the separation equipment into the spray zone. Returning fines promotes an agglomerating effect, leading to the production of a powder that is coarser, freer flowing and "dust free".

7.0 Spray Dry Nozzle Selection

7.1 BETE Twist & Dry Selection

The BETE Nozzle Wizard is a simple tool that can be used to determine the correct Twist & Dry nozzle for any set of operating conditions. The Nozzle Wizard presents a number of swirl/orifice combinations that will achieve the desired flow rate. From these combinations, the user will choose the one that is the closest match to the desired spray angle and droplet size.

7.2 Replacing Spray Dry Nozzles Made by other Manufacturers

Most spray dry nozzles made by other manufacturers can be replaced by the BETE Twist & Dry. Because of differences in operating characteristics, BETE recommends a consultation with one of our experienced applications engineers before substituting the Twist & Dry for a nozzle made by another manufacturer.

Please contact Applications Engineering for help in choosing the appropriate nozzle:

Email: appeng@bete.com
Phone: 413-772-0846 ext. 341

8.0 Spray Nozzle Maintenance

8.1 Nozzle Wear

Nozzles used for spray drying are generally operated at high pressures. Feedstock is abrasive and travel through the nozzles at high velocities, removing material from the internal components. As the nozzle components wear, the performance degrades. The most common symptoms of worn nozzles are an increase in flow rate, degradation of spray pattern uniformity and an increase in droplet size.

8.2 Swirl

There are three areas of the swirl that will show the first visible signs of wear: the narrow "tongue" that forms one side of the inlet, the corner between the bottom and wall of the chamber and the bottom of the chamber itself. Of these three areas, the one that will have the most effect on the spray pattern will be the tongue. Once the tongue shows significant signs of wear, the swirl should be replaced.

8.3 Orifice disk

In most cases, the orifice will wear uniformly and the hole diameter will grow in size, causing the flow rate to increase. BETE recommends that operators change orifice disks when the flow rate increases by 5%, which is equivalent to a hole diameter increase of 2.5%.

8.4 Seals

Leaking nozzles in a spray dryer can cause serious problems, including ruined product, fires and explosions. For this reason, it is critical to ensure that the nozzles will not leak during operation.

Most Twist & Dry nozzles use o-rings as seals. Because of the high operating pressures and high temperatures of the spray dry chamber, BETE recommends that the o-rings be replaced each time that the nozzle is disassembled. BETE recommends the use of a USDA approved lubricant on all o-rings. Twist & Dry nozzles with o-ring seals are designed to be assembled with very low torque. BETE recommends that these nozzles be assembled handtight only.

See the HT Assembly Tips Guide for detailed assembly instructions.

8.5 Body
The velocity of feedstock through the internal passages of the body are much lower than the velocity through the swirl and orifice and, as a result, wear rates are much lower. The body is attached to the feed pipe either by welding or by tapered pipe threads. For bodies with a threaded connection to the supply pipe, BETE recommends the use of Loctite 272 thread sealant.

To apply Loctite 272 thread sealant:
1. Clean threads with wire brush.
2. Clean thoroughly with clean, untinted alcohol
3. Apply a coating of Loctite 7471 primer to the threads and allow 15 minutes to cure. The primer ensures clean threads and assists with rapid setting of the thread sealant.
4. Apply a generous coating of Loctite 272 thread sealant to the male thread.
5. Assemble the nozzle body onto the feed pipe.
6. Remove excess sealant
7. Allow sealant to cure before using. At room temperature, curing time is approximately 24 hours. At 100-120°F (40-50°C) the curing time is reduced to approximately 1 hour.

8.6 Carrier
The carrier is connected to the body with nonsealing, parallel threads. BETE manufactures the body (218 SS) and carrier (303 SS) with different grades of stainless steel to reduce the chances of the threads galling during assembly and disassembly. For added insurance against thread galling in food processing operations, BETE recommends the use of SAF-T-EZE anti-seize compound (made by STL Compound Corporation, Lombard, IL) on the body-carrier threads. BETE offers several carrier nose geometries. The standard design is #2 (Fig 8.6.1), which is used for the widest range of applications. The knife-edge carrier #10 (Fig. 8.6.2) was designed to reduce product buildup in high fat dairy applications.

8.7 Disassembly and cleaning
Dryer operators usually use a dilute caustic solution (1-2% NaOH) for nozzle cleaning. When drying dairy products such as cheese, whey, and milk, the nozzles must be cleaned immediately following shut down in order to prevent the parts from getting stuck together. Some operators clean the complete nozzle in place (CIP), while some remove the wear parts and soak them in the

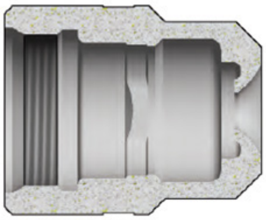


Fig 8.6.1

Fig 8.6.2

caustic solution. Once the swirl and disc are taken out for cleaning, a spare carrier is often installed to reduce flow during CIP.

BETE offers the BETE Twister™ to aid in the removal of swirl units.

9.0 Spray Dry Applications
BETE has detailed information from published reference sources for many specific spray drying applications. The following are brief descriptions of the broad applications.

9.1 Chemical industry
Applications for spray drying in the chemical industry are growing faster than in any other industrial segment.

The huge increase in the use of synthetics has triggered a demand for plastic resins. The spray drying of PVC is a particular stand out. There are two main techniques of PVC production that may require spray drying: emulsion polymerization (E-PVC) and suspension polymerization (S-PVC). Spray drying using either nozzles or rotary atomizers is the only practical way to dry E-PVC. Spray drying of S-PVC is usually dried in drum dryers or flash/fluid bed dryers, but it may occasionally be dried in spray dryers.

Melamine, urea formaldehyde, SBR and ABS resins are usually atomized with rotary atomizers. Polycarbonate resins are often atomized with nozzles.

Chemical products
AB and ABS latex
melamine formaldehyde resin
phenol formaldehyde resin
polyacrylate-emulsion-type
polyacrylonitrile
polycarbonate
polyethylene
polyvinyl acetate
polyvinyl butyrate
polyvinyl chloride (PVC)
polyvinyl pyrroligone
polyvinyl toluene

rubber latex
SBR latex
urea formaldehyde resin

9.2 Ceramic materials
Spray dried powders in the ceramics industry are ideal for pressing and sintering operations. Spray dryers produce free-flowing ceramic powders that allow rapid filling of pressing dies. Spray dryers for ceramic materials use either rotary atomizers or nozzles. Nozzles are mainly used to produce coarse powders in medium-to-low-capacity dryers.

Spray drying, using both rotary atomizers and nozzles is used extensively in manufacturing ceramic oxides. Nozzles are normally used to produce coarse (250-300 micron) powders.

Hard ferrites (barium and strontium iron oxides) are used extensively in the manufacture of permanent magnets. Soft ferrites (manganese-zinc and nickelzinc-iron oxides) are used to produce electromagnets. Spray dryers with rotary atomizers do the initial drying of green materials prior to calcining. Spray dryers with nozzle atomizers produce the final coarse powder from the calcined material.

Steatite, a material used to manufacture electrical insulators, is generally produced in spray dryers using nozzle atomizers. Spray dried glass is used for insulating material.

Carbide (tungsten, titanium, tantalum and niobium) suspended in organic milling liquids is spray dried with nozzle atomizers. Because of the explosive hazard caused by the organic materials, these dryers are closed-cycle.

Abrasive grits are spray dried in order to produce a dried product of uniform moisture and narrow size distribution. Because of the extreme abrasiveness of the material, rotary atomizers are normally used for this, but occasionally low-pressure nozzles are used.

Ceramic products
aluminum oxide (alumina)
beryllium oxide
carbides
carborundum
electro-porcelain
enamels
floor tile material
ferrite
grinding wheel material
glass powder
insulator material
iron oxide
kaolin
silicon dioxide
spark plug material
steatite
titanates
tungsten carbide
uranium oxide
wall tile material
zinc oxide
zirconium silicate

9.3 Detergents, soaps and surface active agents
The production of washing powders is one of the most common spray dry applications. Countercurrent dryers with nozzle atomization are preferred for high-bulk-density detergents. Open-cycle dryers are most commonly used, but some installations use self-inertizing designs. Co-current dryers are used for low-bulk-density detergents.

Optical brighteners are chemicals used to brighten fabrics during washing. Optical brighteners are spray dried in co-current dryers with rotary atomizers or nozzles.

Scents for washing powders are spray dried in cocurrent dryers with either rotary atomizers or nozzles. During the spray drying process small droplets of perfume oil are micro-encapsulated within a protective colloid capsule. The colloid forms a protective skin to prevent the loss of fragrance due to evaporation.

Soap and detergent products
alky-aryl sulphonates
detergent enzymes
dispersing agents
emulsifying agents
fatty alcohol sulphate
heavy-duty detergents
light-duty detergents
mono and dipotassium orthophosphate
mono and disodium orthophosphate
nitrilo tri-acetic acid salts
optical brightener
phosphates saponine
sodium lauryl sulphate

9.4 Pesticides, herbicides, fungicides, and insecticides
Pesticide manufacturing operations use open, semienclosed or closed-cycle dryers. Toxic pesticides are dried in closed-cycles dryers in order to prevent exposure of the operators. Spray dryers for herbicides, fungicides, and insecticides normally use rotary atomizers.

Pesticide products
Calcium arsenate
Copper oxychloride
Cuprous oxide
2,4 DBA sodium salt
2,4,6 TBA sodium salt
DDT with filler
2,4 dichloro-phenoxyacetic acid
2,4 dichloro-phenoxypropionic acid momo-methylamine salt
Dichloro-phenoxypropionic acid

Dichloro-propionic acid sodium salt
Dimethly-dipyridyl dichloride
Lead arsenate
Mangano-ethylene-bis-dithiocarbamate
Methyl-chloro-phenoxyacetic acid
Methyl-chloro-phenoxypropionic acid
Methyl-chloro-phenoxybutyric acid sodium salt
Sodium aluminum fluoride
Sodium fluoride
Sodium methyl arsenate
Sodium penta-chlorophenolate
Sulphur colloidal
Zinc-ethylene-bis-dithiocarbamate
Zinc diethyl dithiocarbamate
Zinc dimethyl dithiocarbamate

9.5 Dyestuffs, pigments
Organic dyes are well suited to spray drying. Due to their heat sensitivity, they can only be dried in cocurrent dryers. Rotary atomizers are used to produce particles in the 50-120 micron range, while nozzles are used to produce particles in the 120-250 micron range. Many dyestuffs have fire or explosive risks associated with them and the use of closed-cycle dryers is common. Inorganic pigments differ from organic dyes in that they are less heat sensitive. Titanium dioxide may be dried in a co-current dryer using rotary atomizers, or in a mixed-flow dryer with nozzles.

Dyestuff and pigment products
Basic dyes
Ceramic colors
Chrome-yellow
Copper oxide
Cosmetic colors
Dyestuff intermediates
Formulated dyestuffs
Food colors
Indigo dye
Ink pigments
Inorganic pigments
Iron oxide
Kaolin
Lithopone
Milori blue
Organic pigments
Paint pigments
Paper colors
Phthalocyanines
Plastic pigments
Soluble and microdisperse textile dyes
Titanium dioxide
Water colors
Zinc chromate
Zinc potassium chromate
Zinc tetroxychromate

9.6 Fertilizers
Spray cooling, or prilling, is an important step in the production of ammonium nitrate. In this step, a concentrated solution is atomized with pressure nozzles located at the top of a tall tower through which cool air is circulated.

Free flowing, low dust ammonium phosphate powder is produced in spray dryers using pressure nozzles or low-speed rotary atomizers.

Super phosphates are normally produced in spray dryers using rotary atomizers.

Spray dryers are sometimes used in waste incineration plants to flash-cool hot air and gases leaving the incinerator. Rotary atomizers are normally used in this application.

Fertilizer products
Nitrogen fertilizers
Ammonium salts
Urea
Phosphoric acid fertilizers
Superphosphates
Potash fertilizers
Sewage sludge
Two component fertilizers (N-P, N-K, P-K)
Three component fertilizers (N-P-K)

9.7 Mineral flotation concentrates
Mineral ore flotation concentrates are spray dried using rotary atomizers.

Mineral and ore products
Copper ore
Cryolite
Iron ore
Lead ore
Manganese ore
Molybdenum ore
Nickel ore
Platinum ore
Silver ore
Tungsten ore

9.8 Inorganic chemicals
Cement slurries are dried prior to calcining operations in spray dryers using either rotary atomizers or pressure nozzles.

Spray drying is well established in the preparation of catalysts. Due to the great variation in catalyst requirements, rotary atomizers, pressure nozzles and two-fluid nozzles are used.

Both rotary atomizers and pressure nozzles are used to spray dry sodium silicate (waterglass).

Sodium hydroxide in pellet form is manufactured by the spray cooling process. Sodium hydroxide melt is atomized by pressure nozzles operating at low pressure to give a coarse atomization in a mixed flow or counter current flow cooling chamber.

Inorganic chemical products

Abrasive grits
Aluminum (metallic)
Aluminum chloride
Aluminum hydroxide
Aluminum oxide
Aluminum phosphate
Aluminum silicate
Aluminum sulphate
Ammonium chloride
Ammonium molybdate
Ammonium nitrate
Ammonium phosphate
Ammonium sulphate
Antimony sulphide
Arsenic oxide
Barium carbonate
Barium chloride
Barium hydroxide
Barium sulphate
Barium titanate
Bauxite waste liquor
Bentonite
Beryllium dioxide
Bismuth aluminate
Bismuth carbonate
Borax
Boric acid
Boron phosphate
Calcium carbonate
Calcium chloride
Calcium hydroxide
Calcium chromate
Calcium hypochlorite
Calcium nitrate
Calcium phosphates
Calcium silicates
Calcium sulphate
Catalysts
Cement
Chrome-iron oxide
Chromium sulphate
Copper chloride
Copper oxide
Copper oxychloride
Copper sulphate
Copper sulphide
Cupric oxide
Cryolite
Feldspar
Ferric sulphate
Ferrous sulphate
Graphite
Gypsum
Kaolin
Lead zirconate
Lime slurry
Lithopone
Lithium chloride
Magnesium aluminum silicate
Magnesium carbonate
Magnesium chloride
Magnesium hydroxide
Magnesium oxide
Magnesium phosphates
Magnesium sulphate
Magnesium trisilicate
Magnesium uranate
Manganese carbonate
Manganese chloride
Manganese oxide
Manganese sulphate
Molybdenum disulphide
Nickel carbonate
Nickel chloride
Nickel sulphide
Potassium acetate
Potassium bicarbonate
Potassium bichromate
Potassium carbonate
Potassium chlorite
Potassium chromate
Potassium fluoride
Potassium metaphosphate
Potassium nitrate
Potassium permanganate
Potassium phosphate
Potassium silicate
Powdered metals
Silica gel
Silicon dioxide
Silicon carbide
Sodium aluminate
Sodium aluminum sulphate
Sodium arsenate
Sodium bicarbonate
Sodium bichromate
Sodium bisulphate and sodium sulphate
Sodium bisulphide
Sodium borate
Sodium carbonate
Sodium chloride
Sodium hypochlorite
Sodium fluoride
Sodium formate
Sodium hydroxide
Sodium perborate
Sodium phosphate
Sodium silicate
Sodium silicon fluoride
Sodium sulphate
Sodium thiosulphate
Thorium carbonate
Thorium nitrate
Titanium dioxide
Titanium tetrachloride
Tungsten carbide
Uranium dioxide
Zinc arsenate
Zinc carbonate
Zinc chloride
Zinc sulphate
Zirconates

9.9 Organic chemicals
Organic products include dyestuffs, plastics, resins, rubbers and pesticides previously mentioned. Food and pharmaceutical products also fall into the organic category and are discussed elsewhere.
The remaining organic products fall into three main categories: organic acids, organic salts and nitrogen containing compounds.

Most waxes are spray cooled to produce large spherical particles. Both rotary atomizers and pressure nozzles may be used.

Organic chemical products
Aluminum stearate
Aluminum triformate
Amino-naphthol-sufphonic acid
Para-Aminosalicylic acid
Amino acid
Ascorbic acid
Ammonium di-nitro-ortho cresol
Barbituric acid derivate
Barium ricinoleate
Calcium acetate
Calcium butyrate
Calcium gluconate
Calcium caseinate
Calcium lactate
Calcium propionate
Calcium saccharates
Calcium stearate
Carboxymethyl cellulose
Chloramine
Chlorohexidine gluconate
Chloromycetine succinate-calcium salt
Chlorophyll
Choline salts
Citric acid
Dicyandiamide
Dicyclehexylphthalate
Diethyldiphenylurea
2,4-dichlorophenoxy-acetic acid sodium salt
Dodecylbenzenesulphonate sodium salt
EDTA salt
Glutamic acid
Glyoxal
Lactose
Lysine
Maleic acid
Methyl acrylic acid
Methyl arsenic acid-disodium sulphate
Mono-carbonic acid
Mono-ethanol aminosulphate
Monochloroacetic acid sodium salt
Oxalic acid
Para-Nitro phenol
Pantholtenates
Perfumes
Potassium acetaldehyde sulphoxylate
Potassium acetate
Potassium isopropylxanthogenate
Potassium phthalate
Potassium sorbate
Quinoline sulphonate
Sodium acetate
Sodium benzene sulphonate
Sodium benzoate
Sodium di-oxalate
Sodium dimethyl dithiocarbamate
Sodium monochloroacetate
Sodium salicylate
Stearic acid
Tartaric acid
Thiocarbamates
Thionine
Urea
Waxes
Xanthates
Zinc stearate

9.10 Spray Absorption (FGD)
Spray dryer absorbers (SDA) feature the atomization of a suitable absorbent within a chamber through which flue gas is passing. The liquid droplets provide intimate contact with the toxic components of the flue gas. Absorbents include lime and limestone slurries and sodium carbonate solutions.

A dry product is formed and recovered at the dryer base, and the scrubbed gas passes through a bag house or electrostatic precipitator for fines removal. SDAs are primarily used for waste incinerator plants. Both rotary atomizers and two-fluid nozzles such as the BETE SpiralAirTM are used in SDAs.

9.11 Spray Concentration (Purification)
In the manufacture of titanium tetrachloride, a spray dryer is operated as a spray purifier. Both nozzles and rotary atomizers are used.

9.12 Spray Reaction
Sodium carbonate can be produced in a spray drying chamber used as a spray reactor. Liquid caustic soda is sprayed into a hot gas atmosphere containing carbon dioxide. The caustic soda reacts with the carbon dioxide to form sodium carbonate. Either nozzles or rotary atomizers may be used in the process.

9.13 Milk Products
By volume of product dried, the dairy industry is by far the largest user of spray dryers for food processing. Skim milk, whole milk and fat-enriched milk are the most important milk products that are spray dried. Other dried milk products include casein, caseinate, whey, sweet whey, acid whey, deminerialized whey, whey protein, infant formula, coffee whitener, cheese, ice cream mix, butter milk, butter, flavored milks and cream.

Milk is always concentrated in falling-film evaporators to a solids content of 45%-55% before spray drying because the cost of removing water in an evaporator is about 1/10 the cost of removing it in a spray dryer.

Both rotary atomizers and pressure nozzles have been used to atomize milk products in the past, but in recent years, rotary atomizers have been replaced almost entirely by nozzles.

Whey is a by-product of cheese making, but it is a commercial product in its own right. Whey is used in soups, cake mixes, baby foods and nutritional supplements.

Spray dried milk products are re-dissolved or dry mixed when utilized. Important powder characteristics are: flow properties, wettability, sinkability, dispersability and solubility.

The general properties of milk powders are: acidity, microbiological properties, state of fat (physical and chemical), organoleptic properties, composition (% fat and % solids, and functional additives.

The properties of milk powders that are influenced by processing are: free moisture, particle size distribution, bulk density, wettability, dispersibility, sinkability, rate of hydration, flow properties, friability, hygroscopicity, caking and shelf life.

Milk powder faults influenced by processing are: solubility index, scorched particles, free fat, scum, white flecks and specks.

Milk products
Baby food
Butter (high fat products)
Buttermilk
Casein
Caseinates
Cheese
Cocoa milk with sugar
Coffee whitener
Fat-filled milk
Fat-filled whey
Hydrolyzed milk products
Cream
Ice cream mix
Malted milk
Milk replacer
Mixed milk products
Skim milk
Whey
Whey mother liquor
Whey permeate
Whey protein
Whole milk

9.14 Egg products
Eggs are broken, separated (unless processed whole) and pasteurized. Spray drying takes place in co-current dryers using either nozzles or rotary atomizers.

Egg products
Egg white
Egg yolk
Whole egg

9.15 Food and plant products
Instant coffee powders have been produced for more than 50 years, but recent advances in the process have resulted in much improved flavor. Prior to spray drying, the coffee is cleaned, blended, roasted and granulated. The ground beans are then put through an extraction process that produces a liquor or extract that is subsequently spray dried. The drying is done in co-current flow dryers with nozzle atomizers.

Edible plant protein can be extracted from soybeans, peanuts, sunflower seeds, leaves, forage crops and potatoes. One type of soybean processing yields “isolated protein”, which contains up to 92% protein in the spray-dried powder. Another soybean process produces “concentrated protein”, which contains 60%-70% protein.

Protein powder from peanuts is used extensively in infant and vegetarian foods, sausages, meat products, soups, breads and bakery products. The processing of potatoes for starch results in large quantities of contaminated water (fruit water) that contains proteins. The protein can be recovered by spray drying.

Food and plant products
Artichoke extracts
Beef broth
Bouillon
Cake mixes
Chamomile tea
Cereals, pre-cooked
Chicken broth
Chlorophyll
Cocoa mixtures
Coffee-extracts
Coffee-substitute extract
Decaffeinated coffee extract
Fat-flour mixtures
Fish proteins
Flavorings
Food coloring
Frangula
Garlic
Hip-extract
Lactose
Licorice extract
Malt extract
Meat puree
Milk-coffee mixture
Pimento
Plant protein
Protein hydrolysate
Rennet
Soup mixes
Tea extract
Whiteners (coffee/tea)

9.16 Fruits, vegetables
Fruit pulps, juices and pastes can be spray dried. Due to their sugar content, most fruits require the addition of fillers in order to be successfully dried. Tomato is the fruit most extensively spray dried. A wide range of vegetables can be spray dried. The drying process is easier for vegetables than for fruits. Vegetable powders are used in dry soup mixes.

Fruit and vegetable products
Apricot
Asparagus
Banana
Beans
Beetroot
Carrot
Citrus fruits with filler
Mango
Onion
Peach
Soft fruits
Tomato

9.17 Carbohydrates and similar products
Corn starch, corn syrup solids and steep water are corn products that are spray dried. Shelled corn is soaked for up to 40 hours in a weak solution of sulphurous acid and water (steep water). The steep water (which contains valuable nutrients) is drained, concentrated and spray dried. The soft corn kernels are milled and starch and oil removed. The remaining hull and gluten fractions are mixed with steep water to form a corn gluten for spray drying.

Most corn starch can be spray dried as an aqueous suspension using rotary atomizers or as a gelatinized feed using two-fluid or pressure nozzles.

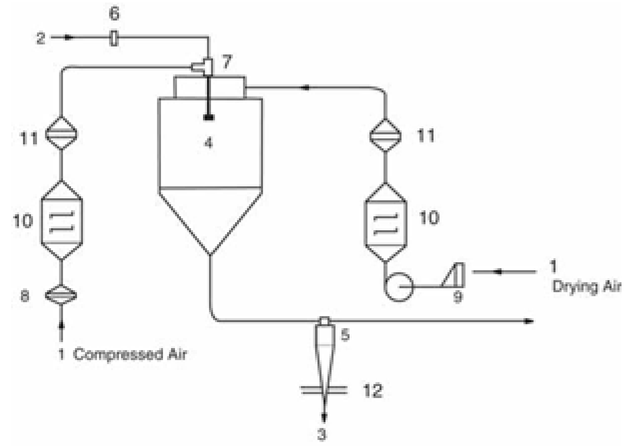
Wheat gluten can be spray dried using pressure nozzles or rotary atomizers in co-current flow dryers.

Carbohydrate products
Baking compounds
Corn steep liquor
Corn syrup
Glucose
Gum arabic
Maize gluten
Pectin
Sorbitol sorbose
Starches
Sugar/gelatin mixtures
Sweeteners
Total sugar
Wheat flour
Wheat gluten
Wort

9.18 Pharmaceutical products
Many pharmaceutical and biochemical products are spray dried, including antibiotics, enzymes, vitamins, yeasts, vaccines, and plasma. The spray drying capacity required for these products ranges from high, in the case of yeasts to low, as in the case of plasma.

Spray drying systems used for pharmaceutical/biochemical applications include: open-cycle, aseptic open-cycle and closed-cycle.

Aseptic Layout
Fig. 9.18.1



1. air
2. feedstock
3. dried product
4. drying chamber
5. cyclone
6. sterile filter for feed
7. two-fluid nozzle or pressure nozzle
8. prefilter for atomizing air
9. prefilter for drying air
10. indirect air heater
11. HEPA filters
12. clean room for packing

Most spray drying of pharmaceutical and biochemical products is done using two-fluid or pressure nozzle atomizers.

Pharmaceutical products
Algae
Antibiotics and moulds
Bacitracin
Penicillin
Streptomycin
Sulphatiazole
Terramycin
Tetracyclin
Dextran
Drugs (selected)
Enzymes
Hormones

Lysine (Amino acids)
Pharmaceutical gums
Sera
Spores
Tabletting constituents
Vaccines
Vitamins

9.19 Yeast products
Yeasts are widely used as food and food supplements for both humans and animals. Yeasts are a source of high-quality proteins and B-vitamins. Raw materials include sulfite waste liquors, molasses, whey, corn by-products, wash water from fruit canneries and petroleum products. Following propagation and fermentation, the liquor is centrifuged and the solids content increased to about 25% by evaporation before spray drying.

Yeast products
Brewers yeast
Fodder yeast
Single-cell protein (SCP)
Yeast extracts
Yeast hydrolysates

9.20 Tannins
Tannin is a water soluble mixture of polyhydroxybenzoic acid that is used in the curing of leather, as a dispersant in oil-drilling muds and other industrial applications. Natural tannins are extracted from certain woods, barks and fruits, most of which are found in Africa and South America. Most tannins extracted from woods are spray dried using rotary atomizers, while tannins extracted from fruit may be spray dried using either rotary atomizers or nozzles.

Tannin products
Tannins from bark
Mangrove extract
Mimosa extract
Oak extract
Pine and fir extract
Tannins from wood
Quebracho extract
Chestnut extract
Tannins from fruits
Dividivi extract
Myrobalan extract
Tannins (synthetic)

9.21 Cellulose
In the manufacture of pulp for paper making, sulfite waste liquor is produced as a by product. The liquor may be processed with spray drying to obtain lignosulphates, yeasts and other chemicals. Spray dryers for processing sulfite liquor may use either nozzles or rotary atomizers.

Cellulose products
Sulfite waste liquor
Lignosulphonates

9.22 Slaughterhouse products
Approximately 25% of the weight of slaughtered animals consists of usable by-products, blood, entrails and glands. These by-products are perishable and can be processed by spray drying into more stable forms.

About 3% of animal weight is blood, which contains 18% solids that have the same nutritive value as meat. Blood can be spray dried either as whole blood or after separation into plasma and red albumin. Blood products are dried at low temperatures to prevent coagulation. Both nozzles and rotary atomizers are used in co-current flow dryers.

Slaughterhouse products
Animal protein
Blood
Bone glue
Excreta
Gelatin
Glands
Tissues

9.23 Fish products
Large volumes of stickwater (fish solubles) containing scales, vitamins and proteins are a byproduct of fish processing plants. These valuable constituents can be recovered by vacuum evaporation and spray drying.

Fish products
Fish flour
Fish hydrolysates
Fish meal
Fish pulp
Fish stickwater (solubles)

10.0 Spray Dry Terminology

ABSORBER Spray dry systems using reagent feedstock to absorb and react with toxic gases, such as S02, and HCL. The resulting compounds are nontoxic powders.

ACIDIC Tending to form an acid (pH below 7.0). after-treatment The joining together of two or more spray dried wet particles to form a larger, porous particles in a fluid bed instantizer (2-stage spray drying). Used to provide "instantizing" qualities to the powder.

AIR ATOMIZATION Feed atomization by 2-fluid (or 3-fluid) spray nozzles using compressed air energy to break up the feed into fine spray droplets.

AIR BROOM Low pressure air used to sweep clean and/or cool dryer chamber walls.

ALKALINE Tending to form a base (pH greater than 7.0).

ANNULUS A circular ring-like passageway for air or liquid, as in an air atomizing spray nozzle.

SPRAY DRY MANUAL

ATOMIZER Equipment that breaks bulk liquid into small droplets, forming a spray. Spray nozzles and rotary atomizers.

ASEPTIC SPRAY DRYING A spray drying system designed and maintained to provide sterile conditions for production of powders free from disease-producing and putrefying micro-organisms.

BAG COLLECTOR A filter that separates dried powder from the exhaust drying air. (bag house)

BALL MILLING Pulverizing equipment having a rotating cylinder containing steel or iron balls.

BED DRYING Drying of particles by hot air passing through a perforated base plate, above which are the fluidized particles being dried.

BLUNGING Mixing of ceramic materials in a liquid by agitation.

BOX DRYER A rectangular, box-shaped spray dryer with nozzles spraying horizontally into the drying chamber. (horizontal dryer)

BTU (British Thermal Unit) A unit of heat energy to raise 1 lb. of water 1°F at atmospheric pressure. (1 BTU = 252 Calories)

BULK DENSITY Weight of dry powder product per unit volume.

CAKING The collection of powders in a solid dry crust, usually by continued heating of adhering wet particles.

CALCINER A furnace which produces a chemicalthermal reaction in a product, without melting the product.

CALORIES Amount of heat energy required to raise 1 gram of water 1°C at atmospheric pressure. (1 Calorie = 0.004 BTU).

CAPACITY Liquid flow rate (atomizers); Liquid evaporation rate (spray dryers); Product production rate (spray dryers).

CAVITATION Formation of gas or vapor filled cavities within liquids by mechanical force.

CENTIPOISES A unit of viscosity equal to 0.01 poise.

CENTRIFUGAL ATOMIZATION Breaking up of a liquid into droplets by rotary atomizer.

CIP CLEAN-IN-PLACE. Nozzles or manifold systems installed in processing equipment and used for cleaning.

CLOSED SYSTEM A spray drying system that recycles the hot, inert gas, such as nitrogen as well as the liquid in the feedstock. A closed system has no exhaust into the atmosphere. (Closed Loop)

COLLECTORS Equipment to separate powder from exhaust drying air by filters, cycles, or precipitators.

CO-CURRENT FLOW The flow of hot drying air/gas in the same direction as the atomized feed.

CONCENTRATOR Equipment that concentrates liquids by evaporating some of the water or solvent. This process increases the percentage of solids content in the food.

CONGEALING The process of solidifying spherical droplets of low melting point materials by contacting them with cooling air/gases. Examples of congealed materials: waxes, caustic soda and sulfur.

COUNTER-CURRENT FLOW The flow of the hot drying air/gas in the opposite direction to the atomized feed. Spray nozzles are mounted at top of vertical dryer and the hot air enters dryer from the bottom.

CRITICAL MOISTURE The moisture content of a droplet at the point where the drying rate drops sharply, but continues to dry slowly.

CRYSTALLIZATION Formation of crystalline substances from solutions.

CYCLONES (WET OR DRY) Conical chambers where solid particles are removed by centrifugal action. Wet cyclones use spray nozzles to wet particles for easier recovery.

DEGRADATION Deterioration or destruction of desirable powder qualities, as by overheating.

DIRECT HEATING System providing direct contact between spray dried materials and the gaseous products of combustion. Highly efficient.

DISPERSABILITY The property of dried powders which allows them to scatter freely in all directions when put into water.

DROPLET DIAMETER Diameter of atomized feedstock droplet, usually measured in microns (micrometers). Since spray nozzles provide a distribution of droplet sizes rather than the same size diameter, droplet size references are usually made in terms of Volume Median Diameter (DV0.5) or Sauter Mean Diameter (D32).

DROPLET SIZE DISTRIBUTION Describes the range of spray droplet diameter sizes in relation to the complete spray.

DROPLET SIZE RANGE The sizes of the largest and smallest droplets in a spray.

DRY SCRUBBING The process used in the control of toxic and obnoxious gases. Sprayed feeds react chemically with the gases, forming harmless nontoxic compounds, which are collected as a powder.

DUST Very fine powder particles capable of temporary gas/air suspension.

DWELL TIME The amount of time that a spray droplet spends traveling through a drying chamber before it is deposited as a dried powder. (retention time, residence time)

EMULSION A stable dispersion of one liquid in a second immiscible (non-mixing) liquid, such as milk.

ENCAPSULATING The encasing of particles in a protective carrier to help preserve the physical and chemical properties of the particle.

EVAPORATOR Equipment to concentrate or increase the solids content of feedstock prior to spray drying operations.

EXTRACTOR Equipment used in instant coffee and tea production to concentrate feedstock prior to spray drying operations.

EXTERNAL MIX NOZZLE Air-atomizing nozzle which provides the air-liquid contact outside of the nozzle.

FALLING FILM EVAPORATOR Equipment used to increase solids concentration of feedstock. The liquid flows downward through metal tubes, forming a thin film on the inside surface. The outside surface of the tubes are is heated by steam.

FEED Liquid solutions, slurries, suspensions, melts, sludges or pastes which are atomized in a spray dryer. (Feedstock)

FGD FLUE GAS DESULPHURIZATION. Removal of toxic or obnoxious gases, such as SO2, HCL from flue gases.

FINES Extremely small liquid droplets or solid particles

FLASH Rapid evaporation of moisture from particles by sudden reduction in pressure, or by placing them in updraft of hot air/gas. This process is usually used with temperature sensitive materials to prevent product degradation. (Flash Drying)

FLOWABILITY Ability of solid particles to move by flowing. Depends on particle size distribution.

FOAM SPRAY DRYING Producing puffed powders by spraying a liquid concentrate into which a liquefied gas has been injected in the high pressure line between the pump and the atomizer.

FLUID BED AGGLOMERATORS Fluidized beds used after the first spray drying stage, where additional feed is sprayed on the particles to increase their size or to add other ingredients. Occasionally additional feed is not required, but only warm moist air is used to cause the wet particles to join together, forming larger particles as they dry.

FLUID BED Perforated bed through which drying or cooling air passes and suspends particles over the bed.

FLUID BED DRYER Fluidized bed using hot air or gas to complete the drying process.

FLUID BED COOLER Fluidized bed using cold air or gas to cool particles.

FRIABLE Powders capable of being easily crumbled or pulverized.

GRANULATION The process of reducing solid materials to smaller particles by mechanical action.

HEAT DEGRADATION Deterioration of the quality of heat sensitive products exposed to high temperatures.

HEAT SENSITIVE MATERIAL Product whose desirable properties are damaged or destroyed by heat.

HOMOGENIZER Equipment that blends or emulsifies a substance by forcing it through fine passages.

HORIZONTAL DRYER Spray dryer with a rectangular drying chamber with nozzles usually spraying horizontally. (box dryer)

HYDRATION Combining with water.

HYGROSCOPIC Readily absorbing moisture, such as from air.

INDIRECT HEATING The process in which the drying air or gas is heated using a heat exchanger.

INSTANT PROPERTIES The properties of powders that allow them to be wetted very quickly, sink into the water, disperse, and quickly dissolve.

INSTANTIZER Equipment that produces instant products.

INSTANTIZING Process of transforming spray dried powder particles into porous agglomerates through the use of a 2-stage spray drying process. The “instantizing” quality of spray dried products describes the rapidity with which they dissolve in water, and is the result of the combined wetability, sinkability, dispersability, and solubility properties of the dried powders.

INTEGRATED FLUID BED SPRAY DRYER A spray dryer with a fluidized bed section.

INTERNAL MIX NOZZLE Air atomizing nozzle that provides the liquid/atomizing air contact inside the nozzles.

SPRAY DRY MANUAL

INTERSTITIAL AIR Air space between dried powder particles. Affects the bulk density.

ISOSTATIC A dry pressing process in which spray dried free-flowing ceramic agglomerates are compacted by applying simultaneous direction hydraulic pressure to the powder. This newly formed “green” compact is then used for further shape forming operations, such as turning , drilling and grinding.

KINETIC ENERGY Energy possessed by a mass in motion, such as liquid flowing under pressure.

LATENT HEAT The amount of heat needed to change the state of a material from solid to liquid or liquid to gas. In order to change water from a liquid to a gas, the latent heat of vaporization must be added.

LECITHIN A group of phosphatized products made commercially from egg yolk and used in processing foods.

LOW TEMPERATURE Spray drying process that uses dehumidified air, warmed slightly, to dry products that are extremely heat sensitive.

MECHANICAL SWEEP A mechanical arm that moves the spray dried powder from the drying chamber floor to a conveyor, primarily in a horizontal (box) dryer.

MICRON Unit of linear measure. One micron = 0.001mm = 1/25,4000 of an inch. Symbol is µ or µm. (Micrometer)

MIXED FLOW DRYER A dryer in which the drying air/gas enters counter-currently to the spray direction, but leaves the dryer in the same direction as the dried powder.

MOTHER LIQUOR Liquid that remains after a processing operation. Can be the effluent or product. (Discharged Liquor)

MULTI-STAGE DRYER A dryer in which the sprayed, wet powder falls onto an integrated, stationary fluid bed for preliminary drying, after which it goes to a vibrating bed or fluid bed for agglomeration, cooling, or further drying.

NEWTONIAN FLUID Fluid that has flow characteristics of water, except as affected by viscosity. The liquid shear is proportional to the stress.

NON-AQUEOUS SOLVENTS Solvents not containing water.

NON-NEWTONIAN FLUID Fluid that does not flow as water. The liquid shear is not proportional to the stress.

OCCLUDED AIR Air trapped inside particles.

ONE STAGE DRYING A drying process that produces a finished dried powder in a single operation.

OPEN SYSTEM A spray drying system that uses hot air with combustion gases as the drying medium, which is later exhausted into the atmosphere.

OVER DRYING The problem in which dried powder has less moisture content than required, and its desirable properties may be degraded or destroyed.

OXIDATION A chemical reaction of the sprayed product often caused by the presence of oxygen.

PARTICLE DENSITY Density of individual particles; as distinguished from bulk density.

PARTICLE SIZE For spherical dry particles it is the diameter of the particle. For non-spherical particles it is the mean distance between the long and short sides of the particle as measured through its center of gravity.

PASTE A soft, smooth, very viscous, moist substance.

PASTE NOZZLE An air atomizing type nozzle used for spray drying pastes.

PENETRABILITY Ability of a powder to sink into water after being wetted.

PERCENT SOLIDS Percentage of solids by weight in feedstock.

PITOT TUBE Instrument for measuring air velocities in ducts.

PNEUMATIC ATOMIZATION Feed atomization by 2- fluid or 3-fluid spray nozzles using compressed air energy to break up the feed into fine spray droplets. (Air Atomization)

PNEUMATIC CUP In rotary atomizers, the combination of a rotating cup with an air flow directed at the cup rim.

POISE Unit of liquid viscosity. Equals 100 centipoise.

POROSITY Property of solid particles proportional to the amount of open space within the particle.

PRESS CAKE Non-flowing, uniformly dispersed mixture of water and solids.

PRESSURE SPRAY NOZZLE Spray nozzle that uses the energy of liquid under pressure to atomize feedstock.

PRILLING The formation of pellets or crystals by the cooling action of upward flowing cooling air in towers, through which spray droplets are falling. The melting temperatures of the feeds are above the temperature of the cooling air, and usually above the temperature of the ambient air. (spray cooling)

PUFFING The enlargement of a particle caused by a vapor that is formed within the droplet and expands as the droplet temperature increases.

PSEUDO PLASTIC A fluid whose apparent viscosity decreases with an increase in shear rate.

REACTOR Process vessel in which chemical reactions take place during a chemical conversion process. E.G.: FGD spray dry systems, in which the sprayed feedstock combines chemically with toxic components of a flue gas to form new compound powders which are non-toxic and disposable. (Reactor Tower)

RECONSTITUTION The process of wetting powders to return them to their original fluid-solid suspension state

RESIDENCE TIME The amount of time that a spray droplet spends traveling through a drying chamber before it is deposited as a dried powder. (dwell time, retention time)

RE-WET AGGLOMERATION An agglomeration process in which moist spray dried powders are sprayed with water or feedstock while over a fluidized bed, causing wet particles to join together before the final cooling and drying over a fluidized bed. This process makes dustless granules. (spray fluidizer)

REWET INSTANTIZER Equipment for the re-wet agglomeration process.

ROTARY DRYER Rotating drum dryer through which hot air passes to dry the product tumbling or cascading in the dryer.

ROTARY VALVE Equipment that provides a controlled discharge of a powder from a hopper, while maintaining either a positive pressure or vacuum inside the container. (rotary air lock)

SAUTER MEAN DIAMETER (D32) The diameter of the particle whose ratio of volume to surface area is equal to that of the entire sample.

SCRUBBER Equipment for removing solid particles, or toxic or obnoxious gases or fumes from gas streams; usually flue gases.

SEALED CLOSED-CYCLE SYSTEMS A spray drying system in which the hot, inert drying gas and the liquid in the feed are recycled, and not released into the atmosphere.

SELF-INERTIZING SYSTEM A spray drying system in which the dried product must not contact large amounts of oxygen due to the risk of a powder explosion or product degradation by oxidation. Also used to limit atmospheric emissions, because the amount of air bled from the system is closely controlled and is very small in relation to the total gas flow required for the drying operation. Usually used with gas-fired heaters in which the combustion air used by the burner is precisely controlled, resulting in a drying gas flow with a very low oxygen content. This is a form of semi-closed cycle system.

SEMI-CLOSED CYCLE Compromise between opencycle and closed cycle plants in which the dryer is not gas tight. The purpose of this layout is to limit the amount of gases sent into the atmosphere. See self inertizing system.

SENSIBLE HEAT The total heat content of a substance.

SEPARATION The process of removing dried particles from the drying air/gas exhaust. single-fluid nozzle Spray nozzle that uses the energy of liquid under pressure to atomize feedstock. (pressure nozzle)

SINKABILITY Same as penetrability.

SLUDGE Semi-solid mass.

SLURRY Suspension of solid particles in a liquid.

SOLUBILITY The rate of at which a powder dissolves in a liquid.

SOLUTION A single homogeneous liquid mixture in which the components are uniformly distributed.

SPECIFIC GRAVITY (SG) Ratio of density of a material relative to the density of water, which weighs 8.34 lbs. per gallon and 62.4 lbs. per cubic foot (1 kg per liter).

SPIN FLASH DRYER Equipment for converting wet granules, paste or filter cake into powder by dispersing the feed into drying chamber with a rotating agitator into a stream of hot drying air.

SPINNING DISC Rotating wheel of a rotary atomizer.

SPRAY ABSORPTION Absorption of gases by sprayed droplets. See Absorber.

SPRAY CONCENTRATION Evaporation of a small amount of the liquid in feedstock by spraying into a hot air/gas stream. The product remains as a liquid, with a higher solids concentration.

SPRAY COOLING The formation of pellets or crystals by the cooling action of upward flowing cooling air in towers, through which spray droplets are falling. The melting temperatures of the feeds are above the temperature of the cooling air, and usually above the temperature of the ambient air. (prilling)

SPRAY FLUIDIZER See Re-wet Agglomeration

SPRAY DRYER Equipment in which an atomized feedstock is dried into a powder by direct contact with a flow of hot air/gas.

SPRAY FREEZE DRYING Process of spraying product into freezing air, following which the frozen particles are subjected to a vacuum, thereby sublimating/evaporating the moisture from the particles. Sometimes the particles are also heated to remove the trapped vapors.

SPRAY REACTION Process of spraying liquids into hot gases for the purpose of achieving a chemical reaction between the gas and liquid. See Absorbers.

STATIONARY FLUID BED A non-vibrating fluid bed that can be an integral part of the spray drying chamber.

STRAIGHT-THROUGH DRYER A spray dryer in which fines are returned to the atomization zone in the drying chamber for initial agglomeration.

SURFACE TENSION The force acting on the surface of a liquid to minimize it's surface area. Liquids with high surface tension are difficult to atomize.

SUSPENSION Liquid containing solid particles.

THERMOPLASTIC Material that would melt or become sticky at spray drying temperatures.

THIXOTROPIC Property of certain gels that liquefy when subjected to shaking or vibration and then solidify when left standing. The viscosity decreases as the shear force increases.

THREE-FLUID NOZZLE A nozzle that uses the energy provided by two separate streams of compressed gas (usually air or steam) to atomize a liquid.

TOWER DRYER A spray dryer whose drying chamber is in the form of a vertical cylinder with a conical bottom. (tall-form dryer)

TWO-FLUID NOZZLE A nozzle that uses the energy of compressed gas (usually air or steam) to atomize a liquid.

TRAY DRYER Vertical process tower filled with a series of trays designed to cause intimate contact between the falling liquid droplets and a rising current of hot drying air/gas.

TURNDOWN RATIO Ratio of the maximum capacity to the minimum capacity of a nozzle within an acceptable spray performance range.

TWO-STAGE DRYER A spray dryer in which the first drying stage is combined with a fluidized bed acting as an after-dryer, cooler, or agglomerator.

VIBRATING FLUID BED A fluid bed with a vibrating perforated plate above which spray dried particles are fluidized by a flow of hot air through the perforated plate. (vibro fluidizer)

VISCOSITY The flow resistance of liquids, usually stated in poise, centipoise, or Saybolt Seconds Universal (SSU) units.

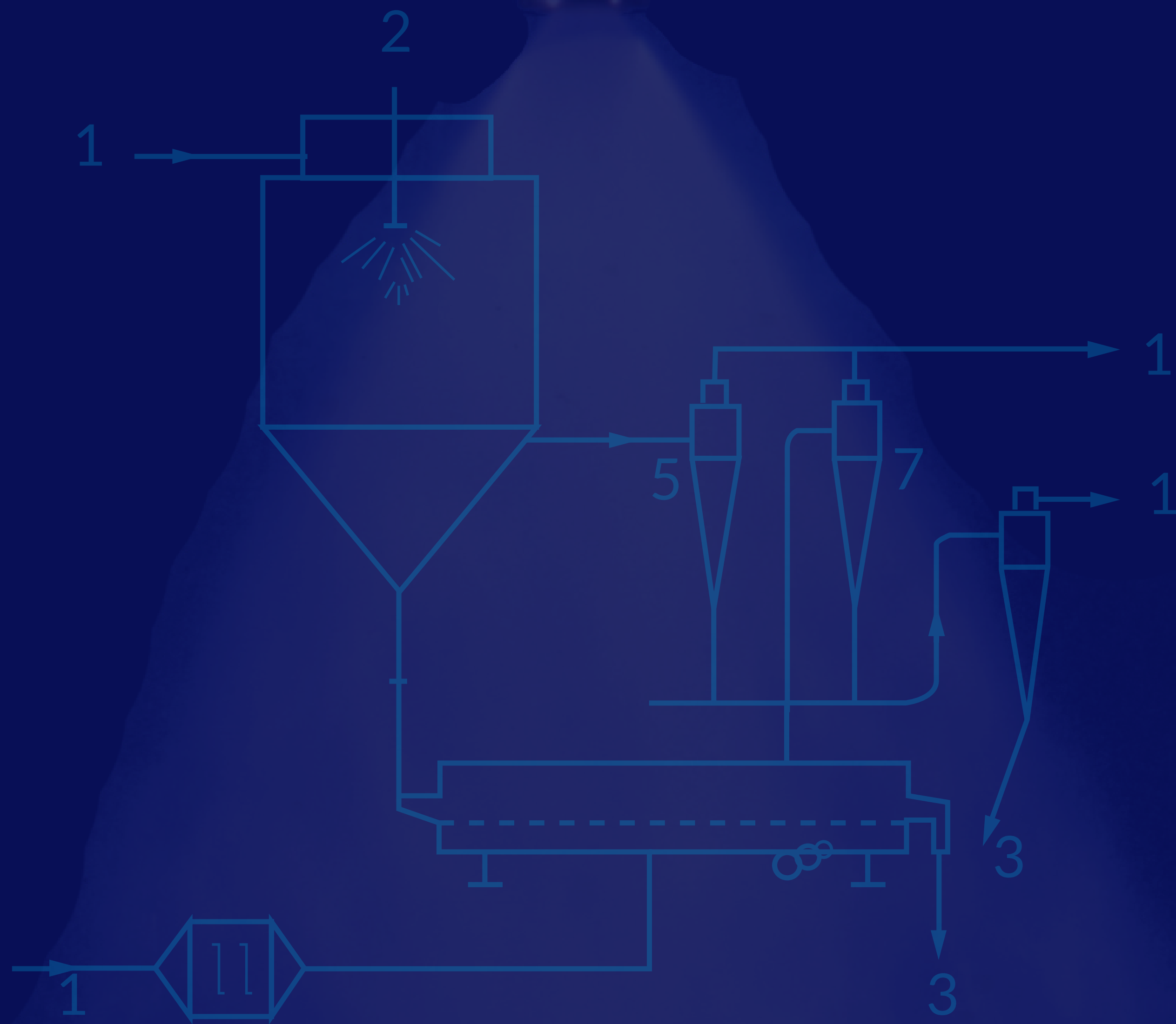
VOLUME (MASS) MEDIAN DIAMETER (DV0.5) The diameter of the particle that divides the volume or mass of the sample into two equal halves. One half of the sample will be composed of droplets or particles with diameters less than the DV05, and the other half of the sample will be composed of particles with diameters greater than the DV05.

WALL SWEEP An air flow from perforated sheets or straightening vanes in a spray dryer for the purpose of keeping the drying particles from settling on the dryer walls.

WETABILITY Ability of the particle to absorb water on its surface..

WET SCRUBBER Equipment for removing solid particles or gases from an air/gas stream by using liquid sprays.

WHEY The watery part of milk separated from the curd in the cheese making process.



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