

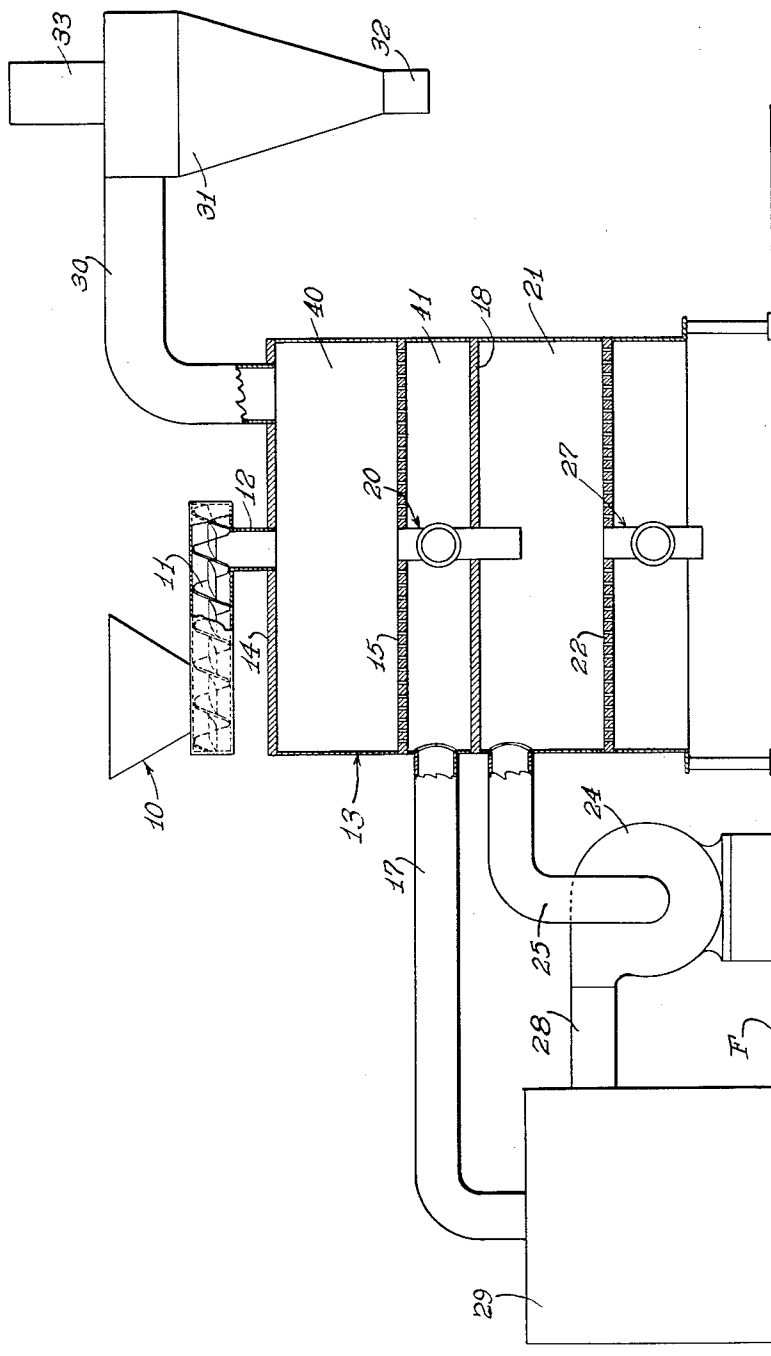
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METHOD OF AND APPARATUS FOR DRYING PARTICULATE MATERIAL

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METHOD OF AND APPARATUS FOR DRYING
PARTICULATE MATERIAL

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This invention relates to a method of and apparatus for drying particulated material. The invention can also be applied to the removal of physically absorbed water from crystalline materials such as moist salt, sand, and the like, and the process can also be used for the removal of other wetting fluids from particles, for example, for the removal of organic solvents used in crystallization processes.

The process of the present invention is also applicable for the removal of chemically held water, such as for the removal of water from gypsum to produce plaster of Paris, and for the removal of water of hydration from hydrates such as calcium sulfate, calcium chloride, sodium sulfate and the like.

The present invention provides a process which is particularly applicable to the drying of a moist salt such as sodium chloride. In the more common methods for drying salt, a large portion of the heat put into the process is ordinarily lost because of the necessarily high temperatures of the exhaust vapors, and the high temperatures to which the dry material is heated. This results in a low efficiency of heat utilization for the process, expressed in terms of heat input per unit of liquid evaporated. Another problem presented in the methods now employed for drying salt is that of local over-heating of the salt particles being dried, resulting in discoloration and fracture of the salt particles. Still another disadvantage of commonly used methods for salt drying is the fact that they frequently require large equipment for carrying out the process and produce nuisances such as noise and dust. In addition, conventional driers discharge the dried salt at a high temperature, requiring that separate cooling equipment be provided.

The most extensively used equipment for drying salt particles is the rotary drier. While this apparatus has the features of mechanical simplicity and ease of operation, it is handicapped by inefficient heat transfer, high power requirements, large equipment, large space requirements, and frequently by excessive noise and dust.

An object of the present invention is to provide a process for efficiently drying particulated materials which is economical to operate and which minimizes the possibility of localized over-heating of the particles being dried.

Another object of the present invention is to provide a method for the drying of salt or similar particles to a predetermined moisture content with a high efficiency of heat utilization.

Another object of the present invention is to provide a convenient method for simultaneously cooling dried salt particles and preheating a drying gas before introducing the heated gas into the drying chamber.

Still another object of the present invention is to provide an improved apparatus for drying particulated material and for transferring the dried material into a cooling chamber where the heat content of the dried material is used to preheat a stream of drying gas.

The present invention provides a process including two fluidized operations, the first being used to dry the par-

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ticulated material, and the second to cool the dried material and to heat exchange the material with the incoming gases used for drying in the drying step. In both fluidized operations, the particles are suspended in dense phase suspension in a fluidizing gas which is inert to the particles being treated. A dense phase suspension is one in which the particles are suspended by the gas introduced at a sufficient mass gas velocity so that the particles become freely suspended in dense phase, that is, sufficiently suspended to move and mix vigorously and give the appearance of a boiling liquid, but not suspended to the extent that substantial amounts of the particles are entrained in the gas.

Control of the mass gas velocity of the fluidizing gas is important in order to obtain maximum utilization of the heat input. The mass gas velocity, expressed in terms of pounds of fluidizing gas per square foot of cross-sectional area of the particle beds necessary to maintain the particle bed in a state of dense phase suspension has been determined to be on the order of 150 pounds per hour per square foot in the case of unsized granulated salt. The mass gas velocity is substantially independent of the bed depth, but is a function of at least seven factors: (1) particle size; (2) particle density; (3) particle shape; (4) particle size distribution; (5) particle surface roughness; (6) gas density; and (7) gas viscosity.

The process of the present invention is preferably operated in a continuous manner, but batch-wise operation is also feasible. Relatively moist particles are introduced into a drying chamber to form a bed of a depth which, for the particular material, will assure uniform dense phase suspension and mixing of the particles in the bed. The less the weight of material per unit cross-sectional area of the bed, the less is the pressure head against which the hot gas must be circulated. The material is disposed on a perforated or porous plate having perforations therein of a size which will retain substantially all of the particulated material on the plate. Alternatively, a series of bubble caps can be provided to insure intimate contact between the fluidizing gas and the particles. A heated fluidizing gas is then passed upwardly through the plate and through the bed of material at such a mass gas velocity that the material particles become freely suspended in a dense phase suspension. Heating of the bed of material by the incoming gas is continued until the temperature of the material reaches the temperature desired for drying. In the case of sodium chloride particles being dried to a bone-dry state, this temperature is above the boiling point of water, and is preferably on the order of 220° F. to 250° F. On the other hand, many materials can be dried to the desired extent at temperatures substantially below that of boiling water.

After the moisture content of the particles in the drying chamber has been reduced to a predetermined value by continued treatment with the fluidizing gas, the particles are continuously withdrawn from the drying chamber and passed into a cooling chamber. In the latter, the particles are again fluidized by a gas stream which is relatively cool. The intimate mingling of the dried, still hot particles with the relatively cool fluidizing gas serves to cool the particles substantially, and to preheat the fluidizing gas. After heat exchange with the fluidized particles, the fluidizing gas is passed continuously to a furnace or other similar device for further increasing the heat content of the gas. The gas leaving the furnace is then passed into the drying chamber where it serves to suspend the moist particles being introduced into the chamber in dense phase suspension.

A further description of the present invention will be made in connection with the attached sheet of drawings which illustrates a plant assembly for carrying out the process of the present invention.

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As shown on the drawings:

Moist salt or other particulated material is introduced into a hopper 10 which feeds a conveyor screw 11. The particles are transported by the conveyor screw 11 into a conduit 12 through which they are introduced by gravity into the top of a casing 13. The casing 13 is generally cylindrical and comprises a plurality of vertical superimposed sections defining different functional zones. An upper drying zone 40 is provided between a top or cover 14 and a perforated bed plate 15 supported in said casing below the top 14. The bed plate 15 may consist of a metallic or ceramic plate with perforations therein, or may consist of a porous, compressed metal powder plate. The plate may also be perforated with a suitable bubble cap arrangement. The size of the perforations in the plate 15 will depend upon the size of the particles being treated, but for drying salt particles, the size of the perforations may be on the order of 0.050 inch. If the openings in the plate are too large, the material may leak through the plate when the fluidizing gas is shut off. The size of the perforations has been exaggerated in the drawings for purposes of clarity.

Below the bed plate 15 is a plenum chamber 41, which is defined by the wall of the casing 13 and an imperforate bottom plate 18. A stream of hot fluidizing gas enters the plenum chamber 41 through a conduit 17. The hot gases entering through the conduit 17 are at a sufficient mass gas velocity as they pass through the perforated bed plate 15 to suspend the particles in the drying chamber 40 in dense phase suspension.

After treatment in the drying chamber under conditions sufficient to achieve a predetermined moisture content, the dried particles are continuously removed from the drying chamber through a mechanical discharge lock, generally indicated by the reference numeral 20, into a cooling zone 21. The base of the cooling zone 21 is defined by a perforated bed plate 22 disposed in the casing 13 below the level of the imperforate plate 18. Relatively cool air is drawn from the outside through the bed plate 22 and through the bed of material in the cooling chamber 21 by means of a blower 24 having its inlet end fed by a conduit 25 leading from the cooling chamber 21 above the level of the particulated material contained therein. As shown in the drawing, the base of the casing 13 is so arranged with respect to the flooring F, as to provide free access of surrounding air to the under surface of the bed plate 22 for passage there-through into the cooling chamber 21.

The air drawn through the bed plate 22 has a sufficient mass gas velocity to suspend the still hot salt particles in dense phase suspension within the cooling chamber 21. In passing through the cooling chamber 21, the incoming air stream is heated, and the fluidized, dried salt particles are cooled. Preferably, the mass gas velocity is such as to cool the bed of fluidized particles to a temperature in the range from about 160° to 170° F., at which temperature the particles are withdrawn from the cooling chamber 21 through a mechanical discharge lock 27. At a temperature of 160 to 170° F., the salt particles are easy to handle and may be passed directly to storage or packaging.

The air drawn through the blower 24 is passed by means of a conduit 28 into a furnace 29. In the furnace 29, the air may be heat exchanged with gases leaving the furnace in order to increase the heat content of the air stream, or the air may be used directly for the combustion of fuel in the furnace 29 provided that carbon dioxide and other constituents of the resulting flue gases are not harmful to the particles being treated. The heated gases leaving the furnace whether in the form of heated air or as a flue gas are conducted by the conduit 17 into the plenum chamber 41 for passage through the perforated bed plate 15 to fluidize the moist particles in the drying zone 40.

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The hot fluidizing gas containing water vapor and any extremely fine particles suspended in the gas stream leave the drying chamber 40 through an outlet conduit 30 and pass to a gas-solids separating device such as a cyclone separator 31. Fines recovered from the cyclone separator 31 are removed through the discharge outlet 32 while the gases are passed by means of an outlet line 33 to be vented or reused.

Many modifications may be made to the type of apparatus shown in the drawings without departing from the spirit of the invention. For example, where large amounts of material are to be handled, the moist particles may be introduced at more than one point into the drying chamber. Further, if the salt particles are to be cooled to a relatively low temperature, additional cooling can be obtained by the introduction of supplemental cooling air into the cooling bed, even though all of this supplemental air may not later be carried through the furnace and into the drying bed.

One of the more important factors which determines the mass gas velocity to be used is the particle size of the material being treated. The following table illustrates the mass air velocities required to just attain a state of dense phase suspension for various particle sizes of sodium chloride.

Particle Size (U. S. Standard Mesh)	Mass Air Velocity, lbs./hr./sq. ft.
-35 +40 mesh-----	260
-40 +45 mesh-----	200
-45 +50 mesh-----	160
-50 +60 mesh-----	120
-60 +70 mesh-----	100
-70 +80 mesh-----	80
-80 +100 mesh-----	65
-100 +120 mesh-----	50
-120 +140 mesh-----	32

The following table illustrates the effect of particle density on the mass air velocity required, where the fluidizing gas is air, to just attain dense phase suspension.

Particle Size, U. S. Standard Mesh	Material	Absolute Density, lbs./cu. ft.	Mass Air Velocity, lbs./hr./sq. ft.
-80 + 100 mesh-----	Sodium Chloride--	135	65
-80 +100 mesh-----	Sodium Iodide----	229	120

The temperature and moisture content of the salt or other particulated material to be dried may be varied over a considerable range. It is customary in dehydrating brine to remove sufficient water so that the salt particles contain about 3% moisture. Salt particles having a water content of this value can be used effectively in practicing the present invention, although the moisture content may be as high as 12% or more in the feed material.

The temperature of the wet salt feed will depend on the previous treatments to which the salt has been subjected. In treating salt from brine which has been processed to a moisture content of about 3%, the salt can be recovered at a temperature in the neighborhood of 150° F. and introduced into the fluidizing system at that temperature. In the drying of salt, the temperature of the fluidized drying bed can be controlled so that it is below the boiling point of water and still induce substantial evaporation of moisture. However, in order to reduce the salt to a bone-dry condition (having a moisture content less than 0.05%), the temperatures of the particles in the fluidized drying step are preferably above the boiling point of water and ordinarily in the range of from 220° to 250° F. It has been found that the last 0.25% moisture cannot readily be removed from the salt at a temperature below the boiling point of water, presumably because of chemical or adsorptional binding with the salt. The maximum temperatures employed in the fluid-

ized drying zone depend primarily upon the amount of heat which it is economically feasible to retain in the exhaust gases, and upon the susceptibility of the particular material to damage by high temperatures. The process of the present invention has been carried out with inlet fluidizing gas temperatures as high as 600° F. with good results. Such elevated temperatures do not cause localized over-heating of the salt because of the excellent mixing which occurs in the material of the bed.

When drying materials other than salt, a complete drying may be accomplished entirely by surface evaporation at temperatures approaching room temperature. Conditions in the fluidized bed are conducive to a large degree of surface evaporation at liquid phase vapor pressures substantially below atmospheric pressure. Where the wetting liquid is not combined chemically to the solid material to any great degree, the minimum temperature at which complete evaporation of the liquid can be effected is limited only by the dew point of the heating gas with respect to the evaporation product it contains.

While air is by far the most common fluidizing medium, other gases inert with respect to the material being treated may also be used. Such gases may include flue gas, nitrogen, methane, hydrogen, oxygen, carbon dioxide, and the like.

Another modification of the process shown in the drawings consists in operating two or more drying zones in series, one above the other, with wet material being fed to the top bed and transferred successively to the lower beds. At the same time, the hot fluidizing gas is passed successively upwardly through the beds. The use of multiple drying beds is very often desirable in drying material which requires an unusually high final drying temperature to remove the last traces of liquid. In this type of process, the multiple bed arrangement has the advantage that the first top bed is at a lower temperature, so that the gases are exhausted at a lower heat content. The disadvantage of such a system lies in the fact that the total head loss through the system is a direct function of the number of beds. The choice of suitable number of drying beds is thus determined by a comparison of heat loss in the exhaust gases with the head against which the hot drying gas must be circulated.

The intensive mixing realized in maintaining material in a state of dense phase suspension assures freedom from localized over-heating and prevents localized thermal decomposition of the material being dried. Each particle in such a dense phase suspension appears to be cushioned by a surrounding atmosphere of gas to the extent that mechanical abrasion is minimized. Comparing the screen analyses of dried salt products of the present invention with those of the products contained from rotary driers makes it evident that the present practice produces substantially more coarse particles than appear in the products of rotary driers. A comparison of the screen analyses follows.

	Present Invention	Rotary Driers
	Percent	Percent
Coarser than 30 mesh.....	1.0	1.0
Coarser than 40 mesh.....	18.5	11.5
Coarser than 50 mesh.....	67.0	54.0
Coarser than 70 mesh.....	93.0	90.5
Coarser than 100 mesh.....	99.0	98.0

In addition, the dried material produced according to the present invention has no traces of thermal damage, where salt crystals recovered from rotary driers evidence much incipient cracking, probably due to thermal stresses. Salt crystals dried by the present invention are free from cracks and are distinctly clearer and brighter in reflected light than are crystals recovered from rotary drying.

As will be noted from the foregoing description, combined drying and cooling operations are carried out under

fluidized conditions and therefore do not require the use of mechanical agitating, spreading or tumbling equipment to effect gas-to-solids contact. This feature eliminates much of the noise nuisance of present drying apparatus and also reduces power requirements.

It will be evident that various modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

I claim as my invention:

1. In a drying apparatus, a casing, means for introducing particulate material into the top of said casing, a first perforated plate vertically spaced from the top of said casing and defining a drying chamber between said first perforated plate and said top, an imperforate plate supported in said casing parallel to and below said first perforated plate and defining a second chamber therebetween, a second perforated plate disposed parallel to and below said imperforate plate and defining a cooling chamber between said second perforate plate and said imperforate plate, a blower having a gas inlet and a gas discharge, a heater associated with the blower for heating the gas pumped by the blower, first conduit means interconnecting the blower inlet and the cooling chamber for drawing gas through said second perforate plate and said cooling chamber, second conduit means interconnecting the blower discharge and the second chamber for blowing gas upwardly through said first perforated plate and into said drying chamber, and third conduit means interconnecting said drying chamber and said cooling chamber, said third conduit means opening through said first imperforate plate for drawing off particulate material from the bottom of said drying chamber, said blower drawing gas through said second perforate plate and forcing gas through said first perforate plate to maintain the particulate material in a fluidized state in both the drying and the cooling chambers.

2. A method of drying moist crystalline salt particles, which comprises the steps of (1) introducing said particles into a first bed in a drying zone, (2) urging a stream of drying gas at a given superatmospheric pressure against the bottom of said first bed to fluidize the particles therein, (3) withdrawing dried hot particles from the bottom of said first bed and introducing the dried hot particles into a second bed in a cooling zone, (4) drawing a stream of cooling gas at subatmospheric pressure upwardly through said second bed to fluidize the particles therein, and (5) withdrawing the stream of cooling gas from the cooling zone, increasing the pressure in the stream to superatmospheric pressure and heating the gas in the stream, and then introducing the stream into the drying zone for carrying out step (2), whereby step (3) is carried out by removing particles from a zone under superatmospheric pressure to a zone under subatmospheric pressure.

3. In a drying apparatus, a casing, means for introducing, means for introducing particulate material into the top of said casing, a first perforated plate vertically spaced from the top of said casing and defining a drying chamber between said first perforated plate and said top, an imperforate plate supported in said casing parallel to and below said first perforated plate and defining a second chamber therebetween, a second perforated plate disposed parallel to and below said imperforate plate and defining a cooling chamber between said second perforate plate and said imperforate plate, a conduit extending from the cooling chamber to the second chamber for conducting gas from the cooling chamber through said first perforated plate and into the drying chamber, a blower in said conduit, a heater in said conduit, and a mechanical discharge lock opening flush with said first perforated plate to remove particulate material from the drying chamber and passing through said imperforate plate to discharge the particulate material into the cooling chamber, said blower drawing gas through said second perforated plate and forcing gas through said first perforated plate to maintain

the particulate material in a fluidized state in both the drying and the cooling chambers.

4. In a drying apparatus, a casing, means for introducing particulate material into the top of said casing, a first perforated plate vertically spaced from the top of said casing and defining a drying chamber between said first perforated plate and said top, an imperforate plate supported in said casing parallel to and below said first perforated plate and defining a second chamber therebetween, a second perforated plate disposed in said casing parallel to and below said imperforate plate and defining a cooling chamber between said second perforated plate and said imperforate plate, a conduit extending from the cooling chamber outside the casing and into the second chamber, a heater in said conduit, a blower in said conduit discharging through said heater for drawing gas from the cooling chamber and through said first perforated plate and into the drying chamber, a first mechanical discharge lock opening flush with said first perforated plate to remove particulate material therefrom and passing through said imperforate plate to discharge particulate material into the cooling chamber, and a second mechanical discharge lock opening flush with said second perforated plate to remove particulate material therefrom, said blower drawing gas through said second perforated plate and forcing gas through said first perforated plate to maintain the particulate material in a fluidized state in both the drying and cooling chambers.

5. A method of drying moist crystalline sodium chloride particles, which comprises the steps of (1) introducing said particles into a first bed in a drying zone, (2) urging a stream of drying gas up through the bottom of said first bed to fluidize the particles therein at a temperature in the range from 220° F. to 250° F., (3) withdrawing dried hot sodium chloride particles from the bottom of said first bed and introducing the dried hot particles into a second bed in a cooling zone, (4) drawing a stream of cooling inert gas upwardly through the bottom of said second bed to fluidize the particles therein while cooling the same, and (5) withdrawing the stream of cooling gas from the cooling zone, heating the gas in the stream, and then introducing the stream into the drying zone through the bottom of said first bed for carrying out step (2).

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