METHOD OF MAKING METAL POWDER


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3 Claims. (Cl. 18—47.3)

This invention relates to the production of metal powder and, more particularly, to a novel method by means of which molten metal may be atomized to convert it into powder.

An important object of the invention is the provision of an improved method of atomizing molten metal which permits substantial control of the size of particles in the produced powder whereby a higher percentage production of powder particles of a desired size range may be obtained from the molten metal.

A further important object is to provide a method of making metal powder whereby the production capacity may be readily and conveniently varied as desired.

The foregoing and other important objects and advantages are achieved under this invention by a method wherein a falling stream of molten metal is subjected to atomizing jets of fluid arranged to converge upon said stream downwardly, oppositely and at substantially similar angles. In a preferred form of the invention, a plurality of atomizing jets of air are employed at opposite sides of the stream of molten metal. These jets are directed oppositely and downwardly upon the metal stream across an area which extends beyond the width of the stream so that the latter is completely within the zone of the atomizing fluid blast.

The invention is more or less diagrammatically illustrated in the accompanying drawings and set forth in its fundamentals in the following specification, without, however, limiting the invention to the particular embodiments shown and described.

In the drawings:

FIGURE 1 is a fragmentary, perspective view including the essential, and some non-essential, portions of apparatus for atomizing metal molten metal according to one embodiment of this invention.

FIGURE 2 is a vertical sectional view of said apparatus substantially on the line 2—2 of FIG. 1.

FIGURE 3 is an elevational view of the inner side of one of two similar atomizing fluid pipes viewed on the line 3—3 of FIG. 1, showing one of the many possible orifice arrangements therefor.

FIGURE 4 is a plan view of the invention in which atomizing nozzle pipes are disposed to discharge atomizing fluid in four directions upon a stream of molten metal rather than only in two directions as with the apparatus shown in FIGS. 1 and 2.

FIGURE 5 is a perspective view of an atomizing nozzle pipe arrangement according to still another embodiment of this invention.

FIGURE 6 is a fragmentary, perspective view of an atomizing nozzle pipe illustrating another orifice arrangement which may be used for making metal powder.

For the purpose of the present invention, one or more free-falling molten metal stream designated by the numerals 10 in the figures may be used, said streams being provided by any suitable equipment (not shown) such as a crucible or melting pot or any other container wherein the metal or alloy to be atomized in accordance with this invention is maintained in a sufficiently molten state to permit emergence of the stream or streams from appropriate discharge openings provided at the bottom of such container. When more than one metal stream is employed as shown in FIGS. 1 and 3, the openings which are generally of such size to provide one or more streams of about % to % of an inch in diameter are preferably arranged equidistant from each other and in a straight line so that the multiple streams emerging therefrom lie in substantially the same plane as schematically indicated in FIG. 1.

If desired, tubes extending from the base of the container such as feed tube 11 shown in FIG. 5 may be used to protect the molten stream from excessive oxidation particularly in those instances where the specific metal or alloy to be converted to powder form happens to be highly susceptible to oxidation. Such feed tubes positioned in appropriate alignment with the molten metal discharge outlets and suitably arranged with their lower or discharge ends in a straight line terminating sufficiently above the convergence point of the atomizing fluid blast may be heated, if necessary, by any suitable means (not shown) to assure uninterrupted delivery of the molten metal stream to the zone where atomization occurs. With such susceptible substances, the use of a protective atmosphere is generally necessary to preclude contact of the molten material with air, and in comparatively few situations the atomizing fluid itself must also be non-oxidizing.

Referring now to the embodiments shown in FIGS. 1 through 3 at opposite sides of the molten metal stream or streams 10 are disposed similar atomization nozzle pipes or duct means 12, which, in the embodiments being described, are horizontal and parallel to each other and are spaced laterally from the molten metal streams 10 so as to be approximately equidistant therefrom. The atomizing nozzle pipes 12 have apertures or orifices 14 drilled or otherwise formed therein to permit emission therefrom of jets of atomizing fluid under pressure from said pipes. As described herein, the fluid employed is a gas such as air but, within the invention, the atomizing fluid may be water or other suitable liquid or gas. Atomizing fluid pressures generally ranging from about 50 to 300 p.s.i. or even higher may be used, the relatively low pressures being suitable for the production of comparatively coarse powders and higher pressures, usually over about 150 p.s.i., being conducive to the formation of powders of rather fine particle size.

The ends of the pipes 12 are preferably closed by caps 16 and said pipes are connected by screw couplings 18 to fluid-supply pipes 20. The adjacent ends of the fluid-supply pipes may be rigidly and, preferably, adjustable supported by any suitable means, as, for example, by clamping members 22, 24 between which the ends of pipes 20 are firmly but adjustably clamped by means of clamping bolts or screws 26. By temporarily loosening the bolts or screws 26, the supply pipes 20, and with them the nozzle pipes 12, may be moved in a horizontal plane either toward or away from each other to enable adjustment of the distance A (FIG. 2) therebetween or along the longitudinal axes of pipes 12 to enable adjustment of the opposing nozzle orifices 14 as desired. These adjustments would obviously require the use of flexible connections or pivotal joints (not shown) between supply pipes 20 and the source of atomizing fluid.

The clamping member 22 may be mounted rigidly, but with provision for vertical adjustment, upon an adjacent stationary support 30. The adjacent ends of clamping member 22 may be bent upwardly to provide integral flanges or brackets 28 and the latter may be provided with vertical slots 32 through which headed bolts 32 extend and thread into stationary adjacent parts 34 of the apparatus.

To adjust the positions of the pipes 20 and vertically, the bolts 32 are loosened and, after the said pipes are positioned as desired, said bolts are tightened to hold the pipes firmly in their desired positions. The pipes 12 may
be turned about their longitudinal axes by merely turning them in the couplings 18, or alternatively by temporarily loosening bolts 26 to permit rotation of pipes 12 and 20 together with the flue-supply pipes 28 which are associated with flexible connections from the atomizing gas source. Such turning of pipes 12 is sometimes desirable to alter the angularity of issuance of atomizing fluid from the orifices 14 relative to the vertical direction of molten metal stream 10 as will be hereinafter discussed. However, the best results obtained with the apparatus and method herein disclosed are dependent in addition to the atomizing fluid pressures utilized, upon a number of other variables principally including (a) the size, number and spacing of the orifices in the atomizing nozzle pipes, (b) the angle at which the atomizing jet issuing from said orifices is directed against the molten metal stream, (c) the distance between the opposed atomizing nozzle pipes, (d) the atomizing fluid used and the temperature thereof, and (e) the characteristics of the molten metal or alloy being converted to powder form. To one skilled in the art, the determination of conditions and apparatus arrangement conducive to best results in any given case should be readily apparent particularly in view of the further discussion and specific examples hereinafter presented which are pertinent to the aforesaid variables and to the basic concepts comprising the present invention.

Illustrative of one of the numerous orifice arrangements which may be used is the embodiment shown in FIG. 3 consisting of a plurality of drilled holes aligned in three horizontal rows. Such an orifice arrangement having holes of uniform size preferably between 3/64 and 3/32 of an inch in diameter and about 1/16 of an inch from center to center has been found to be very satisfactory for the production of metal powders having relatively coarse particle size as, for example, about 40 to 60-mesh size. Actually a single, double or other number of rows or series of holes or other shape orifices may be used, the latter being illustrated by the longitudinal slot shown in the embodiment of FIG. 5. For finer particle size production, an orifice arrangement in the form of a U- or V-shape (the latter being shown in FIG. 6) is preferred, it being possible with such orifice configurations to more effectively concentrate the atomizing blasts provided by the opposing nozzle pipes 12 within a limited zone. Actually within this invention, there is considerable latitude permissible regarding orifice sizes, shapes and arrangements depending to some extent on the material being processed and the specific results desired.

With the use of U- or V-shaped orifice arrangements, it will be understood that a series thereof may be extended along the length of each atomizing nozzle pipe 12 depending upon the number of molten metal streams 10 being simultaneously used. The alignment of the orifices 14 should be such that each metal stream falls entirely between the arms of the U or V as the case may be, with the opposing nozzle pipes preferably being so arranged that the corresponding orifices on each pipe bear substantially the same relationship to said stream whereby the atomizing effect exerted against the stream from opposite sides is essentially the same. With any orifice arrangement utilizing a plurality of orifices in each atomizing nozzle pipe 12 there appears to be some advantage in utilizing pipes as a unit provided that fluid-supply pipes are formed such that their respective axes in each pipe are parallel as shown in FIG. 2. This, however, is not considered to be essential provided the atomizing jets 36 (indicated by the broken lines in FIG. 2) emitted from orifices 14 are all directed downwardly to some extent and that the atomizing direction of atomizing fluid jets 36 from pipes 12 is substantially downward so as to define an angle of convergence (designated X in FIG. 2). For best results, the angularity of each of the opposing jets 36 should be approximately equal with reference to stream 10. Although three streams of molten metal 10 are shown in FIG. 1, it will be appreciated that a greater or lesser number may be employed as desired. Where a small amount of material is to be processed, the use of a single stream may prove entirely adequate, but for large scale commercial operations, as many as ten or even more streams of molten metal may be simultaneously used in conjunction with opposing atomizing nozzle pipes 12 provided with appropriate orifices and sufficient atomizing pressures for making coarse or fine powder as the case may be. The principle of the invention, however, may be more readily understood by reference to FIG. 2 considering only a single molten metal stream 10 in relation to the opposed atomizing nozzle pipes 12 and the orifices 14 from which atomizing fluid is discharged downwardly to impinge against said single molten metal stream.

Referring now to FIG. 2 wherein the orifices are shown to be parallel-drilled and assuming that the orifices are arranged in three horizontal rows with the orifices being equally spaced but staggered (as shown in FIG. 3) but recognizing the inventive concept is not intended to be limited thereby, the first prerequisite is that the molten metal stream 10 be narrower or smaller than the band or width of atomizing jets 36 impinging downwardly thereupon. In other words, the orifices 14 along the longitudinal dimension of pipes 12 should always overlap the diameter of the relatively thin molten metal stream 10 to assure effective comminution of said stream in its entirety. It is also essential that the atomizing jets 36 be directed downwardly such that angle X is always acute with the opposing pipes 12 being arranged such that the corresponding orifices lie one matched or similar position relative to each other and also with respect to the molten metal stream. By directing the opposing atomizing jets 36 angularly downward against stream 10 in the manner indicated utilizing a convergence angle X generally between 10 and 75° and preferably about 20° while pipes 12 are similarly spaced with each other by distance A which may be varied from as close together as possible without obstructing the passage of the molten metal stream therethrough to as much as 6 to 8 inches apart depending upon the desired particle size, available pressure, etc., a highly effective atomizing or disintegrating action is obtained. The metal stream is so completely broken up by the opposing atomizing jets that the particles which become quickly cooled out of contact with each other possess substantially improved uniformity irrespective of the particle size range being produced.

With respect to the control of particle size, the atomizing pressure used is of principal importance with the proper selection of orifice arrangement also having an important bearing on the results as previously indicated. In this connection, however, the significance of distance A and angle X should be carefully considered since it will be realized that if the distance between the atomizing nozzle pipes is greatly enlarged, or if the convergence angle formed by the atomizing jets is greatly reduced, a condition will arise wherein satisfactory atomizing will not occur regardless of the other factors. This is obviously due to excessive diffusion in the longer jets of atomizing fluid (measured by average length of lines 36 shown in FIG. 2). Thus it will be seen that these adjustments actually determine the force or intensity of the impingement action against stream 10 which directly affects the coarseness or fineness of the resulting powder produced thereby. Since it has been found to be advantageous to maintain an angle X of 20° or thereabouts, however, in the production of either coarse or fine powders, the appropriate adjustment of distance A in either case becomes all the more important. As previously indicated, this distance should be very small (less than one inch) for very fine powders, the distance being progressively increased as required to meet the actual particle size specifications in any given case.

The embodiment illustrated in FIG. 4 differs from that of FIGS. 1-3 in that the shown arrangement of orifices for the atomizing fluid is limited to use with a single stream 10 of molten metal. Instead of having the jets
of atomizing fluid directed upon the stream at only two opposite sides as in FIG. 1–3, pipes 12a are so arranged, and orifices therein are so disposed, that the jets of atomizing fluid emitted from said pipes are directed downwardly upon the stream of metal at four equidistant points about the latter.

Under conditions wherein the method and apparatus of this invention are employed over a continuous or long period of time to yield powder of which the particles are of a specified metal and of certain size, a simple embodiment, such as is shown in FIG. 5, may be employed. As illustrated in that figure, pipes 12b are integral and of a U or yoke shape and are rigidly connected at the base of the U or yoke to a single supply pipe 20b. Although the pipes 12b are shown with a slight curvature causing them to more or less embrace or extend about the stream 10, it should be understood that the fluid-emitting portions of said pipes, alternatively, may be straight, as with pipes 12.

In the embodiment illustrated in FIG. 5, a single slot 14c is provided in each of the pipes 12b. These slots are directly opposite each other and are in such an arrangement and so formed and downwardly directed that sheets or jets 36a of atomizing fluid issuing therefrom impinge against the metal stream 10 in such a manner that the stream 10 is disengaged in the embodiements of FIGS. 1–4. This particular embodiment lends itself to simple adjustment of the width of slot 14c merely by loosening or tightening cap 16 in conjunction with coupling 18a whereby the slot may be expanded or narrowed. In this manner the impinging force imparted to the metal stream may be varied as desired within predetermined limits based on available pressures and slot lengths. It should be understood that the determination as to whether slots or orifices, be they circular or of any other shape, are to be provided does not depend on the particular shapes or arrangement of pipes 12, 12a and 12b or of any other possible pipe arrangements. Thus, single or multiple slots could be used in the embodiment of FIGS. 1 through 4 and round orifices arranged in various geometrical patterns may be used in the embodiment of FIG. 5.

The embodiment of FIG. 4 might lead to the erroneous belief that, within this invention, the opposed orifices or slots 14 or 14c could advantageously be replaced with a continuous circular slot which would direct the atomizing fluid downwardly in the form of a cone into atomizing engagement with a stream falling into said cone. Under such an arrangement however, it has been found that the continuous sheet or cone of atomizing fluid results in the creation of back-pressure in the cone that causes particles of molten metal to bounce back against the circular slot, thereby fouling the latter and impairing operation.

An important distinction to be observed, therefore, between the present invention and such a continuous circular slot arrangement is that, under the present invention, the orifices or slots, even though they may be arranged at plural points about the metal stream as in FIG. 4, are sufficiently interrupted or spaced apart around the stream that they do not form a complete or unbroken cone of atomizing fluid. In this manner, any tendency on the part of the disintegrated particles to be deposited on either the atomizing nozzle orifices, or the metal discharge outlets, or both is completely overcome, thereby greatly facilitating uninterrupted operation of the apparatus.

In practice applications of this invention, most of the above-mentioned variables can be determined and adopted without need for further variations. For example, in given apparatus, a specific pressure and a certain temperature of the atomizing fluid may be provided, the orifices 14 may be formed to a specific size of hole or slot and thereafter remain unchanged; and where apparatus according to this invention is to be used continuously for producing powder of a specific fineness of a certain metal, the distance A and the angularity X may be fixed and remain fixed. However, the hereinbefore described adjustable mounting of pipes 12, 12 (or equivalent means for adjusting pipes 12, 12) is advantageous in that, where such adjustability is provided, the apparatus may be adapted to atomizing of different metals as well as meeting different specification requirements for the same metal or alloy. In addition to the various adjustments already mentioned, the range of particle size distribution may also be extended somewhat, if desired, merely by angularly shifting the pipes 12 in a horizontal plane to establish a different distance A with respect to each of a plurality of streams.

Experience shows that this invention is useful for atomizing any metal which is molten or in liquid state. It has been used with success in the atomizing of brass, copper, bronze, stainless steel, and copper-lead alloys, and it has become apparent that it is useful for atomizing other metals. The invention is illustrated in the following specific examples wherein the effects of certain variables are indicated, it being understood, however, that the invention should not be construed as limited to details described therein:

**Example I**

A ½" diameter stream of molten brass (80% copper and 20% zinc) was atomized using ordinary air at 175 p.s.i. The two atomizing nozzle pipes arranged in a symmetrically opposed and aligned relationship relative to the vertical stream were each provided with a single V arrangement or orifices consisting of five holes of ⅛” diameter forming a V with a vertex angle of 60° and a maximum distance between the arms of % of an inch. With the use of a distance A of % of an inch and an angle X of 20°, the resulting powder amounting to better than 98% of the molten alloy charged had the following particle size distribution as determined by screen analysis:

<table>
<thead>
<tr>
<th>Mesh size (inches)</th>
<th>+100</th>
<th>-100/+150</th>
<th>-325</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of total product</td>
<td>33.8</td>
<td>38.8</td>
<td>27.4</td>
</tr>
</tbody>
</table>

Upon increasing angle X to 40°, the other variables being unchanged, the resultant powder was comparably finer as indicated by the following screen analysis:

<table>
<thead>
<tr>
<th>Mesh size (inches)</th>
<th>+100</th>
<th>-100/+150</th>
<th>-325</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of total product</td>
<td>30.0</td>
<td>38.8</td>
<td>32.2</td>
</tr>
</tbody>
</table>

When distance A was increased, all other conditions being unchanged, the resultant powder was coarser.

**Example II**

The use of water as the atomizing fluid is illustrated by the following example wherein bronze was atomized utilizing (1) an atomizing pressure of 600 p.s.i., (2) a pair of opposed nozzle pipes each having a single row of ⅛” diameter holes spaced ¼ of an inch apart covering a length close to 2 inches, (3) three molten metal streams positioned equidistant therebetween said streams being about ⅛ inch apart, (4) a distance A of ¼ an inch, and (5) an angle X of 40°. Screen analysis of the resultant powder indicated the following particle size distribution:

<table>
<thead>
<tr>
<th>Mesh size (inches)</th>
<th>+100</th>
<th>-100/+150</th>
<th>-325</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of total product</td>
<td>27.3</td>
<td>7.6</td>
<td>33.1</td>
</tr>
</tbody>
</table>

**Example III**

Illustrative of the use of slots rather than round orifices is the following procedure wherein ordinary air at 150 p.s.i. was used employing a single slot (.015 inch wide and...
2 inches long) in each of two opposing atomizing nozzle pipes arranged with respect to three streams of molten bronze to provide a distance A of 2½ inches and an angle X of 20°. Under these conditions, a comparatively coarse powder was obtained having the following particle size distribution:

<table>
<thead>
<tr>
<th>Mesh size (microns)</th>
<th>+40</th>
<th>-40 +60</th>
<th>-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of total product</td>
<td>28.5</td>
<td>34.7</td>
<td>37.3</td>
</tr>
</tbody>
</table>

The amount of minus 40 plus 60 powder which is the size generally used in the making of porous articles such as filters and the like is significant in that prior art practices are ordinarily capable of producing less than one-half the indicated recovery within the designated particle size range.

**Example IV**

Copper was atomized using the equipment and conditions described in the preceding example excepting that an atomizing pressure of 185 p.s.i. was used and distance A was decreased to 1¾ inches. A powder of finer particle size was obtained as indicated by the following screen analysis results:

<table>
<thead>
<tr>
<th>Mesh size (microns)</th>
<th>+100</th>
<th>-100 +150</th>
<th>-150 +250</th>
<th>-250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of total product</td>
<td>45.8</td>
<td>22.8</td>
<td>22.5</td>
<td>4.7</td>
</tr>
</tbody>
</table>

**Example V**

A single stream of molten bronze atomized using opposing nozzle pipes each having five holes (½” diameter) arranged in an 85° V with the maximum opening between the arms of the V being ½ an inch and further utilizing unheated air at a pressure of 150 p.s.i. with distance A and angle X being set at ½ an inch and 20° respectively again resulted in better than 98% recovery of material as product. Based on the total powder recovered the data below shows nearly all of the product to be below 100-mesh size with nearly 93% thereof being below 150-mesh.

<table>
<thead>
<tr>
<th>Mesh size (microns)</th>
<th>+100</th>
<th>-100 +150</th>
<th>-150 +250</th>
<th>-250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of total product</td>
<td>1.9</td>
<td>5.4</td>
<td>20.3</td>
<td>42.4</td>
</tr>
</tbody>
</table>

**Example VI**

The conditions described in the preceding example were used for atomizing 316 stainless steel excepting that the atomizing pressure was increased to 300 p.s.i. Better than 72% of the powder product thereof was below 100-mesh size.

Experiments with these and other metals show that, with respect to any metal atomized by means of this invention, an increase in distance A or a decrease in angle X yields a coarser powder and a decrease in distance A or an increase in angle X yields a finer powder. As previously noted, however, the most effective atomizing action generally appears to be associated with the use of a convergence angle X of 20° or thereabouts. Accordingly, the other variables should be selected and adjusted such that this preferred angle is used whenever possible.

The high degree of particle size control afforded by the present method and apparatus coupled with the enhanced atomization efficiency attained in operation permit excellent recoveries within the various relatively narrow particle size ranges. Under appropriate conditions of operation, for example, no difficulty is encountered in obtaining high recoveries (better than 97-98%) of minus 100-mesh size metal powder product. The improved per of fine powders and excellent control of particle size is formance particularly with reference to high recoveries largely attributable to elimination of the so-called "bounce" of the metal stream achieved by directing the opposingly balanced atomizing forces downwardly and similarly against each of the metal streams. In most of the prior art methods wherein bounce of the metal stream is encountered, the problem has not been satisfactorily solved, the usual result being relatively poor recoveries with the powder frequently being quite coarse and non-uniform.

In addition to the foregoing advantages and improvements, it will be apparent that for the purpose of the present invention the need for expensive and complicated equipment is entirely eliminated as are frequent shut-downs necessitated by mechanical failures caused by plugging and the like commonly experienced in other metal atomizing methods. Thus equipment, operation and maintenance costs are substantially lower by comparison with most of the prior art methods. This is all the more true when it is appreciated that no need generally exists for the use of either preheated or special atomizing fluids since ordinary air may be used with excellent results in most applications. Then too, the production capacity of the apparatus may obviously be easily doubled, tripled or otherwise enhanced merely by increasing the number of molten metal streams and extending the atomizing zone coextensively therewith.

It is obvious that the present inventive concept may be employed in various ways other than shown and described herein while departing from the invention as set forth in the following claims.

What is claimed is:

1. The method of making metal powder comprising melting metal, discharging at least one free falling molten metal stream of relatively small diameter to an atomizing zone provided by opposing jets of atomizing gas overlapping the diameter of said metal stream, simultaneously impinging said atomizing gas under a pressure of at least 125 p.s.i. against only two opposing sides of said metal stream, the impinging jets of atomizing gas being downwardly directed to form an acute convergence angle of from 15 to 75°, centering the metal stream in relation to the atomizing zone so as to substantially bisect said acute convergence angle therewith, adjusting the atomizing gas pressure, convergence angle and the horizontal distance between said opposing jets to effect the atomization of the metal to the desired particle size and collecting and cooling the atomized metal particles in a protective atmosphere.

2. The method of claim 1 wherein the atomizing gas is air.

3. The method of claim 1 wherein the atomizing gas is steam.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,009,205
November 21, 1961

Walter T. Monson et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 63, for "stream" read -- streams --;
column 4, line 67, for "becomes" read -- becomes --;
column 5, line 26, for "distegrated" read -- disintegrated --;
line 32, for "predetermined" read -- predetermined --;
line 68, for "practice" read -- practical --;
column 7, line 54, after "product" insert -- produced --;
line 62, for "generally" read -- generally --;
line 64, for "should" read -- should --;
column 8, line 3, strike out "of fine powders and excellent control of particle size is" and insert the same after "high recoveries" in line 4, same column 8;
line 33, for "within" read -- without --.

Signed and sealed this 24th day of April 1962.

(SEAL)
Attest:

ESTON G. JOHNSON
Attesting Officer

DAVID L. LADD
Commissioner of Patents