Jan. 19, 1943. G. E. BEST 2,308,584

PRODUCTION OF METAL POWDER

Filed Aug. 3, 1940

Fig. 1,

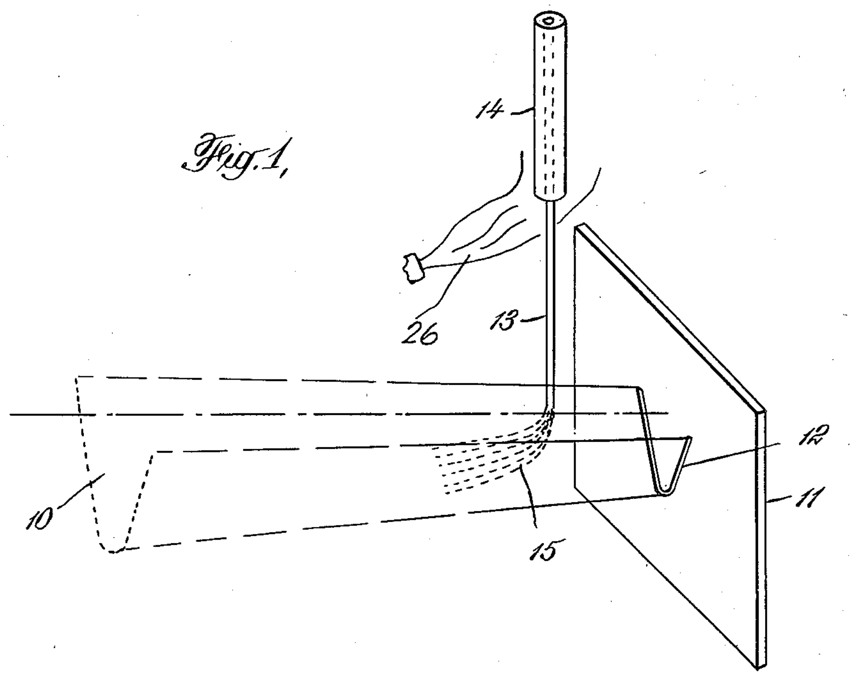
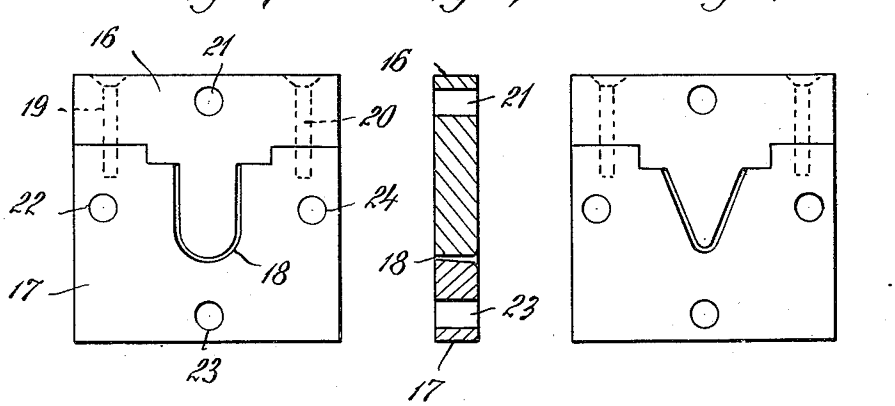


Fig. 2, Fig. 3, Fig. 4.



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PRODUCTION OF METAL POWDER

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11 Claims. (Cl. 83—91)

This invention is concerned with the production of metal powder by atomizing molten metal and congealing the resultant drops to form solid particles. It contemplates improvements in methods and apparatus for conducting such atomization to the end that metal powder of more uniform particle size is produced and excessive oxidation of the metal is avoided.

It has been proposed heretofore to produce metal powder by atomizing molten metal in a jet of gas, but there has been a wide variation in the size of the powder particles with high proportions of excessively coarse or fine particles, or both.

In the course of my investigations, I have discovered that an improved metal powder of more uniform particle size is produced if the atomization is conducted employing a non-convergent trough-shaped jet of gas into which a thin stream of molten metal (i. e., relatively thin with respect to the width of the jet) is directed transversely. The jet is preferably U- or V- shaped in cross section and produced by forcing the gas, preferably cold, through a nozzle having a U-shaped or V-shaped orifice. Thus my invention contemplates the improvement in the manufacture of metal powder by atomization which comprises directing a gas through orifices so disposed as to form a jet of trough shape having downwardly converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

The stream of molten metal should be concentrated and straight, i. e., wavering and spattering of the stream should be avoided. It is directed (as by dropping vertically) into the trough of the U- or V-shaped jet and preferably enters the trough slightly off center.

A preferred apparatus for producing the desired non-wavering non-spattering stream of metal is a reservoir for molten metal, say, a melting pot, into the bottom of which is tapped a discharge tube the lower end of which is uniform in bore, or, at least, non-flaring. A flaring discharge opening should not be employed because it spreads the metal stream and causes wavering and spattering.

Conveniently, the discharge opening may be directed downwardly so that the metal falls as a substantially vertical stream into the trough of a more or less horizontally directed jet of gas.

The inner walls of the jet should be non-converging longitudinally of the jet, i. e., the nozzle delivering the U- or V-shaped jet preferably is so formed that the two sides of the jet are parallel or diverging but not converging. When the two sides of the jet are convergent, a vacuum or condition of turbulence is set up between the face of the nozzle and the point of atomization, and under certain operating conditions, i. e., a high rate of metal feed or a high jet velocity, some of the metal is directed backward toward the face of the nozzle, with resultant formation of coarse metal particles, and spattering and freezing of metal on the face of the nozzle with consequent interference with nozzle operation and performance. A V-nozzle does not give so much trouble in this respect as a U-nozzle, but with both of these types of orifice convergence should be avoided, for non-converging trough-shaped jets have a greater atomizing capacity and may be operated at higher pressures and with higher metal feed rates without bringing about the formation of excessively coarse or fine particles or clogging of the nozzle.

Gas pressures ranging from 75 to 180 pounds per square inch are satisfactory when the jet is non-converging.

These and other features of my invention will be the more thoroughly understood in the light of the following detailed description taken in conjunction with the accompanying drawing in which:

Fig. 1 is a fragmentary diagram of a metal atomizing apparatus constructed in accordance with my invention;

Figs. 2 and 3 illustrate the construction of a U-shaped nozzle plate for use in the apparatus of Fig. 1; and

Fig. 4 illustrates a V-shaped nozzle plate for use in the same apparatus.

Referring now to Fig. 1, it will be observed that a diverging V-shaped jet 10 of cold air is projected horizontally from a nozzle plate 11 (which forms the face of a conventional air chamber, not shown) through a V-shaped orifice 12. A thin and substantially non-spattering, nonwavering stream 13 of metal drops vertically into the trough of the jet and slightly off-center of the jet (i. e., to one side or the other of a vertical center line drawn through the apex of the V from a vertical pipe 14 of uniform bore that extends downwardly to a point slightly above the jet. The metal, in seeking to fall through the jet, is atomized and projected as a stream 15 of drops that freeze almost immediately to form metal powder.

The metal may be supplied to the apparatus from any conventional reservoir, such as a conventional melting pot (not shown) disposed substantially above the outlet of the metal from the pipe 14 so as to provide an adequate head.

It is desirable to maintain the temperature of the molten metal in the reservoir (say, the melting pot) about 50° C. to about 100° C. above the melting point of the metal. Thus, the following are preferred operating temperatures for a number of metals:

	Melting point	Atomizing temperature
	°C.	°C.
Zinc	419	475-500
65-35 brass	925	1000
70-30 brass	950	1000
90-10 brass	1050	1100

Low temperatures of metal may result in freezing in the tube. Temperatures of metal substantially higher than 100° C. above the melting point may create difficulties due to oxidation.

Oxidation of the metal where the stream leaves the tube may bring about the following difficulties:

(1) Blockage of the discharge orifice of the tube by accumulations of oxide at this point with gradual decrease in rate of metal flow and final complete interruption thereof;

(2) Shift in direction or form of metal stream due to formation of oxide accretions at the orifice. Thus, oxide accretions, if permitted to form, may divert the stream away from its optimum position of entry into the air jet slightly off the center line of the U or V, or may cause the stream to waver or spatter; and

(3) Formation of oxide skin on the metal stream, causing the stream to be "bent" away from the air nozzle and resulting in inefficient atomization as well as contamination of the product.

It is difficult to compensate for the irregularities in metal flow thus brought about by changing the direction or velocity of the gas jet, but objectionable oxidation and the consequent variations in metal flow may be prevented to a great extent by playing a flame on the discharge orifice. An oxyacetylene flame is preferred, but a hydrogen-air flame may also be employed.

In certain cases, oxidation of alloys during atomization may be controlled by the addition of aluminum to the alloy.

Nozzle plates having the dimensions and proportions shown in Figs. 2-3 and Fig. 4 have good operating characteristics and are convenient to clean and assemble. The nozzle plate illustrated in Figs. 2 and 3 is formed of upper piece 16 and lower piece 17 which form, respectively, the upper and lower walls of the U-shaped orifice 18. The two pieces are held together by screws 19, 20 that project downwardly through the upper piece into the lower on either side of the orifice. Four holes 21, 22, 23, 24 are provided in the face of the plate for bolting it to the wall of the air chamber. The nozzle plate of Fig. 4 is identical with that of Figs. 2 and 3, except that its orifice is V-shaped. In each case, the slot through which the gas (air) is discharged is about .020 inch wide but is (as shown in Fig. 2) wider at the point of gas discharge than at the point at which the gas enters. Thus, the "upper" wall of the slot, as defined by the upper piece of the plate, is at right angles to the face of the plate, but the "lower" wall of the slot (as defined by the lower piece) is tapered toward the gas discharge point by an angle of about 10° from the perpendicular. In other words, the non-converging trough-shaped jet is produced by forcing the gas through an opening corresponding generally in cross-section to that of the jet and that flares outwardly in the direction of gas passage. This structure results in the production of a diverging jet when gas is forced through the plate (from left to right as shown in Fig. 3).

Typical dimensions of the U-shaped orifice are:

	Inch
Total height	¾
Height of the bent portion of the U	¼
Width of U	½

In the case of the V-shaped orifice, typical dimensions are as follows:

	Inch
Total width of V	⅝
Total height of V	⅝
Diameter of V at point where curvature begins in the apex	About ⅛

Considerably larger nozzles with wider slot openings may be employed to atomize at high rates of metal feed, with larger volumes of air.

When nozzle plates of about the size illustrated in Figs. 2-4 are employed, the apparatus is adjusted so that the jet cuts the metal stream at a point 3 to 4 inches below the end of the pipe from which the stream of metal falls.

The distance from nozzle plate to metal stream is dependent not only upon nozzle design but also upon air volume and pressure, the rate of metal feed, etc. Ordinarily, a distance of ¾ to 1 inch from nozzle plate to metal stream is appropriate with V and U nozzles that produce divergent jets. If the sides of the jet are convergent, this distance should be slightly less, particularly in the case of the U nozzle.

As indicated hereinbefore, the gas, preferably cold air, is supplied to the nozzle at relatively high pressure, say 75 to 180 pounds per square inch (gauge) and produces a jet of high velocity. The metal directed into the trough of this jet is atomized and chilled to form metal particles that are much more uniform in size than are particles formed in jets that are other than trough-shaped. The reasons for the improved uniformity of the product produced in accordance with my invention and for the absence of excessive proportions of extremely coarse and extremely fine particles are not completely understood. It is probable, however, that the formation of coarse particles is obviated because any large drops of molten metal broken off the stream by the relatively low velocity air at the top of the jet are reduced to fine drops by high velocity air at the core or apex of the jet, for none of the metal can escape from the trough of the jet without thus encountering the high velocity air.

A great variety of metals, (for example, copper, zinc, lead, brass, bronze, etc.) may be converted advantageously into metal powder in accordance with my invention. Jets of non-oxidizing gas may be employed, but ordinarily a satisfactory product may be obtained employing cold air, probably because the trough-shaped jet atomizes and cools the metal so quickly that opportunity for oxidation is minimized.

As indicated above, it is desirable to play a flame 26 (preferably an oxy-acetylene flame) on the end of the pipe 14 from which the metal stream 13 issues.

The atomized metal powder may be collected in any conventional collecting system, such as a settling chamber, followed by a cyclone or a bag room.

I claim:

1. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a jet of trough shape having downwardly converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

2. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a trough-shaped jet having a shape selected from the group consisting of U and V shapes, in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal, whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

3. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a trough-shaped jet of V-shape in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

4. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a trough-shaped jet of U-shape in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

5. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a jet of trough shape having downwardly converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving and to one side, longitudinally, of the lowermost portion of the trough, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

6. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas at a pressure from about 75 lbs. to about 180 lbs. per square inch through orifices so disposed as to form a jet of trough shape having downwardly converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

7. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a jet of trough shape having downwardly

converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal at a temperature of about 50° C. to about 100° C. above its melting point into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

8. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a jet of trough shape having a downwardly converging bottom in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet diverge longitudinally of the trough, directing a thin stream of molten metal into the diverging trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the diverging trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

9. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a jet of trough shape having downwardly converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet diverge longitudinally of the trough, directing a thin stream of molten metal from a discharge opening into the diverging trough-shaped jet transversely to the direction in which the jet is moving, congealing the resulting drops of metal substantially immediately in the diverging trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited, and directing a flame upon the metal discharge opening.

10. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas through orifices so disposed as to form a jet of trough shape having downwardly converging side walls which form the bottom of the trough in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal from a non-flaring discharge opening into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving, and congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal powder particles is inhibited.

11. In the manufacture of metal powder by atomization, the improvement which comprises directing a gas at a pressure of from about 75 lbs. to about 180 lbs. per square inch through orifices so disposed as to form a trough jet having a shape selected from the group consisting of U and V shapes, in which the gas is moving longitudinally of the trough and in which the side walls of the trough-shaped jet are non-convergent longitudinally of the trough, directing a thin stream of molten metal at a temperature of about 50° C. to about 100° C. above its melting point from a non-flaring discharge opening into the non-convergent trough-shaped jet transversely to the direction in which the jet is moving and at one side, longitudinally, of the center of the trough, congealing the resulting drops of metal substantially immediately in the non-convergent trough-shaped jet, the side walls of the trough being at such an angle to one another vertically and so spaced from one another that the gas forming the respective side walls cooperates to act upon the molten metal, whereby the atomizing capacity of the jet is increased and the formation of excessively fine and excessively coarse metal particles in inhibited, and directing a flame on the metal discharge opening.

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