

[54] **METHOD OF CENTRIFUGAL
ATOMIZATION**

[75] Inventors: Daniel J. Klaphaak, Lawrence G. Barnes, both of Royal Oak, Mich.

[73] Assignee: Atomization Systems Inc., Birmingham, Mich.

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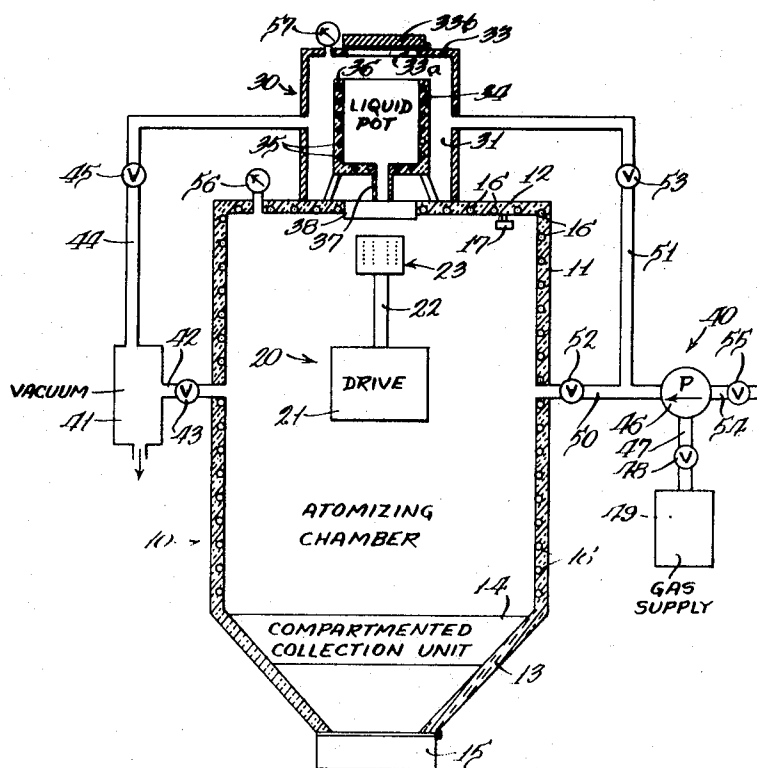
Primary Examiner—Robert F. White

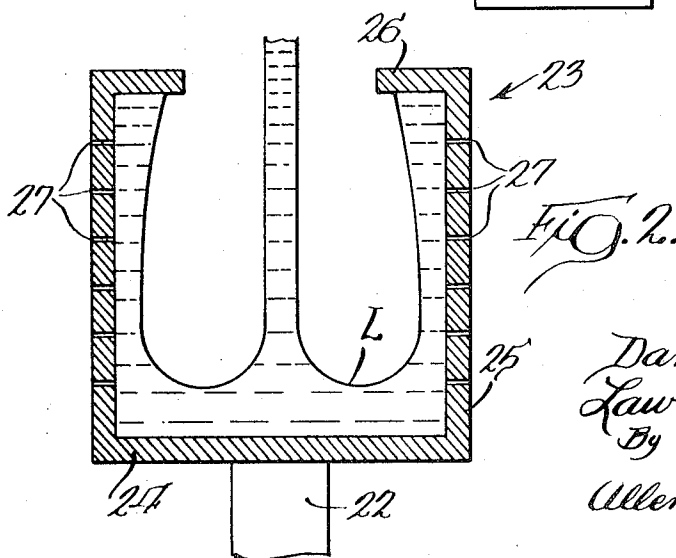
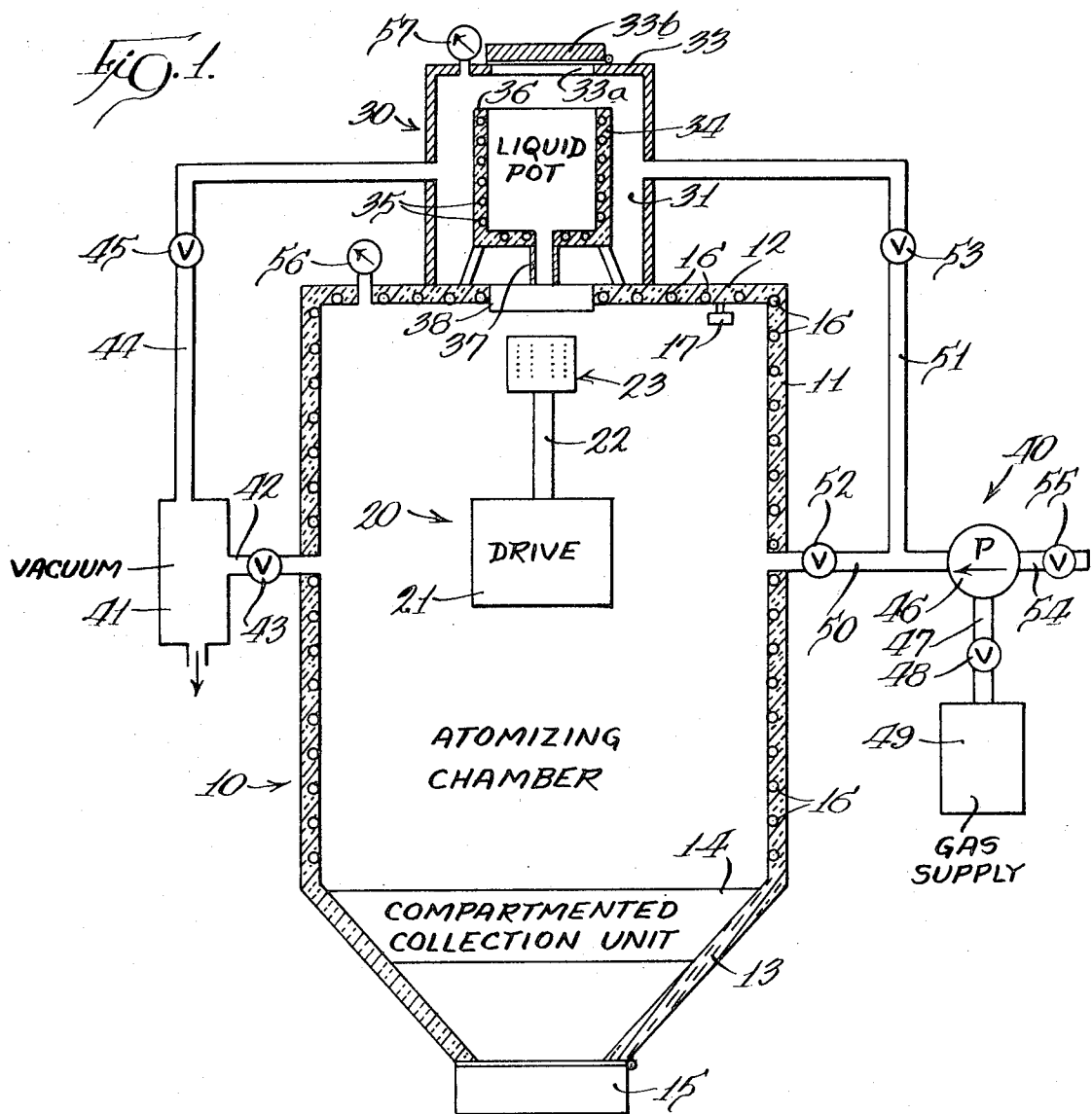
Assistant Examiner—J. R. Hall

Attorney—Axel A. Hofgren et al.

[57] **ABSTRACT**

Method of carrying out centrifugal atomization of a liquid to form solid particles, by spinning the liquid in a cup having a perforated upright sidewall so as to project fine streams of the liquid at high velocity through the perforations into a sealed chamber in which a stagnant gaseous medium is maintained at a temperature to form solid particles from the liquid, while the composition and density of the medium are coordinated to maintain a ratio of viscosity to density which is substantially less than that of air at atmospheric pressure. Preferably the stagnant gaseous medium is maintained at a pressure substantially in excess of one atmosphere. The method is applicable to the formation of powders from melted solids or to centrifugal spray drying of solids in solution.

15 Claims, 2 Drawing Figures



Inventors:
Daniel J. Klaphaak
Lawrence S. Barnes
By Hofgren, Wegner,
Allen, Hellman & McCord
Attys

METHOD OF CENTRIFUGAL ATOMIZATION

BACKGROUND OF THE INVENTION

One of the oldest and best known techniques for producing, generally spherical particles is by centrifugal atomization. It is used in producing powders of metal, ceramics and glass; and is also used in the production of fine particle size materials in centrifugal spray drying. In all such operations a stream of liquid is poured onto or into a spinning member from which it is flung by centrifugal force, and the design of the spinning member in combination with its peripheral speed is relied upon to control the size of the resulting solid particles. With any given liquid material, the greater the peripheral speed of the spinning member the finer is the particle size of the resulting powder.

The range of particle sizes produced in such an operation has been known for some time to depend upon the structure of the spinning member; and for production of powders within the narrowest possible particle size range a spinning cylindrical cup with a sidewall having holes of uniform diameter produces the best results. Payton patent 2,994,102 discloses that a spinning cup having holes .052 inch in diameter produces aluminum shot having the narrowest range of size distribution; and we have verified that this is also true for other materials.

Centrifugal atomization is carried out either by projecting the liquid into a stagnant gaseous medium or into a rapidly flowing gaseous stream. The former is generally preferable because it permits more precise control of operating conditions than is possible with a high velocity gas stream or jet.

One of the fastest growing fields of powder production at the present time is that of powder metallurgy, because of the extreme uniformity of metal ingots that can be produced from sintered or pressure compacted metal powders. For this purpose the finest and most uniform particles are the most desirable. However, the principal problem in producing very fine metal powders by centrifugal atomization into a stagnant gaseous medium is that the rate of rotation of the spinning member must be almost prohibitively high to produce powders of the desired fineness for this purpose. Thus, for example, high-speed tool steel alloys must be maintained at a temperature of about 2,500°F. and projected from a cup rotating at about 18,000 rpm to provide a product in which the log-mean diameter of the particles is about 100 microns. At such temperatures and rates of rotation there are few materials which will stand up, the likelihood of centrifugal explosion of the cup is very high, the distance that the particles are projected through the air is so great as to require a large particle recovery area, and the cup drive necessarily has a relatively short life.

Because of the foregoing problems with centrifugal atomization of high melting point alloys, the production of metal powders of such alloys, and of other metals too, has usually been performed by other methods which are inherently more complex and more expensive to operate. On June 16, 1970, Stora Kopparberg of Sweden issued a press release describing a process for producing metal powders from molten high-speed tool steel alloys by discharging jets of molten steel through nozzles into high speed jets of argon gas. The process is not subject to anywhere near the

close control of particle size that is attainable with a properly constructed spinning cup atomizer.

Another technique which has been used for the production of powdered metals is the rotating electrode process of U.S. Pat. No. 3,099,041.

SUMMARY OF THE INVENTION

We have discovered that the diameter of particles produced by atomization of any particular liquid projected at a predetermined velocity into a stagnant gaseous medium varies inversely with the density of the medium and directly with the viscosity of the medium — i.e., lower viscosity of the gaseous medium results in smaller particles and higher density of the gaseous medium also results in smaller particles. Thus, by coordinating the viscosity of the gaseous medium and the density of the gaseous medium to produce the lowest ratio of viscosity to density, the smallest particles may be produced at any given velocity of the particles through the gaseous medium.

The viscosity of a gas increases with increased temperatures, so atomization should be carried out at the lowest feasible temperature. An ideal gas either does not react with the material being atomized or reacts with it only in a completely controllable way to produce a desired result; and in addition the ideal gas is one having relatively low viscosity and relatively high density at atmospheric pressure. A generally satisfactory gas for this purpose is CO₂ which has a viscosity slightly lower than that of air, a density of about 50 percent greater than that of air at any given temperature and pressure; and a viscosity to density ratio which is about 58 percent of that of air.

By placing the stagnant gaseous medium at a pressure substantially in excess of one atmosphere, and preferably at a pressure of several atmospheres, while maintaining the temperature of the gaseous medium at the lowest feasible level, very fine particles may be produced at relatively low particle velocities and thus at relatively low rotational speeds of the spinning cup atomizer. In addition, by operating at a gas pressure of several atmospheres the distance that the particles can travel through the gas is very greatly reduced and thus permits the use of much smaller equipment.

As specific examples of the foregoing we cite the following:

Copper at its melting point of 1,982°F. atomized from a 4 inch diameter spinning cup with 0.050 inch diameter holes into air at 70° and a pressure of one atmosphere produces particles having a log mean diameter of 270 microns when the peripheral velocity of the cup is 100 feet per second. By increasing the peripheral velocity of the cup to 300 feet per second (about 18,000 rpm) the log mean particle diameter is reduced to 100 microns. On the other hand, the peripheral velocity of the cup may be maintained at 100 feet per second (about 6,000 rpm) and by increasing the air pressure to three atmospheres the log mean particle diameter is reduced to 120 microns. By atomizing in CO₂ at three atmospheres the log mean particle diameter may be reduced to 80 microns at the same peripheral cup speed.

When a lead alloy at its melting point of 300°F. is atomized in air at 70°F. and a pressure of one atmosphere, molten particles are detected 12 feet from

the atomizing cup. If the air pressure is increased to three atmospheres the maximum distance at which molten particles are detected is reduced to four feet.

Thus, the principal object of our invention is to provide an improved method of centrifugal atomization of liquids to produce solid particles.

Our invention is applicable to the atomization of molten metals, ceramics, glass, and other materials that can be melted and returned to a solid state; and especially those with a fairly sharp melting point.

The method is also applicable to particle size control in spray drying of such materials as powdered milk, powdered eggs, pharmaceuticals, and other spray dried products. For this purpose, of course, lower gas pressures must be used because of the rapid increase in the temperature required for solvent evaporation at higher gas pressures.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic illustration of suitable apparatus for carrying out the process of the present invention; and

FIG. 2 is a central sectional view of the atomizer cup substantially as it appears with liquid pouring into it at a typical rotational speed of the cup which might be employed in the present method.

DETAILED DESCRIPTION OF THE INVENTION

The process of the present invention is based upon a general equation that we have developed for all types of spinning disc atomizers. Several variables in this equation were never before known to have an effect upon the particle size of centrifugally atomized particles. It has previously been known that surface tension of the material being atomized, the dimension of the sheet or stream of liquid ejected from the rotary atomizer, and the velocity of the sheet or stream were factors affecting the particle size of the particles, and it has also been known that for any given material having, of course, a fixed surface tension, and working with any particular atomizing unit that would afford a controlled dimension of the sheet or stream of liquid, there is a generally inverse relationship between stream velocity and particle diameter.

We have now found that in addition to the above previously known factors the following are also controlling in the determination of particle size:

The density of the stagnant gas environment;
the viscosity of the stagnant gas;
the viscosity of the liquid and the density of the liquid.

The general equation that we have developed for all types of spinning disc atomizers is:

$$DV\rho_g/\eta_g = K(\gamma_l/\nu\eta_g)^a (TV\rho_g/\eta_g)^b (\eta_l/\eta_g)^c (\rho_l/\rho_g)^d$$

where

D = a representative particle diameter, usually the mean of the log-normally distributed particle size distribution expressed in microns

V = Velocity of the liquid ejected from the atomizer periphery into a stagnant gas, commonly given as the peripheral speed of the disc in feet per second

ρ_g = the density of the stagnant gas environment, which depends upon the particular gas used and upon its temperature and pressure

η_g = the viscosity of the stagnant gas, which depends upon the particular gas used and upon its temperature and pressure

γ_l = the surface tension of the liquid being ejected from the atomizer, which depends principally upon what the liquid is and its temperature

I = a selected dimension of the sheet or stream of liquid ejected from the atomizer. For discs (flat or dished) and vaned discs T is the thickness of the sheet flung off the atomizer. For a perforated cup T is the diameter of the stream ejected from the atomizer, and may be taken as the diameter of the perforations.

η_l = the viscosity of the liquid

ρ_l = the density of the liquid

a, b, c and d are constants that are essentially independent of atomizer design

K is a constant that depends on atomizer design and on the units of measurement used for the variables in the equation.

At any given temperature and pressure the surface tension, density and viscosity of a specific liquid are fixed; so the particle size of the atomized liquid at a specified temperature and pressure varies with its velocity and with the viscosity and density of the gaseous medium. Further, the constants a, b, c and d are small enough that for practical purposes they can be ignored in computing particle size. In addition, for an atomizer using a particular perforated cup the value of T is fixed, and at any given value of V the equation reduces to the following:

$$D \cong K' \eta_g / \rho_g$$

In accordance with the foregoing simplified equation, the diameter of the atomized particles of any selected liquid atomized at a predetermined velocity from a particular spinning disc or cup may be controlled by controlling the ratio of viscosity to density of the gaseous medium into which the particles are projected from the spinning atomizer. Accordingly, to produce the smallest particles a gas should be selected which has a low viscosity and an inherently high density, and the density may then be greatly increased with no material change in viscosity by increasing the pressure of the gas without significantly raising its temperature. Generally speaking, of course, it is most desirable to atomize a material, and especially a normally solid material that is atomized in the liquid phase, in a gaseous medium that does not react with the liquid phase material; although for certain purposes it may be useful to atomize into a gaseous medium which reacts with the atomized liquid in a known way and to a controllable extent so as to modify the characteristics of the atomized liquid.

Because of the fact that the viscosities of gases increase with increases in temperature, a liquid should be atomized at the lowest temperature which is practicable for the particular material being atomized. Thus, for example, in the atomization of molten metal in a gaseous medium which is in a sealed chamber at super atmospheric pressure, the gaseous medium should be held at the lowest temperature which it is practical to maintain in the closed chamber with the molten metal flowing into it and being discharged from the spinning member into the gas. The effect of temperature change on particle size is illustrated by the following com-

parison of copper atomized from a spinning cup having 0.05 inch diameter holes, at a peripheral velocity of 100 f.p.s., into an atmosphere of CO₂ at two different temperatures and a fluid pressure of one atmosphere.

Gas temp. ° F.	π_g (gm/cm ³)	η_g (centipoise)	Log-Mean Particle D (Microns)
70	0.0017	0.015	180
290	0.0012	0.023	320

Where the process is used in centrifugal atomization of material during spray drying, in which it is necessary to flash evaporate the solvent in which the solid material is dissolved, the process should be carried out at the lowest temperature at which flash evaporation will occur.

The following tabulation shows viscosity, density, and ratio of viscosity to density of five common gases at a pressure of one atmosphere and at three different temperatures; and the tabulation shows how the ratio of viscosity to density varies between gases and varies at different temperatures.

	-100° C.			0° C.			100° C.		
	η/ρ ¹	ρ ²	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
Air	.011	2.04	.005	.017	1.29	.013	.023	.94	.024
Ar	.021	1.78	.012	.027	1.30	.021	.027	1.30	.021
CO ₂	.009	3.05	.003	.014	1.96	.007	.019	1.43	.013
He	.014	.28	.05	.018	.18	.10	.023	.13	.18
N	.017	1.25	.014	.021	.91	.023	.023	.91	.023

¹ Centipoises. ² Gm./liter.

The foregoing tabulation shows that for the atomization of liquids where a completely inert gaseous medium is required Argon is satisfactory. However, the extremely low viscosity to density ratio of carbon dioxide makes it by far the preferred gas except in the very exceptional case where the liquid being atomized does react with carbon dioxide.

(1) Centipoises

(2) gm./liter

The following tabulations are useful for the purpose of comparing the effects of:

1. Changes in particle velocity (peripheral velocity of cup) at constant temperature and pressure;
2. Changes in pressure of the stagnant gaseous medium (in atmospheres) at constant temperature and velocity;
3. Changes in gaseous medium at constant pressure, temperature and velocity; and
4. Changes in temperature of a single gaseous medium, at constant pressure and velocity.

Likewise, by comparing the tabulations concerning atomization of copper at 70°F. with those concerning atomization of glass under identical conditions the effect on particle size of differences in surface tension of the liquid being atomized may be observed.

ATOMIZATION USING A SPINNING CUP (4-INCH DIAMETER WITH 0.050 INCH DIAMETER HOLES.

COPPER WITH A SURFACE TENSION OF APPROX. 1,200 DYNES/CM AT ITS MELTING POINT OF 1982°F.

Gas	Gas temp ° F.	Gas press. ⁽¹⁾	π_g (gm/cm ³)	η_g (2)	V ft./ sec.	Log-mean part.diam. microns
Air	70	1	0.0012	0.018	100	270
Air	70	1	0.0012	0.018	200	150
Air	70	1	0.0012	0.018	300	100

Air	70	2	0.0024	0.018	100	160
Air	70	3	0.0036	0.018	100	120
CO ₂	70	1	0.0017	0.015	100	180
CO ₂	290	1	0.0012	0.023	100	320
CO ₂	290	2	0.0024	0.023	100	190
CO ₂	290	3	0.0036	0.023	100	140

(1) Atmospheres
(2) Centipoises

GLASS WITH A MELTING POINT IN THE VICINITY OF 1,500°F. AND A SURFACE TENSION OF APPROX. 600 DYNES/CM.

Gas	Gas Temp ° F.	Gas Press. ⁽¹⁾	π_g (gm/cm ³)	η_g (2)	V of Cup ft./ sec.	Log-mean particle diameter microns
Air	70	1	0.0012	0.018	100	250
Air	70	1	0.0012	0.018	200	140
Air	70	1	0.0012	0.018	300	90
Air	70	2	0.0024	0.018	100	150
Air	70	3	0.0036	0.018	100	110
CO ₂	70	1	0.0017	0.015	100	170

(1) Atmospheres
(2) Centipoises

In each of the above tabulations, lines 1, 2 and 3 show the effect of changes in velocity in a particular gaseous medium at constant temperature and pressure.

Lines 1, 4 and 5 of each tabulation, and lines 7, 8 and 9 of the copper tabulation show the effect of changes in pressure of the gaseous medium at a constant temperature and velocity.

Comparison of lines 1 and 6 in both tabulations shows the effect of changing the gaseous medium with no change in temperature, pressure or velocity.

Comparison of lines 6 and 7 of the copper tabulation shows the effect of a change of temperature of a particular gaseous medium while maintaining constant pressure and velocity.

All of the foregoing figures on log mean particle diameter in microns are derived mathematically from a simplified version of our general atomizer equation hereinabove set out, the simplified equation being as follows:

$$DV\rho_g/\eta_g=K(\gamma/V\eta_g)^a(TV\rho_g/\eta_g)^b$$

As previously indicated, the values of the constant c and d are very small, and can be ignored. Approximate values for a and b are $a=0.11$ and $b=0.24$. For the particular cup, $K=36$.

In accordance with the foregoing detailed description, our process controls particle diameter of centrifugally atomized liquid particles, independently of particle velocity, by controlling the ratio between the viscosity and the density of the gaseous medium into which the particles are projected from the spinning atomizer; and this ratio is dependent upon the composition of the stagnant gaseous medium, and the temperature and pressure at which it is maintained.

The term "stagnant gaseous medium" is used in the claims to distinguish over those methods of atomization in which the liquid is projected into a rapidly flowing gaseous stream the velocity of which is a major factor in atomizing the material.

The log mean diameter of particles is commonly used to designate particle size where, as in centrifugal atomization, particle size necessarily varies over a range. The logarithm of the particle diameter of centrifugally produced particles is normally distributed with respect to weight percent (in a mathematical

sense) and may be represented by a straight line when plotted on a logarithm graph paper. When particles are distributed over a broad range of sizes, the line has a great slope; while a horizontal line represents particles of a single size. The log mean diameter of particles, therefore, is the mean particle size as shown by a logarithmic plot of the weight percent of particles of different diameters throughout the size range of the particles produced. Diameter is commonly expressed in microns.

Suitable apparatus for practicing the method of the present invention is illustrated diagrammatically in FIG. 1 and includes an atomizing chamber, indicated generally at 10; atomizing means, indicated generally at 20, within the atomizing chamber; liquid supply means, indicated generally at 30; and a gas supply and pressure control system, indicated generally at 40.

The atomizing chamber 10 is defined by an insulating side wall 11, an insulating top wall 12, a hopper bottom 13, a compartmented collection unit 14, and a collected particle release means 15 at the lower end of the chamber. The insulated side wall 11 and top wall 12 of the atomizing chamber contain a network of conduits 16 which are in direct contact with the inner surface of the insulated wall 11 so that they may be used to control the temperature of the interior of the atomizing chamber. If the apparatus is to be used for atomizing molten metals, the conduits 16 may be connected with cooling means (not shown) which may be refrigerating system or a source of cold water, depending upon the level at which the temperature within the chamber must be maintained.

If the apparatus is to be used for a process such as spray drying, the conduits 16 will be arranged to heat the interior of the atomizing chamber, and for this purpose they may carry electrical resistance heating coils, or they may be connected to a source of heated fluid (not shown).

Whether the interior of the atomizing chamber is to be cooled or heated, a temperature sensing element 17 may be mounted in the atomizing chamber and used to control the temperature of the conduits 16 by operation of a thermally controlled fluid valve or electrical switch in the usual manner.

The compartmented collection unit 14 is not illustrated in detail. Briefly, it includes a series of concentric circular walls providing annular compartments so as to automatically sort the particles which drop to the bottom of the atomizing chamber in accordance with the principles taught in U. S. Pat. No. 80,764, dated Aug. 4, 1869; U.S. Pat. No. 1,358,375, dated Nov. 9, 1920; U.S. Pat. No. 1,461,777, dated July 17, 1923; and U.S. Pat. No. 1,517,509, dated Dec. 2, 1924.

Since our atomizing process is carried out in a controlled gaseous environment, and usually at super atmospheric pressure, the atomizing chamber 10 is a sealed pressure vessel. Accordingly the discharge gate 15 at the lower end of the atomizing chamber closes upon a suitable annular seal and is constructed to withstand the planned operating pressures. It is, of course, opened only after the chamber has been vented to return it to atmospheric pressure.

The atomizing means 20 in the atomizing chamber 10 includes a drive 21 including an electric motor and stepup gearing to drive a vertical shaft 22 surmounting

which is an atomizing cup, indicated generally at 23. If the apparatus is to be used in carrying out the atomizing process at a predetermined and fixed surface speed of the cup 23, then a single speed drive may be used; but more commonly conventional speed control means (not shown) is provided to permit the cup to be rotated at any speed up to a maximum which may be computed for each particular installation in accordance with the material or materials to be atomized, the operating pressure and temperature, the stagnant gas being used, and the desired log mean particle diameter of the powder to be produced.

The atomizing cup 23 is best seen FIG. 2 to include a bottom wall 24, a cylindrical side wall 25, and an annular top flange 26 which confines the liquid L which is being centrifugally atomized. Holes 27 in the cup wall are of a diameter which is calculated to produce a desired dimension T of the liquid streams projected from the cup in operation. As previously indicated, for most metal atomization the optimum diameter of the holes 27 is 0.052 inch. A cup which is 4 inches in diameter has a surface speed of 100 f.p.s. at approximately 6,000 rpm.

The liquid supply means 30 includes a liquid supply compartment, indicated schematically at 31, which is defined by a continuous side wall 32 the lower end of which is sealed to the top wall 12 of the atomizing chamber, and a top wall 33, with the liquid supply compartment being capable of withstanding the same internal pressure as the atomizing chamber 10. A charging opening 33a in the top wall 33 is sealed by a closure 33b.

Within the supply compartment 31 is a liquid pot 34 having a bottom wall 35 and a side wall 36; and the liquid pot is constructed to maintain a liquid supply at the required temperature for introduction to the atomizing chamber. Thus, for centrifugal atomization of molten metal the liquid pot is a crucible, and suitable means are provided either in the bottom 35 and side 36 of the pot, or externally of the pot within the liquid supply compartment to melt the metal in the crucible. On the other hand, for spray drying, the liquid pot 34 may be constructed to maintain the liquid at any temperature below the vaporization point of the solvent.

A liquid supply pipe 37 connects the bottom of the liquid pot with the upper end of the atomizing chamber through a valve, indicated schematically at 38, so that liquid to be atomized may be admitted to the atomizing chamber and drop into the atomizing cup as illustrated in FIG. 2 under the control of an operator.

The gas supply and pressure control system 40 is designed to provide both the atomizing chamber and the liquid supply compartment with a controlled gaseous atmosphere at any pressure up to a predetermined maximum. In order that the liquid may be atomized in a gaseous medium other than air, the system 40 includes a vacuum pump 41 which is connected to the atomizing chamber 10 by a line 42 controlled by a valve 43, and it is connected to the liquid supply compartment 31 by a line 44 controlled by a valve 45.

A high pressure pump 46 is connected through a line 47 having a valve 48 with a gas supply 49; and gas supply lines 50 and 51 controlled, respectively, by valves 52 and 53 connect the Pump 46 with the atomizing chamber 10 and the liquid supply compartment 31,

respectively. Furthermore, in order that the atomizing chamber may be charged with air at super atmospheric pressure, the pump also has an intake connection to atmosphere through a pipe 54 controlled by a valve 55. The atomizing chamber 10 is provided with a gas pressure gauge 56, and the liquid supply compartment 31 is provided with a gas pressure gauge 57.

In operation, the atomizing chamber 10 and the liquid supply compartment 31 initially are at atmospheric pressure, and the liquid pot 34 is charged through the charging port 33a after which the compartment closure 33b is sealed. When a metal is to be atomized using air as a gaseous medium the liquid pot (crucible) is charged with small metal slugs which are melted; whereas for spray drying, the liquid pot is charged with the dissolved material which is to be spray dried. The pressure in the atomizing chamber 10 and the liquid supply compartment 31 are then elevated to any desired pressure as indicated by the gauges 56 and 57 by operating the pump 46 with the valves 52, 53 and 55 open, and the valves 43, 45 and 48 closed. When the desired air pressure has been reached in the atomizing chamber and the liquid supply compartment the valves 52 and 53 are closed and the pump 46 is stopped; and if at that point the liquid to be atomized is ready for atomizing the drive 21 is started to rotate the atomizing cup 23 at a desired speed and the valve 38 is then opened to admit liquid from the pot to the cup as illustrated in FIG. 2. If the particular atomizing conditions require it, of course, the necessary cooling or heating of the atomizing chamber through the conduits 16 is initiated while the pressurizing is taking place so as to minimize the total time required for the operation.

After the full charge in the liquid pot has been atomized (which may be indicated by any appropriate type of sensing device at the bottom of the pot) the drive 21 is shut off, the valves 43 and 45 are opened to vent the atomizing chamber and the liquid supply compartment through the vacuum pump 41 which may also be vented to atmosphere for that purpose, and the discharge gate 15 is opened to drop the solid atomized particles from the compartmented collection unit 14 at the bottom of the atomizing chamber.

Where atomization is to be carried out in a gaseous medium other than air, after the liquid pot has been charged and the closure 33a has been sealed the atomizing chamber 10 and the liquid supply compartment 31 are purged of air to the greatest practical extent by operating the vacuum pump 41 with the valves 43 and 45 open and the valves 52 and 53 closed. When the desired degree of vacuum in the compartment 31 is reached the valve 45 is closed and the vacuum pump is operated further until the same degree of vacuum is reached in the atomizing chamber as indicated by the gauge 56. The valve 43 is then closed, the vacuum pump is stopped, the valves 52, 53 and 48 are opened, and the atomizing chamber and liquid supply compartment are charged to the desired pressure, which may be atmospheric or higher, by operation of the pump 46 supplying gas from the gas supply 49. The rest of the operation is similar to that previously described.

It is apparent that in order to conserve the gas supply where a gas other than air is used, when an atomizing operation is completed the gas from the atomizing chamber and the liquid supply compartment should be

returned to the gas supply tank 49 either by reverse operation of the pump 46 with the valves 52, 53 and 48 open, or by some other means. In that event, of course, the atomizing chamber and the liquid supply compartment are at sub-atmospheric pressure when the gas salvage operation is completed, and must be returned to atmospheric pressure as by admitting air through the valve 55 and pump 46.

The foregoing detailed description is given for clearness of understanding only and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

We claim:

1. In a process of forming solid particles from a melted material which is atomized by projecting it in the form of droplets generally horizontally at a predetermined velocity into a stagnant gaseous medium, said medium being maintained substantially at a selected pressure which is not less than one atmosphere and substantially at a selected temperature which is in a range below the melting point of the atomized material so as to form solid particles of said material in said medium, the improvement comprising:

50 said gaseous medium having a ratio of viscosity to density at said selected pressure and at said selected temperature substantially below that of air at atmospheric pressure and at said selected temperature,

55 whereby the solid particles have a smaller log mean diameter than would particles formed by projecting the same liquid at the same velocity into air at atmospheric pressure and at said selected temperature.

2. The process of claim 1 in which the gaseous medium at said selected pressure and at said selected temperature has a viscosity less than that of air at said selected pressure and at said selected temperature.

3. The process of claim 2 in which the gaseous medium at said selected pressure and at said selected temperature has a density greater than that of air at said selected pressure and at said selected temperature.

4. The process of claim 1 in which the gaseous medium at said selected pressure and at said selected temperature has a density greater than that of air at said selected pressure and at said selected temperature.

5. The process of claim 1 in which the gaseous medium is carbon dioxide.

6. The process of claim 1 in which the gaseous medium is maintained at a pressure substantially in excess of one atmosphere.

7. The process of claim 6 in which the gaseous medium is maintained at a pressure in excess of two atmospheres.

8. The process of claim 1 in which the material is projected centrifugally as discrete streams of droplets.

9. In a process of forming solid particles from a liquid which consists of a solid material dissolved in a solvent, said liquid being atomized by projecting it in the form of droplets generally horizontally at a predetermined velocity into a stagnant gaseous medium which is maintained substantially at a selected pressure which is not less than one atmosphere and substantially at a selected temperature which is in a range within which said solvent flash evaporates to leave particles of said solid material in said gaseous medium the improvement comprising:

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said gaseous medium having a ratio of viscosity to density at said selected pressure and at said selected temperature substantially below that of air at atmospheric pressure and at said selected temperature,

whereby the particles of solid material have a smaller log mean diameter than would particles formed by projecting the same liquid at the same velocity into air at atmospheric pressure and at said selected temperature.

10. The process of claim 9 in which the gaseous medium at said selected pressure and at said selected temperature has a viscosity less than that of air at selected pressure and at said selected temperature.

11. The process of claim 10 in which the gaseous

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medium at said selected pressure and at said selected temperature has a density greater than that of air at said selected pressure and at said selected temperature.

12. The process of claim 9 in which the gaseous medium at said selected pressure and at said selected temperature has a density greater than that of air at said selected pressure and at said selected temperature.

13. The process of claim 9 in which the gaseous medium is carbon dioxide.

14. The process of claim 9 in which the gaseous medium is maintained at a pressure substantially in excess of one atmosphere.

15. The process of claim 9 in which the material is projected centrifugally as discrete streams of droplets.

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