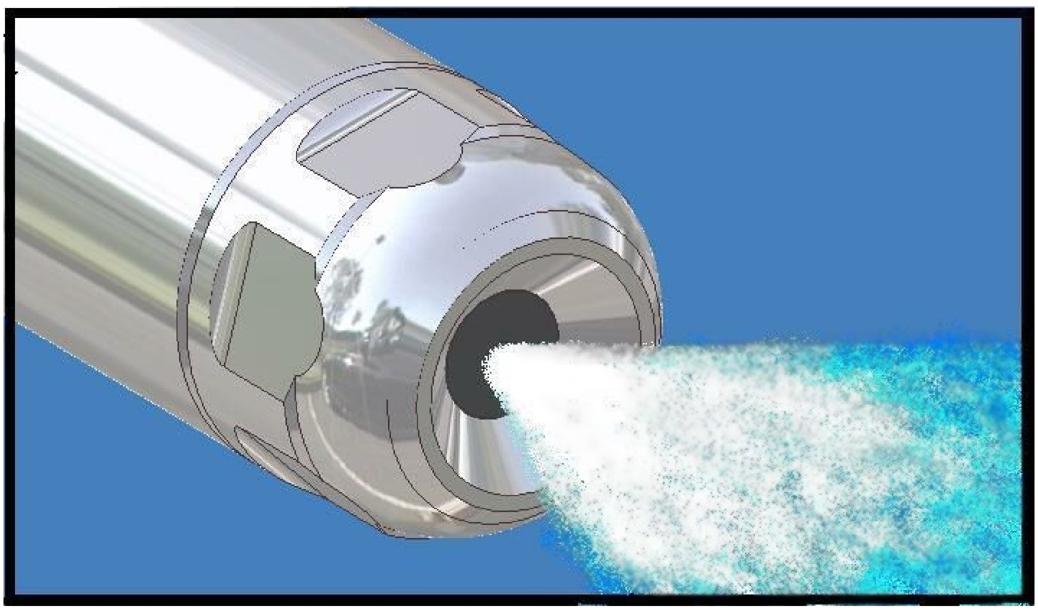
TECHNICAL MANUAL NO. 402

SPRAY DRYING

NOZZLES AND APPLICATIONS



Spraying Systems Co.®
Experts in Spray Technology

Spray Nozzles Spray Control Spray Analysis Spray Fabrication

Spray Drying Nozzles and Applications Manual

…including information on spray drying nozzle selection, performance, maintenance and cleaning

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Section I - Introduction

Objective

This manual outlines the basics of spray drying with an emphasis on nozzles and atomization. Complete and detailed information on nozzles and accessories is offered in Spraying Systems Co. Bulletins 447, 504, and 527 including nozzle listings, spray performance data, part numbers, materials, and ordering information. For more comprehensive information on specific applications, refer to spray drying industry books and periodicals, as well as to equipment manufacturers' technical literature.

Spray Drying Industry Progress

Spray drying emerged more than 100 years ago, with significant applications occurring in the early 1900's in the milk and detergent industries. The most rapid industry growth took place in the early 1940's due to the heavy overseas demand for dried dairy and egg products. It was at this time that Spraying Systems Co. introduced its SprayDry® nozzles and accessories specifically designed to serve this rapidly expanding industry. Since then other nozzle types have been added to make the SprayDry® nozzle line the most complete in the industry.

As advances in spray drying technology continued, the process was used for a wider variety of food products, as well as for various chemical, ceramic, and pharmaceutical products.

In recent years variations of the spray drying technique have evolved into other applications including economic recovery of waste materials such as whey, spent liquors, fermentation residues, and sewage sludge; scrubbing flue gases to remove toxic constituents such as sulfur dioxide; spray cooling (prilling) applications involving the "solidifying" of products with melting points above ambient temperatures ...as well as spray freeze drying, wherein the actual "drying" occurs by sublimation.

Other Product Drying Methods

The spray drying industry is large and diversified, but spray dried products are only a small percentage of the total products being dried commercially. Most of the product drying continues to be done by other methods such as rotary drum dryers, rotating tray dryers, fluid bed dryers, conveyor dryers, tunnel dryers, steam tube dryers, freeze dryers, vacuum filters, and flash dryers. The choice of a drying system depends on many factors including the equipment available, the properties of the feed stocks and dried products, the capacity requirements, and the investment, operating, and maintenance costs.

Advantages of Spray Drying

Spray drying is a continuous and complete operation, automatically controlled, producing a finished and packaged powder product from the original liquid feed stock. Almost any pump able solution, slurry, suspension, gel, paste, or emulsion can be spray dried. The spray drying process is energy efficient and economical with respect to the handling, labor, operating, and maintenance costs.

Heat and oxygen sensitive materials, high purity products, flammable and explosive materials, odorous products, and toxic products can be spray dried in closed-cycle spray drying systems.

Corrosive feeds can be economically handled, since the corrosive activity of dried products is minimal.

Atomizers - The Key To Successful Spray Drying

A spray drying operation involves several very important factors including the nature of the feed stock and product, drying gas temperatures, and the type of spray dryer and atomizer used. Each spray drying application is customized to suit a specific combination of these important factors.

In each successful spray system the most essential element is proper atomization of the feed stock. Without it the application will fail. This atomization is accomplished by one of three different spray nozzle types; 1) pressure spray nozzles, small and medium capacity sizes operating at high pressures; 2) pressure spray nozzles, larger capacity sizes operating at lower to medium spraying pressures; and 3) two-fluid (or three-fluid) air atomizing spray nozzles. For information on spray nozzle atomizers see sections V and VIII.

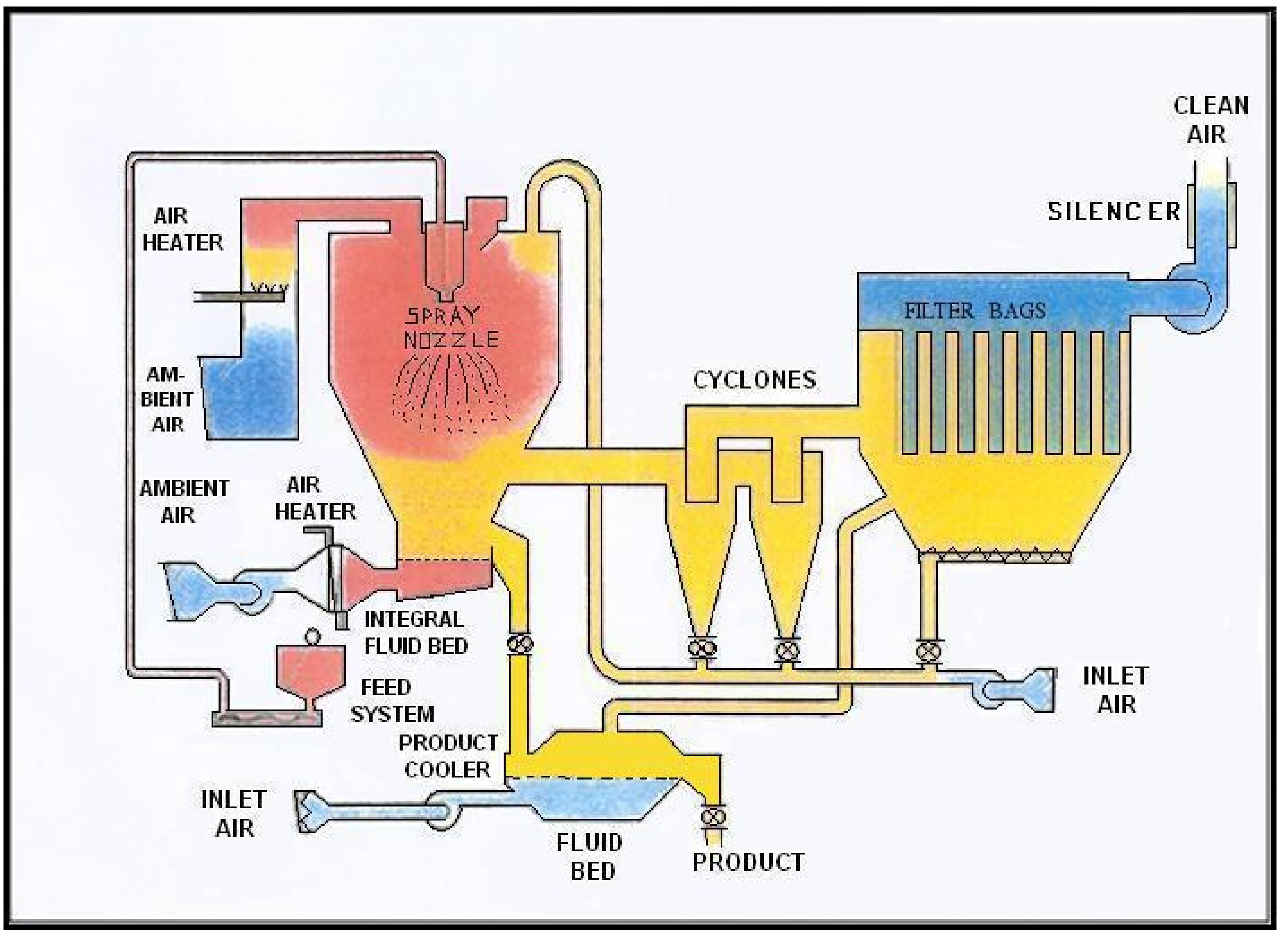
Section II - Spray Drying Systems – General Information

Process stages

Spray drying processes consist of many stages, including (A) preparation of feed stock, (B) atomization of feed stock, (C) contacting the droplets with hot air to cause evaporation of the water, (D) evaporation of water, and collecting and packaging the dried powder products. In some installations multi-stage dryers are used wherein the drying in the first stage is incomplete, and the final drying occurs later in a fluidized bed stage. Additional functions required of the system include: separating the dried powder from the exhaust gas stream; cleaning exhaust gases; controlling process stages; and possible further treatment of the drying product.

Typical Open Cycle Co-Current flow layout.

Exhaust to Atmosphere



Spray Dryers

The "heart" of the spray drying system is the spray dryer chamber. Finely atomized spray droplets are brought into contact with the hot resulting in the rapid evaporation of about 95% of the water from the droplets, usually in a matter of 15 to 40 seconds, depending on the dryer type, size, hot air temperature and volume, and flow system.

There are many varieties of spray dryers, but most are variations of either the vertical (tower) type -or -the horizontal (box) type.

Vertical (Tower) Spray Dryers

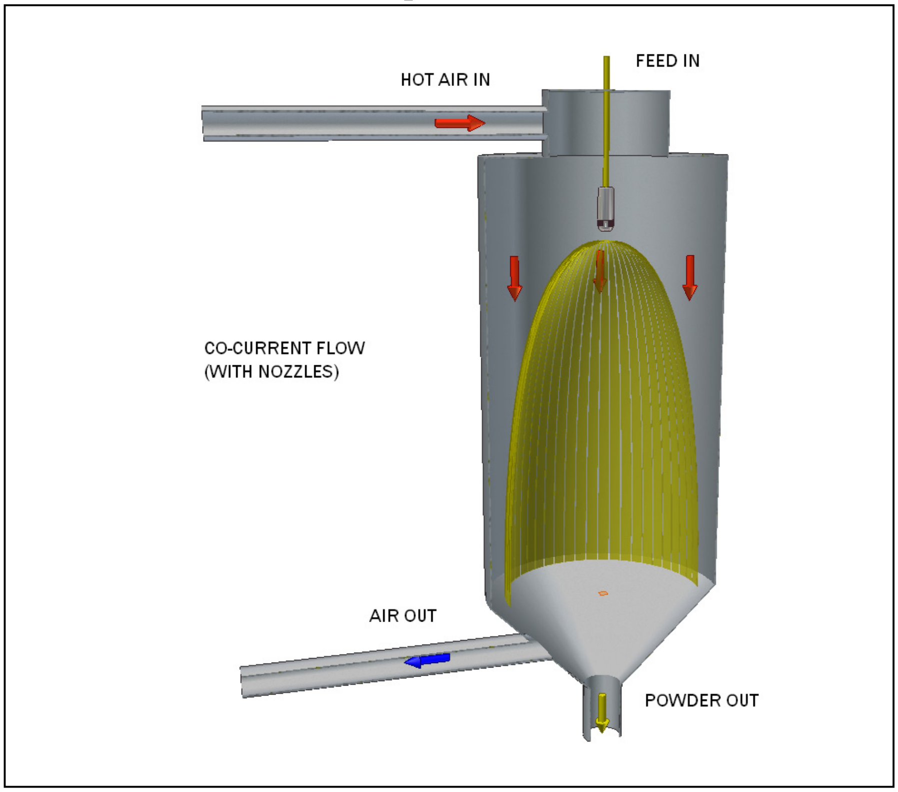
Vertical spray dryers are tall cylindrical chambers with pressure or two-fluid type spray nozzles located at the top or bottom of the chamber with rotary atomizers located at the top. The inlets for the hot air (or gas) can be at the top, bottom, or side of the chamber when using spray nozzles ...but only at the top when using rotary atomizers. The positioning of the spray nozzle depends on whether a co-current (con-current), counter-current, or mixed flow system is used.

In a co-current flow system the spray droplets and hot air flow in the same direction, with the spray nozzles positioned close to the hot air inlet. In this arrangement the spray evaporation is rapid, since the hottest air is contacting droplets containing the most moisture. During this short and rapid evaporation period the spray droplet temperature remains low, since the droplet remains at the wet bulb temperature; therefore, up to this point the product is not subjected to any heat degradation. As the drying continues, the hot air carrying the drying particles has been cooled somewhat, thereby further minimizing the potential for heat damage.

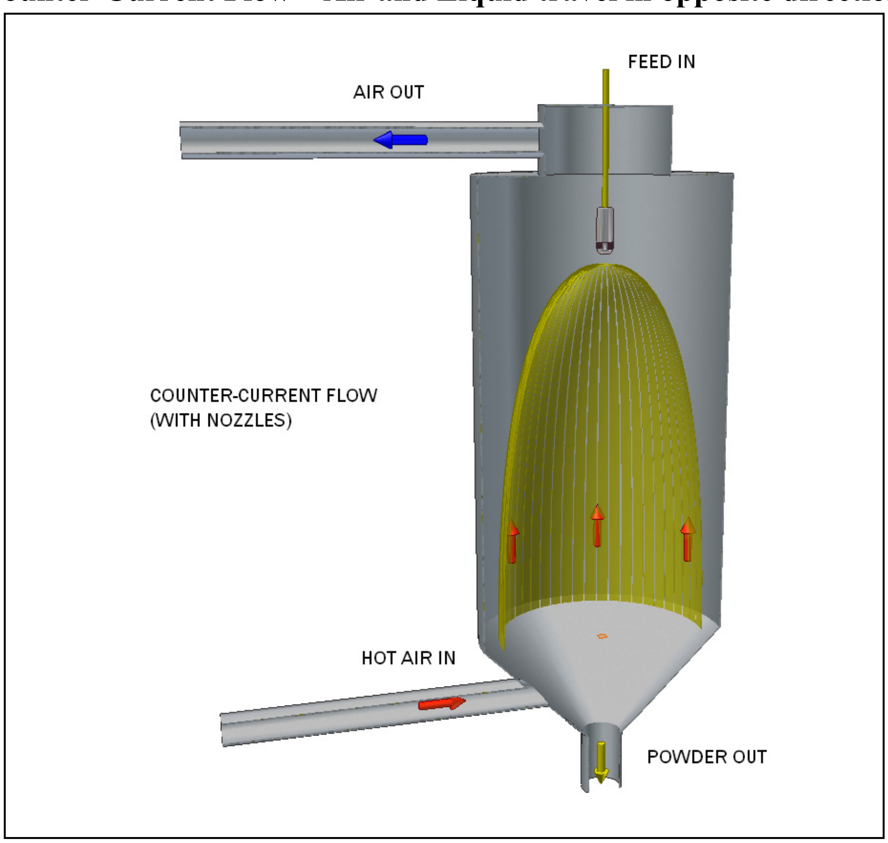
In a counter-current flow system the hot air and the spray droplets travel in opposite directions with the spray nozzles at the top and the hot air inlet located at the bottom of the chamber. In this counter-current flow system the "almost-dried" particles are exposed to the highest temperature, since the hottest gas contacts the driest particles first. While this system provides an excellent use of heat energy, it is not used with heat sensitive materials.

In a mixed flow system the feed and hot air inlets are at opposite ends of the vertical drying chamber as in the counter-current flow, but with the spray nozzle atomizers positioned at the bottom, spraying upwards. As in the counter-flow system, the powder is subject to relatively high temperatures; therefore, the mixed flow system is usually not used for heat sensitive products.

Co-Current Flow – Air and Liquid travel in same direction



Counter-Current Flow – Air and Liquid travel in opposite directions



Closed-Cycle and Semi-Closed Systems

In applications involving a feed stock or product which is oxygen sensitive, inflammable, toxic, odorous, explosive, or requires high purity, closed-cycle systems are used. In these cases a hot inert gas, possibly nitrogen, is used in place of air as a drying medium. The inert gas is not exhausted into the atmosphere, but remains in the system to be recycled.

A modification of the open-cycle and closed-cycle is described as a closed system, or as a "self-innertizing" installation. This is accomplished by controlling the amount of excess combustion air fed to a direct-fired air heater. This results in a hot drying gas flow having a low oxygen content, as required with oxygen sensitive feeds or products. A semi-closed system is also used with products that create odors, or contain toxic materials, which require the exhaust gases to be treated before being discharged into the atmosphere. By limiting the amount of excess combustion air a minimum amount of exhaust gas must be scrubbed or treated, thereby lowering the investment and operating costs of the system.

Horizontal (Box) Spray Dryers

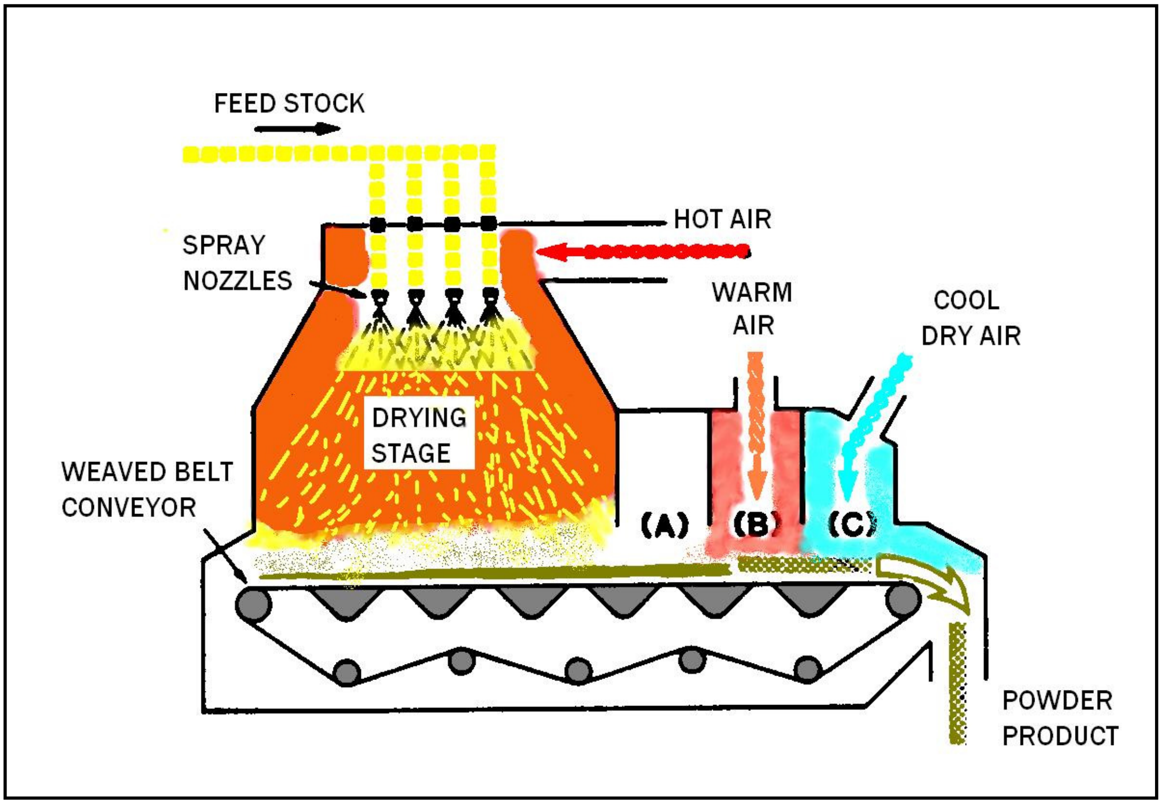
Spray nozzles in a box dryer usually project the atomized feed horizontally into the chamber, contacting the hot air, with the resulting dried powder falling to the chamber floor or a “V” shaped bottom. Since these dryers are relatively short, it is important to provide very fine atomization to the spray droplets to achieve the proper drying in the limited dwell time available in the drying chamber.

Two-Stage (Multi-Stage) Dryers

In a single-stage dryer, the usual final moisture content in spray dried products ranges from 2 to 5%. In a two-stage unit, the first stage is controlled so as to produce a powder particle having 5 to 10% moisture as it reaches the bottom of the chamber and enters the second stage. The second stage can be a vibrating bed dryer or fluidized bed dryer, with the drying process continuing in this stage until the product moisture drops to the 2 to 5% level. Since the first stage maintains a relatively wet particle, it is important to keep the wet particles from contacting the wall of the chamber. The basic advantage of a two-stage process is that it permits the use of lower drying air temperatures in both stages while providing savings in energy costs and making it most effective in processing heat sensitive materials.

In some applications the second stage is used as an agglomeration process, wherein moist particles from the first stage are deposited on a vibrating bed, causing these particles to join together to form larger particles. This second stage agglomeration process usually provides higher bulk densities, better solubility, improvement of the flowing properties, and less dust. In other installations, the wet particles from the first stage are sprayed with additional feed in the second stage to soften their surfaces and/or to enlarge or “grow” the particles, as a result of the additional spray build-up and the joining of wet particles. This process is called "rewetting agglomeration" or "instantizing”.

Agglomeration on a conveyor belt in stage (A).
Drying and cooling in stages (B) and (C).



Section III - Feed Stock Properties

The feeds to be atomized can be solutions, slurries, pastes, gels, emulsions, molten materials, multi-component materials, suspensions, or sludge...so long as they are pumpable. In each spray drying application the feed stock is prepared for the spray drying process with its specific constituents at the required temperature. At the same time, these feeds have important physical properties which can affect the spraying process, including the following:

Solids Content (Concentration): This property is indicated by a percentage of the solids content, and may range from 20% to 70%, depending on the nature of the feed, dryer capacity, and atomizers used. The solids concentration factor affects the spray atomizer choice in terms of spray-ability, spraying pressure, atomizer wear life, as well as clogging. Higher total solids in many feeds result in higher particle density and powder bulk density.

Specific Gravity (Density): This feed characteristic primarily affects the flow rate of atomizers. The flow rate (GPH) (l/min) from a pressure spray nozzle is inversely proportional to the square root of the specific gravity of the feed. Therefore, if water capacity tabulations are used as the basis of nozzle choice, the nozzle capacity, when spraying a liquid lighter or heavier than water, can be estimated from its specific gravity. Water, with a specific gravity of 1.0, weighs 8.34 lbs. per gallon (1 kg/l). See section VI, Nozzle capacity, for a Specific Gravity Factor tabulation. Aside from the specific gravity influence on capacity, the feed viscosity can also affect the flow rate.

Viscosity: The feed viscosity is determined by the feed ingredients, solids content, and temperature. A feed with a high viscosity does not atomize as easily or as finely as one with a lower viscosity, thereby resulting in larger droplet/particle sizes as compared to those from a lower viscosity feed, when using the same nozzle and spraying pressure. The viscosity can also influence the flow rate through the spray nozzle, depending on the viscosity level, nozzle type and size, and spraying pressure. In some nozzles an increase in viscosity results in a higher flow rate at the same pressure -or provides the same capacity at a lower pressure. In other type nozzles the influence on flow rates is minor. See section VI, Viscosity effect.

Surface tension: High surface tension liquids are more difficult to atomize and require higher minimum spraying pressures. The surface tension values of most feed stocks vary only within a limited range.

Feed temperature: This property can affect the feed viscosity as well as the heat transfer function in the spray dryer chamber. The temperature factor should also be considered when using spray atomizers containing gaskets, which may be subject to heat deterioration from the drying air as well as the feed liquid.

Melting temperature: This factor is most important in spray cooling (prilling) applications involving feeds which solidify at ambient temperatures.

Thermo plastic: This identifies materials which could melt or become sticky at spray drying temperatures.

Corrosiveness: Some feed stocks may contain corrosive chemicals which attack nozzles. Nozzle materials providing effective corrosion resistance to the specific chemical at its concentration and temperature should be used. This corrosion factor also applies to nozzle cleaning solutions. See section VI, Nozzle Wear and Corrosion, and the following discussion on abrasiveness.

Abrasiveness: The combination of abrasive feeds and high spraying pressures provides a most serious wear problem for nozzle orifice inserts, cores, and whirl chambers. To suit the specific requirements of wear resistance in each application many of these nozzle parts are available in a choice of hardened stainless steel, or a variety of tungsten carbides. Hardened stainless steel is a fraction of the cost of tungsten carbide, but it will need to be replaced more often. It has generally been used where the sprayed chemical is not compatible with our “Y” or “M” carbides. “M” carbide is definitely the longest wearing of our carbides except where chemical compatibility is an issue. Then we suggest the “L” carbide, which is longer wearing with corrosive chemicals than the “Y” or “M”. The “L” carbide will also last many times longer than the hardened stainless steel.

Section IV - Dried Powder Properties

Spray dried powders have many properties, which are normally monitored during the drying operation. These powder properties include:

Particle Shape: While some dried particles have spherical shapes, others do not. For non-spherical particles the shape is defined as the ratio of the length of the side to that of the short side, as measured through the center of gravity. These particles can be hollow, solid, or a variation thereof, depending on the feed stock and drying process.

Particle Size: The unit used to measure the powder particle size is a micron of (1/1000 of 1 mm) (1/25,400 of 1 inch). If the particle is not round, an "apparent diameter" measurement is used. This is the mean distance between extremities of the particle measured thru the center of gravity of the particle. Rotary atomizers usually produce fine to medium size particles, ranging from approximately 25 to 300 microns (micrometers), depending on the wheel diameter and RPM. Pressure spray nozzles normally produce fine to coarse particles in the range of 20 to 600 microns (micrometers), depending on the nozzle type, size, and spraying pressure; while two-fluid air atomizing nozzles can supply very fine particle sizes from 10 to 200 microns (micrometers) and larger depending on the nozzle size, Spray Set-up, and air and liquid pressures. See Table SS-1, section X, for sieve sizes.

Particle Size Distribution: Particle size distribution is a measure of the percentage of spray that is within a certain drop size range. A customer would like all of the spray particles to be in the same range, so the tighter the particle size distribution the better. Pressure nozzles give the tightest drop size distribution.

Particle Density: Powder particles can be hollow, porous, or solid depending on the feedstock and operating variables. It follows that the hollow type and the porous type particles have lower particle densities than the solid particle type. Because of the many interrelated factors, it is difficult to predict particle density. Whether a particle is mostly solid or mostly hollow is usually a matter of the type of dryer that is used. Counter-current dryers produce a more solid particle and co-current dryers produce a more hollow particle. Changes to the degree of hollowness or solidness are controlled by the temperature of the drying air which affects the droplets evaporation rate. Higher solids-content feed stock usually produce a higher bulk density.

Bulk Density: This factor describes the weight of the dried powder per unit volume. This factor influences the size of containers, storage bins, and handling costs. Generally, nozzle spray-dried particles can have higher bulk densities than those from rotary atomizers. Factors affecting the product bulk density include the following:

> **The Range of Particle-Size Distribution:** When the size difference between the largest and smallest spray dried particles is large, the bulk density will be greater than that from narrower range of sizes ...assuming that there is an appreciable amount of product in the smaller size range. This relationship can be explained by the voids between the large particles being filled with the smaller particles, which are usually denser than the larger ones.

Powder Moisture Content: As mentioned previously this property can be controlled by varying the gas temperatures. Particles containing more moisture generally have higher bulk densities.

Drying Air Temperature: In a co-current flow system; increasing the drying air temperature usually decreases the bulk density because the original, faster, evaporation causes an expansion of the particle as it dries.

Percentage of Solids in the Feed: Changing the amount of solids in the feed can change the bulk density, depending on the simultaneous effect on atomization. For instance, decreasing the solids content in some materials produces a smaller particle size with an increase in bulk density. On the other hand, with some food product feeds an increase in bulk density is obtained by increasing the solids in the feed.

Increase in Feed Temperature: While this usually produces somewhat lower bulk densities, if pre-heating de-aerates the feed, the bulk density can increase.

Pre-heating of feed also usually reduces the feed viscosity, thereby improving the atomization. In feeds subject to possible crystallization, heating of the feed will prevent clogging in spray nozzles.

Outlet Air Temperature: Decreasing the outlet air temperature increases the moisture content of the powder, thereby increasing the bulk density

Air Flow: As mentioned in the Counter-current Flow discussion, section II. the particles may be more dense, because the liquid droplets originally contact air which has already been partially cooled and moist, thereby slowing the evaporation rate. Therefore, the particles do not expand as they would have in a co-current air flow system.

Residual Moisture Content in Powder Particles: This property, usually 2-4%, is controlled by the outlet temperature of the drying air, but it can range from 0.5% to 7%.

Heat Sensitivity: This property describes the product's vulnerability to damage from excessive heat exposure. It determines the maximum process temperature limitation for the spray drying operation.

Hygroscopic: Describes products which absorb moisture from their surroundings.

Other Properties: Dried powder products have other characteristics which are important for their final use, such as solubility, dispersability, porosity, flow-ability, sink-ability, wet-ability, color, friability, dust component, oxidation, taste, appearance, and aroma. See section X. Glossary of Terms.

The spray nozzle controls the feed droplet sizes and distribution, which are then reflected in the dried powder particle sizes and distribution. Larger droplet/particle sizes can be obtained by using larger capacity nozzles, lower spraying pressures, higher solids concentrations, and higher viscosities. Conversely, smaller droplet/particles can be produced by using smaller capacity nozzles, higher pressures, lower solids concentrations, and lower viscosities.

Section V - Spray Atomizers - General Information

The spray atomizer performs two functions, (1) accurate metering of feeds and (2) proper feed atomization resulting in an acceptable dried product. The choice of a specific atomizer and spraying pressure is made on the basis of the feed stock properties, the required powder sizes and properties, atomizer capacity, and the dryer type and capacity. The important feed stock characteristics are the solids content, viscosity, and specific gravity. The degree of atomization controls the drying efficiency and the resulting powder particle size distribution and bulk density. Compared to the total costs of a spray drying installation and operation, spray nozzle atomizers are low cost items, which perform a most important function in the spray drying application.

Three basic types of spray atomizers are available; (1) pressure spray nozzles - small capacity type used at high pressures, (2) pressure spray nozzles - high capacity type used at lower pressures, and (3) two-fluid and three-fluid (with two air rings) air atomizing nozzles. Each of these spray nozzle types has its own droplet size performance characteristics, to suit a wide variety of feed stocks and flow rate requirements.

Pressure Nozzles

Hydraulic type spray nozzles are known as "pressure spray nozzles" or " centrifugal pressure nozzles", and derive their atomization energy from the liquid pressure (pump generated) in the feed line. The pressure energy is converted into kinetic energy through the nozzle orifice. The wide variety of pressure spray nozzle types provides a choice of spray performances in pressure ranges from 100 to 7,000psi (7 to 483bar). Feed capacities range from 3.4 to more than 1000 GPH per nozzle at 1000psi (13 to more than 3800 l/h at 69bar). Mean powder particle sizes may range from 20 to 600 microns (micrometers) depending on the nozzle type, capacity, and spraying pressure.

Pressure spray nozzles are used in vertical dryers with the sprays directed vertically upward or vertically downward. In horizontal dryers sprays are directed horizontally. Nozzles are used in co-current, counter-current and mixed flow systems, as well as in open cycle and closed cycle installations.

Pressure spray nozzles provide Median Volume Diameter water spray droplet sizes ranging from 15 to 500 microns (micrometers), depending on the nozzle type, capacity, and spraying pressure. See definition of "Median Volume Diameter" in section X. Glossary of Terms. These same nozzles produce larger spray droplet sizes on feed stocks, depending on the flow properties of the feed, the solids concentration, viscosity, etc. Because of the range of droplet/particle sizes, the resulting powders usually have higher bulk densities as compared to those obtained from rotary atomizers.

Viscous feeds up to 700 centipoise can normally be sprayed through pressure nozzles, depending on the nozzle type, capacity, and spraying pressure. Feeds above 700 centipoise would usually be sprayed through air-atomizing nozzles.

Pressure spray nozzles form a hollow cone spray pattern with relatively fine droplets, thereby providing a large total droplet surface area for maximum effective contact between the droplet surfaces and the hot air flow. There are many different types of pressure spray nozzles, each with its own design parameters and materials, as well as performance characteristics, depending on the nozzle capacity and spraying pressure. One of the most important spraying characteristics is the spray droplet size range, which varies for each nozzle, pressure, and feed stock.

Because even a tight droplet size range provides some fine particles care must be taken to achieve a critical heat as to evaporate -all the droplets, including the largest, without scorching the particles from the finer droplets in that same spray droplet spectrum.

Pressure spray nozzles offer many advantages. They can be used in all types of dryers and flow systems, as well as in open-cycle and closed-cycle installations. Nozzles can provide fine to coarse powder particles, depending on the feed, nozzle size, and spraying pressure, along with a high bulk density, and with low occluded air in the particles. Nozzles can be used with a wide variety of feeds and products, including heat sensitive materials. Nozzle operation and maintenance is simple and easily controlled. They provide a high degree of versatility... including nozzle quantities, nozzle locations and spray direction in the dryer, range of capacities and pressures, as well as spray angles. They are most useful in small and medium capacity dryers, and are used frequently in tall vertical dryers because of their narrow spray patterns. For applications requiring larger particles, large capacity pressure spray nozzles and/or low pressures are required. To obtain smaller particles, low capacity nozzles are used at higher pressures. Another important feature of pressure spray nozzles is the wide choice of materials available in each nozzle type. For instance, hardened stainless steel orifices and cores are sufficiently wear resistant to provide economical performance in many applications, while tungsten carbide is available to handle abrasive feed stocks "L" carbide is used for chemically corrosive feeds and cleaning solutions. These hardened stainless steel and carbide materials are interchangeable within each nozzle type.

Nozzle clogging may occur when small capacity nozzles are used to spray coarse slurries. Clogging may be lessened by using the MFP series of nozzles for the SK and SB lines. These use cores with larger and fewer slots and the internal passages are opened up to let larger particles pass through. The type 104 and SSTC nozzles have the largest free passage but these are the highest flow nozzles and are not suitable for the low flows of the SK series and possibly the mid flow range of the SB series.

NOTE: All references in this Manual to capacities, spray angles, and droplet sizes are based on spraying water. These characteristics will be different for feed stocks, depending on many factors including feed viscosity and specific gravity, and the nozzle type and size. References to spraying pressures are based on the pressures at the nozzles and not at the pump.

Two-Fluid Air Atomizing Nozzles

The spray atomization energy in pressure nozzles comes from line pressure energy; the atomization in 2-fluid air-atomized nozzles is derived from energy in compressed air, gas or pressurized steam. The flow rate and degree of spray atomization in an air-atomized nozzle is controlled by the combination of feed line pressure and air-line pressure. The range of control varies in each application, depending on the nozzle type, nozzle size, Spray Set-up number, feed characteristics, and the air/liquid pressures. Since air atomizing nozzles cause a cooling effect inside the drying chamber with the relatively cool atomizing air, this factor must be taken into account in the heat balance calculations.

Air-atomizing nozzles can provide the finest droplets with a relatively narrow droplet size range. Within each nozzle type and size, the droplet sizes can be changed by varying the combinations of the pressures in the feed stock line and the air line. These two-fluid nozzles can provide very low or very high capacity ranges, and are supplied with either internal or external mix Spray Set-ups.

When using Spray Set-ups with internal mixing of liquid and air, the air and liquid pressures must be balanced within specific ranges to obtain satisfactory atomization and capacity performance. When using external mix Spray Set-ups the feed and compressed air mix externally. External mix round and flat Spray Set-ups can provide a wider range of turndown ratios, because the liquid flow is independent of the compressed air flow rate or pressure. Turndown ratio is the ratio of the maximum capacity to the minimum capacity of a nozzle within an acceptable spray performance range. In external mix pressure Set-ups the compressed air is used primarily to control the degree of atomization.
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Air-atomizing nozzles are useful in laboratory and pilot plant operations, because of the ease of control and flexibility in developing different capacities with droplet size ranges from 10 to 200 microns (Median Volume Diameter) with water. A two-fluid nozzle provides this wide range of capacities and droplet sizes by varying the liquid and/or air pressures. They are also used in production spray drying applications requiring fine droplet sizes, or involving viscous or abrasive materials, in capacities from 2 to 1700GPH (8 to 6400l/h), based on water, depending on the nozzle size and Spray Set-up number. Because the nozzle orifices are relatively large and liquid feed line pressures usually low, feed velocities through air-atomized nozzles are slower, thereby minimizing the wear problem. When abrasive slurries are sprayed, these nozzles can be supplied on a special basis with hardened stainless steel or tungsten carbide fluid orifice inserts to minimize the wear problem. Another advantage of air atomizing nozzles is their relatively large fluid orifice, which minimizes clogging potentials.

Because the atomization energy comes from compressed air/gas or pressurized steam, these nozzles can be used with higher viscosity feeds. Usually fluid nozzles are used, with occasional use of the three-fluid nozzle, which has two separate air passages and one liquid orifice. Generally air atomized nozzles have larger orifices than pressure nozzles and are more flexible in operation, by varying the feed stock and air line pressures.

As with pressure spray nozzles, air-atomized nozzles can be used in current, counter-current, and mixed flow systems. In a closed-system, an inert gas or steam is used instead of compressed air. Two-fluid nozzles are also used in applications involving difficult to spray non-Newtonian liquids, heavy pastes, gelatins, slurries, plastics and glues. See page 49 for more information on air atomizing spray nozzles.

Because of the cost of compressing air or gas, the total energy input in two fluid atomization is greater than the energy required by the pump in a pressure atomization nozzle.

Section VI

Spray Nozzle Selection, Performance, Maintenance and Cleaning

Spray nozzles perform two functions simultaneously; (1) metering the flow of feed stock to provide the required drying performance and powder production, and (2) atomizing the feed stock to result in efficient drying and powder particle sizes. The following pages provide information relating to the selection, performance, maintenance, and cleaning of spray nozzles to help the user choose the best nozzles for the application and to maintain satisfactory performance during production runs. Please note that the references to spray angles, capacities, and droplet sizes are based on water.

Selection of Nozzle and Size

As described in section V. Spraying Systems Co. offers a wide range of spray nozzle capacities beginning at 2GPH (8 l/h), with the two-fluid air atomizing type J nozzles up to the WhirlJet nozzles which provide water capacities up to 1350GPH (5100l/h) at 1000psi (69bar). In between these capacity extremes are the SK and SB series SprayDry® nozzles. See our bulletins 447, 504, and 527 for a complete description of the different types of nozzles and capacities for the WhirlJet type, the SB type, and SK type respectively. While several different nozzles can supply the same capacity at different pressures, the object is to choose the combination of nozzle size and spraying pressure best suited for the specific application requirement. Usually this decision is based on the droplet size requirement. For the same flow rate, smaller droplets will be formed by smaller capacity nozzles at higher pressures, while larger droplets will be formed by larger capacity size nozzles at lower spraying pressures.

In some applications the spray angle can be an important factor, as when nozzles are positioned close to the drying chamber wall. In horizontal dryers wider spray angle nozzles are used to prevent droplets from impinging on the opposite wall. In such cases, references to nozzle performance tables will provide relative nominal spray angle values for different orifice insert-core combinations. See the "Spray Angle" discussion on page 23.

Materials for Nozzle Bodies, and Core Bodies

Standard nozzle bodies, caps, and core bodies are made of type 303 stainless steel. Other materials including type 316 stainless steel are available on special request.

Materials for Orifice Inserts and Core Tips

Once the nozzle type, capacity size, and spraying pressure are selected, the next important step is to choose the best nozzle materials, which are identified in section VIII. for each nozzle type. For applications involving non-abrasive or mildly abrasive feeds, hardened stainless steel orifice inserts and cores will provide a reasonable wear life.

For applications involving abrasive non-corrosive feeds, “Y” and “M” tungsten carbide orifice inserts, cores, and whirlchambers provide excellent wear life. On the other hand, when the feed is both abrasive and corrosive, a better choice is “L” carbide. The “L” carbide provides good wear characteristics, combined with the best general corrosion resistance. When chemical compatibility is not an issue the M carbide will give the longest wear, but L carbide has better chemical resistance and good wear resistance. Specialized carbides and coatings are a available but at a high price.

Corrosion can also be caused by cleaning solutions, depending on the chemical, its concentration and temperature; and exposure time. As with corrosive feeds, L carbides and the specialized carbide also provide better resistance to corrosive cleaning solutions than Y or M carbide. See "Nozzle Cleaning Procedures" later in this section VI. "Static Corrosion Comparison Test" tabulation is shown as a selection guide for three carbides.

Static corrosion comparison tests -on carbide materials*

Key: N – Negligible Attack M – Moderate Attack (-) – No Data
L – Light Attack H – Heavy Attack

CHEMICAL	CONCENTRATION (%)	TEMP. °C	TEMP. °F	M & Y CARBIDE	L CARBIDE
Acetic Acid, Glacial	99.8	20	68	L	N
Acetic Acid, Glacial	99.8	75	167	H	N
Acetic Acid	10	20	68	L	N
Acetic Acid	10	75	167	H	M
Acetic Acid (Unaerated)	4	20	68	M	L
Acetone	-	20	68	N	N
Alcohol	-	20	68	N	N
Calcium Hydroxide	Sat.	20	68	N	N
Calcium Hydroxide	Sat.	75	167	N	N
Citric Acid	10	20	68	L	N
Citric Acid	10	75	167	H	M
Cobalt (I I) Chloride	10	20	68	N	N
Cobalt (I I) Chloride	10	75	167	H	L
Copper (I I) Nitrate	10	20	68	H	N
Copper (I I) Nitrate	10	75	167	H	M
Ethylene Glycol	50	20	68	H	N
Ferrous Sulfide	Slurry in Water	20	68	M	M
Hydrochloric Acid	10	20	68	L	N
Hydrochloric Acid	10	75	167	H	L
Hydrochloric Acid	37	20	68	H	H
Hydrochloric Acid	37	100	212	H	H
Nickel (I I) Sulfate	10	20	68	N	N
Nickel (I I) Sulfate	10	75	167	M	N
Nitric Acid	5	20	68	H	H
Nitric Acid	5	100	212	H	H
Nitric Acid	10	20	68	H	L
Nitric Acid	10	75	167	H	M
Nitric Acid	20	20	68	M	N
Nitric Acid	20	75	167	H	M
Oil, Crude (w/High Sulfur)	-	20	68	M	M

Continued

CHEMICAL	CONCENTRATION (%)	TEMP. °C	TEMP. °F	M & Y CARBIDE	L CARBIDE
Phosphoric Acid	50	20	68	M	N
Phosphoric Acid	50	75	167	H	M
Phosphoric Acid	85	20	68	H	M
Potassium Hydroxide	10	20	68	H	N
Potassium Hydroxide	10	75	167	H	N
Sodium Cyanide	10	20	68	H	H
Sodium Hydroxide	10	20	68	N	L
Sodium Hydroxide	10	75	167	H	N
Sodium Hydroxide	50	20	68	N	N
Sodium Hydroxide	50	75	167	N	N
Sodium Hypochlorite	5	20	68	H	L
Sodium Hypochlorite	5	75	167	H	H
Sulfuric Acid	5	20	68	M	M
Sulfuric Acid	5	100	212	H	M
Sulfuric Acid	10	20	68	M	N
Sulfuric Acid	10	75	167	H	L
Sulfuric Acid	Sat.	20	68	M	N
Sulfuric Acid	Sat.	75	167	M	L
Water, Distilled	Pure	20	68	N	N
Water, Distilled	Pure	75	167	M	L
Water, Sea	-	20	68	N	N
Water, Sea	-	75	167	M	L
Water, Tap	-	20	68	L	L

*NOTE: This information is to be used only as a relative guide. Tests should be made under actual operating conditions to determine material suitability.

Nozzle Capacity

The flow rate through a spray nozzle depends on the feed pressure at the nozzle, not on the pressure at the pump. Because of pressure drops caused by friction losses in pipes and fittings, the pressure at the nozzle can be considerably lower than at the pump. Since all capacity tabulations are based on the spraying pressure at the nozzle, it is important to know this pressure when checking actual spray nozzle performance against capacity tabulations.

Spray nozzle performance tabulations are based on spraying water, having a specific gravity of 1 and weighing 8.34 lbs. per gallon (1kg/l). When feed stocks having different specific gravities are sprayed, the nozzle flow rates are inversely proportional to the square root of the specific gravity of the feed, as based on water flow rate tabulations. The following conversion factor table can be used to estimate flow rates for feeds weighing more than water.

Specific Gravity correlation table

Weight Per Gallon- Lbs./Gal.	9.2	10.0	10.8	11.7	12.5	13.3	14.2	15.0	15.8	16.7
Specific Gravity (or density in kg/l)	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
Multiply Water Cap. by Factor	.95	.91	.88	.85	.82	.80	.77	.75	.73	.71

Typical specific gravity conversion factors for eggs and milk with 24% to 55% solids are approximately .8 and .65 meaning that these feed stocks have only 80% and 65% of the water flow rate respectively.

The specific gravity affect on capacity is a most important factor, but other factors, such as viscosity may also affect the nozzle flow rate, depending on nozzle type, capacity, and pressure. Many operators determine this flow rate variation between the feed flow and water tabulations by checking the actual feed flow rate and then comparing this feed flow rate to the water tabulation rate, at the same pressure at the nozzle. This calculated capacity conversion factor can then be used for the same feed for different orifice/core size combinations of the same nozzle type. However, for other nozzle types, this feed capacity to water capacity conversion factor may be different. The conversion factor for the SK series may not be the same as for the SB or WhirlJet types.

Viscosity Effect on Nozzle Capacity and Spraying pressure

When viscous liquids are sprayed, capacities may vary slightly or substantially from those published for water depending on nozzle design. With viscous liquids, nozzle types SK and SB, which have smaller whirlchamber to orifice diameter ratios, provide capacities relatively close to those tabulated for water, if the specific gravity of the liquid is close to that of water.

However, nozzles having larger ratios of whirlchamber diameter to orifice diameter (SBC and WhirlJet types) produce much higher flow rates with viscous feeds as compared to water tabulated figures for same pressure. Likewise they produce the same viscous feed flow rates as in the water capacity tabulations but at lower pressures. The higher flow rate at the same pressure increases pump and nozzle wear life, but it also can produce larger droplets/particles. This same lower pressure operation with viscous feeds can be matched with the SK and SB nozzles by using orifice-core combinations with larger capacities. In choosing an orifice insert-core combination it is important to aim at achieving the best powder product quality at the lowest acceptable spraying pressure.

As noted in the "Capacity" discussion, the specific gravity of the feed also affects the flow rate. Actual tests are required to determine the orifice insert-core sizes and pressures which produce the best powdered product at the desired flow rate.

The following table, which is based on actual tests, lists a few examples of the effects that higher viscosity fluids with higher specific gravities have on nozzle flow rates.

Fluid Sprayed: Aqueous sugar solution
Specific Gravity: Approximately 1.3

Viscosity: Varies in each test (see tabulation)

1	2	3	4	5	6	7	8
NOZZLE CAPACITY SIZE	**VISCOSITY OF SUGAR SOLUTION**	**SPRAYING PRESSURE PSI (BAR)**	**TABULATED WATER FLOW RATE OF NOZZLE GPH (l/hr)**	**EQUIV. FLOW RATE OF A "NON-VISCOUS" 1.3 S.G. LIQUID GPH (l/h)**	**ACTUAL TEST FLOW RATE OF VISCOUS SUGAR SOL. 1.3 S.G. GPH (l/h)**	**% INCREASE OR DECREASE OF FLOW RATE CAUSED BY VISCOSITY EFFECT ALONE**	**% CHANGE OF FLOW RATE CAUSED BY BOTH VISCOSITY & SPECIFIC GRAVITY**
WhirlJet 2-2	300 cps 30 cps	380(26) 800(55)	62(235) 91(344)	54(204) 80(303)	92(348) 92(348)	+70% +15%	+48% +1%
SBC-8	350 cps 40 cps	1700(117) 3900(269)*	52(197) 79(299)	46(174) 69(261)	75(284) 75(284)	+63% +9%	+44% -5%
SK-56-27	250 cps 30 cps	3300(228) 2900(200)	84(318) 79(299)	74(280) 69(261)	65(246) 65(246)	-12% -6%	-23% -18%
SK-69-21	350 cps 30 cps	3800(262) 4600(317)	37(140) 41(155)	32(121) 36(136)	31(117) 31(117)	-3% -14%	-16% -24%

*Maximum pressure recommended for type SBC-nozzles is 2000 psi

The figures in the first three columns and in the sixth column were derived from, "The Effect of Viscosity on the Pressure-Flow Rate Relationship of Some Centrifugal Pressure Atomizing Nozzles", by Dr. C. G. Bloore, New Zealand Dairy Research Institute, and published in the New Zealand Journal of Dairy and Technology. Data is used with permission of author.

Dr. Bloore's report summary concludes that the degree of viscosity sensitivity is related to the nozzle design. Specifically it indicates that larger ratios of "whirlchamber" diameter to orifice diameter produce higher flow rates when spraying high viscosity feeds. This is borne out in the tabulation which shows capacity increases in the WhirlJet and SBC nozzles, while the SK nozzles show decreases in capacities.

The tabulated data in the four columns was calculated based on values estimated from curves shown in the test report and should be considered approximate. As noted in the "Capacity" discussion, nozzle flow rates are also affected by the specific gravity of the feed.

In column 5 the equivalent flow rate of the sugar solution, based on the 1.3 specific gravity alone, was obtained by multiplying the water flow rate by .88 (see "Conversion Factor" tabulation on page 21). This means that the higher specific gravity effect alone on the solution would have been lower flow rates for this sugar solution as compared to water flow rates.

Therefore, it follows that the difference between these lower equivalent 1.3 specific gravity liquid flow rates and the actual sugar solution flow rates is caused by the higher viscosity of the sugar solution. This difference expressed as a + or - % figure is tabulated in column 7. Column 8 tabulates the actual capacity % change caused by the combination of the higher viscosities and specific gravity.

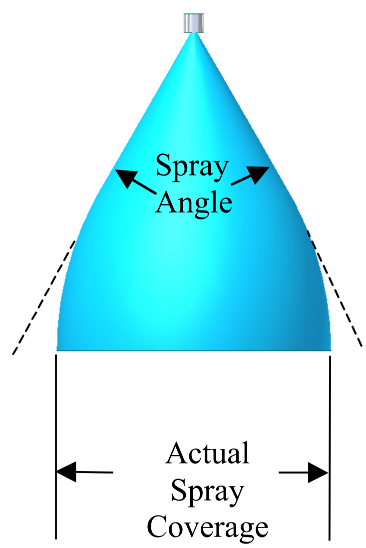
In summary we conclude that the decrease in capacity caused by the specific gravity applies to all spray nozzle types equally, while nozzles with larger ratios of diameter to orifice diameter produce increased capacities for higher viscosity fluids. On the other hand, the usual higher viscosity influence on type SK nozzles is shown to be a capacity decrease, as expected, because of the smaller ratio of "whirlchamber" diameter to orifice diameter. To adjust for these flow rate decreases, or to use lower spraying pressures, higher capacity orifice insert-core sizes can be used.

It should be noted that the MFP versions of the SK and SB nozzles do not experience as much pressure drop due to viscosity as the non-MFP versions. This is an added benefit of the opened passages leading to the core.

NOTE: The above data is based on a few selected nozzle types, sizes, and on a sugar solution at several viscosities. The numerical conclusions reached apply only to these specific of factors and would not necessarily apply to other solutions, nozzle types and sizes, or pressures.

Spray Angle

Occasionally, as when spray nozzles are close to a chamber wall, the spray angle from a nozzle can become an important factor. Published nominal spray angle values are based on spraying water at 1000psi (69bar); these readings were obtained by protractor measurements.



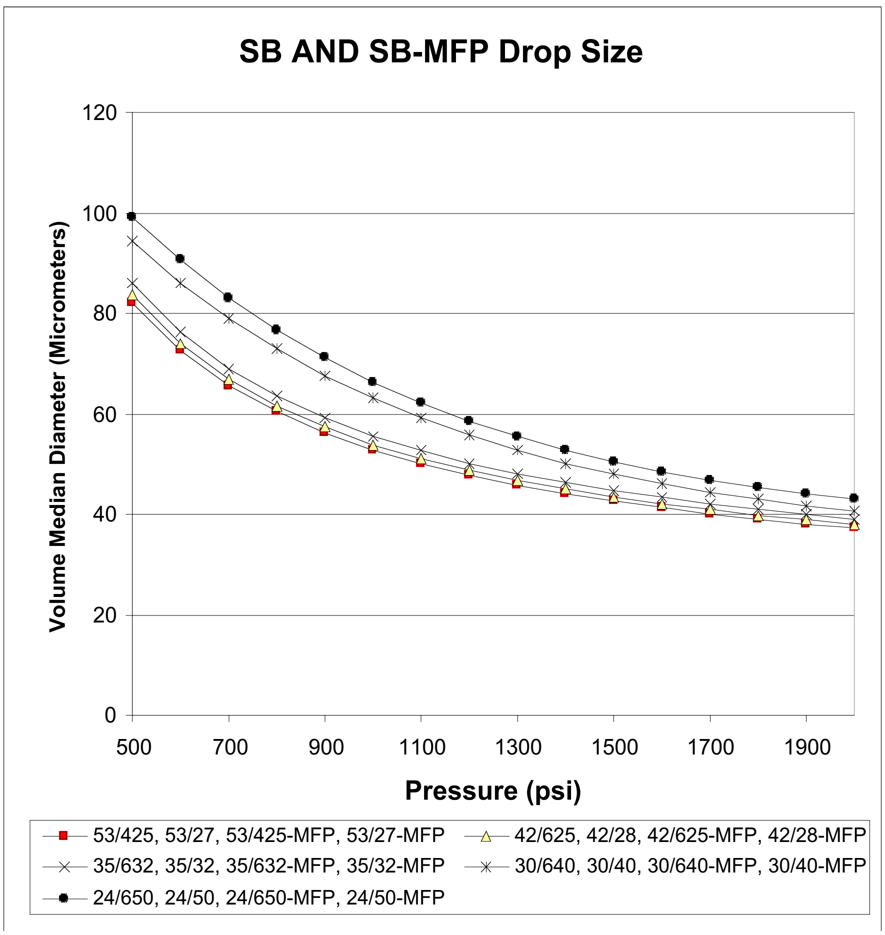
But, this spray angle pattern holds only for the first one or two feet from the nozzle at 1000psi. At higher pressures the spray pattern “pulls in”, and does not get wider but begins to move in the same axis as the nozzle and remains about the same, rather than spreading out. The accompanying sketch illustrates this point. The distance from the nozzle at which the spray angle "pulls in" varies with the nozzle type, size, feed, pressure, air direction and velocity. The only purpose for including a spray angle value in tabulations is to provide a general guide as to the relative spray coverage of different spray nozzle sizes and not for calculating or estimating actual spray pattern dimensions.

Droplet Sizes

Droplet sizes are critical in spray drying applications, since they control the dried powder particle sizes as well as the drying process efficiency. Spray atomization from a nozzle results in a range of droplet sizes, rather than one uniform size. In practice, this droplet size spectrum is a function of the nozzle type and capacity, spraying pressure, feed stock properties, and to a much lesser extent the spray angle.

Smaller spray droplets are obtained by using smaller capacity nozzles and/or by spraying at higher pressures. Larger capacity spray nozzles and/or spraying at lower pressures produce larger droplets/particles. Wider spray angles may provide somewhat smaller droplet sizes, as compared to those from narrower spray angle sprays, for the same nozzle capacity and pressure.

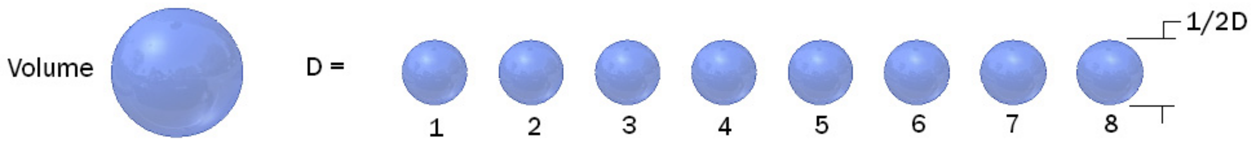
Below is a representative curve of drop size verses pressure for select SB type nozzles. Note the characteristic leveling off in drop size as pressure increases toward 1900 psi. Below about 2000 psi the drop size increases rapidly as pressure decreases but above 2000 psi not as much change in drop size can be attained from a change in pressure.



The Information above is based on spraying water, but this information serves only as a guide for comparing dried powder particle sizes. Droplet sizes in water sprays also provide larger dried particle sizes. Particles can either shrink or expand during the drying phase depending on the feed and dryer performance. The smallest droplet sizes can be obtained by the use of two-fluid air atomizing nozzles. For droplet size range information see Section V "Pressure Nozzles".

Miscellaneous Data on Droplet Sizes and Droplet Surface Areas

1. The volume of one large droplet equals the volume of eight droplets having diameters of one-half that of the large droplet.



Also note that the surface area of the 8 small droplets is twice that of the one large droplet.

2. If the total suspended droplet surface area is doubled, the absorption of heat and evaporation rate will double.

3. If the droplet retention time in the spray chamber is doubled the absorption of heat and the evaporation amount will also double.

Nozzle Wear/Corrosion

All spray nozzle orifices and cores wear, especially so with abrasive feeds at higher pressures. Wear varies, depending on solids in the feed stock, orifice and core sizes, spraying pressure, and nozzle materials. It is important to note that the wear problem may be aggravated by corrosion from the feed stock or from the nozzle cleaning chemical solutions. Our spray nozzle orifice inserts and cores can be supplied in different materials such as hardened stainless steel, M tungsten carbide and L tungsten carbide. Therefore, the wear/corrosion problem can be minimized by a proper choice of nozzle materials, cleaning solutions, and cleaning procedures. Also, special materials for the nozzle body, cap, and core body can be supplied on special request.

How can wear be detected? As the orifice and core slots wear, several spray performance changes take place. First, the nozzle capacity gradually increases. Secondly, depending on the location and the extent of the wear, the spray pattern deteriorates, usually by forming "streaks". Simultaneously, while capacity is increasing and streaks are forming the spray droplets become larger and the powder may contain more moisture than desired. As the wear continues, it will causes problems of wet powders, and possibly caking on the chamber wall.

To prevent the costly consequences of worn nozzles, preventative steps should be taken during production runs. Since each spray drying application has it’s own set of operating factors and product requirements, a single generalized statement as to the “permissible” degree of wear would be unwise. Precautionary procedures include an on-going inspection of the powder, as well as the spray nozzle orifice inserts and cores.

<u>Checking Worn Orifices and Cores</u>

Determining exactly when worn orifice inserts and cores should be replaced is not a simple matter. In each application the operator makes the decision based on product quality, with the objective of getting the most wear life without jeopardizing the product quality. Therefore, this decision is based on anticipating the point at which product deterioration begins, and replacing the worn items before this happens.

It is important to point out that the final quality control decision on the orifice insert and core during their original manufacturing processes is based on a water flow rate check at 100psi (6.9bar), and not on a dimensional inspection of the orifice and slot sizes. For this reason, during a spray drying process, a check which is based solely on the orifice and core slot dimensions is not recommended, as it is not a reliable indication of the actual amount of change in flow rate, although it does confirm that wear is taking place.

An effective way of visually checking the extent of wear on the orifice and core slots would be to view them through a microscope. This type of viewing would confirm that the wear effect is not equally distributed over the orifice or slot surfaces, and, therefore, would be difficult to measure. Also, it could be seen that some types of wear, like the rifling grooves worn inside of orifice insert chambers, do not materially affect the flow rate of the orifice insert-core combination, but they can affect the atomization and pattern distribution.

Specifically the recommended flow rate check can be made by two different methods:

1. The preferred method is to check the water flow rate and spray pattern, at 100psi (6.9bar) or higher, of the orifice insert-core combination being used, and compare it to the flow rate and pattern of this same combination when it was new and unused. The flow rate check can be done by spraying into a calibrated graduate or flask for given time period, with these readings repeated at different times during the spray drying process to determine the percentage increase in flow rate. At the start of this test it is suggested that the operator tap the nozzle gently to make sure that the floating core seats itself properly against the orifice insert. At these lower pressures the cores may not always seat themselves properly against the orifice insert. The worn orifice insert and core should be replaced when their increased flow rate reaches pre-determined level, based on powder quality.

2. However, if the orifice insert and core are found to wear at drastically different rates, they can be checked independently of each other, to determine whether one or both of them should be replaced.
    a. <u>To check for orifice wear only:</u> Check the flow rate of the orifice insert with a new core which should be the standard testing core and never used in the spray drying process.
    b. <u>To check for core wear only:</u> Check the flow rate with a new orifice insert which should be the standard testing orifice insert and never used in the spray drying process.

Testing procedure (1) is recommended, because it gives the surest protection for high quality products. Replacing the used orifice insert and core simultaneously is suggested, rather than to try to obtain a bit more wear life out of the “less worn” orifice insert or core, and possibly damage some of the powder product quality.

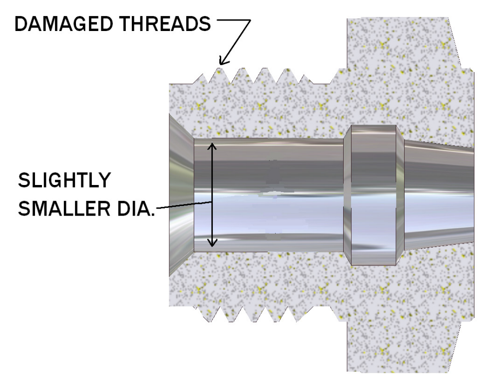
Pressing Orifice Insert into Cap

Nozzle caps can be purchased with orifice inserts already pressed into position, but many operators choose to reuse undamaged caps by replacing worn orifice inserts as required. This practice is satisfactory for hardened stainless steel orifices, but carbide orifice inserts should be retained in the caps to prevent damage when they are removed and replaced in caps.
We recommend the use of our Orifice Insert Presses which are specifically designed to simply and accurately remove and install orifice inserts in and out of caps ...without damage. This is especially important when installing carbide orifice inserts which are brittle and chip if mishandled. Once a carbide insert is pressed into a cap, it should not be removed until it wears out because of the possibility of cracking or chipping. Several orifice insert press models are available for installing and removing orifice inserts from caps or bodies of nozzles. See the "Orifice insert presses" paragraph in section IX and Data Sheet 22779.

Nozzle Leakage Problem in Nozzles with Gaskets

To prevent leakage through the nozzle gasket area, between the cap and nozzle body, care must be taken to make certain that each nozzle has a new and undamaged gasket. Damaged or worn gaskets can cause serious leakage problems which can result in damage to the powder. Further, the caps should be tightened properly, but not over tightened, to provide a leak-tight engagement. The recommended torque wrench setting is 50 to 60 ft-lbs (70 to 80 Newton-meters) for the SK series, 60 to 70 ft-lbs (80-95 Newton-meters) for SB series, and 75-85 ft-lbs (100-115 Newton-meters) for the 104 and SSTC series. Each time a nozzle cap is removed from the nozzle assembly, the gasket should be inspected carefully and replaced if it is damaged or ineffective in any way. This will eliminate the need to over tighten the cap and thereby extend its useful life.

It is also important to point out that "over tightening" the nozzle cap can damage the cap threads' and distort the internal chamber of the cap. This core chamber distortion can cause a core fit problem; if the core cannot slide freely in and out of the chamber, the cap should be replaced. For proper spraying it is necessary for the core tip to seat properly against the inside beveled surface of the orifice insert; otherwise the spray nozzle will not provide the proper capacity and atomization. As soon as damaged cap threads or distorted core chambers are noticed, the cap should be replaced.



Over tightening is not a problem with the SKH and SBH series since they use O-rings for sealing and only require hand tightening. Torque spec recommendations are 20in-lbs (1.48 Newton-meters) and 30in-lbs (3.4 Newton-meters) respectively. O-rings and back-up rings should be replaced after every usage. See MI ABSKH-KIT and MI ABSBH-KIT.

Clogging Problems

If clogging occurs in the nozzle orifice or in the core slots, the clogging material should be removed carefully with a fine probe that is not as hard as the insert or core, so as to not damage the orifice or slot surfaces. Tabulated orifice and core slot dimensions should be checked and an orifice insert and core size chosen to minimize clogging whenever clogging becomes a problem.

Occasionally nozzle clogging takes place in the core chamber of the nozzle cap, between the chamber wall and the core body. If clogging is an issue the MFP versions of the SK and SB series nozzles should be used. Actually all customers can use the MFP versions since it has been determined experimentally that drop size remains the same with MFP versus non-MFP versions of the SK and SB series. The 104 and SSTC WhirlJet nozzles are larger in capacity and therefore their passages are larger so that they usually do not experience clogging.

Nozzle Cleaning Procedures

Periodic nozzle cleaning is a most important factor in providing proper metering and atomization as well as in clogging prevention procedures. Since corrosive chemicals are often used for cleaning nozzles, it is important to choose the chemicals and nozzle materials to be compatible on the basis of their corrosion action and resistance. For instance, an occasional complaint is made that nozzle orifices and cores wear out in much shorter times than previously, and it is usually directed at "defective" materials for the orifice and core. In many of these cases, it was found that the cleaning chemicals and/or procedures were changed since the last production run, to the point where nozzle parts were being corroded by new chemicals, higher chemical temperatures, or longer periods of contact with the chemical. Therefore, it is important to note that chemical cleaning solutions can corrode nozzle parts. If corrosion occurs, consideration should be given to changing the chemical solution, temperature, or the contact time between the chemical and parts. Another option is to change the materials in the spray nozzle to those having better resistance to the specific chemicals in the cleaning operation. Chemical corrosion can also be caused by chemicals in the feed stock, thereby accelerating the wear/corrosion on the orifice and core. If so, the nozzle materials should be changed to minimize the corrosion problem.

Also, when cleaning carbide cores and orifices, special care should be exercised not to chip this brittle material, since this results in defective spray performance.

For a typical cleaning procedure we warn against soaking the tungsten carbide components in acid solutions and strong detergents. Both of these chemicals are known to affect the service life of tungsten carbides by corroding the binder metals. Cleaning is more easily carried out if the nozzles are removed and disassembled before the feed stock dries on the components. Our cleaning instructions shown on data sheet 22779 states that only a mild dish soap and brush should be used on the carbide. After washing and rinsing the components should be blown dry with compressed air if they are not used right away. In general the L carbide can handle stronger acids and bases than the M carbide.

Typical Problems in Spray Drying Applications

Feed stock - To provide consistently acceptable spray drying performance in repetitive production runs it is necessary to maintain strict control over each of the process factors. This control begins with providing the same composition, viscosity, and temperature of feed stock. Variations in the feed stock can result in variations in nozzle wear life or powder quality problems -and necessitate changes in other factors such capacity size, spraying pressure, air temperatures, etc.

Excessive Nozzle Wear or Corrosion - This problem can often be corrected by a choice of better wear resistant and/or better corrosion resistant materials. For instance, if hardened stainless steel orifices and cores are used, more wear life could be obtained from M carbide (note M and Y carbide are similar in chemistry, but M carbide is longer lasting than Y). If the nozzle has M (or Y) carbide orifices and cores, the "wear" problem may actually be one of corrosion. In this case the L carbide should be used. Please note that the L carbide has better chemical resistance than the M or Y carbides, but may not last as long in situations where chemical attack is not an issue. It is better to begin with the M carbide and if a drastic change in wear life is noted, then SSCO will work with the customer to determine if chemical attack is an issue, in which case the L carbide should be suggested. The corrosion problem can be caused by chemicals in the feed stock or by chemicals in the nozzle cleaning solutions. In these cases, the corrosive solution must be identified in order to choose the proper nozzle materials. Also, higher temperature solutions are usually more corrosive. Another factor is the amount of time that the parts are kept in the cleaning chemicals. See page 19 for information on the relative corrosion resistance of carbide materials.

Another important factor in nozzle wear life is the high velocity of abrasive feed stock through the orifices and cores. Nozzle wear can be reduced by lowering the feed pressure. However, occasionally this change adversely affects product quality. Another option is the use of multiple orifice nozzles _-3SK at lower pressures to provide three separate spray patterns with relatively large total capacities and smaller droplet sizes. Still another possible solution would be to use more smaller capacity nozzles at lower pressures, to achieve the same total product quantity with the desired droplet/particle sizes.

Occasionally an operator notices that the orifice inserts and cores do not last as long as previously and concludes that the insert and core materials are defective. However, in almost all of these cases it has been found that the problem was not in the nozzle materials, but in a process change such as: change of feed stock temperature or composition; change of pressure; or change in cleaning solution, temperature, concentration, or exposure time. When this happens, the process or cleaning changes should be reconsidered or a better material for the orifice insert and core should be substituted.

<u>Powder Moisture Content Too High</u> -This can occur when (1) nozzle flow rates are too high, (2) the droplet sizes are too large, (3) not enough heat is supplied for the evaporation process, and/or (4) excess water in feed.

Possible changes include (1) using smaller capacity nozzles, (2) using higher pressures, (3) increasing the heat input in the drying chamber, and/or (4) decreasing water in feed.

<u>Powder Moisture Content Too Low</u> -This can occur when (1) nozzle flow rate is too low, (2) droplet sizes are too small, (3) too much heat in drying chamber, and/or (4) not enough water in feed.

Possible changes include (1) using larger capacity nozzles, (2) increasing droplet size by lowering the pressure, (3) reducing the heat input into the drying chamber, and/or (4) increasing water in feed.

<u>Caking of Chamber Walls</u> -This problem can be caused by (1) spray droplets being too large, (2) nozzles being too close to the wall or having wide spray angles; and/or (3) not enough heat input into the drying chamber, with the drying air temperature or volume being too low.

Possible changes include (1) providing smaller droplets by increasing the spraying pressure, possibly with smaller capacity nozzles, (2) positioning further away from the wall or use narrower spray angle nozzles, and/or (3) introducing more heat into the drying chamber with higher air temperatures with more hot air.

<u>Too Many Fines in Powder</u> -This can be caused by spray nozzles producing too many fine droplets. In this case, a larger capacity nozzle, spraying at a lower pressure should be considered. If an air atomizing type nozzle is used, the air pressure could be reduced, or the feed pressure increased. However, from a practical point of view all of the fine droplets cannot be completely eliminated from sprays.

Another possible consideration would be to increase the solids concentration of the feed. Also, the original dried powder may be of the correct size, but if these particles are over-dried, they may be fractured or broken during the product collection and conveying process.

In some installations fines are returned to the system thru the chamber ceiling to become agglomerated with the atomized wet droplets. In other installations products are instantized by agglomerating in two stages. Powder agglomeration is achieved by allowing the powder to be moist on leaving the chamber; the moist powder particles then agglomerate, and are finish dried on a vibrating bed. The final powder particles are coarse and free of fines.

<u>Bulk Density Too Low</u> -This problem may have several possible causes. If there is a low solids feed concentration, it can be increased. Possibly the hot air or feed temperature in a co-current flow system is too hot, with the particles becoming puffed up in size, due to the high vapor pressure of the rapidly evaporating water. Also, it is possible that the moisture content is too low because the powder is being over-dried. See "Bulk Density" discussion in section IV.

Factors Affecting Powder Properties

As noted above, spray drying operations are complex, in that they involve many inter-related factors. Each specific property of a spray-dried product can be affected by several different factors.

For instance, product bulk density can be affected by powder moisture content, particle size distribution, porosity of particles, drying air temperature, and percentage of solids contents in the feed.

Moisture content of the particles varies with the drying air temperature, humidity, droplet sizes, and the retention times of droplets as they drop through the chamber.

Particle size distribution is controlled by the nozzle type and capacity, spraying pressure, agglomeration tendency, and various drying conditions.

Powder flow ability is affected by powder moisture, as well as by the particle sizes, size distribution, and particle shape.

Powder dispersability depends to a great extent on bulk density of the product, the porosity of the powder particles, and particle size distribution.

Properties such as purity, taste, and color can be affected by the feed, particle sizes and distribution, dwell time of the droplets in the chamber, spray pattern, air flow interface, and drying air temperature.

NOTE: In making process changes only one factor should be changed at one time, so that a proper relationship of cause-and-effect can be established.

As discussed above, each product, combined with a specific set of spray drying conditions, must be handled in a manner which provides the best final powder product. To do this, each operation has to be customized in all aspects, and constantly controlled and monitored in all operations. Based on trial-judgment procedures, ultimately each spray dried powder project becomes a standardized repeatable routine.

Section VII - Spray Drying Industries and Products

Food industry... including carbohydrates, dairy products, egg products, flavoring products, food products, plant extracts, fruits, and vegetables.

Chemical industry... including ceramic materials, soaps, detergents, dye fertilizers, mineral oil concentrates, cements, pesticides, plastics, resins, and organic and inorganic chemicals.

Bio-chemicals industry… pharmaceuticals, antibiotics, drugs, enzymes, hormones, vaccines, vitamins, amino acids, and yeast products.

Timber industry... tanning extracts from bark and wood, and cellulose.

Slaughter house and fish industries...animal protein, blood, gelatin, fish flour, fish meal, and fish soluble.

Products listed below have been spray dried with spray nozzles and others with rotary atomizers

Abrasive Slurries
Acetates
Acrylates
Agar-Agar
Albumin
Alcoholic extracts
Alfalfa
Alumina gels
Alumina
Aluminates
Aluminum
Aluminum chloride
Aluminum hydroxide
Aluminum hydroxide gels
Aluminum sulfate
Amino acids
Ammonium chloride
Ammonium phosphate
Animal blood
Antibiotics
Apples
Arsenates
Arsenic acid
Ascorbic acid
Aureomycen
Azo dyes

Baby foods
Bacitracin
Baking Compounds
Bananas
Barium Chloride
Barium Ferrite
Barium Hydroxide
Barium Sulfate
Barium titanate
Bark extracts
Beef extracts
Beet root
Bentonite
Benzoate
Berylia
Bile extract
Bismuth carbonate, nitrate
Black liquor
Blast furnace slag
Bleaching agents
Blood-Albumen, Serum Whole
Borates
Boric Acid
Bouillon
Brain
Bran

Cabbage
Cake Mix
Calcium Butyrate
Calcium chloride
Calcium phosphate
Calcium saccharate
Carbamide Resin
Carbon black
Carbonates
Carborundum
Carbowax
Carboxymethycellulose
Carnallite
Carrots
Casein, acid
Casein hydrolyzed
Caseinates
Catalysts
Cauliflower
Cellulose acetate
Cellulose hydrate
Celery
Ceramics
Ceramic colors
Ceramic enamels
Cereals
Cermets
Cheese
Chelates
Chicken broth
Chicken slurry
Chicory
China clay
Chlorides
Chlorinated rubber
Chlorophyll
Chromates
Chrome-iron oxides
Chromium sulfate
Citrates

Clays
Cocoa
Coffee
Color Pigments
Copper Oxide
Copper Sulfide
Corn Starch
Corn steep liquor
Corn syrups
Cosmetics
Cream
Cyanide, sodium

Dairy products - skim milk, butter, buttermilk, chocolate milk, whey, cheese, sodium caseinate, cream, edible casein)
Dates
Detergents
Dextran
Dextrose
Diatomaceous earth
Dioxides
Distillery by-products
Dithane

Eggs, whites, yolks
Emulsified enamels
Enzymes
Epoxy resins
Fabric softeners
Fats (spray cooling)
Feldspar
Ferric Chloride
Ferric Oxide
Ferric Sulfate
Ferrites
Ferrous Oxide
Ferrous Sulphate
Fertilizers
Fish albumen
Fish meat, hydrolized
Fish pulp
Flavors
Fluorides
Food colors
Formaldehyde resins
Formate sodium
Forsterite

Freon
Fruit juice
Fruit pulp
Fullers' earth
Fungicides

Garlic
Gels
Glands
Glauber salt
Glazes
Glucose
Glues
Glutens
Graphite
Ground glass
Gums
Gypsum

Herbicides
Hexamine
Hip
Hormones
Hydride, magnesium
Hydroxides
Hypochlorites

Ice Cream Mix
Inorganic Chemicals
Insecticides
Instant Coffee, Tea
Iron Oxide

Kaolin

Lactates
Lactose
Latex
Lead zirconate
Lemons
Licorice
Ligonin
Lithium chloride
Liver
Liver extract

Magnesium Carbonate, Silicate
Magnesium Oxide, Salts, Sulfates
Maleic acid

Malt extract
Malt syrup
Maltase
Malted Milk
Mangos
Mayonnaise
Meat protein
Mealmine resins
Mercury compounds
Metal powders
Metallic soaps
Milk
Mimola
Mineral concentrates
Molasses
Monoglycerides

Nickel compounds

Olive paste
Oranges
Organic compounds
Ovaries
Oxalic acid
Oxide ceramics

Pancreas
Pantothenate, calcium
Papaya
Paper fiber
Paprika
Peanut milk
Pectin
Penicillin
Pentachlorophenate
Pepsin
Peptones
Perfumes
Peroxides
Pharmaceuticals
Phenolic resins
Phosphates
Phosphoric acid
Phosphors
Photographic emulsions
Pigments
Plastic clay
Plastic emulsions
Pollen extracts
Polycarbonate
Polyethylene

Polymers
Polymethacrylate
Polypropylene
Polystyrene
Polyvinyls
Porcelain
Potassium acetate
Potassium carbonate
Potassium nitrate
Potassium phosphate
Potassium sulfites
Potatoes
Potato waste liquor
Powdered metals
Propionates
Proteins
Pudding powder
PVC emulsions

Quartz slurries
Quaternary salts

Refractory clays
Rennet
Resins
Resin soap
Rubber chemicals
Rubber latex
Rutile

Salicylic acid
Salicylates
Seat water
Sea weed extract
Selenides
Senna
Sequestering agents
Shellac
Silica-Alumina gels
Silicates
Silicon carbide
Soap
Sodium acetate
Sodium Adipate
Sodium Bisulfate
Sodium chloride
Sodium Chlorite
Sodium fluoride
Sodium hypochlorite
Sodium phosphate
Sodium silicate
Sodium sulphate
Sorbate
Sorbose
Soups
Soy bean protein
Soy flour
Soy isolates
Spinach
Starch products
Stearates
Stearic acid
Steatite slurries
Stick water (fish soluble's)
Streptomycin
Sugar
Sulfates
Sulfide, zinc
Sulfate spent liquors
Sulfite Lye
Sulfonates
Sulfur suspensions
Sulphonated Naphtalene
Surface active agents

Talc
Tannin extract
Tapioca
Tartaric acid
Tartrates
Tea
Teepol
Titanates
Titanium Dioxide
Tobacco,extracts,pulp

Tomatoes
Tungsten Oxide

Undecylenates
Uranium Oxides
Urea-Formaldehyde

Vanadium Oxides
Vegetables extracts
Vegetables fats
Vegetables proteins
Vitamins

Wall tile slurries
Waste products
Water glass
Wax
Weed killers
Wetting agents
Wheat glutin
Whey

Yeast
Yeast extract
Yeast hydrolysates

Zeolites
Zinc Ammonium Chloride
Zinc Arsenate
Zinc Chromate
Zinc Stearate
Zinc Sulfate

Section VIII - Spraying Systems Co. Spray Nozzles

General performance features of SSCo. SprayDry® nozzle types

1) Hydraulic Atomizing Nozzles

   A) Low Capacity / High Pressure
   B) Medium Capacity / High Pressure
   C) High Capacity / Medium Pressure
   D) Miscellaneous Nozzles

2) Two – Fluid Atomization

   A) 1/4J
   B) 1/2J
   C) 1J

General performance features

1) Hydraulic Atomizing Nozzles

   A) Low Capacity / High Pressure Nozzle type SK series including SK, SK-MFP, SKH-MFP, and SKHN-MFP. See Bulletin 527.

   - Hollow cone spray pattern

   - Water capacities from 32.8 to 400 gph (10.8 to 1460 l/hr) based on water at 70 degrees F.

   - Maximum pressure 7000 psi (483 bars)

   - Three spray angle sizes for every capacity increment

   - Orifice insert and core material: specially treated hardened stainless steel, and tungsten carbide.

   - Flow rates not drastically affected by viscosities below 400 cp.

   - SK-MFP, SKH-MFP, and SKHN-MFP have maximum free passage for dramatically reduced clogging.

   - SKH-MFP has hand tight o-ring seal

   - SKH-MFP has an anti-bearding front end

- SKH-MFP has an integrated check valve to keep liquid from draining into the tower when the pump is shut off.

- SKHN-MFP has all the features of the SKH-MFP except it does not have the check valve.

B) Medium Capacity / High Pressure SB series Nozzles including SB, SB-MFP, SBH-MFP, and SBHN-MFP. See Bulletin 504.

- Hollow Cone Spray Pattern

- Water capacities from 38.9 to 1508 gph (148 to 5510 l/hr)

- Maximum pressure 7000 psi (483 bars)

- Three spray angle sizes for every capacity increment

- Orifice insert and core material: specially treated hardened stainless steel, and tungsten carbide.

- Flow rates not drastically affected by viscosities below 400 cp.

- SB-MFP, SBH-MFP, and SBHN-MFP have maximum free passage for dramatically reduced clogging.

- SBH-MFP has hand tight o-ring seal

- BKH-MFP has an anti-bearding front end

- SBH-MFP has an integrated check valve to keep liquid from draining into the tower when the pump is shut off.

- SBHN-MFP has all the features of the SBH-MFP except it does not have the check valve.

C) High Capacity / Medium Pressure 104 series nozzles. See Bulletin 447.

- Hollow Cone Spray Pattern

- Water capacities from 16.1 to 3019 gph (61.5 to 11340 l/hr)

- Maximum pressure 5000 psi (340 bars)

- Three spray angle sizes for every capacity increment

- Orifice insert and core material: tungsten carbide.

- Flow rates increase drastically with viscosity increases.

- Whirchamber type nozzles have maximum free passage for dramatically reduced clogging.

D) Miscellaneous Nozzles

- 3SK series has three of the SK orifice and cores along with a built-in strainer

- SSTC Whirlchamber type nozzles use the same whirlchamber and orifice as the 104 style but is only rated to 1000 psi. Use the 104 style for new customers.

- SBC nozzles are rated to 2000 psi. Use the SK-MFP style for new customers.

2) Two – Fluid Atomization. 1/4J, 1/2J, and 1J

- Cone and flat spray patterns

- Droplet sizes from very fine to medium

- Capacities from 2 to 1700 gph (8 to 6400 l/hr), based on water

- External mix round and flat spray set-ups permit wide range in atomization without affecting feed flow rates.

-Internal mix round and flat spray set-ups can provide variations in atomization accompanied by simultaneous changes in feed flow rates.

- Low pressure operation: less than 125 psi (8.6 bars) for compressed air and feed.

- Choice of brass, stainless steel, hardened stainless steel, or tungsten carbide orifice inserts available.

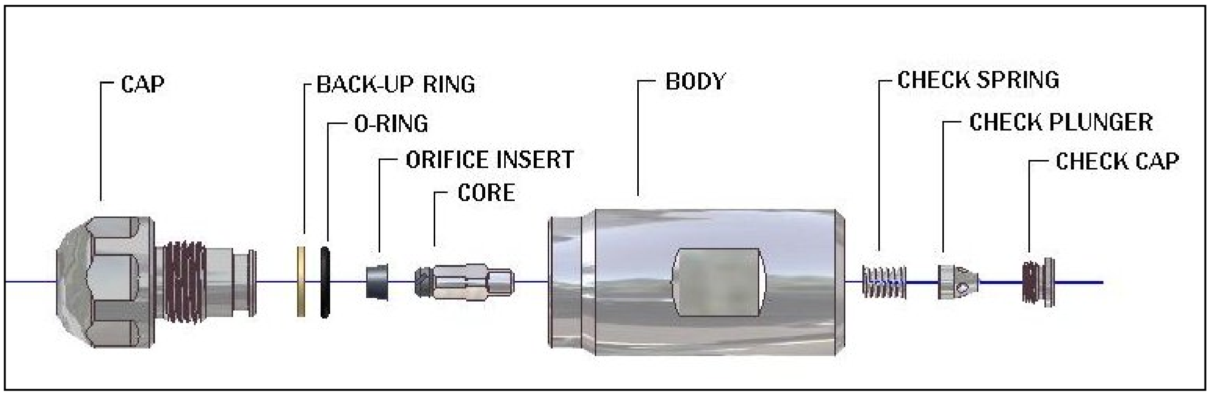
- Spray can spray viscous liquids over 700 cp and with less viscous liquids the nozzles can produce many fine mist-like droplets.

1) Spraying Systems Co. Pressure Spray Nozzles

Spraying Systems Co. pioneered the development of specialized nozzles for the spray drying industry in the early 40's. It continues to offer a wide choice of nozzle types, flow capacities and spray angles, materials of construction, operating pressure ranges, droplet sizes, and pipe connection sizes. SprayDry® nozzles are designed to provide good atomization with uniform spray distribution throughout the hollow cone circular pattern in a wide range of spraying pressures. These precision built nozzles are of durable construction and are designed to allow quick and easy assembly and disassembly. For complete information on these spray nozzles and their performance data see Bulletin 527 for the SK series, Bulletin 504 for the SB series, and Bulletin 447 for the 104 and other WhirlJet series.

A) SK SprayDry® Nozzles – Low Capacity / High Pressure Nozzles

SKHN-MFP SprayDry Nozzle



The type SK nozzle series provides orifice insert-core combination sizes with a water capacity range from 2.8 to 400 GPH (10.8 to 1460 l/hr). The spray angles, as measured close to the orifice, vary from 45° to 90°, depending on the orifice-core combination. The SK series offers a selection of interchangeable materials for the orifice insert and core tip, to meet the erosion and chemical resistance requirements in each spray drying application.

The nozzle body, cap, and core body are made of 303 stainless steel. Type 316 stainless steel parts are also available. The interchangeable orifice inserts and cores are supplied in specially treated and hardened stainless steel, tungsten carbide in either the Y or preferred M versions and also the L carbide. The Y and M grades of tungsten carbide are similar chemically but the M carbide is a finer and longer lasting grade. New customers should be directed to the M carbide and an effort should be made to change over our existing Y customers to the M carbide. The L carbide is formulated to have more chemical resistance than the Y or M. When chemical compatibility with the Y or M is not an issue then the Y or M will last significantly longer than the L. SSCO headquarters will work with the sales offices and customers to be sure L carbide is the correct choice.

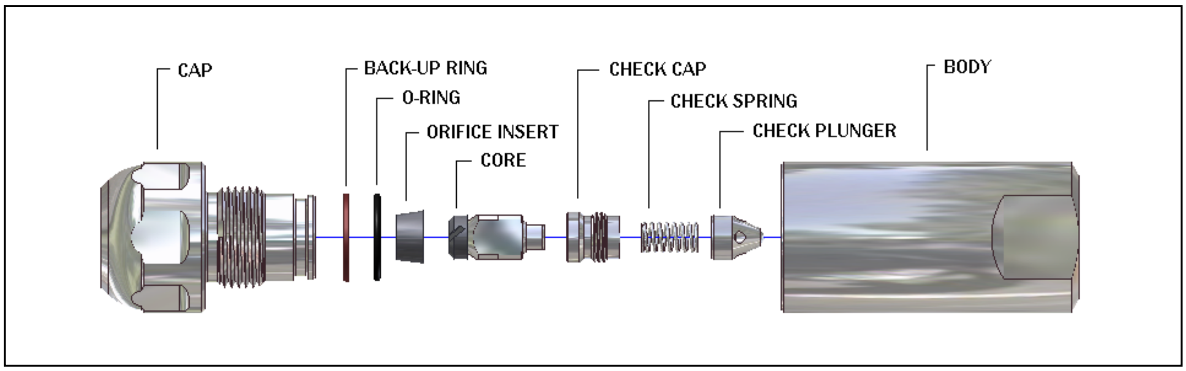
NOTE: All references in this Manual to capacities, spray angles, and droplet sizes are based on spraying water. These characteristics will be different for feed stocks, depending on many factors including feed viscosity and specific gravity, and the nozzle type and size. References to spraying pressures are based on the pressures at the nozzles and not at the pump.

SprayDry® is a trademark registered by Spraying Systems Co.
For the SK and SK-MFP versions, the maximum recommended temperature when spraying varies with the choice of gasket materials: fiber is rated at 300°F (150°C); nylon, 300°F (150°C); aluminum 1000°F (540°C). For the SKH-MFP and SKHN-MFP the standard O-ring is Viton and the standard back-up ring is PEEK. The operating temperature rating is 400°F (240°). A higher temperature Kalrez gasket is also available with a rating of 600°F (316°C). Pipe connection sizes are _, 3/8, and 1/2 in either NPT or BSPT female. Thread-less welded bodies are also available on request. Drop sizes vary with the properties of the feed stock and are in the Medium Volume Diameter range of 20 to 120 microns based on spraying water.

There is no longer a cup top version of the SK series nozzles. These have been replaced with the MFP design. The MFP design, like the old cup top version, provides less pressure drop when spraying viscous liquids and will, therefore, provide better atomization. The MFP design also is a dramatic improvement when clogging is an issue. For complete nozzle and spray performance information see Bulletin 527.

B) SB SprayDry® Nozzles -larger capacities

SBHN-MFP SprayDry Nozzle



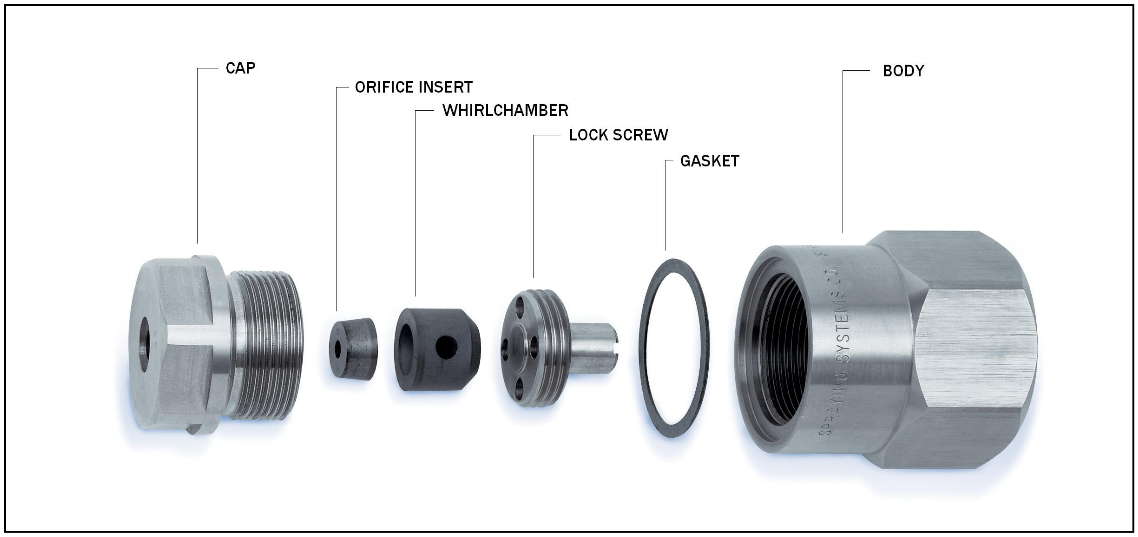
Type SB SprayDry® nozzles are the same design as type SK except that the SB nozzles are larger and provide higher capacities. With water the SB nozzles provide a capacity range from 38.9 to 1508 GPH (148 to 5510). Depending on specific orifice insert-core combinations, the spray angles at the orifice range from 34° to 109°.

The nozzle body, cap, and core body are made of 303 stainless steel. Type 316 stainless steel parts are also available. The interchangeable orifice and cores can be supplied in a choice of specially treated hardened stainless steel or tungsten carbide in either the Y or preferred M versions and also the L carbide. The Y and M grades of tungsten carbide are similar chemically but the M carbide is a finer and longer lasting grade. New customers should be directed to the M carbide and an effort should be made to change over our existing Y customers to the M carbide. The L carbide is formulated to have more chemical resistance than the Y or M. When chemical compatibility with the Y or M is not an issue the L should not be specified because the Y and M will last significantly longer than the L. SSCO headquarters will work with the sales offices and customers to be sure the L carbide is the correct choice.

Flat top cores are standard however cup top cores are still available in all materials. New customers should be directed to the flat top MFP version of the M carbide if possible. The cup top option was made to provide better atomization of viscous liquids by reducing the pressure drop leading up to the core slots. The MFP flat top version does a better job of reducing pressure drop in viscous liquids and is longer lasting; along with dramatically reducing the chance of clogging. Existing customers of the cup top cores should also be encouraged to use the flat top MFP as the better option.

C) TYPE 104 WhirlJet® Nozzles

AA104 SprayDry Nozzle



Type 104 SprayDry® WhirlJet® nozzles are used for larger capacity requirements, as well as for larger drop sizes, usually at lower spraying pressures. Water capacities range from 16.1 to 3019 GPH (61.5 to 11340 l/hr).

Supplied with an internal slope bottom design type WC-X whirlchamber minimizes erosion on the whirlchamber bottom and results in longer wear life. Standard design, flat bottom type WC-whirlchambers are also available. Orifice inserts and slope bottom whirlchambers are offered in tungsten carbide.

Body, cap, and lock screw are made of type 303 stainless steel. The whirlchamber is held securely in place with a lock screw, while the orifice insert is pressed into the nozzle cap. Large passages and large holes in the whirlchambers make this a maximum free passage design.

Interchangeable caps and bodies provide over 150 different capacities and spray angles. For tabulation and spray performance information see Bulletin 447.

The maximum recommended spraying pressure is 5000psi (345bar). The maximum recommended temperature while spraying depends on the gasket: 300°F (150°C) for fiber and nylon gaskets; 1000°F (540°C) for aluminum gaskets.

Type 104-AA nozzles have 1/4”, 3/8”, and 1/2” NPT (F) inlet connections. Type 104-3/8 has a 3/8” NPT (M) inlet, while type 104-1/2A has a 1/2” NPT (F) inlet connection, also available with BSPT connections. The range of droplet sizes for type 104 spray nozzles, spraying water is from 25 to 275 microns, Median Volume Diameter.

D) Miscellaneous Nozzles

1/4-3SK Multi-orifice SprayDry® Nozzles, with strainers: This multi-orifice nozzle has three orifice mounted in the cap. Capacity is three times that of SK nozzles. Built-in strainer. Type 303 stainless steel construction. High flow rates with small droplet sizes. Specially treated hardened stainless steel orifice inserts and cores.

Orifice inserts and cores are available in the same materials as the standard SK series. Inlet connections are also available in 3/8 and _ NPT(F) an also BSPT.

Maximum recommended spraying pressure is 7000psi (483bar). Maximum recommended temperature when spraying is based on the gasket: fiber-300°F (150°C); aluminum-1000°F (540°C). Overall length is 5-1/2” (14cm), with 1-7/8” (4.8cm) body outside diameter. See Bulletin 527 for orifice and core sizes and PL 3SK for other components.

TYPES AA-SSTC, BB-SSTC AND AAA-SSTC WhirlJet® Nozzles: Type AA-SSTC WhirlJet® nozzles have 1/4”, 3/8”, and 1/2” NPT (F) inlet connections; type 3/8BB-SSTC has a 3/8” NPT (M) inlet; and the type 1/2AAA-SSTC has a 1/2” NPT (F) inlet connection, also available with BSPT. Their spray performances are identical to those of the type 104- WhirlJet® spray nozzles except that the pressure rating is a maximum of 1000psi..

Type SSTC WhirlJet® nozzles consist of six parts: nozzle body, cap, gasket, internal spring, whirlchamber, and orifice insert. The nozzles are type 303 stainless steel construction, with abrasion resistant carbide whirlchambers and orifice inserts.

The optional slope bottom whirlchambers provide an extended wear life and are supplied in tungsten carbide. Standard flat bottom whirlchambers are also made in tungsten carbide.

Orifice inserts are available in tungsten carbide. All whirlchambers and orifice inserts are interchangeable, thereby providing over 150 different combinations of capacities and spray angles. For listing of sizes and spray performances see SprayDry® Nozzles Bulletin 447.

Maximum recommended operating pressure is 1000psi (69bar); maximum recommended spraying temperature varies with the gasket: fiber 300°F (150°C); Teflon 300°F (150°C); and aluminum 1000°F (540°C). Since there are no internal obstructions, performance is clog-free.

SBC SprayDry® Nozzles: The compact type SBC nozzles provide a hollow cone spray with uniform distribution of droplets. Interchangeable orifice insert sub-assemblies are changed by simply unscrewing the nozzle cap. BY-HSS-orifice insert sub-assemblies contain a hardened stainless steel orifice while the BY-HSSTC-sub-assemblies have a tungsten carbide orifice insert. No need to change cores since the same core, without slots, is used for all capacity sizes.

With water at 1000psi (69bar), the Median Volume Diameter droplet sizes range from 50 to 120 microns with a capacity range from 15 to 70GPH (57 to 262l/h). The square body cores provide larger passages, thereby reducing clogging.

Five part nozzle: nozzle body, core, cap, gasket, and orifice insert sub-assembly. All SBC-nozzle assemblies use the same (not-slotted) hardened stainless steel core. Body and cap are 303 stainless steel. Nozzle capacity sizes are changed simply by interchanging the orifice insert sub-assemblies. Maximum recommended spraying pressure is 2000psi (138bar). The maximum recommended spraying temperature is based on the gasket used: fiber-300°F (150°C); nylon-300°F (150°C); or aluminum-1000°F (540°C). Inlet connection is 1/4" NPT (F), also available with BSPT.

The flow rate range of this older SBC design is in the range of the SK series and the SKH-MFP should be specified for new customers. Existing customers of the SBC may also benefit by switching to the SKH-MFP.

See Data Sheet 24311 for capacity data.

2) Spraying Systems Co. Two-Fluid Air Atomizing Nozzles

1/4JBC Air Atomizing Nozzle

1/4J Air Atomizing Nozzle

Two-fluid nozzles are used to obtain very fine particles and to spray viscous or abrasive feeds (above 700cp), which cannot be properly atomized with pressure spray nozzles. Frequently used in laboratory and pilot plant installations. The atomizing energy in a two-fluid nozzle is supplied by the compressed air, pressurized steam, or a pressurized inert gas, which shears the fluid leaving the fluid nozzle orifice, thereby forming very fine spray droplets.

When spraying abrasive feeds, external-mix air-atomizing nozzles are used. In these external mix set-ups, the contact between the feed and the compressed air, gas, or steam takes place outside of the nozzle chambers. This minimizes erosion and clogging problems.

The feed capacity range can vary depending on the specific application, nozzle type, spraying pressures, and spray set-up. The spray pattern can be round or flat, depending on the spray set-up chosen. See the most recent Spraying Systems industrial catalog for the 1/8J, 1/4J, 1/2J, and 1J options.

Water capacities can range from 2 to 70GPH (8 to 262l/h) with 1/8J- and 1/4J- type nozzles type having 1/8" and 1/4" NPT (F) connections. Larger water capacities up to 1700GPH (6400l/h) can be obtained by using larger size 1/2J and 1J air atomizing nozzles having 1/2" or 1" NPT (F) connections. Also available with BSPT connections. All type J nozzles are available in brass or stainless steel. Other materials are available on special request. Droplet sizes depend on many factors, including the spray nozzle size, Spray Set-up, feed stock, and the air and feed stock pressures. Spraying water, the Median Volume Diameter droplet size ranges from 10 to 200 microns. For applications requiring wear resistant materials, hardened stainless steel and tungsten carbide orifice inserts can be supplied on a special basis.

Maximum recommended pressure is 125psi (8.6bar). The maximum recommended spraying temperatures depend on the gasket materials: Buna-N 300°F (150°C); Teflon 600°F (320°C); aluminum and copper 1000°F (540°C).

Typical applications using Spraying Systems Co. nozzles

Because of the many different possible combinations of spray dryer types and capacities, feed stock properties, product quality requirements, temperatures, and pressures used, the choice of spray nozzle and spraying pressure for a specific application is made by a trial and judgment process. In many cases different types and sizes of nozzles, operating under different dryer conditions, can produce similar quality products. Normally the same type nozzle is used in different plants for the same product but with different orifice inserts, cores, and spraying pressures; in each case a high quality product results.

For instance, type SK-spray drying nozzles are used for many applications including dye stuffs, food powders, milks, gelatins, pharmaceuticals, proteins, vegetable powders, wheat gluten, lard, whey, and yeast, animal blood, blood plasma, sodium caseinate, cheese, eggs, fruit powders, acids, animal milk replacement, digestive animal bi-products, sodium laurel sulfate, whipped topping, proteins, and tea.

Applications for larger capacity type SB nozzles include: cheese, coffee, dye stuffs, eggs, food powders, milk, cocktail drink mixes, sugar substitutes, wheat starch, vegetable oils, proteins, tea, wheat gluten, and whey. Type 104-WhirlJet spray nozzle applications include: animal blood, detergents, and catalysts (petrol). Type SSTC WhirlJet nozzles are used frequently for spray drying coffee, detergents, dye stuffs, tungsten carbide, cobalt, acetone, and paraffin. Typical applications for type SBC--spray drying nozzles include detergents, eggs, meat extracts, and milk.

Similarly, type J two-fluid air atomizing nozzles have been used for spray drying very viscous liquids, starches, gelatins, synthetic resins and rubbers. Laboratory and pilot plant installations are frequently operated with air atomizing nozzles.

Section IX - Appendix

GLOSSARY OF TERMS

ABSORBERS (Dry) -Atomizer systems using reagent feed stocks to absorb and react with toxic gases, such as SO_2, HCL, etc. The resulting newly formed compound is a non-toxic dried powder.

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 particle in a fluid bed instantizer (2-stage spray drying). Used to provide "instantizing" qualities to the powder.

AIR ATOMIZATION -See Pneumatic Atomization.

AIR BROOM -Blowing air to sweep clean and/or cool dryer chamber walls.

ALKALINE -Tending to form a base

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

ATOMIZER -Equipment which breaks up liquid bulk into small droplets forming a spray, such as spray nozzles or rotary atomizers.

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

BAG COLLECTOR -A filter which separates dried powder from the exhaust drying air.

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

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

BLUNGING -Mixing of ceramic materials in a liquid by agitation.

BOX DRYER – (Horizontal) -A rectangular shaped spray dryer with nozzles spraying horizontally into the drying chamber.

BTU (BRITISH THERMAL UNIT) -A unit of heat energy to raise 1 lb. of water 1°F at atmospheric pressure. (1 BTU = 252 Calories) (1 Calorie = 0.004 BTU).

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 chemical-thermal reaction in a product, without melting the product.

CALORIES -Unit of heat energy to raise 1 gram of water 1°C at atmospheric pressure. (1 BTU = 252 calories) (1 Calorie = 0.004BTU).

CAPACITY -Flow rate per unit of time (atomizers); or amount of water evaporated per unit of time dryers); or amount of product produced per unit of time (spray dryers).

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

CENTIPOISE-A unit of viscosity equal to 0.01poise.

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

C.I.P. -Clean in place ...nozzles or manifold systems installed in processing equipment and used for cleaning.

CLOSED SYSTEM (Closed Loop) -a spray drying system that recycles the hot inert gas, such as nitrogen...as well as the liquid in the feed stock. (No exhaust into the atmosphere.)

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

CO-CURRENT FLOW (Con-current flow) -The flow of hot drying in the same direction as the sprayed feed.

CONCENTRATOR -Equipment which 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 ...such as waxes, caustic soda, sulfur, etc.

COUNTER-CURRENT FLOW -The flow of the hot drying air/gas in the opposite direction as the sprayed 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 drying droplet at the point where the drying rate drops sharply, but continues at a falling rate.

CRYSTALIZATION -Formation of crystalline substances from solutions.

CYCLONES (WET OR DRY) -Conical chambers wherein solid particles are removed by centrifugal action. Wet type cyclones use spray nozzles to wet particles for easier recovery.
DEGRADATION -Deterioration or destruction of desirable powder qualities, as by overheating.

DIRECT HEATER SYSTEM -Provides direct contact between spray dried materials and the gaseous products of combustion. Efficiency ranges from 95% to 98%.

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

DROPLET DIAMETER -Diameter of atomized feed stock droplet, usually measured in microns (micrometers). Since spray nozzles provide a distribution of droplet sizes rather than the same size diameter, droplet size usually made in terms of Median Volume Diameter (Volume Median Diameter) or Sauter Median Diameter.

DROPLET SIZE DISTRIBUTION -Describes the array of spray droplet diameter sizes in relation to the volume percentages of the spray.

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

DRY SCRUBBING -The process used in absorbers (for toxic and obnoxious gases), wherein sprayed feeds react chemically with the gases, forming harmless non-toxic compounds, which are then collected as solid powder particles. See ABSORBERS (Dry).

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

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

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

ENCAPSULATING -The encasing of particles in an inert protective carrier to help preserve the quality of the (particle) ingredients.

EVAPORATOR -Equipment for concentrating feed stocks to provide a higher percentage solids content, usually prior to spray drying operations.

EXTRACTOR -Equipment for concentrating feed stocks to provide higher percentage solids content, usually prior to spray drying operations ...as in the process of spray drying coffee.

EXTERNAL MIX NOZZLES -Air atomizing nozzles which provide the liquid atomizing air contact outside of the nozzle, at the liquid and air orifices location.

FALLING FILM EVAPORATOR -Equipment used for concentrating feed stocks, wherein the liquid flows downward forming a fine film on the inside of metal tubes, which are heated (on the outside) by steam. Evaporation of some liquid increases solids concentration in feed.

FEED (FEED STOCK) -Liquid solutions, slurries, suspensions, melts, sludge's or pastes which are atomized in spray dryer.

FGD (FLUE GAS DESULFURIZATION) -Removal of toxic or obnoxious gases, such as SO_2, HCL, etc. from flue gases. See ABSORBERS.

FINES -Extremely small sizes of liquid droplets or solid particles (approaching dust-like).

FLASHING (FLASH DRYING) -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.

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 spray.

FLUID BED AGGLOMERATORS -Fluidized beds, used after the first spray drying stage, wherein additional feed is sprayed on to the fluidized bed particles to increase the size of the particles, 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 above the bed.

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

FLUID (FLUIDIZED) BED DRYERS -Fluidized bed using hot air or gas to complete the drying process.

FRIABLE -The property of powders capable of being easily crumb led 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 by being exposed to (too) high temperatures.

HEAT SENSITIVE MATERIALS -Products whose desirable properties are damaged or destroyed by heat.

HOMOGENIZER -Equipment that blends or emulsifies a substance by forcing it through fine passages against a hard surface.

HORIZONTAL (BOX) DRYER -Rectangular shaped drying chamber with nozzles usually spraying horizontally.

HYDRATION -Combining with water.

HYGROSCOPIC -Readily absorbing or abstracting moisture, such as from air.

INDIRECT HEATER DRYING -The process in which the drying air or gas is heated by contacting the metal fins of tubes through which steam or hot combustion gases are flowing. Efficiencies range from 70% to 85%.

INSTANT PROPERTIES -The properties of powders which allow them, upon being put into water, to be wetted very quickly, sink down into the water, disperse in the water, and quickly dissolve.

INSTANTIZER -Equipment that produces instant products. See REWET AGGLOMERATION.

INSTANTIZING -Process of transforming spray dried powder particles into porous agglomerates through the use of a 2-stage spray drying process. See REWET AGGLOMERATION. The “instantizing” quality of spray dried products describes their quickness in dissolving in water, and is the result of the combined wet-ability, sink-ability, dispersability, and solubility properties of the dried powders.

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

INTERNAL MIX NOZZLES -Air atomizing nozzles which provide the air contact inside the nozzles in the internal r of the

INTERSTITIAL AIR -Air space between dried powder particles, affecting 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, thereby consolidating the powder. This newly formed "green" compact is then used for further shape-forming operations, such as turning, drilling, grinding, etc.

KINETIC ENERGY -Energy 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 ... such as water being evaporated, from a liquid to a vapor.

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

LOW TEMPERATURE SPRAY DRYING -Spray drying process which uses dehumidified air, warmed moderately over the ambient temperature, to dry products which are extremely heat sensitive.

MECHANICAL SWEEP -A mechanical arm which moves the spray dried powder from the drying chamber floor to a conveyor.

MEDIAN VOLUME DIAMETER (MVD) -A unit (usually expressed in microns or micrometers) used as a liquid droplet size reference and based on the volume or mass of the liquid sprayed. Specifically it is the droplet diameter size where 50% of the total volume or mass of the liquid sprayed is made up of droplets with diameters larger than the Median Volume Diameter and 50% of the mass or volume is in droplet diameters smaller than the Median Volume Diameter. Also known as VMD (Volume Median Diameter) and

MICRON (MICROMETRE) -Unit of linear measure. (One micron = .001mm = 1/254000 of an inch). Symbol is or m.

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 (DISCHARGED LIQUOR) -Liquid which remains after a processing operation; can be the effluent or product.

MULTI-STAGE DRYER -A dryer in which the sprayed wet powder falls onto an integrated stationary fluidized bed for preliminary drying, after which it goes to a vibrating bed or fluidized 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 without any water.
NON-NEWTONIAN FLUID -Fluid which does not flow as water. The liquid shear is not proportional to the stress.

OCCLUDED AIR -Air which is trapped inside particles.

ONE STAGE DRYING -A drying process which produces a finished dried powder in one operation.

OPEN SYSTEM -The usual spray drying system which 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 perhaps, its desirable properties have been degraded or destroyed.

OXIDATION -A chemical reaction which increases the oxygen content of the product. This can be prevented by spray drying in a self-innertizing system or in a closed system.

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 "apparent" diameter, which 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, and moist substance.

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

PENETRATIBILITY -Same as sink-ability.

PERCENT SOLIDS -Percentage of solids in feed stocks (by weight).

PITOT TUBE -for measuring air velocities in ducts.

PNEUMATIC ATOM ZATION (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.

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

POISE -A unit of liquid viscosity. Equals 100centipoise.

POROSITY -Property of solid particles relating to the minute open spaces within the particle.

PRESS CAKE -Nonflowing uniformly dispersed mass of mixture of water and solids.

PRESSURE SPRAY NOZZLES -Spray nozzles which provide feed stock atomization high pressure feed flows through small orifices..

PRILLING (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.

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

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

REACTOR (REACTOR TOWER) -Process vessel in which chemical reactions take place during a chemical conversion process such as in dry FGD systems, in which the sprayed feed stock combines chemically with toxic components of a flue gas to form new compound powders which are non-toxic and disposable.

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

RESIDENCE -See Dwell Time.

RETENTION -See Dwell Time.

REWET AGGLOMERATION (SPRAY FLUIDIZERS) -An agglomeration process wherein moist spray dried powders are sprayed with water or feed stock while over a fluidized bed, thereby causing wet particles to join together, before the final cooling and drying over a fluidized bed. This process makes dustless granules.

REWET INSTANTIZER -Equipment for the rewet agglomeration process.

ROTARY AIR LOCK (VALVE) -Equipment which provides a control led discharge of a powder from hopper, while maintaining either a positive pressure or vacuum inside the container.

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

SAUTER MEAN DIAMETER -The Sauter Mean Diameter expresses a uniform droplet size diameter in terms of the actual total surface area produced by the totality of droplets in a given spray. It is obtained by summing the surface areas of all the droplets produced by the spray in a given time, and the total volume of all the droplets. The total volume of all the droplets is then divided by the total surface area of all the droplets to find the diameter of a droplet having the same volume to surface area ratio. This droplet diameter value is the Sauter Mean Diameter. It is used in heat-transfer applications.

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 where 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 using aqueous feeds where the dried product must not contact large amounts of air/oxygen due to the risk of a powder explosion or product degradation (by oxidation). It is also used to limit atmospheric emissions whenever necessary, since the amount of air bled from this system is closely controlled and is very small in relation to the total gas flow required for the drying operation. It is usually used with gas fired heaters and with the combustion air (used by the burner) precisely controlled, resulting in a drying gas flow with a very low oxygen content. This is a form of semi-closed cycle. See section II.

SEMI-CLOSED CYCLE -This is a compromise between open-cycle and closed-cycle plants. The dryers are not gas tight. The basis of this layout is to limit the amount of gases sent into the atmosphere. See SELF INITIALIZING SYSTEM.

SENSIBLE HEAT -The total heat content of a substance.

SEPARATION -The process of removing dried particles from the drying exhaust.

SINGLE FLUID NOZZLE -Pressure spray nozzle which provides atomization by liquid pressure alone.

SINKABILITY -Ability of a powder to sink down into the water after being wetted.

SLUDGE -Semi-solid mass.

SLURRY -Suspension of solid particles in a liquid.

SOLUBILITY -The rate of dissolving...or the total solubility, such as the solubility index.

SOLUTION -A single homogeneous liquid mixture in which the components are uniformly distributed.
SPECIFIC GRAVITY -Ratio of density o f another material to that of water, which weighs 8.34 lbs. per gallon and 62.4 lbs. per cubic foot (1kg per liter).

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

SPINNING DISC-Rotating wheel of a rotary atomizer.

SPRAY ABSORPTION -Absorption of gases by sprayed feed droplets. See Absorbers.

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

SPRAY COOLING -See Prilling

SPRAY FLUIDIZER -See REWET AGGLOMERATION

SPRAY DRYER -Equipment in which an atomized feed stock is dried into a powder by direct contact with a flow of hot

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 purpose of achieving a chemical reaction between the gas and liquid. See Absorbers.

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

SULFONATION -Chemical for converting compounds, such as benzene, into an acid (by adding an SO_2H group).

STRAIGHT-THROUGH DRYER -One 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.

SUSPENSIONS -See Slurry

TANGENTIAL VELOCITY -The instantaneous linear velocity of a body moving in a circular path; its direction is tangential to the circular path at the point in question.

THERMOPLASTIC PRODUCTS -Products which would melt or become sticky at spray drying temperature.

THIXOTROPIC -Property of certain gels which liquefy when subjected to shaking or vibration and then solidify when left standing.

THREE-FLUID NOZZLE -An air atomized nozzle with one central liquid orifice surrounded by two channels or annular rings of air outlets. Used for more viscous materials.

TOWER DRYER -A tall vertical round spray dryer as contrasted to the box type horizontal spray dryer.

TWO-FLUID NOZZLE' -An air atomizing nozzle usually with one central fluid orifice and with the atomization energy provided by high velocity compressed air through the nozzle.

TRAY DRYER -Vertical process tower having the height 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 usual 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. This type fluid bed also has a self emptying feature.

FLUIDIZER -See Vibrating Fluid Bed.

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

VOLUME MEDIAN DIAMETER (VMD) -See MEDIAN VOLUME DIAMETER

VORTEX -A continuous powder discharge technique for cyclones, used with pneumatic power conveyors.

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.

WETTABILITY -Ability of the particle to absorb water on its surface...to be wetted.

WET SCRUBBER -Installation for removing solid particles or gases from an stream by using liquid sprays.

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

Celsius-Fahrenheit Temperatures							
°C	°F	°C	°F	°C	°F	°C	°F
20	68	74	165	128	262	182	360
22	72	76	169	130	266	184	364
24	75	78	172	132	270	186	367
26	79	80	176	134	274	188	370
28	82	82	180	136	237	190	374
30	86	84	183	138	280	192	378
32	90	86	187	140	284	194	382
34	93	88	190	142	288	196	386
36	97	90	194	144	291	198	389
38	100	92	198	146	295	200	392
40	104	94	201	148	299	205	401
42	108	96	205	150	302	210	410
44	111	98	208	152	306	215	419
46	115	100	212	154	310	220	428
48	118	102	216	156	314	225	437
50	122	104	220	158	317	230	446
52	126	106	223	160	320	235	455
54	129	108	226	162	324	240	464
56	133	110	230	164	327	245	473
58	136	112	234	166	330	250	482
60	140	114	237	168	334	255	491
62	144	116	240	170	338	260	500
64	147	118	244	172	341	265	509
66	151	120	248	174	345	270	518
68	154	122	251	176	349	275	527
70	158	124	255	178	352	280	536
72	162	126	259	180	356	285	545
						290	554
						300	572

Conversion Factors - U.S. to Metric		
Multiply	**By**	**To Obtain**
British Thermal Units (Btu)	252	Calories (cal)
Cubic Feet (ft^3)	28.3	Liters (l)
* Fahrenheit (quantity)	.56	* Celsius (quantity)
Feet (ft)	.3	Meters (m)
Gallons (U.S.) (Gal)	3.79	Liters (l)
Gallons (U.S.) per Minute (GPM)	3.79	Liters per Minute (l/min)
Gallons (U.S.) of Water (Gal)	3.79	Kilograms of Water (kg)
Miles per Hour (MPH)	1.61	Kilometers per Hour (km/h)
Pounds (Lbs.)	.45	Kilograms (kg)
Pounds per Square Inch (psi)	.069	Bar (bar)
Pounds per Square Inch (psi)	.068	Atmospheres (atm)
Pounds per Square Inch (psi)	.070	Kilograms per Square Centimeters (kg/cm^2)
Pounds per Square Inch (psi)	6.9	Kilopascals (kPa)
Square Feet (ft^2)	.093	Square Centimeters (cm^2)

Note: One U.S. Gallon equals .83 Imperial Gallons

*This is not a conversion factor for temperature readings. This factor specifically converts a temperature drop (or rise) in °F to °C, and vice-versa.

Example: A temperature drop (or rise) of 10° F equals a temperature drop (or rise) of 5.6° C

TABLE SS-1 - SIEVE SIZES				
SIEVE OPENING		**MESH NO.**		
INCHES (APPROX.)	**MICRONS (MICROMETRES)**	**U.S. STD.**	**BRITISH STD.**	**GERMAN STD.**
.033	841	20		
.031	800			0.80
.028	710		22	
.0278	707	25		
.031	630			0.63
.024	600		25	
.023	595	30		
.020	500	35	30	0.50
.017	420	40	36	
.016	400			0.40
.014	355		44	
.014	354	45		
.0124	315			0.315
.012	300		52	
.0117	297	50		
.010	250	60	60	0.25
.008	210	70	72	
.0078	200			0.20
.0071	180		85	
.0070	177	80		
.0063	160			0.16
.006	150	100	100	
.005	125	120	120	0.125
.004	105	140	150	
.0039	100			0.1
.0035	90	170	170	0.09
.0031	80			0.08
.0030	75		200	
.0029	74	200		
.0027				0.071
.0025	63	230	240	0.063
.0022	56			0.056
.0021	53	270	300	
.002	50			0.050
.0018	45		350	0.045
.0017	44	325		
.00153	39			
.0015	37	400		0.04

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SPRAYDRY EVALUATION FORM

Company____Date__________________
Address____
Telephone No.___________________________ FAX No.______________________________
Contact Person__________________________ Position______________________________
Email Address____

Liquid Feed Stock____
Slurry______ Solution______ Other____
Total Liquid Feed Rate_______________ GPH/LPH. Density (Specific Gravity)__________
Temperature______F/C. Viscosity at temp.________. Surface tension at temp.__________
Percent Solids______________ PH level___________________ Abrasive________________

Dryer Mfgr.____
Tower Specs_______________Dia. ft/m Height of straight section_____________________ft/m
Total Hight____________________ft/m
Box Type ______________Length ft/m Width_____________ft/m
Height______________ft/m
Air Flow: Co-current_____________ Counter-current_____________ Mixed______________
Number of nozzle ports_________ Number of nozzles used___________
Location of nozzles in dryer____

____
Inlet gas/air volume__________________scfm/ nm^3/hr. Inlet gas/air temp.______________F/C
Outlet gas/air temp.________________F/C
If media not air, specify gas____

Pump Mfgr.____________________________ Max. pressure_____________________psi/bar
Operating pressure __________________________psi/bar

Atomizer Mfgr.____
Pressure nozzles(s)_______ Two fluid_______ Rotary__________
Model No.__________________________ Inlet connection size________________NPT/BSPT
Orifice Insert No._______________________________ Material________________________
Core/Whirlchamber No.____________________________ Material______________________
Other____

Cleaning Procedure:
Is atomizer cleaned prior to use________
Method of cleaning. Mechanical, brushes, probes, etc_________________________________
Ultrasonic______________________ Other_______________________
Cleaning solution_____________________________ Percent concentration_______________
Temperature___________F/C Duration of soaking____________________________________

Spraying Systems Co.®

Average wear life of Orifice______________________ of
Core_____________________________

Dried Product: Name____
Bulk Density________________________ Percent Moisture____________________
Particle Size (range)_______________________________(microns/ US mesh)
Output__________________________________lbs per hr / kg per hr

Quality of Results

____
____
____

Additional
Comments:____
____
____
____
____

Sketch: