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H. MARKUS ET AL

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PRODUCTION OF CELLULAR METALS

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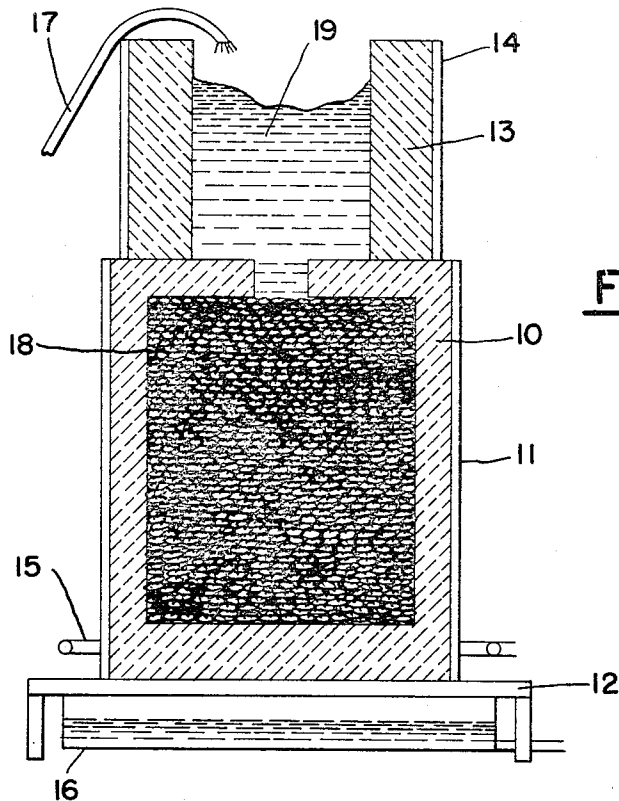


FIG. 1.

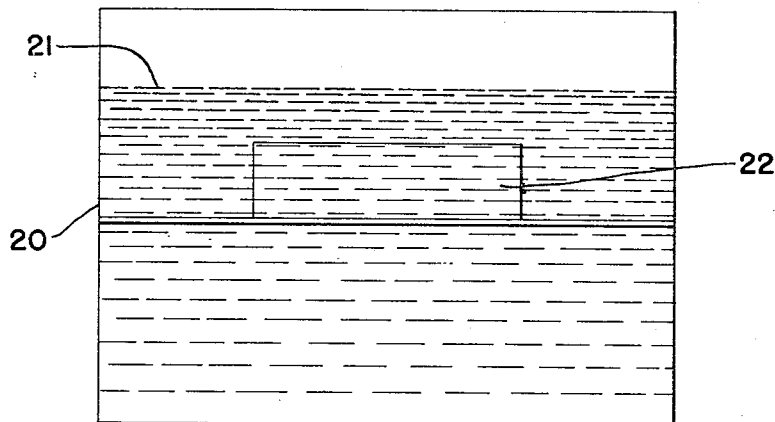


FIG. 2.

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3,523,766

PRODUCTION OF CELLULAR METALS

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Continuation of application Ser. No. 10,006, Feb. 19, 1960.

This application Jan. 16, 1969, Ser. No. 800,325

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U.S. Cl. 29—180

42 Claims

ABSTRACT OF THE DISCLOSURE

A porous, cast metal structure containing many randomly interconnected empty chambers occupying substantially the entire volume thereof and connected at points of contact with each other thus forming random, tortuous passageways throughout its structure. The structure is produced by preparing a mass of preformed solid objects composed of soluble granules which have a higher melting point than the metal and which are soluble in a solvent, heating said mass to a temperature approximating the melting point of the metal, infiltrating the interstices between said solid objects in said mass with the metal in molten form, cooling the composite metal and granules to solidify said metal and removing the granules by leaching with said solvent to form a metallic article having interconnected voids corresponding to the said solid objects distributed therethrough.

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to us of any royalty thereon.

This application is a streamlined continuation application of our copending application, Ser. No. 10,006, filed Feb. 19, 1960, now abandoned, which, in turn, was a continuation-in-part of our then co-pending patent application, Ser. No. 814,355, filed May 19, 1959 (now abandoned) for "Production of Cellular Metals" and has for an object a method of producing a metal casting having a controlled distribution of interconnecting cells.

This invention relates to the production of cellular metals, and more especially to a method for producing cast metals having interconnecting cells of controllable size, shape and distribution.

Prior art processes result in metal castings containing isolated voids by adding to the melt a material which releases hydrogen during solidification, the hydrogen so released being utilized to produce the desired voids in the metal. The difficulty in the prior art is the lack of control of the void size, shape, distribution and location. The placing of the voids cannot be positively controlled, and, what is more important for most applications, the voids are not interconnected.

This invention overcomes prior art difficulties by providing a direct casting technique whereby the cells in the casting are formed by using a soluble, interconnecting core material which is removed after casting.

By controlling the size, shape and distribution of the core material, similar control is reflected in the characteristics of the metal casting.

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An object of this invention is to provide an improved metal casting having a controlled distribution of interconnected cells.

The invention will be better understood from the following description when considered in connection with the accompanying drawings, and its scope is indicated by the appended claims.

Referring to the drawings:

FIG. 1 is a sectional view of a refractory mold suitable for mixing the molten metal with the core material and thereafter cooling the mixture with a desired thermal gradient in the solidifying metal, and

FIG. 2 illustrates a type of equipment suitable for leaching the core material from the solidified metal.

A refractory mold 10 is mounted within a metal casing 11 and supported upon a base 12. Resting on the mold 10 is a riser, which allows for the building up of a metallostatic head, and feeds metal to the mold during shrinkage, consisting of a refractory lining 13 and a metal casing 14. For maintaining a thermal gradient such that the molten metal is cooled without shrinkage there is provided means 15 which spray cool water upon the lower periphery of the mold, cooling said mold, and a drain pan 16 for receiving the cooling water. A heating torch 17 may be provided if required to maintain the molten metal at the desired temperature.

The process herein of producing a cellular casting in accordance with the present invention is a standard foundry process, and molds are prepared according to standard practices. The molds are then filled with a suitable grade of granules soluble in a reagent which normally is harmless to the metal to be cast.

When the granules are placed in the mold, it is necessary that a portion of them contact the mold wall. This insures that this portion, at least, will lie on the surface of the casting, and produce cells that are open to the outside of the casting. Otherwise, leaching would be impossible due to the non-porous nature of the metals involved.

Where it is desired that certain faces of the casting have a continuous metal surface, this is accomplished by placing a combustible liner, such as paper or cardboard, in contact with the mold surface. The granular core grains are then introduced and bonded or positioned in place. During heating, the combustible liner is consumed and, upon casting, the molten metal fills the space formerly occupied by the liner so that the casting has a continuous surface at the desired area.

In filling the mold the granules tend to pack in the most efficient manner permitted by the granule geometry. Vibration may be used to promote this packing. Since none of the granules can remain suspended in space, each granule must contact at least one other granule. Actually, all of the granules touch many neighboring granules. The mold is then heated to a temperature about the melting point of the metal to be cast in preparation for infiltration by the molten metal. During the heating cycle, mold moisture is driven toward the soluble granules and small amounts are condensed on the surface of the granules. This provides a temporary liquid binder for the particles. Where the granules are rock salt (used for most metals with melting points up to but not more than the melting point of aluminum), further heating causes the liquid to evaporate and the salt crystallizing from solution welds

the particles together at points of junction. The mold now contains a continuous phase of granules. The spaces between the granules will eventually be filled by the metal which takes the form of a cellular structure.

The metal is now melted, brought up to its pouring temperature and poured into the prepared mold. The molten metal is caused by pressure built up in the riser, to infiltrate into the spaces between the granules, and permitted to solidify. The casting may now be shaken out of the mold and is ready for machining. In effect, the casting is made up of 2 continuous phases—one composed of the granules, and the other, of the metal. Normally, the continuous phase cellular metal structure may then be exposed by leaching away the soluble granules from the metal-granule composite. Connecting cells exist where adjoining granules had been. It may be seen that this process permits control not only of a cell size, but of cell geometry and size distribution.

As applied to different metals, variations are made, especially with respect to granular material and leaching agents. Thus, any metal which may be cast may be cast in the form resulting from the practice of this invention by the expedient of selecting a granular material such that its melting point is higher than the pour point of the material to be cast and which can be leached out without causing undue harm to the metal.

The suitability of a given salt as a core material is determined on the basis of its solubility in the selected solvent, the chemical inertness of the solution to the metal system under consideration, the stability of the salt over the intended range of temperatures and its melting point in relation to the actual metal pouring temperature to be used. The actual selection would be made on the basis of availability of grades, cost, toxicity and any other factors associated with the casting of the metal or any subsequent processing which may be planned. The following salts are illustrative of those which may be used for base metal systems ranging from low melting alloy systems such as lead through zinc, aluminum, magnesium, copper and the high melting point alloy systems: the metaborate, fluoride, metasilicate and chloride of sodium; the chloride, fluoride and orthophosphate of potassium; and the oxides of magnesium, calcium and barium. These are typical of the soluble substances which are available for the production of cellular metal structures.

When an aluminum alloy is the metal to be cast, for example, the mold 10 is filled with graded rock salt 18. If it is desired to bond the granular particles of salt together, this can be done by wetting the salt with a concentrated salt solution, either before or after packing into the mold, and thereafter, heating to drive off the water. Whether or not the salt solution is utilized, the mold is preheated and placed upon the support 12. (A ceramic screen may be used to position the particles instead of the bonding process, the screen being placed on top of the granules.) The riser 13-14, having been similarly preheated is placed upon the mold 10-11. Molten aluminum alloy is then poured down through the riser and infiltrates down between the salt granules until all the space between them is filled with metal. Where the metal is aluminum alloy and the core is sodium chloride, the pressure generated by the head of liquid metal in the riser is usually sufficient to distribute the metal throughout the mold.

Where fine granules are used, fine cells will result and more pressure may be needed to infiltrate. This may be accomplished by the application of pneumatic pressure on the metal in the reservoir, by suction casting techniques, or by means of vibration where the mold is attached to a vibrator.

During infiltration, it is important that the metal retain its fluid state. This can be done by narrowing the temperature differential between the mold and the molten metal. Thus, the mold should be preheated to a temperature close to the melting point of the metal to be poured. This will avoid the necessity of excessive amounts of

superheat of the metal and sustain its fluid state long enough to permit complete infiltration.

After infiltration, a water spray is applied until the metal solidifies. This type of cooling should be applied over the lower 25-50% of the mold. It is sometimes necessary to supply heat to the riser for a period sufficient to develop and maintain a proper thermal gradient in the solidifying metal. The casting may then be removed from the mold.

If the casting is to be machined, it is often desirable to do so before the leaching process.

The leaching operation is performed by supporting the casting 22 in a tank 20 near the surface of a body of water. As the salt is dissolved in the water, the greater density of the salt-laden water causes it to sink to the bottom of the tank. This sets up a current similar to a thermal convection current so that fresh water is continuously drawn up to dissolve the salt. An overnight immersion is usually sufficient to leach all the salt from a billet twelve inches in diameter. While this method has been found satisfactory, it is apparent that other methods such as high frequency, low amplitude agitation, etc., may be used.

Where the leaching agent is not water, it should be one that is compatible with the cast metal so that there is no deleterious effect on the metal during leaching.

If the liquid used for leaching contains some gas, either in solution or in dispersion, some of this gas may collect in the cells and form an air lock which will retard the leaching process. For this reason, the liquid should be conditioned either by standing prior to use, or by deaeration by vacuum technique.

Other metals may be cast by the above-described process. The selection of the soluble core material is governed by the considerations previously mentioned. For example, a ferrous cellular metal casting may be made of austenitic stainless steel with calcium oxide as the soluble granular material. In this case, the mold 10 is filled with calcium carbonate granules and heated sufficiently to completely calcine the carbonate, driving off the carbon dioxide and leaving calcium oxide granules. These granules were positioned, or held in place, by a ceramic screen or strainer core fitted over the filled mold. The molten metal is then poured into the mold and infiltrated into the granular mass. After solidification, the oxide may be leached out by immersing the casting in dilute hydrochloric or nitric acid.

The following table lists some of the other metals along with suggested working temperatures.

Metal	Melting point (°F.)	Mold temperature (°F.)	Casting temperature (°F.)
Lead.....	621	665	750
Tin.....	459	500	600
Zinc.....	787	840	920

Castings with shaped cell formations may also be produced by this method. Here the granules would be set in the desired shape and bonded together before their insertion in the mold. Whatever the form of the casting, it (1) is light in weight and rigid in structure making it useful in aircraft and missile applications, and (2) has a large surface area which makes it useful in connection with heat exchange systems, metallic filters or the production of high rates of chemical reaction where the metallic material is one of the reactants.

Another possible application of these cellular metals is in the field of composite structures. These structures would be a marked departure from the type currently being used and developed. The cellular casting or skeleton represents a continuous phase of one material. The volume represented by the interconnecting cells can be filled with another material which will also be present in the composite as an independently continuous phase. A composite cast structure of this type may subsequently be subjected to working operations which under certain con-

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ditions will produce metallurgical bonding between the two phases.

Composite structures may be made by using non-soluble materials in the core, and omitting the process of leaching. Also, they may be made by infiltrating a leached cellular casting with another metal, or other material. Where a second metal is used, the pouring temperature of the second metal must be below the melting point of the cellular casting.

Alternatively, the soluble granular compacts can be produced in the form of a core which may be placed in a dried mold cavity of sufficiently large dimension so that upon casting, continuous metal surfaces can be obtained. This technique would most often apply to the production of cellular metal bars of uniform section where a continuous surface is desired. Of course, at least a portion of the surface must be cellular in nature to permit leaching. Bars of this type have been subjected to metal working operations with the soluble material in place and upon completion of these operations have been leached to produce tubular sections which can carry liquids and gases through the interconnecting voids.

The density of a cellular aluminum alloy, for example, has been controlled between approximately 30 to 65 pounds per cubic foot or from $\frac{1}{3}$ to $\frac{1}{2}$ of the base density of the metal, this control being effected by selecting the size distribution of the granules of the core material. Thus if a single size of granule is used, approximately $\frac{1}{3}$ of the volume is represented by the space between the granules. By introducing granules small enough to lie in the spaces between the larger granules, the resulting metal volume in the spaces is reduced and the volume of the voids in the casting is increased. Since the shape factor also influences the packing efficiency, the selection of grain shape also provides a means of density control. These materials should find important application in heat exchange systems as well as in rigid structural members.

The significance of this invention is that the present concepts relating to materials are largely built upon a structure which consists of one continuous phase called a matrix, and a discontinuous phase dispersed through this matrix, as, for example, in the case of concrete.

We claim:

1. A method for producing a metal casting having a controlled distribution of interconnected cells of predetermined size comprising

inserting soluble granules into a mold, at least a portion of said granules being in contact with said mold, said granules having a melting point above that of the pouring temperature of the metal to be cast and being soluble in a reagent,
positioning said granules so that they become stationary,
heating said mold and said granules to a temperature approximating the melting point of said metal,
adding said metal in its molten state to the mold,
exerting pressure on said metal causing said metal to infiltrate the soluble granules,
cooling said mold and said metal, removing the casting from said mold, and
removing the granules from said casting by leaching with said reagent, leaving a plurality of interconnecting cells which correspond to the original size and shape of the said soluble granules.

2. The method of claim 1 wherein the step of positioning the granules inside the mold is effected by covering said granules with a ceramic screen to prevent movement of said granules.

3. The method of claim 1 wherein the step of positioning the granules inside the mold is effected by bonding the granules to one another to prevent movement of said granules.

4. The method of claim 1 wherein the step of exerting said pressure is effected by adding the molten metal to a riser situated on the mold.

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5. The method of claim 1 including the step of vibrating the mold after addition of the metal to be cast to cause said metal to more easily infiltrate the core of granules.

6. The method of claim 1 wherein the step of increasing said pressure is effected by applying a vacuum to the base of the mold whereby said metal will infiltrate a core of fine granules on the order of 100 mesh.

7. The method of claim 1 including the additional steps for obtaining a bi-metal casting comprising:

inserting the metal casting in a mold,
heating said mold and said casting to a temperature approximating the melting point of a second metal, said second metal having a melting point below the melting point of said metal casting,
adding said second metal in its molten state to the mold,
exerting pressure on said metal causing said metal to infiltrate said metal casting,
cooling said mold and said metal, and
removing resultant bi-metal casting from said mold.

8. In a method for producing an aluminum alloy casting having a controlled distribution of interconnecting cells comprising

inserting sodium salt granules into a mold so that at least a portion of the granules contact the mold,
positioning said granules so that they become stationary,
heating the mold to a temperature about the melting point of the aluminum alloy to be cast,
adding molten aluminum alloy to said mold,
exerting sufficient pressure on said aluminum alloy to force said alloy to infiltrate into spaces between said sodium salt granules,
cooling the mold and the aluminum alloy so that progressive solidification of said aluminum alloy occurs,
removing the aluminum alloy and the sodium salt granules from said mold, and leaching said sodium salt granules from said aluminum alloy to leave an aluminum alloy casting having a continuous phase of interconnected cells which conform to the original distribution of the sodium salt granules.

9. The method of claim 8, wherein the step of positioning the granules in the mold is effected by adding a solution of sodium salt and water thereto and heating the mold, and evaporating said water to leave said granules bonded together.

10. A method for producing a ferrous casting having a controlled distribution of interconnecting cells comprising

inserting calcium carbonate granules into a mold so that at least a portion of the granules contact the mold,
heating said mold to a temperature such that said calcium carbonate granules are converted to calcium oxide granules,
pouring molten austenitic stainless steel into the mold,
exerting pressure on said steel to force said steel to infiltrate spaces between said calcium oxide crystals,
cooling said mold and said steel so that progressive solidification of the steel occurs,
removing said steel and said calcium oxide granules from said mold, and
immersing said steel and said granules in a bath of an acid in which said calcium oxide granules are soluble to thereby leach out the calcium oxide granules.

11. The method of claim 10 wherein said acid is dilute hydrochloric acid.

12. A method for producing an aluminum alloy casting having a predetermined distribution of interconnecting cells comprising,

bonding sodium chloride granules together,
inserting said bonded granules into a mold so that a

portion of said granules come in contact with said mold,
 heating said mold and said bonded granules to a temperature of from 800° to 1250° F.,
 pouring molten aluminum alloy at a temperature approximating the temperature of the mold into said mold,
 applying pressure to said alloy to force said alloy to infiltrate the bonded granules,
 cooling said aluminum alloy and said bonded granules, removing said aluminum alloy and said bonded granules from said mold, and
 leaching said bonded granules from said aluminum alloy to leave a casting containing interconnecting cells of predetermined size, shape and position conforming to the original size, shape and position of said bonded sodium chloride granules.

13. A method for producing a metal casting having a controlled distribution of interconnected cells of predetermined size, said metal being one selected from the group consisting of aluminum, zinc, lead, magnesium, and tin, and including the steps of

inserting soluble granules into a mold, at least a portion of said granules being in contact with said mold, said granules having a melting point above that of the pouring point of the metal to be cast, and being soluble in a reagent, said granules being one selected from the group consisting of: the metaborate, fluoride, metasilicate and chloride of sodium,
 positioning said granules so that they become stationary, heating said mold and said granules to a temperature approximating the melting point of said metal, adding said metal in its molten state to the mold, exerting pressure on said metal causing said metal to infiltrate the soluble granules,
 cooling said mold and said metal,
 removing the casting from said mold, and
 removing the granules from said casting by leaching with said reagent to leave a plurality of interconnecting cells which correspond to the original size and shape of the said soluble granules.

14. A method for producing a metal casting having a controlled distribution of interconnected cells of predetermined size, said metal being one selected from the group consisting of copper and iron, and including the steps of

inserting soluble granules into a mold, at least a portion of said granules being in contact with said mold, said granules having a melting point above that of the pouring point of the metal to be cast, and being soluble in a reagent, said granules being one selected from the group consisting of: the chloride, fluoride and orthophosphate of potassium and the oxides of magnesium, calcium and barium,
 positioning said granules so that they become stationary, heating said mold and said granules to a temperature approximating the melting point of said metal, adding said metal in its molten state to the mold, exerting pressure on said metal causing said metal to infiltrate the soluble granules,
 cooling said mold and said metal,
 removing the casting from said mold, and removing the granules from said casting by leaching with said reagent to leave a plurality of interconnecting cells which correspond to the original size and shape of the said soluble granules.

15. A process for the production of porous metal shapes having interconnected voids of predetermined size which comprises preparing a mass of preformed solid objects composed of an inert, anhydrous inorganic salt which has a higher melting point than the metal and which is soluble in a solvent which has an adverse effect on the metal, heating said mass to a temperature approximating the melting point of the metal, infiltrating the

interstices between said solid objects in said mass with the metal in molten form, cooling the composite metal and salt shape to solidify said metal and leaching the salt therefrom with said solvent to form a metallic article having interconnected voids corresponding to the said solid objects distributed therethrough.

16. In a process for the production of porous metal shapes having interconnected voids of predetermined size, the steps comprising preparing a mass of preformed solid objects composed of an inert anhydrous inorganic salt which has a higher melting point than the metal and which is soluble in a solvent which has no adverse effect on the metal, heating said mass to a temperature approximating the melting point of the metal, infiltrating the interstices between said solid objects in said mass with the metal in molded form, and cooling the composite metal and salt shape to solidify said metal so as to permit leaching of the salt therefrom with said solvent to form a metallic article having interconnected voids corresponding to the said solid objects distributed therethrough.

17. The process of preparing a sponge metal body comprising molten metal onto a plurality of solid objects, said objects having a higher melting temperature than the temperature of said molten metal and being capable of being dissolved by a liquid which does not substantially affect said metal to provide a mixture of said molten metal and said solid objects, cooling said mixture so as to form an article having a metal phase with discrete solid objects embedded therein, treating said article with a liquid that dissolves said solid objects, removing said solid objects from said article by dissolving said objects in said liquid so as to form a solid metal article having interconnecting voids distributed therethrough.

18. The process of preparing a sponge metal body comprising pouring a molten metal onto a plurality of solid objects, said objects having a higher melting temperature than the molten temperature of said metal and being soluble in water, intermixing said molten metal and said solid objects at the molten temperature of said metal, cooling said metal mixture so as to form an article having a metal phase with discrete solid objects embedded therein, treating said article with water, removing said solid objects from said article by dissolving said objects in water so as to form a solid metal article having interconnecting voids distributed therethrough.

19. The process of preparing a sponge metal body comprising pouring a molten metal onto a plurality of solid objects consisting of solid halide salt, said halide salt having a higher melting temperature than the molten temperature of said metal, intermixing said molten metal and said halide salt at the molten temperature of the metal, cooling said metal mixture so as to form an article having a metal phase with discrete solid objects embedded therein, treating said article with water, removing said solid objects from said article by dissolving said objects in water so as to form a solid metal article having interconnecting voids distributed therethrough.

20. Process of preparing a sponge metal body comprising pouring a molten metal onto a plurality of solid objects, said objects having a higher melting temperature than the molten temperature of said metal and capable of being dissolved by acid, intermixing said molten metal and said solid objects at the molten temperature of said metal, cooling said metal mixture so as to form an article having a metal phase with discrete solid objects embedded therein, treating said article with an acid, removing said solid objects from said article by dissolving said objects in said acid so as to form a solid metal article having interconnecting voids distributed therethrough.

21. The process as defined by claim 20 wherein said solid objects are composed of magnesia.

22. The process as defined by claim 20 wherein said solid objects are composed of calcium oxide.

23. The process as defined by claim 18 wherein said solid objects are composed of barium oxide.

24. The process as defined by claim 18 wherein said solid objects are composed of potassium chloride.

25. The process as defined by claim 18 wherein said solid objects are composed of potassium fluoride.

26. The process as defined by claim 18 wherein said solid objects are composed of potassium orthophosphate.

27. The process as defined by claim 18 wherein said solid objects are composed of sodium metaborate.

28. The process as defined by claim 18 wherein said solid objects are composed of sodium fluoride.

29. The process as defined by claim 18 wherein said solid objects are composed of sodium metasilicate.

30. The process of preparing a sponge metal body comprising pouring a molten metal onto a plurality of solid objects, said solid objects having a melting temperature above the molten temperature of said metal, said solid objects consisting of sodium chloride, intermixing said molten metal and said objects of sodium chloride at the molten temperature of the metal, cooling said metal mixture so as to form an article having a metal phase with discrete solid objects of sodium chloride embedded therein, treating said article with water, removing said objects of sodium chloride from said article by dissolving said objects in the water so as to form a solid metal article having interconnecting voids distributed throughout.

31. The process of preparing a sponge metal body comprising pouring molten metal onto a plurality of solid objects, said objects having a higher melting temperature than the temperature of said molten metal and being capable of being dissolved by a liquid which does not substantially effect said metal, intermixing said molten metal and said solid objects at the molten temperature of said metal, cooling said mixture so as to form an article having a metal phase with discrete solid objects embedded therein, treating said article with a liquid that dissolves said solid objects, removing said solid objects from said article by dissolving said objects in said liquid so as to form a solid metal article having interconnecting voids distributed therethrough.

32. A process for the production of porous metal shapes, which comprises introducing molten metal into the interstices of a preformed shape composed of an inert, heat-stable, substantially anhydrous inorganic salt soluble in a solvent which has no adverse effect on the metal, and having a melting point higher than that of the metal, cooling the composite metal and salt shape to solidify the metal and leaching the salt therefrom with said solvent.

33. The process for the production of a shaped porous metal structure, which comprises preparing a structure having a predetermined proportion of interstices and corresponding to the desired shape, and composed of an inert, heat-stable, substantially anhydrous inorganic salt soluble in a solvent which has no adverse effect on the metal, and having a melting point higher than that of the selected metal, introducing the metal in molten condition into and throughout the interstices of the said salt structure, cooling the resulting composite metal and salt structure to solidify the metal, and leaching the salt therefrom with said solvent.

34. The process for the production of a shaped porous metal structure, which comprises substantially uniformly moistening an inert, heat-stable, water-soluble inorganic salt, forming from the moistened salt a structure having a predetermined proportion of interstices, removing the water from the said structure, introducing molten metal into and throughout the interstices of the said structure at a temperature lower than the melting point of the said salt, cooling the resulting composite metal and salt structure to solidify the metal and leaching the salt therefrom.

35. The process for the production of a shaped porous metal structure, which comprises substantially uniformly moistening an inert, heat-stable, water-soluble inorganic

salt, compacting the salt under pressure to form a salt structure having a predetermined proportion of interstices, removing the water from the said structure, introducing molten metal into and throughout the interstices of the said structure at a temperature lower than the melting point of the said salt, cooling the resulting composite metal and salt structure to solidify the metal and leaching the salt therefrom.

36. A process for the production of porous aluminum shapes, which comprises introducing molten aluminum into the interstices of a preformed shape composed of an inert, heat-stable, substantially anhydrous inorganic salt soluble in a solvent which has no adverse effects on the aluminum, and having a melting point higher than aluminum, cooling the composite aluminum and salt shape to solidify the metal and leaching the salt therefrom with said solvent.

37. The process for the production of a shaped porous aluminum structure, which comprises substantially uniformly moistening an inert, heat stable, water-soluble inorganic salt which melts above the melting point of aluminum, compacting the salt in a predetermined shape to form a salt structure having a predetermined proportion of interstices, removing the water from the said structure, introducing molten aluminum into and throughout the interstices of the said salt structure at a temperature lower than the melting point of the said salt, cooling the resulting composite aluminum and salt structure to solidify the metal and leaching the salt therefrom.

38. A process for the production of porous aluminum shapes, which comprises introducing molten aluminum into the interstices of a preformed compacted shape composed of substantially anhydrous sodium chloride, cooling the composite aluminum and salt shape to solidify the metal and leaching the salt therefrom.

39. The process for the production of a shaped porous aluminum structure, which comprises substantially uniformly moistening particulate sodium chloride, compacting the salt in a predetermined shape to form a shaped salt structure having a predetermined proportion of interstices, removing the water from the said structure, introducing molten aluminum into and throughout the interstices of the said structure, cooling the resulting composite aluminum and salt structure to solidify the metal and leaching the salt therefrom.

40. The process for the production of a shaped porous metal structure, which comprises substantially uniformly moistening an inert, heat-stable water-soluble inorganic salt, forming from the moistened salt a structure having a predetermined proportion of interstices, removing the water from the said structure, introducing molten metal into and throughout the interstices of the said structure at a temperature lower than the melting point of the said salt, cooling the resulting composite metal and salt structure to solidify the metal, machining the metal, machining the composite metal and salt structure to the configuration and dimensions desired in the porous metal structure, and leaching the salt therefrom.

41. A porous, cast metal structure containing many randomly interconnected empty chambers occupying substantially the entire volume thereof and connected at points of contact with each other thus forming random, tortuous passageways throughout its structure, said chambers corresponding in number, shape, size and position to a plurality of solid, leachable three-dimensional objects composed of a metal salt having a higher melting point than that of the metal, said metal salt objects being placed in contact as a mass serving as an internal mold used in making said structure.

42. A two-phase composite metal-salt structure consisting of, as a first continuous solid phase, a substantially anhydrous, heat stable, crystalline metal salt which is inert toward the metal used in the composite and which is soluble in a solvent which has no adverse effects on the said metal, said salt being in a configuration with the

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crystals thereof in contact, and containing numerous, randomly located interconnected passageways there-through; and as a second continuous solid phase, dense cast metal having a melting point lower than that of the said salt filling the passageways in the said salt phase; the said structure having at least one face at which the salt phase is exposed to permit leaching of salt from the said two-phase structure.

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10 RICHARD O. DEAN, Primary Examiner

U.S. Cl. X.R.

29—183, 191; 75—20; 164—36 ,65, 71, 79, 95, 132

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,523,766

August 11, 1970

Harold Markus et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 73, before "adverse" "an" should read --
no --. Column 8, line 16, "molded" should read -- molten --.
Column 9, line 32, "effect" should read -- affect --.

Signed and sealed this 2nd day of March 1971.

(SEAL)

Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents