SPRAY DRIER:

Spray drying is the transformation of feed from a fluid state into a dried form by spraying the feed into a hot drying medium. The process is a one step continuous operation. The feed can be either a solution, suspension or a paste. The spray dried product conforms to powder consisting of single particles or agglomerates, depending upon the physical and chemical properties of the feed and the dryer design and operation.

A spray dryer is a co-current/counter current flow spray device for drying, it mixes a heated gas with an atomized (sprayed) liquid stream within a vessel (drying chamber) to accomplish evaporation and produce a free flowing dry powder with a controlled average particle. The dried particles are continuously discharged from the drying chamber and recovered from the drying media using a cyclone or a bag filter. The spent drying media is often treated in a scrubber to meet the environmental requirements before being exhausted to the atmosphere. It can also be re-circulated.

OPERATION OF A CONVENTIONAL SPRAY DRYER

The feed is pumped from the product feed tank to the atomizing device, located in the air disperser at the top of the drying chamber. The drying air is drawn from the atmosphere via a filter by a supply fan and is passed through the air heater to the air disperser. The atomized droplets meet the hot air and the evaporation takes place, while cooling of the air happen simultaneously. After the spray is dried in the drying chamber, the majority of the dried product falls to the bottom of the chamber and enters a pneumatic conveying and cooling system.

The fines, which are the particles with a small diameter, will remain in the air, and it is therefore necessary to pass the air through cyclones to separate the fines. The fines leave the cyclone at the bottom via a locking device and enter the pneumatic system, too. The air passes from the cyclone to the atmosphere via the exhaust fan. The two fractions of powder are collected in the pneumatic system for conveying and cooling and are passed through a cyclone for separation, after which they are bagged off. The instrumentation comprises indication of the temperature of the inlet and outlet air, as well as automatic control of the inlet temperature by altering the steam pressure, amount of oil or gas to the air heater, and automatic control of the outlet temperature by altering the amount of feed pumped to the atomizing device.

A conventional spray dryer consists of the following main components:

- Drying chamber
- Hot air system and air distribution
- Feed system
- Atomizing device
- Powder separation system
- Pneumatic conveying & cooling system
- Instrumentation and automation

The unit operation of spray drying includes the following key components:

1. **Air Filter**– Air is drawn in to the system through a filter. The efficiency of the filter depend on product being dried. Food stuffs and pharmaceuticals require high efficiency filters.

2. **Inlet Fan**– The air is drawn in to the system by an inlet fan. Spray drying requires large volume of air with enough pressure to overcome all resistance in the system.

3. **Air Heater**– An effective gas/air heater either direct or indirect, suitable for the product being dried.

4. **Feed Source**– Feed is introduced to the spray drying system through a balance tank. The type of tank used for the application depends upon on product to be dried. Food and pharmaceuticals feed stock held in an enclosed tank to reduce contamination. Some applications the tank is jacketed to maintain heat to lower the product viscosity.

5. **Feed pump**– Feed pump is critical for the process and must be robust in construction and proper selection is
required to handle viscose and corrosive nature products, temperature, pressure required and amounts to be pumped.

6. **Atomizer**— Feed solution is fed into the spray drier through an atomizing device that breaks down the feed solution into individual droplets. Droplets give maximum exposure to heat in the process of evaporation. Atomization of the feed into droplets can be induced either by a spinning disc or by a pressurized nozzle or by a nozzle using compressed air.

7. **Drying Chamber**— Drying chambers are large open vessels, similar construction to storage silos. The chamber volume is determined by the heat exposure time for the feed material being dried. The air forced through the chamber is heated either direct or indirect heating and pushed by the fan. Feed solution is atomized into the chamber to form droplets on contact with the hot air, liquid evaporate leaving the powder. The amount of time it takes for the particle to fall the length of the chamber is called the residence time.

8. **Air Removal**— Air is removed from the chamber from various ducting arrangements depending upon the chamber design. Simple design remove both air and entrained powder from the base of the chamber and conveyed to a powder/air separator.

9. **Cyclone**— High efficiency cyclone is commonly used for separating dried powder from the exhaust air. Powders enter the cyclone tangentially, air and entrained powder spin down the length of the cyclone wall, while the air is pulled tangentially in the opposite direction creating an inner vortex. Where the two vortex meet at the bottom of the cyclone a dead zone is created, when entrained powder hits the dead zone it is spun out free of vortex while the air pulled from the system. Although over 99% collection efficiency is possible back-up after the cyclone is necessary to meet the emission regulations. Back-up air cleaning is usually provided by a wet scrubber or a bag filter.

10. **Bag Filter**— Air is pulled through the filter drawn by the exhaust fan powder collects on the bags while air is allowed to pass through the filter medium. A compressed air jet dislodges the powder from the bag and drops in to a hopper and out of the system.
**Atomization**— Several types of atomization can be employed in a spray drying system including centrifugal, nozzle, pneumatic and sonic atomization. Mostly used are centrifugal and nozzle type atomizers.

There are two basic types of atomisation:

1. **Nozzle atomiser**
2. **Disc atomiser**

**NOZZLE ATOMIZER:**
Pressure nozzle uses pump pressure to force the liquid through special inserts in the nozzle body to produce the desired pattern and droplet size of spray. Nozzles spraying require a smaller diameter and a longer length of chamber.

- A spray is created by forcing the fluid through an orifice. The energy required to overcome the pressure drop is supplied by the spray dryer feed pump.
- The narrowest particle size distribution used when minimization of “fines” is important to the product.

- The average particle size produced, for a given feed, is a function of the flow per nozzle and the spraying pressure.
- Spraying pressure depends on feed characteristics and desired particle size, and can range from 300 to 3,000 psig.
- The most energy efficient of the atomization techniques.
- Requires a positive displacement, high pressure feed pump, such as a plunger pump or a piston/diaphragm pump.
- Requires routine changing of the nozzle internal pieces, usually made of tungsten carbide. Changing schedule depends upon the application.
- Requires a minimum of approximately 0.10 GPM feed rate, depending upon the size of un-dissolved particles in the dryer feed, due to potential plugging with the small orifice required.
- With multiple nozzle spray dryers, a problem with one nozzle does not shut operations down.
- Control of spray dryer wall build-up can be achieved through variations of the spray angle.

**TWO-FLUID NOZZLE ATOMIZATION**

A spray is created by contacting two fluids, the feed and a compressed gas. The atomization energy is provided by the compressed gas, usually air. The contact can be internal or external to the nozzle.

- A broader particle size distribution is generated.
SPRAY DRIER

- The average particle size produced for a given spray dryer feed is primarily a function of the feed flow per nozzle, and the compressed gas rate and pressure.
- The least energy efficient of the atomization techniques.
- Useful for making extremely fine particles (10-30 micron) because of relatively high wear resistance. Also for the small flow rates typically found in pilot scale dryers.
- Requires periodic changing of the air and liquid caps.
- Can typically use any type of spray dryer feed pump.
- Control of the spray angle is limited.

CENTRIFUGAL ATOMIZATION

- These rotary atomizers are enabled with atomizer wheel that rotates at a high speed and ensure disintegration of the material into fine droplets. These are used to handle wide range of products including slurries with high viscosity.
- A spray is created by passing the fluid across or through a rotating wheel or disk. The energy required for atomization is supplied by the atomizer motor.
- A broader particle size distribution is typically

- The average particle size for most products is limited to under 100 micron due to wall build up issues.
- The average particle size produced for a given feed is primarily a function of the diameter and RPM of the wheel.
- Requires relatively high gas inlet velocity to control wall build-up, which can increase the amount of fines produced.
- Can generally be run for longer periods of time without routine maintenance.
- Usually the most resistant to wear. Requires periodic changing of wheel inserts, usually made of tungsten carbide.
- Control of wall build-up is minimal, due to direction of spray (horizontal) and broad particle size distribution, forcing the dryer to be relatively large in diameter.
- Capital cost of the atomizer is typically high. Comparatively larger diameter spray dryer can increase capital cost. As with any high speed rotating machine, maintenance costs are high.
- A problem with the atomizer will shut down the spray drying operations.

GAS/Spray MIXING

The technique used in spray dryer is to mix the hot gas with the atomized spray is critical to the success of the spray drying process, not only for evaporation, but for particle size control, product density, and heat degradation. The variables that affect how the spray is mixed with the hot gas depends upon the spray dryer configuration and the orientation and velocity of the inlet entry point.

SPRAY DRYER CONFIGURATION

- A. Co-current Flow :
  - Both the spray and the gas flow downward through the dryer
  - The feed is sprayed into the hottest gas, increasing the instantaneous rate of drying.
  - Can be used with all atomization techniques.
  - Can be configured for the most turbulent gas/spray mixing, increasing the instantaneous rate of drying.
  - Can be configured for the slowest mixing, which can provide the narrowest of particle size distributions.
SPRAY DRIER

- Performance generally not affected by production rate or product changes, as airflows can be changed with little effect on particle trajectory time.

- Suitable for the heat sensitive products because the driest particles are exposed to the lowest temperatures.

B. Counter-current Flow

- The feed sprays down and the gas flows up through the spray dryer.

- Sometimes used for the production of large particle sizes because the up-flow of air slows the particle "fall time", allowing for extra drying time.

- The feed is sprayed into the coolest gas, decreasing the instantaneous rate of drying and directionally producing a higher density product.

- Can be used only with pressure nozzle or two-fluid nozzle atomization techniques.

- Performance affected by production rate or product changes if temperature profile is important to product quality.

- Product degradation or burning can occur because the driest particles are exposed to the highest gas temperatures.

- Inlet or outlet gas blast increases fabrication costs.

C. Mixed Flow (Fountain Flow)

- The gas flows down and the feed sprays up, then comes down with the gas.

- Sometimes used for the production of large particle sizes because the particle trajectory is increased, allowing for extra drying time, and decreasing the overall spray dryer height required.

- The feed is sprayed into the coolest gas, decreasing the instantaneous rate of drying and directionally producing a higher density product.

- Can be used only with pressure nozzle or two-fluid nozzle atomization techniques.

- Performance generally not affected by production rate or product changes, as airflows can be changed with little effect on particle trajectory time.

- Product degradation or burning can occur because the driest particles are exposed to the highest gas temperatures.

PRODUCT RECOVERY AND EMISSION CONTROL

A successful spray drying operation depends upon the techniques used for product recovery and emission control.

Chamber Separation

- A portion of the product is collected from the spray dryer lower cone.

- Used to prevent particle degradation when product is friable.

- Used when isolation of the larger particle size cut is desired.

- Adds another collection point, which increases capital and operating costs.

- Separation efficiency largely dependent upon product density and particle size distribution.

Cyclone Collection
**SPRAY DRIER**

- A generally low cost method of collecting up to 98% of product.
- Useful when potential product contamination from multiple products exist.
- Little maintenance required.
- Relatively low fan energy consumption with pressure drop of 5-10 inches w.c.
- Requires back up with bag filter or wet scrubber for emission control.
- Can cause degradation of friable spray dried particles.

**Bag House Collection**

- Relatively low fan energy consumption with pressure drop of 3-6 inches w.c.
- Can be used for single component product collection and particulate emission control with efficiencies up to 99.99% for most products.
- Useful for friable products to prevent particle degradation.
- Used downstream of cyclone for emission control when no liquid effluent is desired.
- Moderate maintenance costs.
- Not good for "sticky" powders.

**Wet Scrubber Collection**

- Typically a venturi type is used.
- High efficiencies possible (up to 99% @ 1.5 micron).
- Requires recycle or treatment of liquid effluent.
- Relatively low maintenance.
- Relatively high fan energy consumption with pressure drop of 15-30 inches w.c.
- Higher level of instrumentation can be required for density and level control.

**Packed Columns**

- Used after particulate is removed and chemical vapors, such as HCl, need to be scrubbed.
SPRAY DRIER

- Can also be used to recover heat from dryer discharge to produce hot water for use elsewhere in the facility.
- Higher level of instrumentation usually required to control density, level, pH, and/or temperature.

ADVANTAGE OF USING A SPRAY DRYER FOR DRYING APPLICATION

1. THE PARTICLE SIZE CONTROL: The dry particle size can be easily controlled by atomization of the liquid feed and the design of the hot gas inlet. The correct spray dryer design and atomization technique can increase yields for products that require classification. Spray dryers can typically produce between 30 to 500 micron average particle size, in a bell shaped distribution.

2. THE FLOW PROPERTIES OF DRY SOLIDS: The shape of most spray dried particles is spherical, which provides for fluid-like flow properties. This makes many downstream operations, such as packaging, pressing, filtering, and handling easier and less costly.

3. THE HOMOGENEOUS SOLIDS MIXTURE PRODUCED: Spray drying produces the most homogeneous product for multi-component solutions and slurries. Each particle will be of the same chemical composition as the mixed feed.

4. THE EVAPORATIVE COOLING OF THE PRODUCT: The heat and mass transfer during drying occurs in the air and vapour films surrounding the droplet. This protective envelope of vapour keeps the particle at the saturation temperature. As long as the particle does not become "bone-dry", evaporation is still taking place and the temperature of the solids will not approach the dryer outlet temperature. This is why many heat sensitive products can be spray dried easily at relatively high inlet temperatures.

5. THE SHORT RESIDENCE TIME REQUIRED: The surface area produced by atomization of the liquid feed enables a short gas residence time, ranging from 3-40 seconds depending upon the application, which permits spray drying without thermal degradation. This allows for fast turn-around times and product changes because there is no product hold up in the spray drying equipment.

6. THE REDUCTION IN CORROSION POTENTIAL: Because a spray dryer is a gas suspended process, the dryer chamber remains dry by design. Therefore, many corrosive materials can be processed with carbon steel as the primary material of construction of the spray dryer chamber, which reduces capital costs.

APPLICATION OF SPRAY DRIER FOR FOLLOWING PRODUCTS

- CHEMICAL INDUSTRY
- CERAMIC MATERIAL:
- DETERGENTS and SURFACTANTS
- PESTICIDES
- DYE STUFFS, PIGMENTS
- FERTILIZER
- INORGANIC CHEMICALS
- ORGANIC CHEMICAL
- FOOD INDUSTRY/EGG PRODUCTS
- FOOD PRODUCTS AND PLANT EXTRACT
- FRUIT VEGETABLES
- CARBOHYDRATES AND SIMILAR PRODUCTS
- BIOCHEMICAL INDUSTRY
- YEAST PRODUCTS

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