Oct. 27, 1942. J. E. EBERHARDT 2,300,353

METHOD OF MAKING SEAMLESS TUBING

Filed May 31, 1941

Fig. 1.

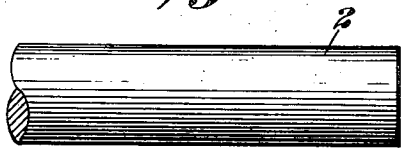


Fig. 2.

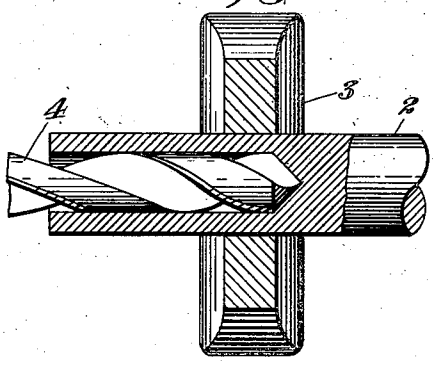


Fig. 3.

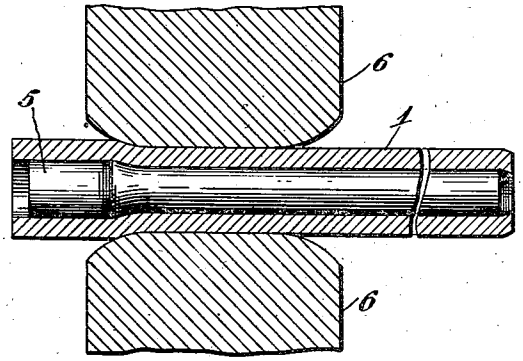


Fig. 4.

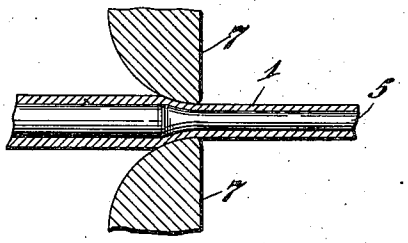


Fig. 5.

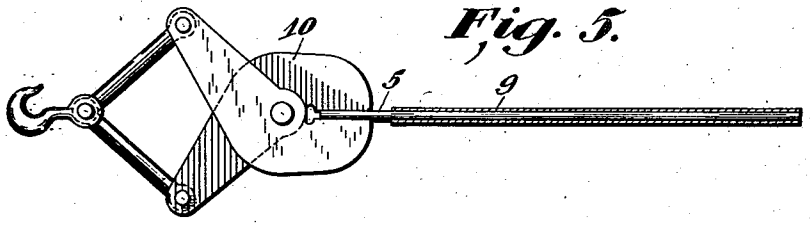
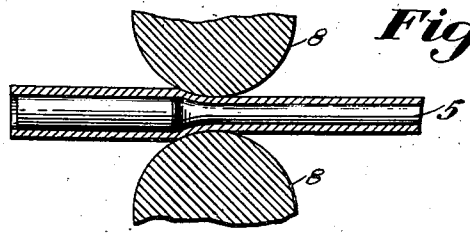


Fig. 6.



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2,300,353

METHOD OF MAKING SEAMLESS TUBING

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3 Claims. (Cl. 29—156)

My invention relates to a process for the manufacture of seamless tubing, and particularly to a process for the manufacture of seamless tubing of molybdenum or tungsten.

Molybdenum is a silver-white, very hard, brittle metal in its pure condition, with the extremely high melting point of 4748° F. (2620° C.). As ferro-molybdenum, calcium molybdate or molyte, its chief use up to the present has been as an alloying element in the manufacture of steel. Despite obvious advantages, its independent use as a metal has been greatly retarded by the lack of suitable working techniques.

Molybdenum tubing, in particular, has not been available either commercially or experimentally, although a considerable demand for it for high-temperature thermo-couple tubes and the like, is known to exist. I have now developed a process which with very minor changes is also adaptable to other highly refractory brittle metals, such as tungsten and the like.

One object of my invention, therefore, is a process for the manufacture of molybdenum tubing.

Another object of my invention is a process of manufacturing seamless molybdenum tubing.

Still another object of my invention is a process of manufacturing tubing of refractory metals for purposes requiring high resistance to heat.

Having thus briefly stated the advantages and objects of my invention, I shall now, in order to make the same more clear, give a detailed description thereof, referring for illustration to the annexed sheet of drawings showing the steps in my invention.

Figure 1 of the drawing is a side elevation of a portion of a molybdenum bar which is to be made into tubing;

Fig. 2 shows a longitudinal hole being drilled in the bar concentric with the outer surface to form a tubular blank;

Fig. 3 is a sectional view showing swaging dies and core mandrel;

Fig. 4 is a fragmentary cross-sectional view showing mandrel and drawing dies in operation;

Fig. 5 is a side elevation, partly in section, showing the method of removing the core from the finished tube; and

Fig. 6 is a side elevation showing the method of forming tubing by rolling.

In my process a tubular blank 1 of suitable dimensions is prepared either by molding a molybdenum ingot with a longitudinal central hole or by boring such a hole through a solid round bar 2, held in a grippping device 3, by a drill 4. The ratio of inside to outside diameter of the tubular blank preferably should be the same as is desired in the finished tube, although it may be larger. An appropriate tubular blank, for example, may be 0.75 inch outside diameter by 0.438 inch inside diameter by 12 inches long. Within the tubular blank is placed as a core a work-hardenable ground steel bar 5 preferably coated with dry slaked lime or the like to facilitate withdrawal of the bar after working. For the size of tubular blank given above, a lime-coated core of drill steel stock .425 inch diameter is suitable, and it should be slightly shorter than the tubular blank to prevent cracking of the blank at the ends.

A high resistance to creep, or plastic flow, under the great stress and high temperatures to which it will be subjected, is the most necesasry property of the steel core. In this regard the grain structure and chemical composition of the steel are very important factors, and austenitic alloy steels have proven to be best adapted for this use. Austenite in steel is a solid solution of carbon or of carbon and other elements in gamma iron, and austenitic steels, particularly of coarse grain structure, show a higher resistance to creep at temperatures above 850° F. than other and finer-grained steels. Alloy steels containing 10 to 14 percent manganese, with which 3 to 5 percent of nickel may form either an addition or a substitute for part of the manganese, have the useful property of rapid work-hardening, so that when slightly deformed initially the tensile strength and hardness at once are multiplied at the point of deformation and necking down is obviated.

The tubular blank and core are heated in a high-temperature gas or electric furnace, and are then swaged and/or drawn to the desired outside diameter. Usually the tube will be swaged to a suitable diameter and finished by drawing. In the swaging operation two things are of paramount importance: (1) the temperature must be carefully controlled so as to be high enough to render the molybdenum workable yet not so high as to unduly soften the steel core; and (2) the surface of the tube must be kept smooth and the diameter must be kept uniform at all stages so as to avoid irregularities in the diameter of the steel core. If at any time the outer surface of the tube becomes irregular, these irregularities are carried into the steel core and cannot be removed by subsequent treatment. That is, every swaging pass must be the equivalent of a finishing pass. In swaging the tubes described above, I reduced

the outside diameter from 0.75 inch to 0.24 inch in fifteen passes, using long bearing finishing dies 6 of tool steel or the like for each pass. The temperature was held at 2300° to 2500° F. for the first passes and, as the working refined the crystal structure of the molybdenum, the temperature was reduced to 2000° to 2200° for the last (0.24 inch) pass.

It was found that in these sizes at lower temperatures the molybdenum split badly, and at higher temperatures the steel core showed severe distortion. The dies should also be heated through to prevent their cracking when they initially come into contact with the hot work.

Improvement in grain structure of the molybdenum with continued working permits a reduction in working temperatures as the tube and core become smaller.

For making very small diameter tubing, however, the swaged tube, coated with graphite or other suitable refractory lubricant, is preferably drawn through suitable dies 7 to the desired diameter. The 0.24 inch diameter mentioned above is not to be taken as necessarily indicative of the proper point at which to start drawing. In general, it is best to start drawing at as large a diameter as is convenient for the purpose. The temperature used in drawing is related to the reduction made in each pass; it must be high enough to avoid splitting of the tube yet not so high as to reduce its tensile strength to the point where it breaks. Again, this temperature is critical since all of the tension in drawing must be supported by the tube, the steel core having negligible strength in smaller diameters when hot. In drawing the tubes mentioned above, I reduced the outside diameter from 0.24 inch to 0.093 inch in seven passes. The temperature was held at 1400° to 1700° F. for the first passes and was reduced for subsequent passes until for the last (0.093 inch) pass it was held at approximately 1100° to 1200° F. Higher temperatures caused the tube to break and lower ones caused it to split. These dies, of course, should also be heated to the proper working temperatures.

Within the temperatures stated, molybdenum tubing may also be reduced by rolling between suitable rolls 8, which must, however, be of great strength and very rigidly mounted.

The steel core is removed from the finished tube 9 by nicking and breaking an end of the tube to expose the end of the core, then stretching the core until its diameter has been sufficiently reduced to permit ready removal by pincers or gripping tongs 10. Depending on the size, it may be necessary to anneal the core by heating the tube and the core a number of times. I used a tensile testing machine in removing the cores from the 0.093 inch tubes, and found that one anneal after a preliminary stretch was usually sufficient.

As used in the following claims, the word "molybdenum" shall be construed to include tungsten and all other metals of like known properties unless I specifically indicate otherwise. In other respects, also although I have described my invention in considerable detail, I do not wish to be limited strictly to the exact and specific steps and details described, but may use such substitutions, modifications or equivalents thereof as are embraced within the scope of the invention or as are pointed out in the claims.

Having thus described my invention, what I claim as new and useful and desire to secure by Letters Patent is:

1. The method of making seamless molybdenum tubing which comprises forming a hollow tubular blank of the metal, inserting a core of a coarse-grained austenitic alloy steel containing substantially 10 to 14 per cent of manganese and coated with lime therein, heating said blank and core to a temperature approximately 2300° to 2500° F., hot-swaging with long-bearing finishing dies through a plurality of passes to improve the crystalline structure of the blank and work-harden the core while reducing the diameter of both the core and the blank, and during swaging allowing the temperature to reduce to 2000° to 2200° F. for the final swaging passes.

2. The method of making seamless molybdenum tubing which comprises forming a hollow tubular blank of the metal, inserting therein a shorter steel core of coarse-grained austenitic steel containing substantially 10 to 14 per cent manganese and 3 to 5 per cent nickel, heating said blank and core to a temperature approximately 2300° to 2500° F., hot-swaging with long-bearing finishing dies through a plurality of passes to improve the crystalline structure of the blank and work-harden the core while reducing the diameter of both the blank and the core, to a temperature approximately 2000° to 2200° F., then coating the exterior of the blank with a refractory lubricant, and further reducing by drawing through dies at gradually diminishing temperatures between 1700° and 1100° F.

3. The method of treating seamless molybdenum tubing which consists in heating the same on a lime-coated austenitic manganese steel core to a proper working temperature, then reducing the diameter of the tubing and core and improving the crystalline structure of the tubing and work-hardening the core by a plurality of swaging passes between long-bearing finishing dies heated to an appropriate temperature, and subsequently removing the core.

JOHN E. EBERHARDT.