Oct. 13, 1970 **F. C. HOLTZ, JR** **3,533,136**

APPARATUS FOR PRODUCING METAL POWDER

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Fig. 1

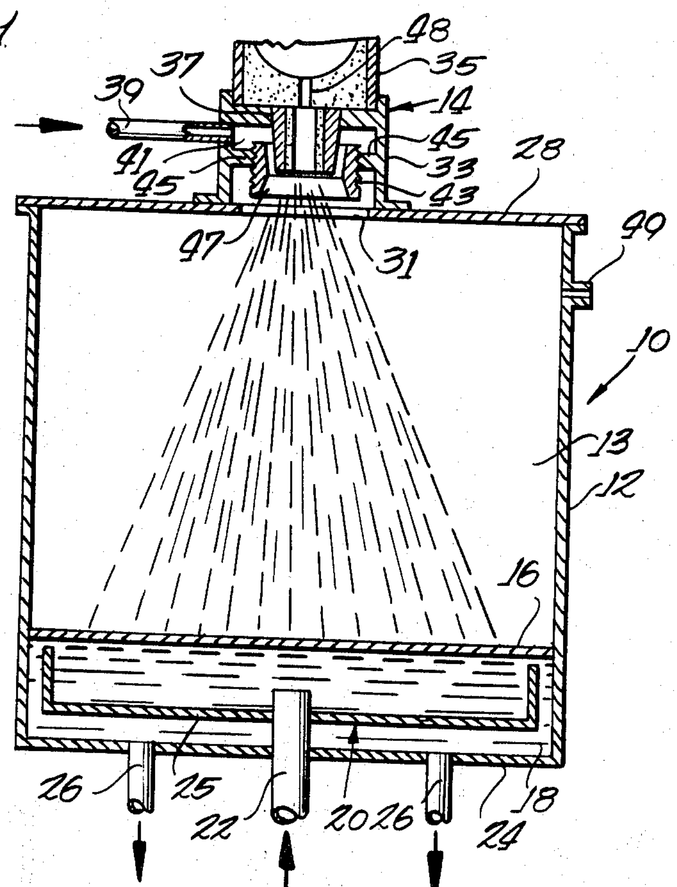
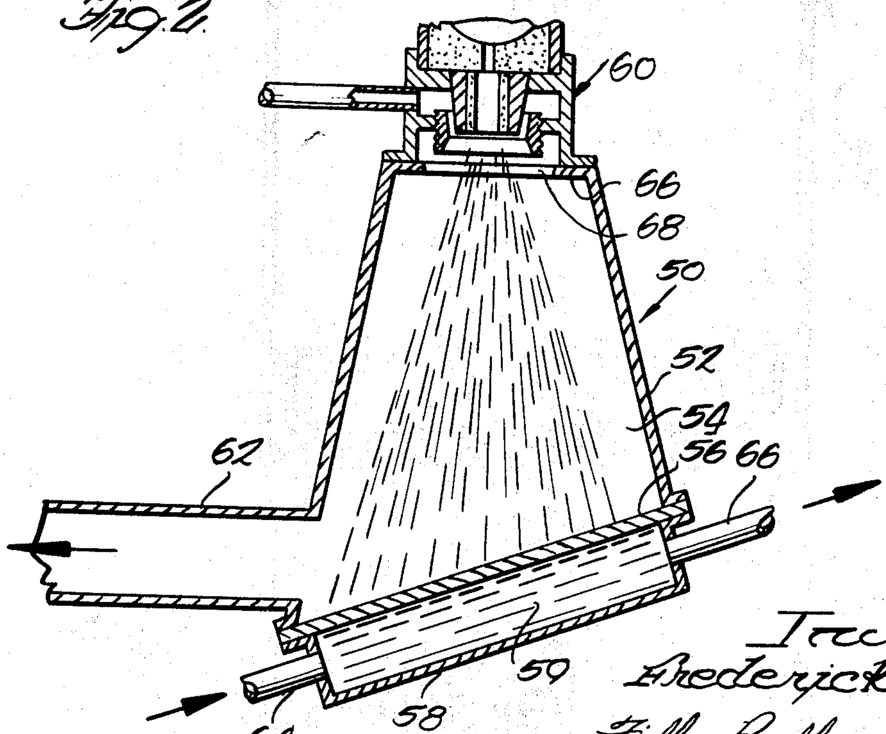


Fig. 2



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APPARATUS FOR PRODUCING METAL POWDER

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ABSTRACT OF THE DISCLOSURE

Method and apparatus for producing prealloyed metal powder includes an atomizer mounted on the top of an atomizing vessel having a metal hearth. A water vessel is mounted on the vessel beneath the hearth for containing a reservoir of recirculating water to directly cool the underside of the metal hearth whereby the top surface of the metal hearth is cooled by conduction. The atomizer sprays molten metal droplets into the interior of the atomizing vessel against the top surface of the metal hearth to rapidly quench the droplets.

BACKGROUND OF THE INVENTION

This invention relates in general to a method and apparatus for producing prealloyed metal powder, and it more particularly relates to a method and apparatus for atomizing and then rapidly quenching molten metal to form prealloyed metal powder for subsequent consolidation into solid stock.

In the past, alloys have been successfully made by a rapid quench atomizing technique followed by a consolidation of the powders thus formed into solid stock. Molten metal was subjected to a blast of gas inert to the metal to produce a finely-divided spray of metal droplets which were directed into an atomizing chamber to rapidly quench the droplets, thereby eliminating sintering or agglomeration of the powders. For this purpose, a water-reservoir in the atomizing chamber fully quenched and collected the particles. Such a technique was not entirely satisfactory, because the stream of gas and hot metal droplets violently agitated the water reservoir within the vessel, whereby unwanted oxide films were produced on the powder surfaces. Also, it was necessary to periodically remove the powder from the vessel and subject the powder to a drying process. In an attempt to overcome these disadvantages, the droplets were sprayed into a tall atomizing vessel, having a height of at least twenty feet, so that the falling droplets released their heat to the surrounding atmosphere before reaching the bottom of the vessel. However, the tall vessels were difficult to purge with the inert gas prior to atomizing the molten metal, and oxide-free powders could only be obtained by using large volumes of costly inert gases. Therefore, it would be desirable to have an atomizing vessel which retains the relatively small size of the water-reservoir type of vessel and which completely eliminates water or other oxidizing materials from the powder collection area.

SUMMARY OF THE INVENTION

Therefore, the principal object of the present invention is to provide a new and improved method and apparatus for producing prealloyed metal powder.

Another object of the present invention is to provide an inexpensive and efficient method and apparatus for rapdily quenching atomized metal droplets without the use of water or other fluids in the powder collection area and without the use of unreasonably tall chambers.

Briefly, the above and further objects of the present invention are realized in accordance with the present invention by providing an atomizing vessel having a droplet-quenching metal health, which has its underside directly cooled so that its top surface is thereby cooled by conduction. A water vessel containing a reservoir of recirculating water is mounted on the vessel beneath the hearth for cooling the underside of the hearth, which forms the top wall of the water vessel.

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The prealloyed metal powder produced by the method and apparatus of the present invention is substantially oxide free as compared to the prealloyed metal powder produced by the prior art water-reservoir vessel. Since no water is present in the atomizing vessel of the present invention, the vessel may be constructed of inexpensive mild steel instead of stainless steel as used in the prior art water-reservoir vessels.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, both as to its organization and method of operation, together with further objects and advantages thereof will best be understood by eference to the following detailed description taken in connection with the accompanying sheet of drawings, wherein:

FIG. 1 is a front elevational view in vertical cross section of an apparatus for producing metal powder in accordance with the present invention; and,

FIG. 2 is a front elevational view in vertical cross section of another apparatus for producing metal powder in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and more particularly to FIG. 1 thereof, there is shown an apparatus **10** for producing metal powder in accordance with the present invention. The apparatus **10** comprises a vessel **12** having an atomizing chamber **13**, a gas atomizing nozzle and tundish assembly **14** mounted on the top of the vessel **12**, a water-cooled metal hearth **16** at the bottom of the chamber **13**, and a water-reservoir chamber **18** disposed beneath the hearth **16** within the vessel **12** for cooling the underside of the hearth **16**. In use, a high pressure jet of inert gas atomizes a stream of liquid metal flowing from the tundish assembly **14** and directs the metal droplets into the atomizing chamber **13** to splatter the droplets against the water-cooled metal hearth **16** at the bottom of the vessel **12** whereby the droplets are rapidly quenched. Most of the solidified particles are blown free of the hearth and are readily removed from the chamber **13**. The remainder, generally not more than 25–30% of the product, is recovered as a solid "splatter" layer which is easily crushed into a fine powder. The products can then be combined and the fine atomized metal powder consolidated by a hot working process.

Considering now the atomizing vessel **12** in greater detail, the water-cooled hearth **16** is disposed at the bottom of the atomizing chamber **13** and is composed of a good-conducting material, such as copper. The hearth **16** is connected to the side walls of the vessel **12** in sealable engagement therewith to form the bottom wall of the atomizing chamber **13** and the top wall of the water-reservoir chamber **18**. An opened-top vessel **20** is disposed within the chamber **18** in close proximity to the underside of the hearth **16** for containing a continuous supply of recirculating water from a pump (not shown) via a water inlet pipe **22** extending through an opening in a bottom wall **24** of the vessel **12** and an opening in the bottom wall **25** of the water vessel **20**. The vessel **20** is disposed in a spaced-apart relationship above the bottom wall **24** so that the recirculating water in the vessel **20** overflows therefrom and flows downwardly under its bottom wall **25** into a pair of water outlet pipes **26** extending through respective openings in the bottom wall **24**. The recirculating water flows from the outlet pipes **26** to the pump for recirculation to the inlet pipe **22**. The water is pumped into the chamber **18** under a sufficient pressure to maintain the chamber in a comlpetely filled condition so that the recirculating water contacts the underside of the hearth **16**.

Considering now in greater detail the gas atomizing nozzle and tundish assembly **14**, the tundish assembly **14** is externally mounted on a detachably-mounted cover **28** of the vessel **12** over a centrally-disposed opening **31** in the cover **28** to permit the stream of gas and atomized metal droplets from the assembly **14** to enter the atomizing chamber **13**. The assembly **14** comprises a housing **33** mounted on the exterior of the cover **28** of the vessel **12** over the opening **31**, a tundish **35** supported by the housing **33**, a refractory lined nozzle or cone **37** mounted at the bottom of the tundish **35** and connected in fluid communication therewith, and a gas inlet pipe **39** for conveying gas inert to the metal to be atomized from a source of inert gas under pressure (not shown) to the interior of the housing **33**. The gas inlet pipe **39** is connected in fluid communication with a chamber **41** within the housing **33**. The inert gas is directed from the chamber **41** to the atomizing chamber **13** by means of a collar **43** surrounding the nozzle **37** within the chamber **41** and threaded into a threaded shoulder portion **45** forming part of the housing **33**. The collar **43** is provided with a bevel-cut inner wall portion **47** at the lower portion thereof beneath the exit end of the nozzle **37** so that a blast of the gas can atomize the molten metal flowing from an opening **48** in the tundish **35** and thence through the nozzle **37** and direct the gas and molten metal droplets toward the opening **31** in the cover **28** of the vessel **12**.

An exhaust port **49** in the side wall of the vessel **12** provides an exist for the inert gas.

OPERATION

An appropriate alloyed charge of the desired composition is first weighed up and melted in a suitable crucible (not shown). With the recirculating water flowing into the inlet pipe **22** and thence out of the outlet pipes **26**. the top surface of the hearth **16** is thereby cooled. The atomizing gas enters the inlet pipe **39** of the tundish assembly **14**, passes through the chamber **41**, and then enters the atomizing chamber **13** to purge it. After purging the chamber **13**, the molten metal charge is poured into the tundish **35** so that the molten metal flows from the opening **48** into the nozzle **37**. As the molten metal leaves the exit end of the nozzle **37**, the atomizing gas strikes the molten metal stream to break up the stream into finely-divided particles. In addition, this impact quenches the molten particles to solidify them even before they are finally cooled upon splattering against the surface of the hearth **16**. After atomization, the gas and atomized metal droplets flow downwardly into contact with the water-cooled hearth **16** to completely quench the metal droplets. Once the surface of the hearth **16** is substantially filled with the spattered metal droplets, the operation of the apparatus **10** is stopped so that the metal droplets can be removed from the hearth **16** by removing the cover **28**. Thereafter, the operation can be repeated.

The metal droplets removed from the chamber **13** are then consolidated into solid stock by a hot working process or other consolidation process such, for example, as the process disclosed in co-pending application Ser. No. 435,733, filed on Feb. 26, 1965, by the present inventor. By comparing the solid stock formed from metal droplets prepared by the method described in this specication with the solid stock consolidated from powder produced by a conventional water-reservoir vessel, it is apparent that the powder produced by the apparatus **10** is substantially oxide free.

Referring now to FIG. 2, there is shown another apparatus for producing prealloyed metal powder in ac-

cordance with the present invention. The apparatus **50** produces metal powder continuously without the necessity of periodically stopping the operation to remove the accumulated powder from the hearth. The apparatus **50** includes as its principal elements a vessel **52** having an atomizing chamber **54** and slanted at an angle with respect to the axis of the vessel **52**, a recirculating water vessel **58** having a chamber **59** containing recirculating water for cooling the underside of the hearth **56**, an atomizing nozzle and tundish assembly **60** for directing a stream of gas and atomized metal droplets onto the hearth **56**, and an exhaust port **62** in the side wall of the vessel **52** at the bottom thereof for withdrawing the quenched metal droplets from the apparatus **50**. In use, the tundish assembly **60** directs a blast of inert gas under a relatively higher pressure than the gas for the apparatus **10**, to produce atomized metal droplets, which are splattered against the cooled metal hearth **56** to rapidily quench the metal droplets. Due to the higher gas pressures, the agitation of the gas stream lifts the quenched droplets in the form of flakes from the hearth **56**. The slanting surface of the hearth **56** causes the metal flakes to rebound from the hearth **56** toward the exhaust port **62**. Therefore, the hearth **56** is continuously cleared of the realloyed flakes to provide a continuing operation of producing the metal flakes. The flakes are conveyed by the exhaust port **62** to a plurality of filter bags (not shown) for collection purposes.

The vessel **52** is in the shape of an inverted truncated cone. The metal hearth **56** is composed of a conductive material, such, for example, as copper. The plane of the hearth **56** is disposed at an acute angle with respect to the vertical axis of the vessel **52** to direct the metal flakes from the surface of the hearth **56** to exhaust port **62**.

The water vessel **58** is mounted on the vessel **52** at the underside of the metal hearth **56** so that the hearth **56** forms the top wall of the chamber **59**. Water under pressure from a pump (not shown) enters the chamber **59** via an inlet pipe **64** and leaves the chamber **59** via an outlet pipe **66** connected to the pump for recirculating the water to the inlet pipe **64**. As a result, the recirculating water cools the underside of the metal hearth **56**, and consequently the top surface of the hearth **56** is cooled by conduction.

The tundish assembly **60** is identical to the above-described tundish assembly **14**. The tundish assembly **60** is mounted on a top wall **66** of the vessel **52** over an opening **68** therein to enable the stream of gas and atomized metal droplets to be projected into the chamber **54**. The inert gas may be recirculated after leaving the exhaust port **62** to the tundish assembly **60**.

Visual examination of the products obtained from the unit shown in FIG. 1 indicate almost a total absence of oxide film in the flakes. When the flakes of alloy A97 (Co-35Cr-10W-5Mo-5Fe-2.5C) were consolided by hot working, an oxide-free structure was obtained. The same alloy prepared in a conventional water-chamber type of unit exhibited a structure having oxides which were originally present on the atomized powder particles prior to consolidation.

Cutting tools were prepared from alloy A97 prepared by conventional methods and by the new atomizing unit. When used to turn AISI 4340 steel of R_C 40 hardness, the conventional material had an average tool life of about 4 min., when cutting at 95 f.p.m. The same alloy prepared in the new atomizing chamber had a tool life of approximately 20 min. under the same conditions.

Alloy A97 prepared conventionally had a modulus of rupture of 265,000 p.s.i., while the same alloy prepared in the unit shown in FIG. 1 had a strength of 331,000 p.s.i.

The advantages of the unit described herein include the following:

(1) Inexpensive construction.

(2) Small size with large production capacity.

(3) Small volume of gas required for purging.

(4) Oxide-free powders or flakes are produced because there is no water in the collection chamber.

(5) Wrought stock made from the powders or flakes has cleaner structures, higher strength, and improved cutting performance in the case of tool alloy powders.

(6) Drying of powders is not required.

(7) Potential for continuous operation.

In view of the foregoing description, there is provided in accordance with the present invention a method and apparatus for producing prealloyed metal powder by recirculating water in contact with the underside of a metal hearth to cool the top surface of the hearth by conduction, atomizing molten metal with a blast of gas inert to the metal, and then directing the atomized metal into contact with the top surface of the cooled metal hearth to quench the atomized metal. Continuous production of the metal powder without interruption of the operation for removal of the powder from the vessel is accomplished by providing an apparatus having a slanting metal-hearth in accordance with the present invention for splattering the metal droplets against the cooled hearth to rapidly quench the metal droplets, and then for directing the quenched droplets in the form of flakes toward an outlet port.

While the present invention has been described in connection with particular embodiments thereof, it will be understood that many changes and modifications of this invention may be made by those skilled in the art without departing from the true spirit and scope thereof. Accordingly, the appended claims are intended to cover all such changes and modifications as fall within the true spirit and scope of the present invention.

I claim:

1. A metal-producing apparatus having a vessel and having means mounted on top of said vessel for atomizing molten metal with a blast of gas inert to the metal to direct the atomized metal into an atomizing chamber of said vessel, wherein the improvement comprises:

a hearth mounted on said vessel and disposed at the bottom of said atomizing chamber;

means mounted on the vessel beneath said hearth for cooling the underside of said hearth thereby to cool the top surface of said hearth by conduction,

whereby said cooled top surface of said hearth quenches said atomized metal;

said top surface of said hearth being dry;

an outlet in said vessel adjacent said top surface of said hearth;

wherein the plane of said top surface of said hearth is disposed at an acute angle with respect to the vertical axis of said vessel to cause said atomizing metal to rebound from said top surface of said hearth to said outlet; and

the distance between said means mounted on top of said vessel and said hearth being sufficiently short so that the atomized metal is not completely quenched at the time it first contacts the surface of the hearth.

2. A metal-powder producing apparatus having a vessel and having means mounted on top of the said vessel for atomizing molten metal with a blast of gas inert to the metal to direct the atomized metal into an atomizing chamber of said vessel, wherein the improvement comprises:

a hearth mounted on said vessel and disposed at the bottom of said atomizing chamber; and

means mounted on the vessel beneath said hearth for cooling the underside of said hearth thereby to cool the top surface of said hearth by conduction,

whereby said cooled top surface of said hearth quenches said atomized metal; and

said top surface of said hearth being dry; and

the distance between said means mounted on top of said vessel and said hearth being sufficiently short so that the atomized metal is not completely quenched at the time it first contacts the surface of the hearth.

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