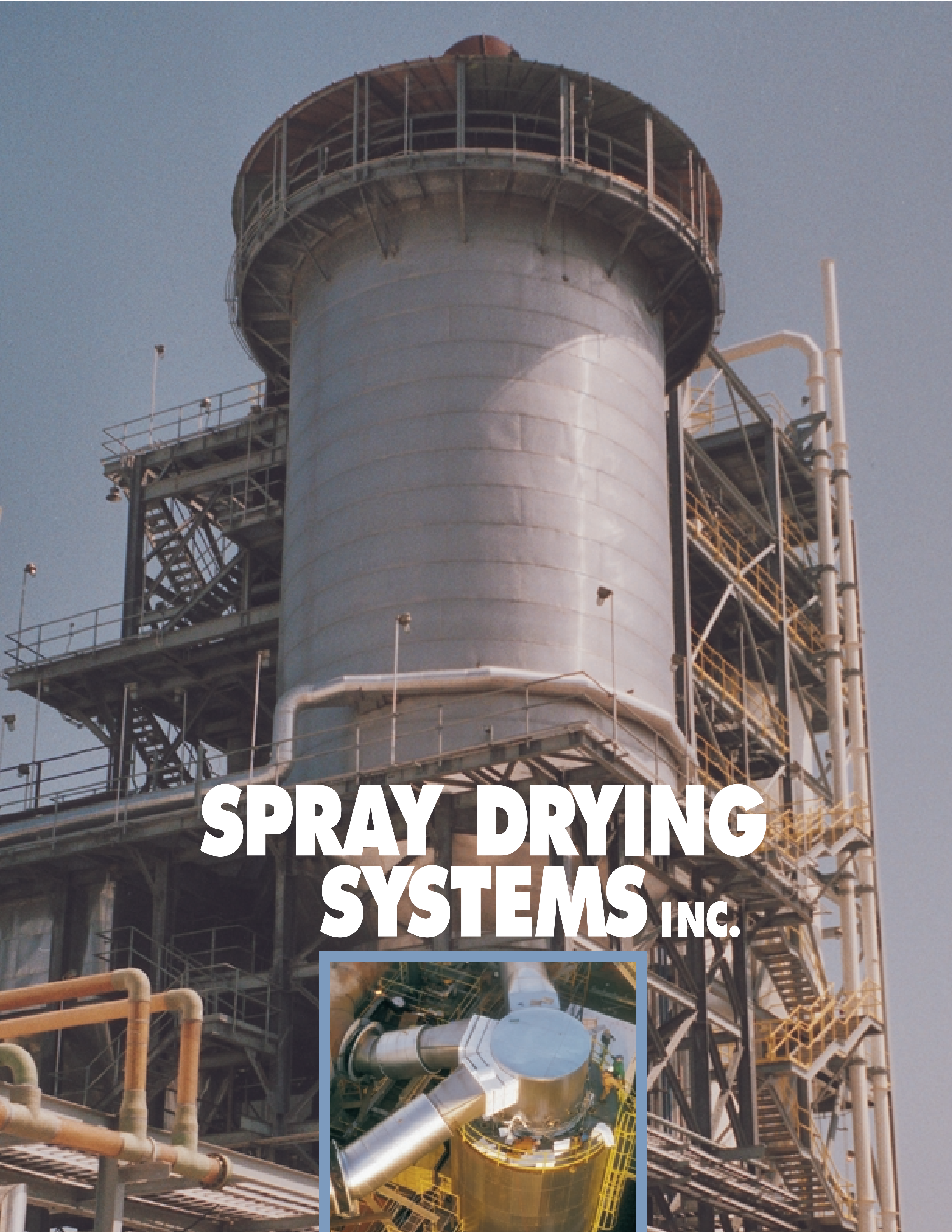
SPRAY DRYING SYSTEMS INC.



Spray Drying Systems, Inc.

WHERE YOUR INVESTMENT HAS THE HIGHEST VALUE

- Superior Technology and Service
- Competitive Pricing
- Shortest Delivery Schedules
- Full Range of Spray Dryer Applications, Sizes, and Designs

Spray Drying Systems, Inc. (SDS), provides expert technology for all ***spray drying applications.*** The process engineers at SDS have the ***experience*** it takes for the successful operation of your new spray dryer. The ***wide ranges of applications*** include industrial chemicals, flavorings, ceramics, pigments, dyestuffs, detergents, catalysts, salts, and extracts. Experienced electrical, mechanical, and civil engineers team with experienced detail designers to ensure your goals and requirements are met. SDS also has full engineering and programming capability for advanced automated controls.

Our goal is to provide the best spray drying technology for our customer's application at ***competitive pricing.***

Standard ***laboratory*** and ***pilot*** spray dryers are available, as well as custom designs for unique research applications.

SDS spray dryers can be used for ***spray cooling*** of process gasses. The gas is cooled by evaporative cooling and the dryer exhausts a dry, cooled gas that can be processed in other units, such as fabric filters. SDS spray dryers are also used in drying of ***waste streams*** to eliminate liquid effluents.

We offer ***superior technical service*** for all existing spray dryer installations for owners who desire ***improved performance*** of their system, such as increased production rates, less wall buildup, and improved quality control.

SDS also offers a ***pressure nozzle*** for use in spray dryers for those interested in lower costs.

PRODUCTS

- Spray Dryers
- Spray Coolers
- Pilot Spray Dryers
- Pressure Nozzles for Spray Dryers

SERVICES FOR EXISTING SPRAY DRYERS

- Engineering and Equipment for Modifications
- Technical Service
- Automated Control System Upgrades

Cover photos:

(large photo) This co-current, parallel flow spray dryer produces a 300 micron average particle size with no buildup. This demonstrates the superior ability of SDS.

(inset photo) A 20 foot diameter spray cooler handles 1600°F flue gases from three separate furnaces to allow fly ash recovery with a bag filter. This unit replaced a refractory lined dilution air cooling unit.

Designing dryers to fit into existing structures is a challenge that SDS engineers welcome.

This spray dryer was designed for a ceramic powder. It can be set up for co-current or mixed flow configuration.

Why Choose Spray Drying Systems, Inc.?

BECAUSE...OUR TECHNICAL COMPETENCE IS PEERLESS.

We have more than 60 years of combined process experience in the design of spray drying systems for all industries. Our strong background in fundamental chemical engineering principles is the backbone of our system designs.

BECAUSE...OUR SYSTEMS ARE OF LOWER INSTALLED COST.

Project engineering is performed by experts in the design, use, and operation of the process equipment, which equates to better mechanical design and faster installation. Our staff includes experienced engineers of all required disciplines that interact as a team to ensure costs are controlled and installation is a success.

BECAUSE...OUR UNDERSTANDING OF PARTICLE SIZE CONTROL IS THE BEST.

Our design capability for the control of particle size in nozzle or rotary type spray dryers has been demonstrated to be the best in the world. The gas inlet design will be specific to the application to insure the best particle size distribution with minimal or no wall deposits.

BECAUSE...WE OFFER SUPERIOR TECHNICAL SERVICE.

SDS process engineers are available to help you make your existing dryer system operate better. We offer the help you need when you need it.

BECAUSE...WHEN YOU HAVE QUESTIONS, WE GET YOU THE ANSWERS FAST.

Whether it is during the proposal, the contract execution, or post plant start-up, the staff at SDS is here to help.

BECAUSE...OUR CAPABILITY SPANS ALL SIZES OF SPRAY DRYERS.

Our staff has designed spray drying systems with airflows from 200 to 250,000 ACFM, feed rates from 0.4 GPH to 200 GPM, dryer diameters from 2 to 43 feet, and inlet gas temperatures from 50°F to 2400°F.

BECAUSE...WE DESIGN TO YOUR APPLICATION.

We do not sell you standard models that *may* fit your application. We design the system to your specific requirements.

BECAUSE...WE INCORPORATE ENERGY SAVINGS.

SDS has experience with partial outlet gas recycle to conserve energy and reduce the cost of environmental equipment. We have used waste heat streams to further recoup energy, and we have designed packed column hot water generators to be used on the tail end of the system to squeeze more energy savings from tight operating budgets.

BECAUSE...WE HAVE EXPERIENCE WITH ALL TYPES OF SOLVENTS.

SDS offers closed loop designs with solvent condensation to contain the solvent and control the drying atmosphere.

SDS always plans ease of installation into it's design. This adds to the overall project savings, a major consideration when selecting your spray drying system supplier.

This dryer designed dryer for centrifugal atomization awaits installation at the plant site.

BECAUSE...WE ARE EXPERT IN THE DESIGN AND APPLICATION OF FLUE GAS SPRAY COOLERS AND FLUE GAS ACID RECOVERY SYSTEMS.

Our spray cooler designs have proven to operate "dry," unlike our competition's. Our know-how of spray drying fundamentals gives us this advantage.

BECAUSE...WE OFFER EXCEPTIONAL ABILITY TO MODIFY OR RETROFIT EXISTING SYSTEMS.

We have successfully modified competitor's dryers which resulted in increased production, improved particle size control and elimination of wall buildup.

BECAUSE...WE HAVE EXPERTISE IN THE DESIGN AND APPLICATION OF POWDER COLLECTION AND EMISSION CONTROL EQUIPMENT.

Our staff has experience in the design and application of all types of emission control equipment used downstream of spray drying systems; from bag filters and cyclones to wet scrubbers and packed bed absorbers.

What is a Spray Dryer?

A **SPRAY DRYER,** as the name implies, is a device for drying, utilizing a spray. Spray drying entails intimate mixing of a heated gas with an atomized (sprayed) liquid stream within a vessel (drying chamber) to accomplish evaporation through a direct contact, adiabatic process.

The unit operation of **SPRAY DRYING** includes the following key components:

- A method for **ATOMIZING** a solution or slurry
- An air/gas **HEATER,** or a source of hot air such as a waste flue gas
- A gas/spray **MIXING CHAMBER** with adequate residence time and droplet trajectory distance for achieving the heat and mass transfer
- A means for **RECOVERING** the solids from the gas stream
- A **FAN** to induce the required air/gas flow through the system

Why Select a Spray Dryer?

BECAUSE OF...THE SURFACE AREA PRODUCED

The unique feature of a spray dryer is the surface area per unit weight generated by atomization of the liquid feed. It is this fact that enables a spray dryer to work. For example, feed atomized to 100 micron average droplet size generates approximately 15,400 ft^2/lb of surface area. The same feed atomized to an average of 20 micron generates approximately 77,021 ft^2/lb! This is like spreading one gallon of feed over 14 football fields! This generation of surface area is why the spray dryer can claim many of the following advantages.

BECAUSE OF...THE PARTICLE SIZE CONTROL

The dry particle size can be easily controlled by atomization of the liquid and the design of the hot gas inlet. The correct dryer design and atomization technique

Spray dryers complete with CIP cleaning systems and PLC control make operations more efficient and improve product consistency.

This installation removes SO_2 and HCI from a flue gas by simultaneously spray drying lime slurry and the spray dryer's wet scrubber effluent.

This spray dryer uses pressure nozzles although the slurry is very abrasive. The tight particle size distribution was required to improve quality and energy efficiency of a downstream process.

can eliminate the need for sizing/classification equipment when the product average particle size is less than 500 microns. "Non-dusting" powders can be made which is beneficial for hazardous products, animal feeds, dyes, and other products.

BECAUSE OF...THE EVAPORATIVE COOLING OF THE PRODUCT

The heat and mass transfer during drying occurs in the air and vapor films surrounding the droplet. This protective envelope of vapor 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.

BECAUSE OF...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 drying without thermal degradation. This allows for fast turn-around times and product changes because there is no product hold up in the drying equipment.

BECAUSE OF...THE REDUCTION IN CORROSION

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, which reduces capital and maintenance costs.

BECAUSE OF...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 (e.g. packaging, filtering, handling) easier and less costly.

BECAUSE OF...THE HOMOGENEOUS SOLIDS MIXTURE PRODUCED

Spray drying produces the most homogeneous product for multi-component solution/slurries. Each particle will be of the same chemical composition as the mixed feed.

BECAUSE OF...THE HIGH INLET TEMPERATURE PERMITTED

Because spray drying uses direct contact heating, materials of construction is the usual limit to inlet temperature. Exceptions are extremely heat sensitive products such as proteins, enzymes, and some highly explosive products. Higher inlet temperatures equate to better energy efficiency and smaller equipment for a given process heat load.

BECAUSE OF...THE CHEMICAL REACTION POSSIBILITIES

The inherent advantage of surface area also makes the spray drying process excellent for gas/solid reactions. For example, recovery of HC1 and SO_2 from a flue gas can be achieved by atomization of a hydrated lime slurry. The combination of absorption and drying results in a dry solid for disposal instead of a liquid effluent.

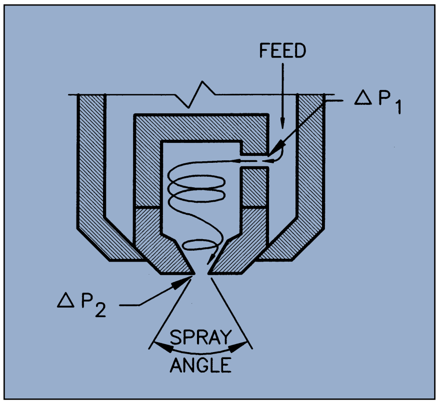


Figure 1: An example of a pressure nozzle

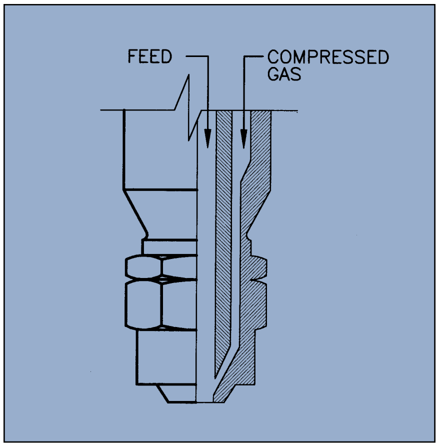


Figure 2: An example of a two-fluid nozzle

Another successful installation taking place.
SDS engineers deliver the complete engineering package.

Spray Dryer Design Considerations

The most important variables in the design of a spray dryer are the evaporation rate and the required particle size distribution of the product. The evaporation rate defines the amount of drying gas needed at a given dryer ΔT, which dictates the sizing and cost of almost all of the system components. The particle size requirement affects the choice of atomization and the size and shape of the dryer.

ATOMIZATION

Producing droplets of specific size and surface area by **ATOMIZATION** is a critical step in the spray drying process. The degree of atomization, under a set of drying conditions, controls the drying rate, and therefore the required particle residence time, and therefore the dryer size. All of the atomizing techniques can give good average particle size control, but there are major differences in the particle size distribution created. The most commonly employed atomization techniques are:

PRESSURE NOZZLE ATOMIZATION:

(See Figure 1)

- A spray is created by forcing the fluid through an orifice. The energy required to overcome the pressure drop is supplied by the feed pump.
- The narrowest particle size distribution is possible with this technique. Must be used when minimization of "fines" is important to the product.
- The average particle size produced for a given feed is primarily a function of the flow per nozzle, the nozzle orifice pressure drop (ΔP_2), and the spray angle. The spray angle is varied by ΔP_1. The higher ΔP_1, the greater the spray angle.
- The most energy efficient of the atomization techniques.
- Requires routine changing of the internal pieces, usually made of tungsten carbide. Changing schedule depends upon the application.
- Limited to approximately 0.4 GPM flow per nozzle with a slurry because of potential plugging with the small orifice required.
- With multiple nozzle dryers, a problem with one nozzle does not shut operations down.
- Typically requires a piston-type positive displacement pump.
- Control of wall buildup can be achieved through variations of the spray angle.
- Can reduce the capital cost for a dryer because of reduced diameter required.

TWO-FLUID NOZZLE ATOMIZATION:

(See Figure 2)

- 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 broad particle size distribution is generated.
- The average particle size produced for a given feed is primarily a function of the flow per nozzle, and the compressed gas rate and pressure.

This co-current, parallel flow spray dryer produces a 300 micron average particle size with no buildup. This demonstrates the superior ability of SDS.

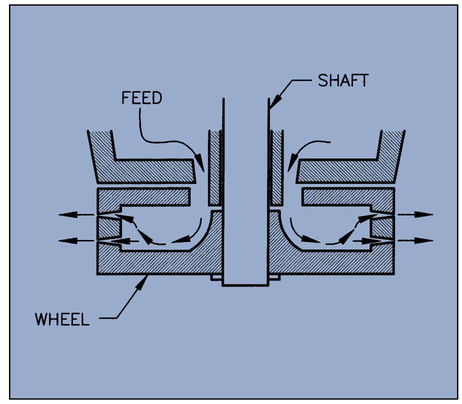


Figure 3: An example of a centrifugal atomizer

ATOMIZATION ENERGY COMPARISON

Examples based upon atomizing 10 GPM of feed to 70 micron droplets

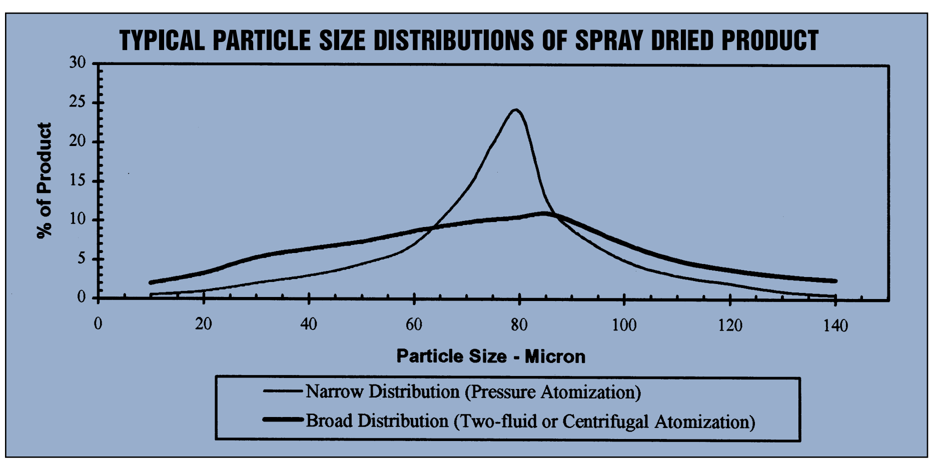
1. Pressure Nozzle	Feed Pump @ 1200 psig:	10 HP
2. Centrifugal	Rotary Drive @ 9000 RPM:	25 HP
	Feed Pump @ 30 psig:	3 HP
3. Two-fluid Nozzle	180 SCFM @ 80 psig:	30 HP
	Feed Pump @ 80 psig:	5 HP

- 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 small flow rates typically found in pilot scale dryers.
- Requires periodic changing of the air and liquid caps.
- Can typically use any type of feed pump.
- Control of the spray angle is limited.
- Capital cost can be lower due to the absence of the pressure pump and rotary atomizer.

CENTRIFUGAL ATOMIZATION:

(See Figure 3)

- 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 broad particle size distribution is generated.
- The average particle size produced for a given feed is primarily a function of the diameter of the wheel and the RPM.
- Requires relatively high gas inlet velocity to prevent wall buildup, which can increase the amount of fines produced.
- Can generally be run for longer periods of time without operator interface.
- Usually the most resistant to wear. Requires periodic changing of wheel inserts, usually made of tungsten carbide.
- Control of wall buildup 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 dryer can increase capital cost. As with any high speed rotating machine, maintenance costs are high. Design of dryer roof and atomizer support add to fabrication cost.



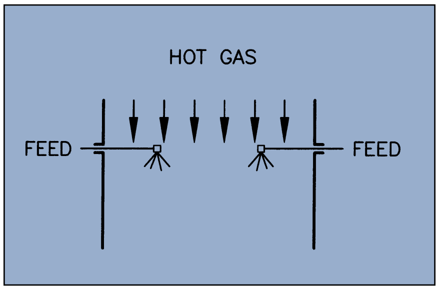


Figure 4: Co-current flow

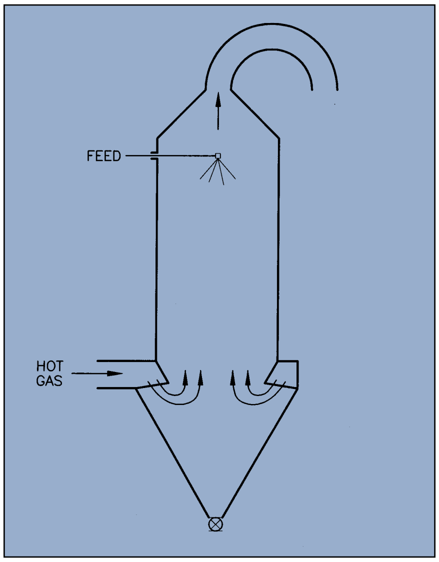


Figure 5: Counter-current flow

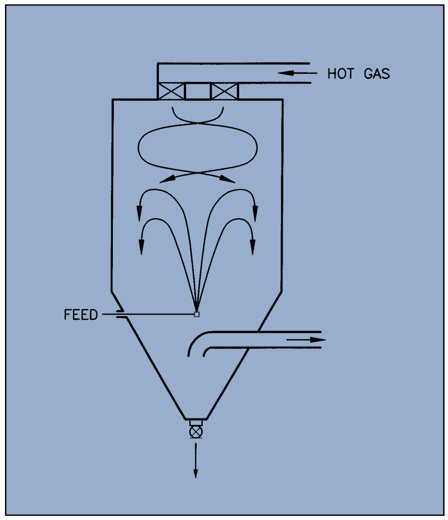


Figure 6: Mixed-flow

Every dryer is rigorously inspected by SDS staff before shipment to the site.

GAS/SPRAY MIXING

The technique used to mix the hot gas with the 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 depend upon the dryer configuration, and the orientation and velocity of the inlet entry point.

CO-CURRENT FLOW

(See Figure 4)

- The spray and gas flow in the same direction.
- 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.
- Performance generally not affected by production rate or product changes, as airflows can be changed with little effect on particle trajectory time.
- Best choice for heat sensitive products because the driest particles are exposed to the lowest temperatures.

COUNTER-CURRENT FLOW

(See Figure 5)

- The spray and gas flow in opposite directions.
- 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 bustle increases fabrication costs.

MIXED FLOW

(See Figure 6)

- The gas flows down and the spray flows up, then falls.
- Sometimes used for the production of large particle sizes because the particle trajectory is increased, allowing for extra drying time, and decreasing the overall dryer height required.

SDS designs systems to meet your needs.
This dryer is designed for use with pressure nozzles or a centrifugal atomizer.

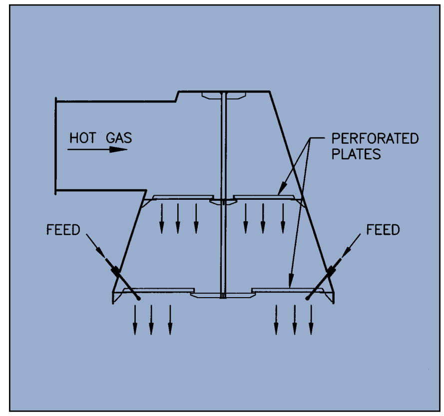


Figure 7: Parallel flow (slow mixing)

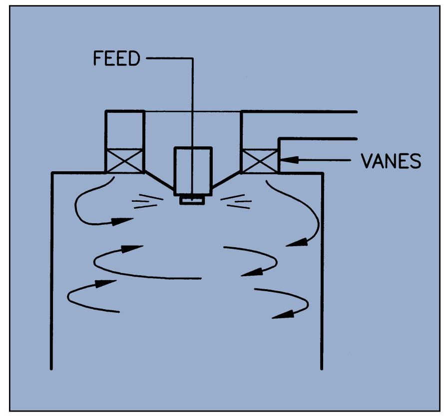


Figure 8: Cyclonic flow (fast mixing)

- 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 discoloration can occur because the driest particles are exposed to the highest gas temperatures.

MIXING TECHNIQUE

With each spray dryer configuration, the mixing technique can vary from slow, parallel flow to fast, turbulent flow. Each technique has its merits; the choice is a function of the application objectives. If evaporation (drying) is the only real objective, a fast mixing technique is used. If other objectives, such as particle size distribution, are important, a slow mixing technique should be used.

SLOW MIXING

(See Figure 7)

- Used when minimization of fines are important (narrow particle size distribution) because the velocity of gas at the point of atomization is lowest.
- Uses full diameter perforated plates for gas distribution.
- Higher product density is possible.
- Generally requires a taller dryer.
- Can be used only with pressure or two-fluid nozzle atomization.

FAST MIXING

(See Figure 8)

- Used when a fast instantaneous drying rate is more important than a narrow particle size distribution.
- Typically uses a vane ring at the gas inlet to induce a cyclonic rotation of the gas.
- Produces a broader particle size distribution, because the high turbulence further atomizes the droplets.
- Can be used with all atomization techniques (required for centrifugal atomization).

PRODUCT RECOVERY AND EMISSIONS CONTROL

A successful spray drying operation depends upon the technique(s) used for product recovery and emission control. The choices can impact the yield, classification of product, product integrity, and environmental compliance.

These quad cyclones are recovering product after chamber bottom separation. A venturi scrubber was used for emission control.

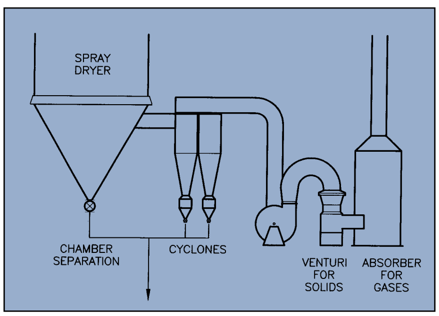


Figure 9: An example of product collection and emission control

CHAMBER SEPARATION

- A portion of the product can be 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

(See Figure 9)

- A generally low cost method of collecting up to 98% of product.
- Useful when potential contamination from multiple products exist.
- Little maintenance required.
- Relatively low fan energy consumption with pressure drops of 5-10 inches w.c.

A packed bed condenser recoups energy by cooling and condensing water evaporated in the spray dryer to heat process water needed in the facility.

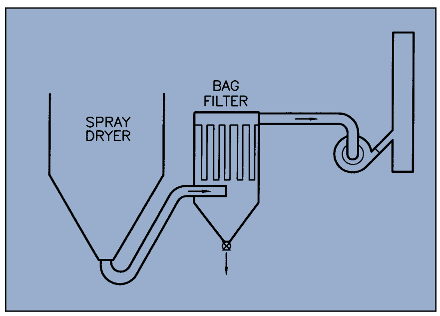


Figure 10: An example of single point bag filter collection

- Requires back up with bag filter or wet scrubber for emission control.
- Separation efficiency dependent upon pressure drop, particle size distribution, inlet velocity, and particle density.

BAG FILTER COLLECTION

(See Figure 10)

- Useful for low density products.
- Relatively high maintenance costs.
- Relatively low fan energy consumption with pressure drop of 3-6 inches w.c.
- Single component for 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.

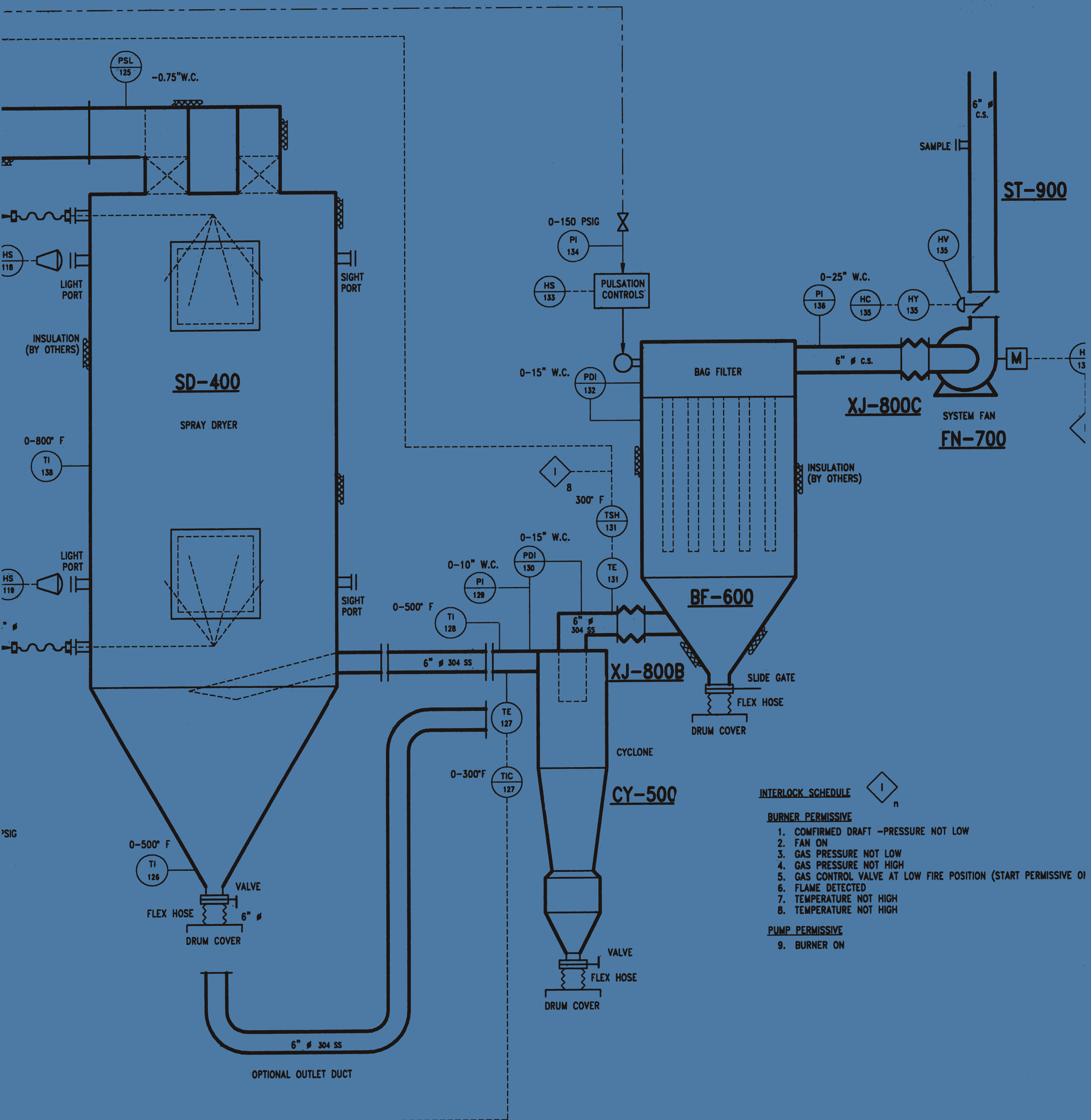
A venturi scrubber is typically used when wet scrubbing is required.

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 10-30 inches w.c.
- Higher level of instrumentation usually required for density and level control.

PACKED COLUMNS

- Used after particulate is removed and chemical vapors, such as HC1, need to be scrubbed.
- 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.



REVISION RECORD	BY	APP	DATE	REV

SPRAY DRYING Systems, Inc.

9635 Liberty Road, Suite
Randallstown, MD 21133
(410) 922-5900 Fax: 922

PIPING AND INSTRUMENTATION DIAGRAM

E: N/A

SPRAY DRYING
Systems, Inc.

5320 Enterprise Street, Suite J
Eldersburg, MD 21784
Phone: 410-549-8090
Fax: 410-549-8091
www.spraydrysys.com
sales@spraydrysys.com