APPARATUS FOR PRODUCING METAL POWDER
Frederick C. Holtz, Jr., Evanston, Ill., assignor to IT Research Institute, Chicago, Ill., a not-for-profit corporation of Illinois.

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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 rapidly quenching 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.

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 waterreservoir type of vessel. If 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 reference to the following detailed description taken in connection with the accompanying sheet of drawings, wherein:

FIG. 1 is a front elevational view in sectional 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 away from 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 “splash” 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 scalable 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 therein 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 completely filled condition so that the recirculating water washes the underside of the hearth 16, etc., as

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 layer of gas can be formed between 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 apparatus 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 purify 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 splattered 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 process, such as, for example, rolling in 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 specification with the solid stock consolidated from powder produced by the conventional water-reservoir vessel, it is apparent that the powder prepared 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 underside of 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 rapidly 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 realoyed 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 58 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-Fe-2SiC) were consolidated 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 Rm 40 hardness, the conventional material had a tool life of about 4 min., while the 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 new apparatus herein include the following:

1. Inexpensive construction.
2. Small size with large production capacity.
(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.

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J. SPENCER OVERHOLSER, Primary Examiner