

June 11, 1963

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3,093,315

ATOMIZATION APPARATUS

Filed March 22, 1960

4 Sheets-Sheet 1

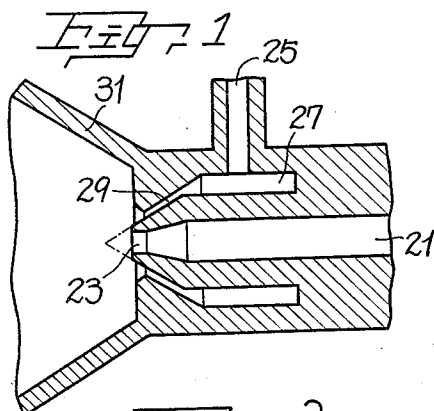
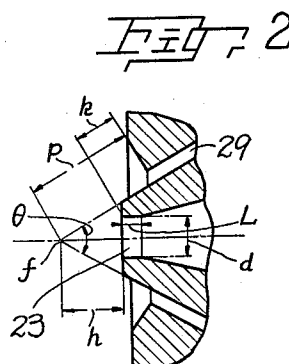


Fig. 3

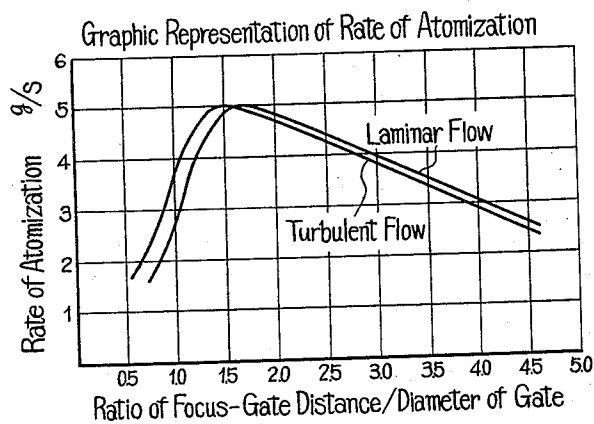
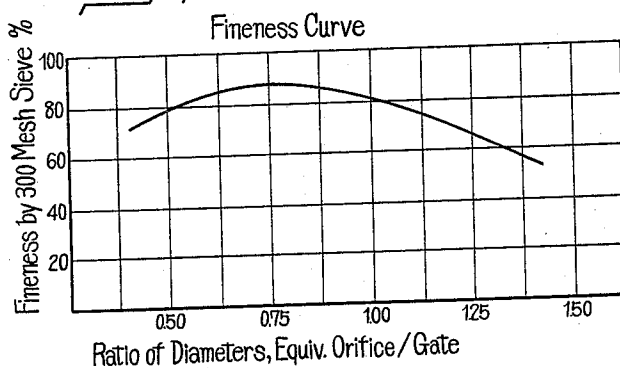


Fig. 4



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FIG. 5

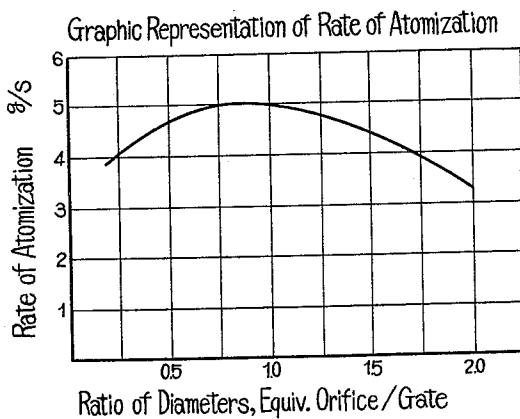


FIG. 6

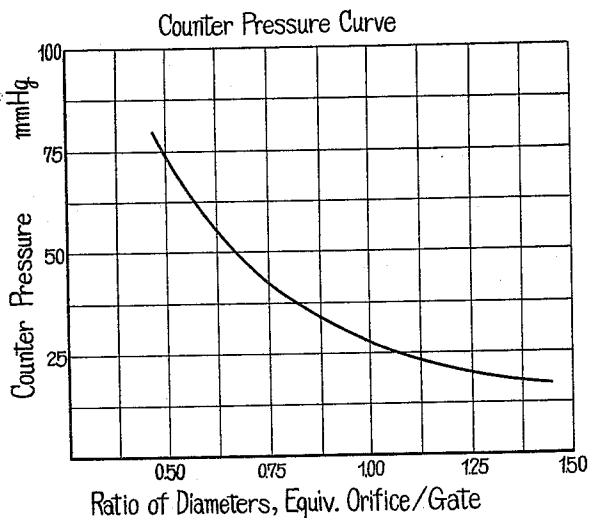
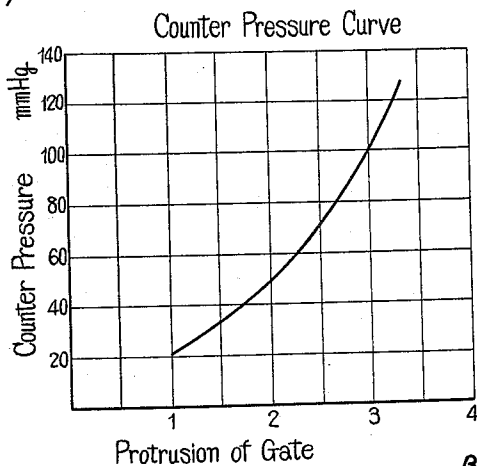


FIG. 7



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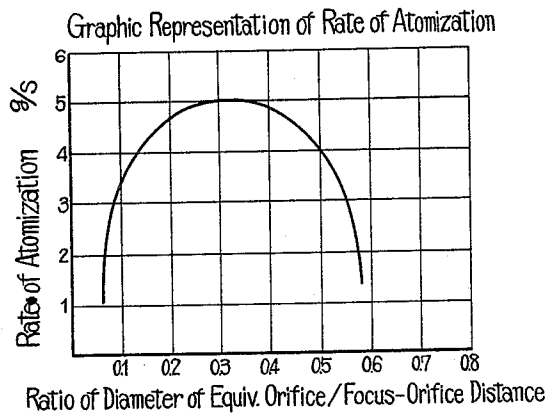
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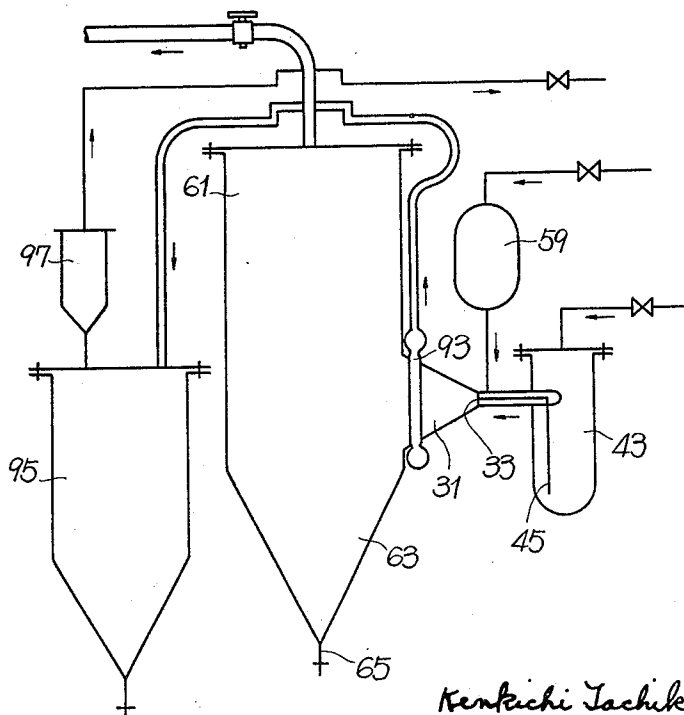
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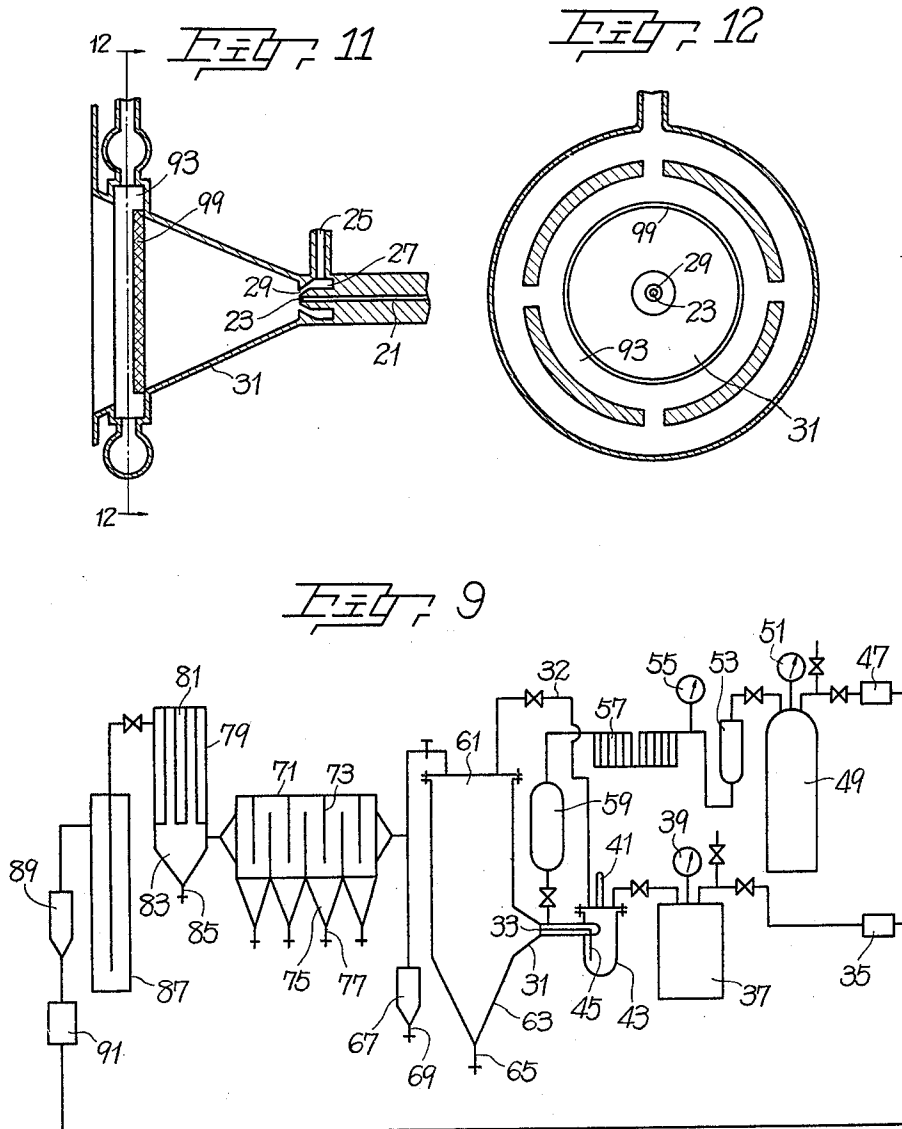
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4 Sheets-Sheet 4



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3,093,315

ATOMIZATION APPARATUS

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This invention relates to atomization apparatus. More particularly, this invention relates to apparatus and installation required for atomizing liquids.

In this specification, we have made frequent use of the expression "liquid," but it is to be understood that this term has been used for liquid substance such as a solution or molten substance such as a molten metal. "Gate" means an opening in a nozzle which the "liquid" passes. "Equivalent diameter" of an orifice means a diameter of another orifice which is equal to the first-named orifice in cross sectional area.

Atomization of liquid by means of jetting gas stream has been studied for appreciably many years, but, since the relation between an orifice from which the gas is jetted and the gate is extremely complicated, the theoretical basis for the study has not been consolidated. Accordingly, various types of process and apparatus have been proposed heretofore in accordance with a variety of studies. Meantime, pulverized metal has been produced by mechanically grinding means which is not suitable for mass production.

An object of this invention is to provide an apparatus whereby it is possible to obtain a higher efficiency in atomization.

Further another object of this invention is to provide an installation whereby it is possible to operate the apparatus completely and advantageously.

A further object of this invention is to provide a means whereby an orifice of the apparatus is prevented from clogging which is a trouble apt to occur frequently in the apparatus.

A further object of this invention is to provide an apparatus having superior performance in metallikon processes.

A further object of this invention is to provide an apparatus having excellent performance in paint spraying processes.

A further object of this invention is to provide a superior process for the production of certain fibrous materials such as glass wool and rock wool.

Generally stated, this invention pertains to apparatus for carrying out the process for atomization of a liquid comprising admitting said liquid to a gate of a nozzle to pass said gate, admitting a gas to at least an orifice of said nozzle, said orifice being arranged around said gate, and jetting said gas towards a focus into which said jetted gas is directed once to be concentrated, said focus being arranged in the axis of said gate in such a manner that the smallest limit of the ratio of the distance between the outlet of the gate and the focus to the diameter of the gate resides between 1.2 and 1.4.

The invention will be better understood and other objects and additional advantages of the invention will become apparent upon perusal of the following description taken in connection with the drawings, and the scope of the invention will be defined in the appended claims.

In the drawings, FIG. 1 is a vertically sectional side elevation of an essential part of an atomizing apparatus in accordance with this invention.

FIG. 2 is an enlarged similar view to the above but showing a nozzle thereof.

FIGS. 3 to 8 are graphic representations of numerical values adopted in this invention, in which FIG. 3 is a graphic representation of the rate of atomization, FIG. 4

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is a fineness curve, FIG. 5 is another graphic representation of the rate of atomization, FIG. 6 is a counter pressure curve, FIG. 7 is another counter pressure curve, and FIG. 8 is still another graphic representation of the rate of atomization.

FIG. 9 is a diagrammatic flow sheet showing a unit of an installation embodying this invention.

FIG. 10 is an explanatory diagrammatic flow sheet of a part of an installation embodying this invention where a clog-proof means is provided.

FIG. 11 is a vertically sectional side elevation of a nozzle and a funnel provided with a suction channel.

FIG. 12 is a vertically sectional front view thereof taken along the line 12-12 in FIG. 11.

Similar numerals refer to similar parts throughout the several views.

We have engaged in study of the atomization and achieved a fruit going several steps ahead of the prior art. Employing molten aluminum as the liquid and gaseous argon as the jetting gas of our studying material and an apparatus as shown in FIGS. 1 and 2 as our studying apparatus, we studied the operation and drafted graphic representations such as shown in FIGS. 3 to 8 on which the functional relations among parts are illustrated, whereby values for an optimum condition for the process and an optimum design of the apparatus are sought ending in to invent this process and the apparatus therefor and the installation therefor.

Referring now to drawings, an annular orifice 29 for jetting gas is provided around a gate 23 in a nozzle 33. At first, we have studied variation in the angle of inclination θ of the orifice 29 resulting in to find that the rate of atomization becomes larger as the angle of inclination θ between the jetting direction and the axis X-X of the gate 23 becomes larger. As shown in FIG. 3, when the axial length L is shorter than twice of the diameter d, the liquid discharged from the gate 23 forms a turbulent flow. In this case, when the distance h from the focus f of the jetted gas to the outlet of the gate 23 is 1.5 times as long as the diameter d of the gate 23, the rate of atomization becomes maximum. When the ratio of the distance h between the focus f and the outlet of the gate 23 to the diameter d is less than 1.2 or the focus approaches the gate 23 to an extent, the rate of atomization diminishes sharply. Therefore, in this invention, the value less than 1.2 for the h/d ratio is not adopted.

When the length L of the gate 23 is twice as long as the diameter d of the gate 23 or more, or the liquid discharged out of the gate 23 forms a laminar flow, it has been found that the rate of atomization reaches the maximum value at 1.7 times in the proportion of the distance h between the focus f of the jetted gas and the outlet of the gate 23 to the diameter d of the gate 23. When the ratio of the distance h of the focus f to the diameter d of the gate 23 becomes less than 1.4 or the focus approaches the gate 23, the rate of atomization falls suddenly. Hence, in this invention, the value less than 1.4 is not adopted for the ratio of h/d. The angle θ of inclination of the gas jetting orifice 29 adaptable to the condition as above is preferred to be in a range of from 60° to 90°. Particularly, 80° is most appropriate for the value of the angle of inclination θ . When these conditions are thoroughly satisfied, the atomized liquid flows along the axis of the gate and in the form of a relatively sharp circular cone having the vertex at the focus f such as a long broom of a comparatively dense fog or smoke which diffuses sparser and sparser as receding from the focus.

In order to embody this invention most effectively, it is necessary to satisfy further several conditions.

First of all, it is necessary to discuss the ratio of the equivalent diameter g of the gas jetting annular orifice 29 to the diameter d of the gate 23. It was found that

the ratio g/d has a close connection with the gas pressure at the focus f of the jetted gas and, accordingly, with the rate of atomization and the counter pressure. The value of the equivalent diameter g of the orifice 29 is calculated by a formula,

$$\pi g^2/4x$$

For example, when the jetting gas is constant in quantity and the ratio of the equivalent diameter g of the gas orifice 29 to the diameter d of the gate 23 is more than 0.75, the concentration of the gas into the focus f becomes inferior, the gas pressure at the focus f falls, the rate of atomization drops, and the particles produced get coarse. When the ratio of g/d becomes less than 0.75, the gas pressure at the focus f increases and the atomization is accelerated temporarily. But when the ratio of g/d becomes further less, although the gas pressure still increases, the rate of atomization is reduced again to produce coarse particles.

FIG. 4 illustrates a study for molten aluminum in which the ordinate represents the throughput of a sieve of 300 mesh by percent while the abscissa represents the ratio of the equivalent diameter g of the gas orifice 29 to the diameter d of the gate 23.

FIG. 5 illustrates a study for molten aluminum again, but the ordinate represents the rate of atomization and the abscissa represents the g/d ratio, in which the diameter d of the gate 23 was 25 mm., the flow of the jetted gas was 3.5 litre/second, and the pressure applied to the molten aluminum was 150 mm. Hg. FIG. 6 represents the relation between such ratio g/d and the counter pressure, in which the pressure at the gas orifice 29 was 2 kg./cm.². As shown in FIG. 6, when the ratio g/d becomes less than 0.75, the counter pressure to the gate 23 ascends abruptly.

In view of the facts as above, such numerical values as is within a range of from 0.5 to 1.5 for the ratio of g/d may be adopted for the atomization in accordance with this invention.

Now the length of a protrusion k was studied which is defined as a distance between the outlet of the gate 23 and the outlet of the orifice 29. The extent of protrusion relates intimately to the counter pressure acting against the gate 23, the gas pressure at the focus f , and the rate of atomization. We obtained a relation between the protrusion k of the gate 23 and the counter pressure as shown in FIG. 7 of the counter pressure curve, in which the diameter d of the gate 23 was 2.5 mm. As the protrusion k increases, the counter pressure lowers sharply. Namely, as the gate 23 approaches the focus f , the counter pressure against the gate 23 increases and, at the same time, the gas pressure at the focus f increases successively ending in to accelerate the rate of atomization. However, if the gas pressure at the focus f is heightened further, the rate of atomization is rather injured resulting in to give coarser particles. On the other hand, if the length k of the protrusion is shortened, the counter pressure becomes reduced but the gas pressure at the focus f is also reduced ending in to give very coarse particles.

There are two contradictory conditions to each other for the gate 23 as above. This contradiction may be harmonized by an extent of length of the protrusion k . Therefore, when the length of the protrusion k of the gate 23 is varied keeping the equivalent diameter g of the gas orifice 29 which is considered to be a basis of the gas stream at a value, the ratio of the distance p between the focus f and the outlet of the gas orifice 29 to the equivalent diameter g of the latter is an important value. Such a ratio g/p is represented on the ordinate of the graph of FIG. 8 while the abscissa thereof represents the rate of atomization so as to illustrate a curve for the rate of atomization. As shown in FIG. 8, the rate of atomization is favourable in a range of from 0.15 to 0.50 for the ratio g/p , particularly in the proximity of 0.30. It

is easily possible to find the length k of the protrusion by the graph of FIG. 8, and from the length k thus obtained it is possible to find a value of the counter pressure by means of the counter pressure curve of FIG. 7. Thus it becomes possible to find a value of the counter pressure which is effectively adoptable in the atomization in accordance with this invention.

When the atomization is effected satisfying these conditions set forth hereinbefore, the gas stream carrying the atomized powder is under influence extremely sensitively of the shape of a funnel 31 which receives the gas stream. If the funnel is too intimate with the gas stream or a gas pocket is to be found on the front surface of the nozzle 33, the flow of the gas stream becomes turbulent disharmonizing the liquid with the gas. Accordingly, it is considered that a shape of the divergent funnel 31 as illustrated in FIGS. 1 and 11 is of the most ideal which diverges along the boundary of the flow of the gas stream. An angle of divergence of the divergent funnel 31 is effective if the angle is more than 20° and it was found that 40° for the angle is optimum especially.

Referring further to the drawings, an aluminum atomizing apparatus which satisfies the above several conditions for carrying out this invention will be explained. In FIG. 1, numeral 21 indicates a runner through which the molten aluminum is conveyed to the gate 23. Numeral 25 indicates a pipe through which the gas supplied. Numeral 27 indicates a gas chamber. Numeral 29 indicates an orifice through which the gas is jetted. Numeral 31 indicates a closed type divergent funnel for receiving the flow of the gas stream carrying the powder. Gaseous argon was employed for this embodiment. It was found that, in general, it is optimum to use a molten metal kept at a temperature which is about 250° C. higher than the melting point of the metal. In order to obtain a powder in the metal state, it is necessary to use a gas to be jetted at a temperature as high as the melting point of the metal.

The conveyance of the molten metal from a reservoir to the gate 23 may be operated by either a gas pressure or gravity. Since the rate of atomization and the fineness of the product are under influence of the pressure applied to the level of the molten metal, it is necessary to pay attention to provision of the apparatus so as to be adjustable precisely for the conditions. It is also necessary to adjust the pressure of the gas to be jetted precisely by means of an adjusting device. As to these adjusting means, explanation will be made hereinafter. Thus the atomized aluminum powder was admitted into a collector through the divergent funnel 31 and collected separating from the gas.

The numerical values obtained by our studies may be adopted for carrying out the process for the production of atomized powder of all kinds of metals and of generally fusible substances, and designing an apparatus therefor. It may be adapted to any of all kinds of materials having a lower melting point or a higher melting point, and further to a solution to be sprayed. Therefore, it is to be understood that the apparatus is to be made of a proper material variable depending upon the property of the liquid to be atomized.

Sometimes, this invention may be embodied employing air as a gas to be jetted, but in case an oxidizable or chemically convertible substance is atomized, it is necessary to use an inactive gas such as helium or argon as the gas to be jetted. In order to effect the atomization effectively, economically, and properly by the apparatus and the process in accordance with the disclosure set forth hereinbefore, it is necessary to combine the apparatus and the proceedings with proper accompanying means which concern adjustment of the liquid as gas stream, collection of the fine powder produced, separation of the fine powder from the gas, recovery of the gas, etc., so as to constitute a unit of an atomizing installation as will be explained hereinafter.

Referring now to FIG. 9, there is an air-tight liquid

reservoir 43. Heretofore, flow of liquid is controlled by extent of opening of a stopper of a liquid reservoir utilizing a head obtained by locating the reservoir above a nozzle for adjusting the flow. We think it is difficult to achieve an accurate adjustment of flow by such a means while the flow is considered to be an extremely important factor upon which the atomizing performance depends. In view of this, in accordance with this invention, the adjustment of flow is effected by adjusting gas pressure subjected to the inside of the air-tight liquid reservoir 43. Since it is possible to adjust the gas pressure precisely, the flow adjustment by means of the gas pressure becomes far precise and accurate comparing with an adjustment by means of the opening control of a stopper. To this end, it is necessary to provide a liquid pressure adjusting tank 37. The volume required of the tank 37 is ten times or more as large as the effective volume of the reservoir 43. It is also desirous of keeping the volume above the liquid level within the reservoir 43 as small as possible for adjusting the liquid pressure. That is, it is preferred to keep the space between the top or a cover of the reservoir 43 and the liquid level as short as possible. However, in case the liquid is a molten substance, as it is desired to provide an appreciably long space between them in order to maintain a temperature of the liquid contained in the reservoir 43, it becomes necessary to provide a volume of the space above the level of the liquid up to an extent. Thus it becomes necessary to harmonize these two matters opposite each other. This space is expressed by the temperature gradient as follows. When the reservoir 43 is a cylinder and the liquid level is 100 mm. in diameter, a temperature gradient of 50°/10 mm. or more is preferred with an optimum of the temperature gradient of 80° C./10 mm. when the diameter of liquid level is 100 mm. The diameter of the liquid level should be in inverse proportion to the temperature gradient so that the longer the diameter the smaller the temperature gradient must be. In other words, the distance between the liquid level within the reservoir 43 and the cover is required to become longer.

Now the path of gas stream is explained. As a general rule, the rate of atomization at a nozzle and the fineness of the powder depend upon the pressure subjected to the gas stream applied to the flow of the liquid. In this embodiment, the adjustment of the pressure is effected at the gas pressure adjusting tank 49. In case of molten substance, it is necessary to provide a secondary gas pressure adjusting tank 59 because the gas is supplied to the nozzle 33 through a gas heating means 57. It is desired that the primary gas pressure adjusting tank 49 is twenty times or more as large as the flow of the gas per second in volume and the secondary gas pressure adjusting tank 59 is five times or more as large as the flow of the gas in volume. In case molten substance is treated, another important factor comparable with the pressure of the gas stream is to be considered. It is the temperature of the gas stream which is most suitable to be kept at a temperature about 0.6 times as high as the temperature of the molten substance.

The powder produced is separated from the gas stream and collected by the following means. It is to be understood that the type and/or number of the means are to be selected in accordance with the property of the material to be treated. The nozzle 33 is connected with the lower part of a settling chamber 61 by means of a funnel 31. In order to reduce the velocity of the gas stream and the powder carried thereby down sufficiently, it is required to provide a sufficiently large volume of the settling chamber 61. In order to give a sufficient settling time to the powder produced, it is necessary, for example, in case the settling chamber 61 is a cylinder to provide a height thereof twice or more as long as the diameter thereof. Even if satisfactorily conditional on the velocity of the molten substance and the gas pressure at the operat-

ing nozzle, the atomizing effect depends further upon the state of the gas stream within the funnel 31.

Sometimes, a turbulent flow of the gas stream, particularly in case of treating molten substance, sticks the produced powder on the inside surface of the funnel 31 whereby a continuous operation of the installation is disturbed and, furthermore, clogging of the orifice may occur. In order to prevent the gas stream from the turbulent flow within the funnel 31, it is necessary that a gas stream within the settling chamber 61 connected with the funnel 31 is aspirated without an appreciable turbulence. To this end, the inside space of the settling chamber 61 must be appreciably large. If the settling chamber 61 is cylindrical, it is desirous of having a diameter of twice or more as long as the diameter of the opening end of the divergent funnel 31. Thus the atomized liquid or powder carried by the gas stream is admitted to the settling chamber 61 through the funnel 31. We experienced frequent troubles in operation of the atomization in the installation of this class owing to the nozzle clogging. Under these circumstances, we studied the cause of the orifice clogging in the nozzle 33, as will be set forth hereinafter.

There is provided a collector 63 below the settling chamber 61 in which the powder settled is collected. The collected powder is removed out of the collector 63 through a powder flow stopcock 65. The gas stream from which the greater part of the powder produced has been separated is admitted to a finer powder separator 71 through a pipe starting from the top of the settling chamber 61. It is necessary to provide a trap 67 branched from the pipe between the settling chamber 61 and the finer powder separator 71. The shape of the finer powder separator 71 has no influence directly on the gas stream within the funnel 31 so that the former is not stricted in shape. For example, the finer powder separator 71 may have a number of baffle plates 73 at intervals of the same distance with each other as shown in FIG. 9. In this example, it is most effective to arrange the baffle plates 22 at regular intervals of the distance which is the same or more with the width of the baffle plate 73. It is preferred to make the baffle plate of a woven fabric, of which a kind depends upon the property of the powder produced. Several finer powder collectors 75 are provided below the finer powder separator 71 and have powder flow stopcocks 77, respectively, through which finer powder thus separated is recovered. A powder filtering chamber 79 follows the finer powder separator 71 which serves complete collection of the most atomized finest powder which is inseparable in the finer powder separator 71. The filtering medium 81 may be an inorganic or organic woven fabric or a fiber bed. FIG. 9 shows a multi-tubular filtering chamber 79 having several tubes made of woven fabric. The finest powder collected in a finest powder collector 83 is removed therefrom through a powder flow stopcock 85. An aspirating pressure adjusting tank 87 follows the powder filtering chamber 79 and a dust proofing trap 89 follows, in turn, the aspirating pressure adjusting tank 87. A suction pump 91 is connected with the dust proofing trap 89 whereby the internal pressure of the whole atomizing installation is adjusted. The exhausted gas of the suction pump 91 is admitted to two blowers 35 and 47 from which the gas is directed to the liquid pressure adjusting tank 37 and the primary gas pressure adjusting tank 49, respectively, so as to circulate the gas throughout the installation. Furthermore, it is necessary to provide a means of supplying the liquid to the reservoir 43 and means of supplying the gas to the liquid pressure adjusting tank 37 and the primary gas pressure adjusting tank 49. In addition, it is necessary to connect the reservoir 43 with the settling chamber 61 by means of a pipe 32 provided with a valve for the purpose of adjusting pressure within the installation at the starting period of the operation of the atomizing installation.

In accordance with this invention, the following series of operations may be effected by means of this installation: (1) A liquid is supplied through a gate of the nozzle under the pressure of air or, if necessary, an inactive gas such as hydrogen, argon, or nitrogen; (2) A gas is jetted through orifices of the nozzle under pressure, and if necessary at an elevated temperature; (3) The liquid is thus sprayed, the funnel is passed by the sprayed liquid so as to produce atomized powder, and the major part of the atomized powder is collected being settled in the settling chamber; (4) The finer powder which is inseparable in the settling chamber is admitted into the finer powder separator together with the gas stream so as to collect the former; (5) The finest powder which is inseparable in the finer powder separator is admitted into the powder filtering chamber together with the gas so as to collect the former completely; and (6) The gas separated from the powder is aspirated by the aspirating pressure adjusting tank and the suction pumps so as to recover the gas when the gas is an inactive gas.

After experiments and studies in connection with the orifice clogging in the nozzle, we found that, analysing substance stuck on the gas orifices of the nozzle when metallic calcium powder was produced, the substances stuck were calcium oxide and calcium nitride. In the case calcium powder in the metal state was produced, argon was used as the gas to be jetted, because it is impossible to use hydrogen, and of course, air, on account of the fact that hydrogen reacts with calcium forming a hydride at an elevated temperature. Gaseous argon on the market contains nitrogen slightly which was purified on that account. It was observed, however, that calcium compounds stick on the gas orifices even if the purified argon was used. We found that the fact as above is derived from contamination of argon owing to air remaining in the installation against purge effected throughout the installation before the operation of the atomization and getting into the installation externally during the operation and change of powder caused by the impure gas. Particularly, it was found that the change is quicker in a metal having a stronger getter action.

We studied then the manner in which the powder sticks on the gas orifices. In general, gas jetted from the orifices flows in a shape of extremely sharp circular cone and diffuses carrying the powder in the regular state. In this case, we found a counter flow surrounding the cone of the gas stream or along the inner surface of the divergent funnel. This counter flow arrives at the orifices. This counter flow consists of the more or less contaminated argon as referred to hereinbefore. Therefore, liquid discharged from the gate of the nozzle combines with the impure gas to yield a product which sticks on the surface of the nozzle. Particularly, when the product has a high melting point, it is always piled up thicker and thicker but not molten and not thus removed. We found that the clogging of the orifice is caused by the above fact. Considering the two causes, we intended to remove either the contamination of the gas to be jetted or the existence of the counter flow for the purpose of preventing the orifice from clogging. To this end, a suction channel is advantageously provided in the inside surface of the divergent funnel in the proximity of the open end thereof so as to inhale the counter flow into the channel. As expected, adherence and pile of the changed powder on the orifice did not occur by virtue of the suction channel. Thus the gas orifices were successfully prevented from clogging.

Referring now to FIGS. 10 to 12, a suction channel 93 in accordance with this invention is provided in the inside surface of a divergent funnel 31 circularly in the proximity of the open end of the funnel 31. A metal net 99 of 100 mesh or more is placed along the open end of the channel so as to filter the atomized powder and prevent the powder as far as possible from being inhaled into the channel 93. However, if the net 99 is placed

so as to cover the whole inlet of the channel 93, it becomes to resist the suction resulting in to make it insufficient for inhaling the counter flow gas. In view of this, it is proper to cover no more than about one third or a half of the width of the circular inlet of the channel 93 from the nozzle side thereof by the metal net 99. By virtue of the arrangement of the metal net, it becomes possible to inhale the counter flow gas into the channel 93 preventing the produced powder from being inhaled thereinto as far as possible.

In general, since comparatively much quantity of impure gas exists within the atomizing installation before an operation thereof is started, if the clog-proof means in accordance with this invention is not provided, the phenomenon of adherence of changed powder on the orifices may occur rapidly after the start of the operation to clog the orifices. Therefore, this clog-proof means acts a very important play for the atomization. Thus during the starting period of the operation, the counter flow gas must be inhaled by means of strengthening the suction. However, when the suction is strong, the gas stream within the funnel 31 is made turbulent and at the same time a more quantity of powder is disadvantageously inhaled into the channel 93. It is not preferable therefore to maintain the strong suction continuously. Accordingly, as soon as the operation at the nozzle 33 becomes in the regular state, it is necessary to weaken the suction of the clog-proof means while the suction along the axis of the funnel 31 must be strengthened. Thus it is necessary to harmonize the suction of the clog-proof means with that of the suction pump 91 along the axis of the funnel 31 always so as to prevent the gas stream within the funnel 31 from occurrence of turbulence.

Therefore, about 50 percent of the whole suction is loaded to the clog-proof means at the starting period of the operation of the nozzle, which is reduced after a short period gradually. Thus gradual reduction of the load, it is brought down to 10 to 15 percent and kept at the value thereafter. By virtue of the clog-proof means in accordance with this invention employed in such a manner as above, it becomes possible to operate the atomizing installation extremely smoothly without any trouble at the gas orifice.

Example 1

In this embodiment gaseous hydrogen is used as the gas to be jetted and molten aluminum is atomized. A nozzle as described hereinbefore and illustrated in FIGS. 1 and 2 is used of which the gate is 2.5 mm. in diameter. 1500 g. of aluminum molten and kept at a temperature of 900° C. was contained in a cylindrical reservoir of 100 mm. in diameter so as to leave a space of 120 mm. in height between the level of the molten aluminum and a cover of the reservoir. The space was filled up with gaseous hydrogen after a sufficient purge. The hydrogen is adjusted in pressure by means of a blower 35 as shown in FIG. 9 so that a pressure of gaseous hydrogen of 150 mm. Hg was applied to the level of the molten aluminum. Another blower 47 supplied gaseous hydrogen to a gas heater 57 through a primary gas adjusting tank 49 and a flow meter 53. The hydrogen heated up to a temperature of 850° C. at the gas heater 57 was fed to the nozzle 33 through a secondary gas adjusting tank 59. Thus the atomizing installation was operated with the gaseous hydrogen and the molten aluminum, the pressure of the former being adjusted by a gas pressure valve and the pressure of the latter being adjusted by a liquid pressure valve. While the internal pressure of the settling chamber 61 and the funnel 31 was kept at 510 mm. Hg by means of an aspirating pressure adjusting tank 87 and a suction pump 91, the hydrogen gas was jetted from the orifice of the nozzle 33 at a rate of 3.5 liters per second under a pressure of 2.0 kg./cm.², whereby the molten aluminum was atomized at a rate of 10 g./s., of which approximately 60 percent was collected in a settling chamber 61 and approximately 40 percent was in

a finer powder separator 71. Aluminum powder thus produced had an extremely active property and was of suitable for the power metallurgical use. 85 percent thereof passes a 300 mesh sieve.

Example II

In this embodiment, production of atomized calcium will be explained. Through our study, it has been found that our invention in accordance with which molten calcium is atomized is far more suitable to a mass production of such powder than a system in which a solid is ground in accordance with the prior art. Since atomized calcium is strongly active to several substances, reactive with air and moisture extremely sensitively, and combinable with nitrogen and hydrogen which are considered inactive to an ordinary metal, forming the nitrides and the hydrides, it is necessary to treat the atomized calcium with the greatest possible care. Considering these facts and as a result of further study, it became possible to obtain atomized calcium of any desired fineness and an extremely much quantity of strongly activated calcium for an unit time, by virtue of a fact that it is most suitable to use gaseous helium or gaseous argon as the gas to be jetted which is inactive to calcium. The inactive gas as above includes gases of the elements of the group zero in the periodic table such as helium and argon.

It is possible to use a material for the apparatus which does not alloy or react with calcium, for example, iron. It is preferred to make the nozzle of a material having a high hardness, for example, titanium carbide in order to satisfy such a premise that the nozzle should not be deformed during heating. When the atomizing apparatus is used to operate the same for the process, temperature is the most important factor. It is necessary to heat up to a temperature of at least 100° C. higher than the melting point of calcium and a temperature of further higher than that will result a more fluid molten metal and easier operation. The secondly important conditions are pressures, flows, and drift velocities, particularly pressure of gas. These factors decide fineness of the product. The efficiency in the capacity of the apparatus is decided depending upon adjustment of the above factors. We had a result where an atomizing apparatus having a gate of 2.5 mm. in diameter was used and produced 4 to 6 g./s. of the powder by virtue of the most appropriate adjustment of the above factors.

In this case, 1000 g. of calcium was molten at a temperature of 950° C. and maintained at the temperature in an air-tight closed type reservoir. Argon gas compressed up to a pressure of 2.0 kg./cm.² was heated up to a temperature of 850° C. and jetted through an orifice of the nozzle of the apparatus. At the same time, the molten metal was further compressed up to a pressure of 150 mm. Hg. Thus 910 g. of atomized calcium was yielded after three minutes of operation. 80 percent of the product was a matter of 44 micron or less in fineness.

The atomized calcium thus produced is, in general, sphere in shape, has an extremely superior property for use in a powder metallurgy, and is also suitable to use as reactant. Fineness of the atomized calcium thus produced is between 10 micron and 50 micron depending upon the producing conditions.

Example III

Referring now to FIGS. 10 to 12, atomization of molten calcium embodying this invention will further be explained. A funnel 31 connected with a nozzle 33 at and end has another end having a diameter of 180 mm. which opens into a settling chamber 16. A circular suction channel 93 is provided in the inside surface of the funnel 31 in the proximity of the open end thereof and 20 mm. in the axial width. A circular metal net 99 of 150 mesh and about 10 mm. in width is placed on the circular inlet of the channel 93 along the nozzle side thereof. The suction channel 93 is communicated with a filter 95

by means of a conduit, whence with a suction adjusting tank 97, whence with a vacuum pump (not shown). It is necessary to bring the gas pressure inside the settling chamber 16 and the funnel 31 up to a pressure of 510 mm. Hg just before the operation of the atomizing installation is started. When the operation is started, a pressure of 120 mm. Hg is applied on the molten calcium contained within a reservoir 43 by gaseous argon while gaseous argon is supplied to the orifice of the nozzle 33 from a gas pressure adjusting tank 59 at a rate of 3.0 liters per second, whereby the molten calcium is jetted through the orifice of the nozzle 33 so as to atomize the molten calcium.

We started the operation of atomization of the molten calcium with adjustment of a valve appended to the suction adjusting tank 97. Thus 50 percent of the gaseous argon was inhaled into the suction channel 93. The valve was then closed gradually down to an extent where 15 percent of the argon was inhaled into the channel 93 as the regular state of operation. Meantime, the flow rate of argon through the orifice of the nozzle 33 was constant and no matter indicating out of order was found at the orifice of the nozzle 33. There was found substantially no change in the flow rate of the gas in operation until the end of a run. After several runs were finished, it was found that less than 5 to 10 percent of the produced powder was inhaled into the suction channel 93 for each of the several runs.

The atomizing apparatus and installation in accordance with this invention would be employable considerably broadly and new use thereof would be found in various fields. For example, the apparatus has a superior performance as a light metal atomizing means. A metal powder made in accordance with the process and by means of the apparatus of this invention employing a molten metal such as aluminum, magnesium, potassium, sodium, cadmium, zinc, tin, or lead and a gas to be jetted such as an inactive gas, for example, argon may be employable as a remarkably excellent material for powder metallurgical processes or a reductant for chemical processes. It is also employable for a material for sintering metal powders. In view of these facts, the process apparatus, and installation would enjoy unlimited development of their new use. Furthermore, it is a remarkably interesting fact that, when the apparatus and the process are used with a molten solid solution having no definite melting point such as glass or other glass-like substances and air as the gas to be jetted, extremely fine fibres such as glass wool and rock wool are produced. Still further, the process and the apparatus in accordance with this invention have superior performance in the metallikon proceedings and the paint spraying.

While particular embodiments of the invention have been illustrated and described, modifications thereof will readily occur to those skilled in the art. It should be understood therefore that the invention is not limited to the particular embodiments disclosed but that the appended claims are intended to cover all modifications which do not depart from the true spirit and scope of the invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An apparatus for atomization of a liquid comprising a nozzle having a gate for discharge of liquid and an orifice for discharge of gas arranged around said gate for jetting said gas so as to converge at a focus on the axis of said gate on the discharge side of said gate, said gate having a protrusion with respect to said orifice, said focus being arranged in such a manner that the smallest limit of the ratio of the distance between the outlet of said gate and said focus to the diameter of said gate is between about 1.2 and about 1.4, the ratio of the equivalent diameter of said orifice to the diameter of said gate being in the range of from about 0.5 to about 1.5, and

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the ratio of the distance between said focus and said outlet of said orifice to said equivalent diameter of said orifice being in the range of from about 0.15 to about 0.50.

2. The apparatus according to claim 1, wherein the angle of inclination of said gas-jetting orifice to said axis of said gate is in the range of from about 60° to about 90°.

3. The apparatus according to claim 1, wherein a funnel is connected to and diverges from said nozzle at the discharge side thereof.

4. The apparatus according to claim 3, wherein said funnel diverges at an angle of at least about 20° from said axis of said gate.

5. The apparatus according to claim 4, wherein the inside surface of said divergent funnel is provided with a circular channel extending around the periphery of said funnel and located in the proximity of the end of said funnel removed from said gate, and said channel is provided with means communicating therewith to provide suction in said channel.

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6. The apparatus according to claim 5, wherein the opening in the inside surface of said divergent funnel formed by said channel is provided with a metal net of at least about 100 mesh which covers from about $\frac{1}{3}$ to about $\frac{1}{2}$ of the width of said opening, said net being positioned to cover the side of said opening closest to said nozzle.

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