

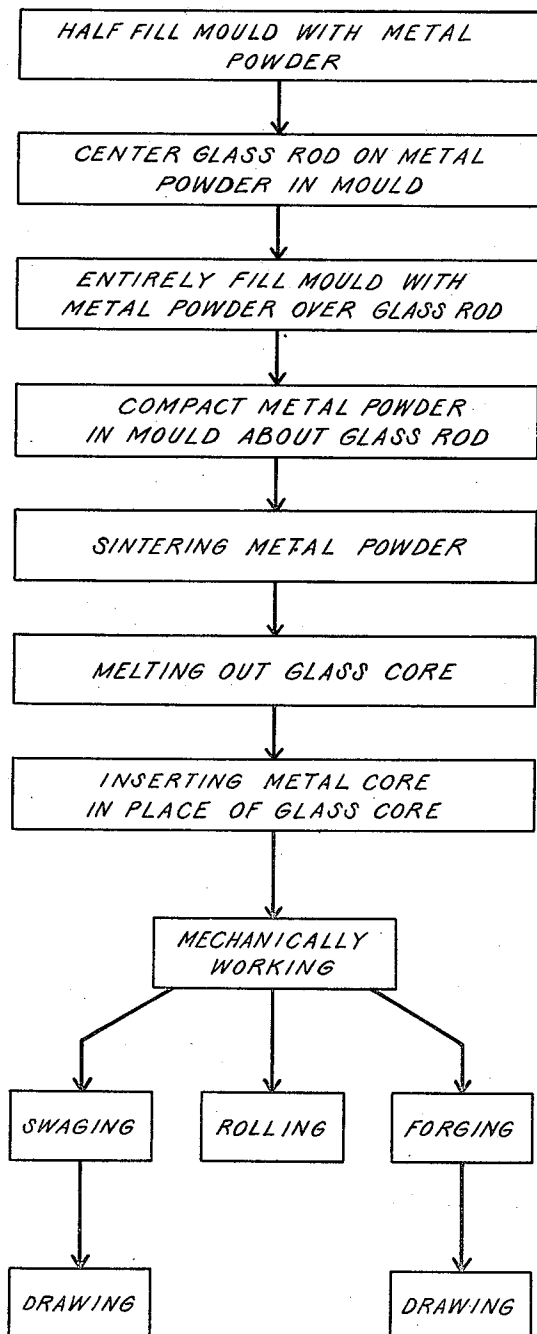
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R. LOWIT

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PROCESS OF MAKING SEAMLESS HOLLOW BODIES OF REFRACTORY METALS

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INVENTOR.

RUDOLF LOWIT

BY

*Charles H. Holland*

ATTORNEY

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## PROCESS OF MAKING SEAMLESS HOLLOW BODIES OF REFRACTORY METALS

Rudolf Lowit, Union City, N. J., assignor to Callite Tungsten Corporation, Union City, N. J., a corporation of Delaware

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The present invention relates to the manufacture of seamless tubes of refractory metals such as tungsten, molybdenum, tantalum and columbium.

It is an object of this invention to provide seamless tubes, tubular parts, or hollow bodies of various cross-sectional shape, which are useful in operations where high temperatures are encountered. For this purpose the high melting point metals above mentioned are distinctly suitable but hitherto no practical method has been devised for manufacturing them in tubular form.

It is contemplated by the present invention to form a hollow body of the metals contained in the group including tungsten, molybdenum, tantalum, and their alloys or composite bodies of said metals, by pressing a body from the metallic powder about a forming core. The pressed body is then subjected to a sintering process during which the metallic powder sinters and frits into a coherent body capable of being forged, rolled or swaged, and subsequently drawn. The forming core may be removed as an incident to the temperatures employed in sintering or fritting the metallic body, which temperatures are sufficiently high to melt or volatilize out the material of which the forming core is made.

If the forming core be of metal, it should ordinarily have a melting point considerably different from that of the metal of which the tube is to be formed. It should also have a coefficient of expansion not greater than said tube metal and preferably considerably lower. Furthermore, the core material, if metal, should either be of a metal that will not readily alloy nor form compounds with the tube metal or else it should be coated or sleeved with such a metal or other compound to prevent such alloying or reaction. Suitable for such cores are alloys of nickel, iron, chromium, etc., and particularly the alloy of nickel and steel known as Invar which has a nickel content of 36% and a very low coefficient of expansion.

I have found various compounds of silicon, such as quartz, pyrex glass, or other boro-silicate glasses, to be especially suitable for use as a forming core. Sillimanite and carborundum may also be satisfactorily used.

According to the preferred method of the invention, a die of the desired shape is partially filled with a refractory metal in finely divided form. This is then tamped down and a rod, which is to be the forming core, is placed centrally on this metal. More of the same metal powder is then placed in the die in such manner that the forming core is disposed within the mass.

The whole assemblage is then subjected to considerable pressure so as to form the metal powders into a compact body about the forming core. This body is then removed and subjected to a preliminary sintering at a temperature sufficient to bring the metallic powders into a coherent body with the forming core still disposed therein in a neutral or reducing atmosphere or in a vacuum. At this point the metallic body attains sufficient coherence to be handled, and it is then placed between electric termini and electric current is passed directly through it until it is heated to a point short of the fusing temperature. This heating may be done by passing a current directly through the body, or by any other means such as by high frequency induction. During this treatment the core crops out, melts out, or distills off according to its nature, through a properly provided opening, and there results a coherent, strong, hollow, metallic body.

The drawing presents a flow diagram showing the various steps of the process.

As shown in the diagram, the die or mould is first filled approximately half full of finely divided metal such as molybdenum which is tamped down. A rod of borosilicate glass is then centered in the die on top of the metal powder. More of the metal powder is then added to fill the die, the glass rod remaining in the center thereof. The metal powder thus in the die is then subjected to a high pressure, hydraulic or otherwise, of the order of 10 or 20 tons per square inch, or even higher, in order to compress and densely compact the metal powder as uniformly as possible. The compacted mass with the glass core still in place is then sintered by placing it in a furnace in a neutral or reducing atmosphere or in a vacuum. The body may be mounted during the sintering step in a vertical position between two electrodes and heated by direct passage of current to slightly below the melting point of the metal. Below this temperature the glass rod melts and flows out or drops out, leaving a smooth, clean passage through the metal body.

The molybdenum body with the cylindrical opening so formed by the removal of the borosilicate glass rod is then removed from the furnace. A rod, which may be of metal or other suitable material, is then inserted in the hole in the center of the body and the assemblage so formed is then introduced into a swaging machine and swaged down in known manner. When the tubing has been reduced to the desired size, the core is removed, mechanically or otherwise, and there results a strong molybdenum tube of fibrous

construction. Instead of swaging, the body may be rolled or forged. The final step may be drawing.

The procedure above described for molybdenum, with slight modifications as to temperature and time, will also apply for tungsten, tantalum, columbium, composite bodies of said metals, or other refractory metal. However, if tungsten metal is used and a pyrex glass core, there would be little, if any, change necessary. Pyrex glass, for instance, will melt and flow at about 1200° C., while silicon oxide distills out at temperatures of the order of 1800° C. or higher.

It is within the contemplation of the invention that the forming core may even be of a metal having a melting point as high as or higher than the melting point of the tube metal. It should, however, have a not higher coefficient of expansion and should not be of a metal that would alloy with the tube metal. For instance, if the tube metal is molybdenum, it would be quite practical and within the scope of the invention to use a rod of tungsten properly coated or sleeved with high melting point oxides such as the oxides of beryllium, magnesium, zirconium, or thorium, as the forming core, although tungsten has a considerably higher melting point than has molybdenum. Its coefficient of expansion, however, is close to that of pyrex glass and because of its coating it will not alloy with molybdenum. There are certain practical advantages in using a tungsten rod in this manner since the tube may be formed about it and, after the sintering step, the whole assembly centered about the tungsten core which still remains may be swaged, forged, rolled and drawn without the necessity of removing the core and inserting a new rod in place thereof. After the swaging, rolling, forging and drawing is completed, however, the tungsten core may be removed mechanically. I may also use as a core material, where the body material is molybdenum, a rod of molybdenum coated with high melting point oxides.

Having thus described my invention, what I claim is:

1. The method of forming a seamless molybdenum tube which comprises pressing finely divided molybdenum powder in a die about a borosilicate glass core, heating said pressed body so formed to a temperature just below the melt-

ing point of molybdenum, thereby sintering said molybdenum body and melting out said borosilicate glass core, inserting a metal rod into the hollow left by said core and swaging down to desired size.

2. The method of making a seamless tube of molybdenum, tungsten or like refractory metal comprising pressing said refractory metal about a borosilicate glass rod, sintering said pressed metal in a neutral or reducing atmosphere by mounting said body between electrodes and passing current through said sintered body, thereby heating it to a temperature slightly below the melting point of the metal, at the same time melting out the borosilicate glass rod, then inserting a rod of metal in the passage formed by the said glass rod and swaging and drawing said tube down to desired size.

3. The method of making seamless tubing of dense molybdenum metal comprising the steps of compacting molybdenum metal powder under pressure of the order of 10 to 20 tons per square inch about a core of borosilicate glass; heating said body so formed to a temperature just below the melting point of molybdenum and above the melting point of the said glass core, thereby sintering the powdered molybdenum and melting out the said glass core; inserting a metal rod into the opening left by said melted out core; mechanically working said sintered body about said metal rod until said body is reduced to dense metallic condition; and then removing said metal rod.

4. Method of making a seamless tube of the group consisting of tungsten, molybdenum, tantalum, columbium and the alloys and composite bodies of said metals capable of being mechanically worked that consists in first providing a die of a suitable form, filling said die approximately half full with finely divided refractory metal, centering a rod of borosilicate glass upon said metal in said die, completely filling said die with more of the finely divided refractory metal with the glass rod remaining centered therein, subjecting the powdered metal in said die to a pressure of approximately 10 to 20 tons per square inch, and then heating to a temperature slightly below the melting point of the metal, thereby sintering said metal and melting out said rod of borosilicate glass.

RUDOLF LOWIT.