Mixer and Blender Options for Vacuum Drying Requirements

A White Paper Prepared By

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Abstract

Throughout the industries, more and more manufacturers are turning to agitated vacuum systems to improve their drying processes. Three common mixing technologies are employed in various vacuum drying requirements: the Vertical Blender/Dryer, Cylindrical Blender/Dryer and Double Planetary Mixer.

This white paper presents the operating theory, advantages and sample applications of each design. The recommendations discussed here are based on Ross's experience as a worldwide mixing and drying equipment supplier for over 170 years.

Introduction

Agitated vacuum drying is an efficient method for removing volatile components from pharmaceutical granulations, chemicals, plastics, ceramics, metals, and other products. Due to the reduced pressure within the dryer, the liquid's boiling point is lower than in atmospheric conditions and drying can proceed at lower temperatures. Vacuum drying is therefore ideal for processing heat-sensitive materials without risk of thermal degradation. It also allows manufacturers to recover costly solvents or safely dispose of any harmful volatiles removed from the closed system.

The combination of deep vacuum, gentle heat and agitation achieves significantly shorter drying times compared to high heat alone. It is not uncommon for atmospheric oven and tray drying operations to run for many hours, sometimes overnight, in order to reach very low moisture levels. The impact on energy costs and production rates is tremendous. Vacuum ovens and tray dryers offer better drying rates than their atmospheric counterparts but agitated vacuum dryers are even more effective. In these systems, materials in direct contact with the dryer's heated surfaces are continuously renewed, ensuring that drying is not only fast but also uniform.

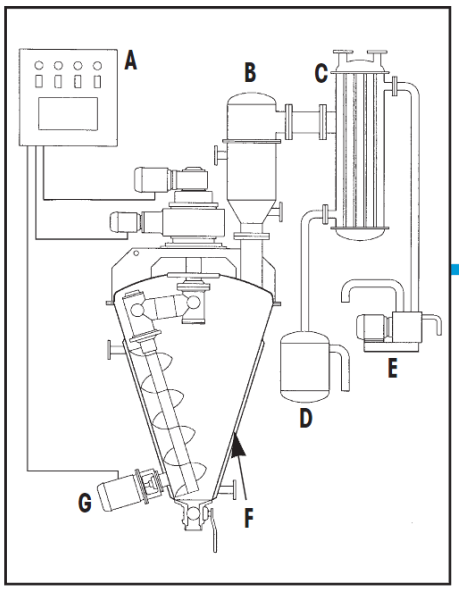
Another advantage of agitated vacuum dryers is the wide range of feed forms that they can accommodate – from slurries, wet cakes and pastes, to granules, pellets and powders. A liquid feed material, for example, may undergo a series of relatively swift changes in physical state – from slurry to a viscous paste, and from a paste to a dry powder. The characteristics of the feed, intermediate and final dried product are all important considerations when selecting the right equipment for a particular application. Process engineers are faced with many options in today's market but the three most common and superior technologies are the Vertical Blender/Dryer, Cylindrical Blender/Dryer and Double Planetary Mixer.

Vertical Blender/Dryers

Vertical Blender/Dryers feature a slow-turning auger screw which orbits around a conical vessel. The screw gently lifts material upward as it advances along the vessel walls. At the same time, materials at the upper most level of the batch cascade slowly back down into regions opposite the moving auger screw. The constant exchange of materials between the heated sidewalls and center of the blender accelerates the drying process.

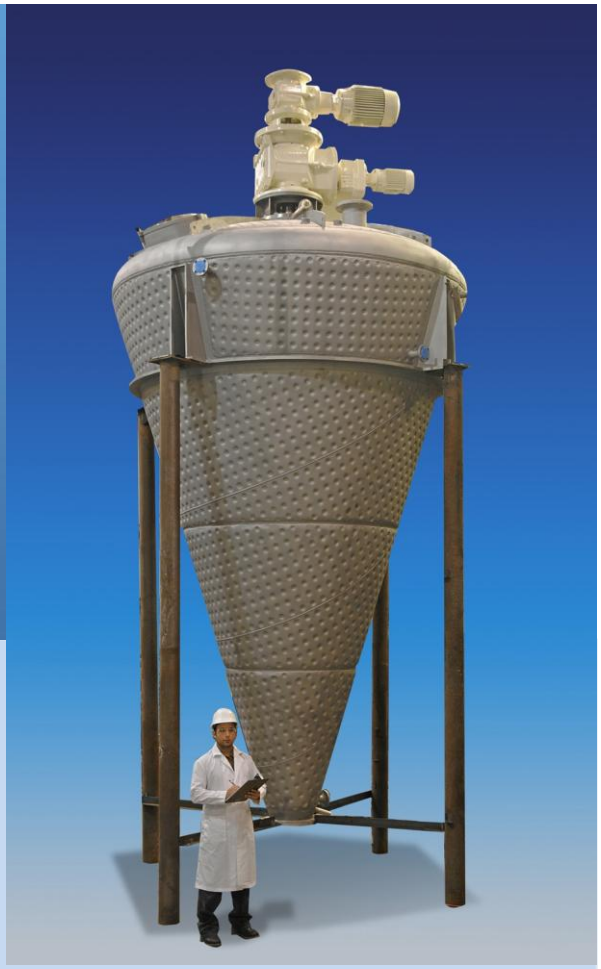
A main issue with agitated dryers is the risk of product attrition or generation of fines. This concern is well minimized on a Vertical Blender/Dryer. The blending action it imparts is very thorough but gentle enough even for the most delicate of applications. The low impact agitation of this dryer is also ideal for highly abrasive materials which would quickly abrade horizontal systems like ribbon or paddle-type blender/dryers. On the other hand, shear input can be increased in a Vertical Blender/Dryer when necessary. For instance, products that contain undesired lumps benefit from the addition of a high speed chopper assembly.

During the drying cycle, hot water, oil or steam is recirculated through the vessel jacket. Due to the lower processing temperatures made possible by the vacuum environment, there is a reduced risk of creating hot spots on the vessel walls where product could bake.



ANATOMY OF A VACUUM BLENDER/DRYER SYSTEM

A Control system monitors and controls all process variables.
B Filter excludes powders from the piping system.
C Condenser, in which vapor is chilled and returned to a liquid state.
D Receiver, where condensed liquids are collected.
E Vacuum pump.
F Heat applied to the jacketed vessel combines with the lowered vapor pressure under vacuum to drive off liquids.
G High speed lump breaker, which accelerates drying in many applications.



Advantages of Vacuum Drying in a Ross Vertical Blender

- *Highly effective moisture removal.* Ross Vertical Blender/Dryers are commonly used for drying materials to less than 0.10% moisture.
- *Fully top-supported screw agitator*. Without a bottom support bearing to get in the way, dried materials are discharged quickly and completely. This design also allows the machine to be operated with very little maintenance.
- *Low energy consumption.* The Vertical Blender/Dryer consumes up to 50% less power than a comparable horizontal blender. Low horsepower to volume ratio, low processing temperatures and short cycle times all contribute to the economical design of this blender/dryer.
- *Customization and flexibility*. Ross can tailor almost any feature of the Vertical Blender/Dryer to suit a specific application and ensure long service life. Standard models range from 1 to 500-cu.ft., each capable of handling volumes as low as 10% of the rated capacity without destroying friable or delicate products.
- *Fast drying rates* on many proven applications including food and beverage powders, botanical extraction, ceramics, detergents, fertilizers and herbicides, glass beads and powders, nutritional supplements and pharmaceuticals, pigments, hygroscopic plastic resins, polymer fillers, metal powders, wood fibers and more.

Sample Application #1: Polymer Powders

A manufacturer of binder resins is using a Ross Vertical Blender for vacuum drying polymer powders from 35% to <1% moisture. The thermoplastic resin was previously being dried in a V-Cone Tumble Blender and transferred to trays for curing in an oven. The powders were then milled to disperse agglomerates that have re-formed during curing. This three-step process took 24 hours to complete.

Simulation trials confirmed that the drying and curing steps can be done in a Ross Vertical Blender/Dryer by following the specified temperature profiles for each stage. The constant agitation prevents agglomerates from forming, therefore eliminating the downstream milling step.

The Ross Vertical Blender/Dryer chosen for this application is designed for 29”Hg vacuum and temperatures up to 500°F. Heating oil is circulated through the 100-psig stainless steel jacket protected with calcium silicate insulation. Discharge through the pneumatically-operated knife gate valve is fast and 100% complete. A Type X purge control panel supplied with the blender enables data collection via Ethernet.

Sample Application #2: Dental Glass Powders

A 40-cu.ft. Ross Vertical Blender/Dryer is being utilized for preparing a blend of silica powders at a facility that makes dental products. The combined blending and vacuum drying operation is completed in less than an hour, producing a homogenous mix and bringing down the moisture content from 1.5% to ~0%.

The gentle blending action of the Vertical Blender/Dryer is well-suited for this abrasive application. As added protection against wear, the auger screw and outlet ball valve are hard-chrome plated.

Sample Application #3: High-purity Ceramic Powders

A major producer of inorganic chemicals is using 200- and 300-cu.ft. Ross Vertical Blender/Dryers for processing different types of ceramic materials. Initial scale-up data were gathered from testing a 1-cu.ft. Vertical Blender/Dryer at the Ross Test & Development Center. In one test, a low-viscosity slurry containing zirconium oxide was charged into the vacuum blender and virtually all solids were recovered in the form of dry granules in less than 3 hours. The company also rented a 10-cu.ft. Vertical Blender/Dryer for further testing on the actual process floor.

The drying trials provided a baseline for expected drying times, optimum vacuum level and anticipated power draw. These parameters allowed Ross engineers to properly size the motors on the large-scale blenders and gave the user enough data to make an informed comparison between other drying technologies. Based on the quality of the dried powders produced in the Ross Vertical Blender/Dryer and the overall efficiency, the manufacturer was able to confirm that this was the best technology for their high-volume needs.

Cylindrical Blender/Dryers

Another popular vacuum dryer configuration is the Cylindrical Blender/Dryer equipped with a ribbon or paddle agitator. Heat transfer is extremely efficient since the jacket surrounds the entire cylinder and end plates. Cylindrical Blender/Dryers are ideal for products that would persistently hang up on the trough of an ordinary U-shaped horizontal blender.

Compared to the rotating screw auger of the Vertical Blender/Dryer, the agitator in a Cylindrical Blender/Dryer is better suited for applications that benefit from more vigorous mixing and a faster exchange of product in contact with the heated surfaces.

One major advantage to the Cylindrical Blender/Dryer is that it can accommodate high temperatures. The gearbox and all bearings are located outside of the drying chamber and are not subjected to the same temperature as the materials being processed. This feature allows for easy lubrication, simple maintenance and long service life.

Ross Cylindrical Blender/Dryers can be designed for high operating temperatures upwards of 700°F. These machines are commonly used for drying pellets, granular materials and other solids as well as transforming slurries and pastes into free-flowing powders.

Sample Application #1: Plastic Additives

A 150-cu.ft. Ross Cylindrical Blender/Dryer is being used for removing solvent from a powdered chemical that is added to plastics to enhance their performance. Temperature in the dryer is tightly controlled – too low a temperature will not effectively remove most of the solvent but too high a temperature can cause undesired changes in color and other properties. The Cylindrical Blender/Dryer holds a deep vacuum (>50 torr) during processing, also a critical factor in ensuring predictable drying times and consistent product quality.

Sample Application #2: Battery Powders

A 10-cu.ft. Ross Cylindrical Blender is utilized for drying crystalline powders which are ultimately used in batteries for medical devices. Designed to operate at 775°F, the Cylindrical Blender/Dryer is equipped with a custom paddle/ribbon agitator, 200-psig baffled jacket, high-performance mechanical seals, heavy-duty RTD thermocouples, pneumatically-operated inlet and discharge valves, high temperature filter unit and vent condenser.

Double Planetary Mixers

Double Planetary Mixers are commonly used for batching viscous formulations such as rubber adhesives, silicone sealants, pharmaceutical gels and highly-filled composites. These devices move material by rotating two identical blades on their own axes as they orbit around the batch on a common axis. The mixing action is very thorough regardless of product rheology. Aside from their primary use in compounding high viscosity formulations, Double Planetary Mixers are also frequently utilized as vacuum drying equipment.

Heat transfer in a Double Planetary Mixer is very effective because the blades continuously advance along the periphery of the jacketed mix vessel, removing material from the walls and transporting it to the interior. This type of agitated vacuum dryer is well suited for applications that first need to be mixed intimately prior to solvent removal. Such a process may occur in several stages: mixing and coating of solids with a liquid binder, application of heat and vacuum while continuing to agitate the mixture, followed by a physical transition from low-viscosity slurry to viscous paste to dry powder.

Planetary Blade Options

Most traditional Double Planetary Mixers utilize blades with a rectangular open paddle design. Others feature finger blades for handling special applications such as delicate fibers.

Today, many modern Double Planetary Mixers come with a new style of blades with a helical profile. Introduced by Charles Ross & Son Company, the High Viscosity "HV" Blades consist of precisely-angled helical flights which pass each other in a slicing motion, enabling them to move through a very viscous batch with less resistance. The slope and spiral of the HV Blades also allow for better control over batch level when mixing and drying thick, sticky or dough-like materials. The blades push product forward, inward and *downward*, ensuring that batch materials do not climb up into the gearbox area.

Rectangular Blades

Finger Blades

High Viscosity Blades
(US Patent No. 6,652,137)

Vacuum-rated Double Planetary Mixers are offered from 1-quart to 750-gallon capacities. Mixer features are easily customized to accommodate any drying application. Options include rotating and sidewall thermocouples, sanitary gearbox, sidewall and bottom scrapers, custom sight/charge ports and CIP spray nozzles.

Sample Application #1: Tungsten Carbide Powders

A manufacturer of tungsten carbide preforms uses two Ross Double Planetary Mixers for vacuum drying their tungsten carbide/heptane slurry in 600-lb batches. Each Double Planetary Mixer produces thoroughly dried tungsten carbide powder in 1-1/4 hours. These mixers replaced conical tumbling driers which could only handle 100-lb batches yet took 6-8 hours to arrive at the finished product. As an added benefit, operators also found the Double Planetary Mixers easier to clean between batches.

"Our final granulation is extremely uniform in terms of size, moisture content, and encapsulation of each tungsten carbide particle. This uniformity is absolutely crucial, because the slightest flaw in the granulation can lead to the failure of a customer's part," says the plant manager. "The Double Planetary Mixer is an entirely closed system, and we are able to reclaim more than 95% of our solvent, easily exceeding EPA regulations and helping to ensure a safe working environment in our plant," he adds.

Sample Application #2: Pharmaceutical Wet Cake

A pharmaceutical drug previously dried in a vacuum oven was transformed from a wet cake (80% moisture) into a free-flowing powder (10% moisture) after several hours of drying at 120°C. Looking to improve this process, the manufacturer conducted drying trials at the Ross Test & Development Center and subsequently upgraded to a sanitary design vacuum-rated Double Planetary Mixer. The new process drastically reduced drying time to just one hour.

Some useful techniques

Make sure you have the right type of vacuum pump to handle the level of vacuum and the operating conditions that your process requires. For example, a rotary vane pump may allow you to draw a deeper vacuum (29.5-29.8" Hg) than a liquid ring pump. However, a liquid ring pump may better accommodate condensate from the batch. Do use the appropriate filter and condenser before the pump to protect it from contaminants.

When removing large quantities of vapor from the batch, purging the vessel headspace with a stream of dry air or nitrogen may help accelerate drying time and prevent premature condensation within the blender or mixer.

Run the agitator at different speeds to confirm the ideal settings that would maximize heat transfer without damaging the product. If complete discharge is an absolute requirement, the Vertical Blender/Dryer is recommended over horizontally agitated dryers. Double Planetary Mixers with a slightly tilted configuration are also available for more effective and complete discharge of dried granulations and powder blends.